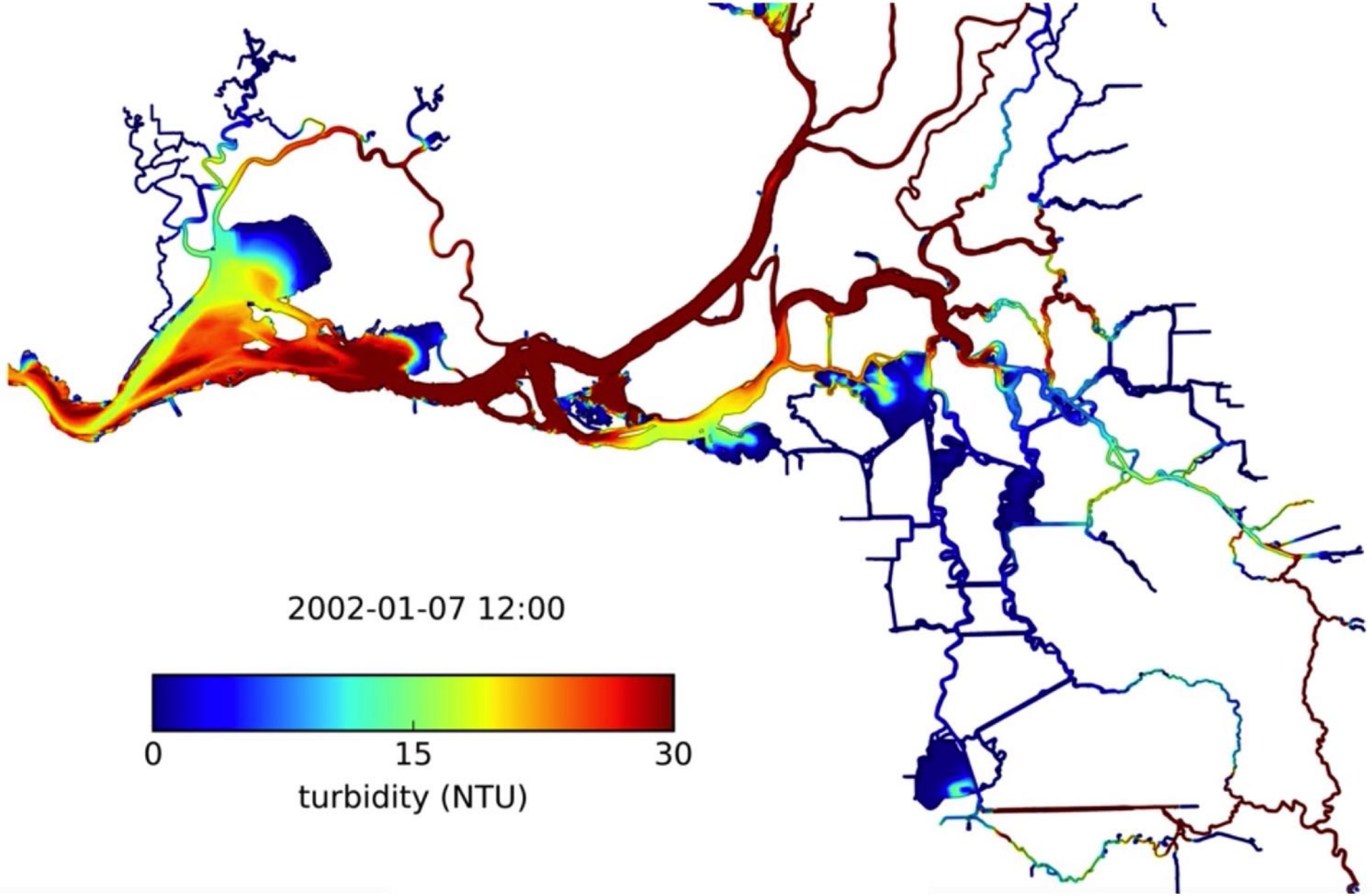
DWR-1358

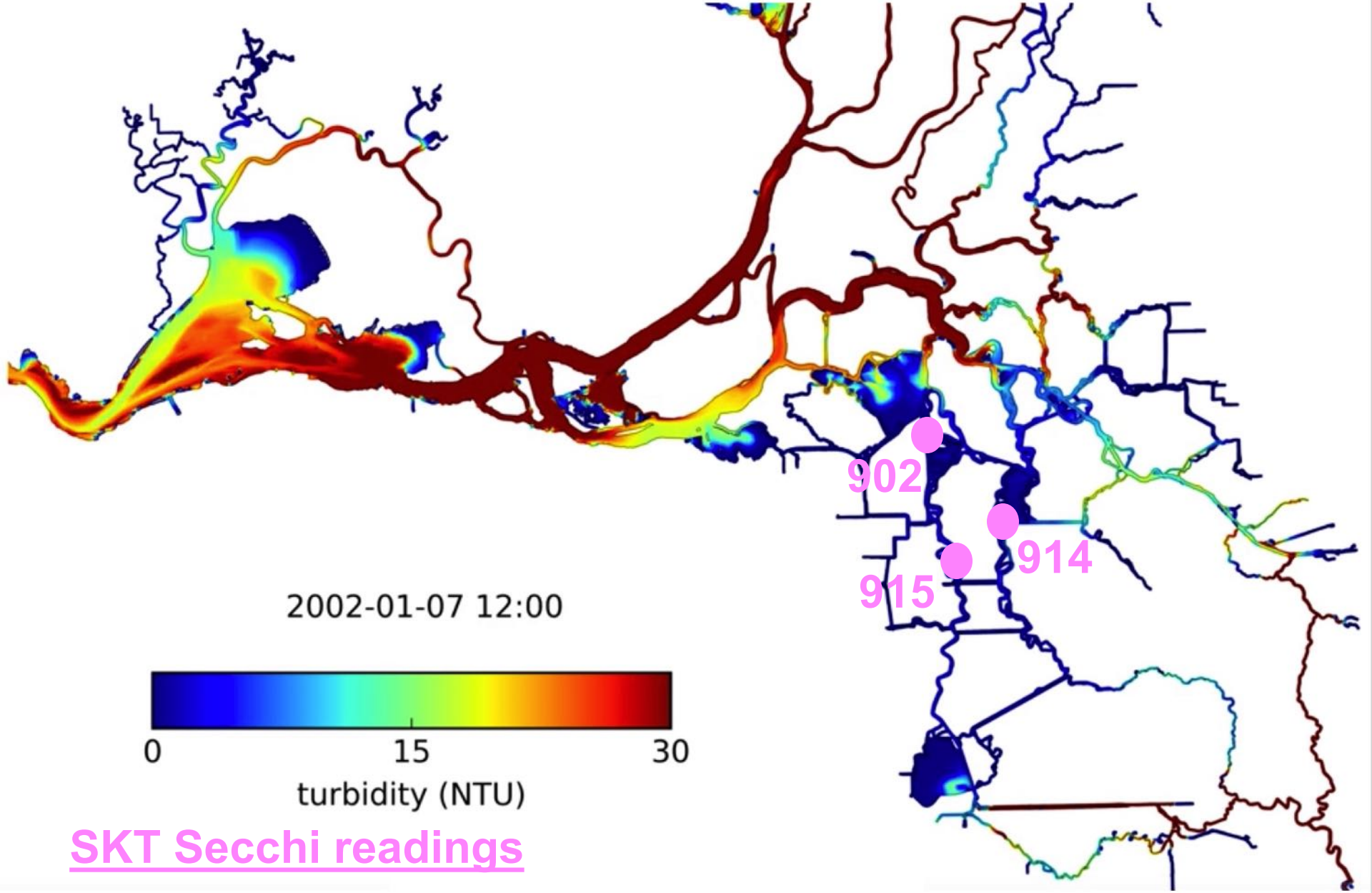
Short Update on Two Issues Discussed at Last Meeting

Two Issues

1. Are the turbidity predictions for water year 2002 too low in the south Delta?

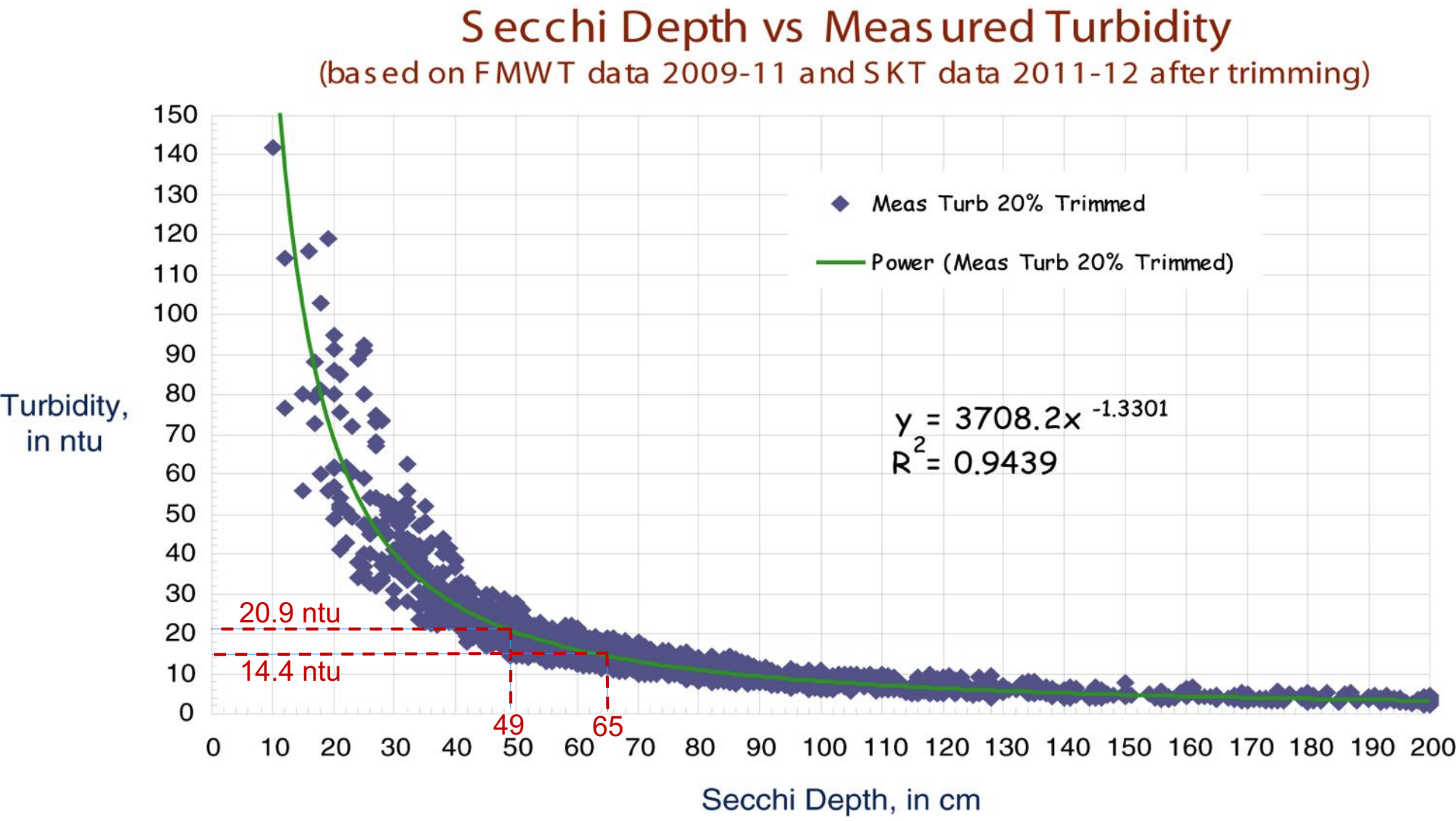
2. What approach does the UnTRIM model use to estimate inflows into CCFB and how might that approach affect the ratio of Delta Smelt entrained between the CVP and SWP?

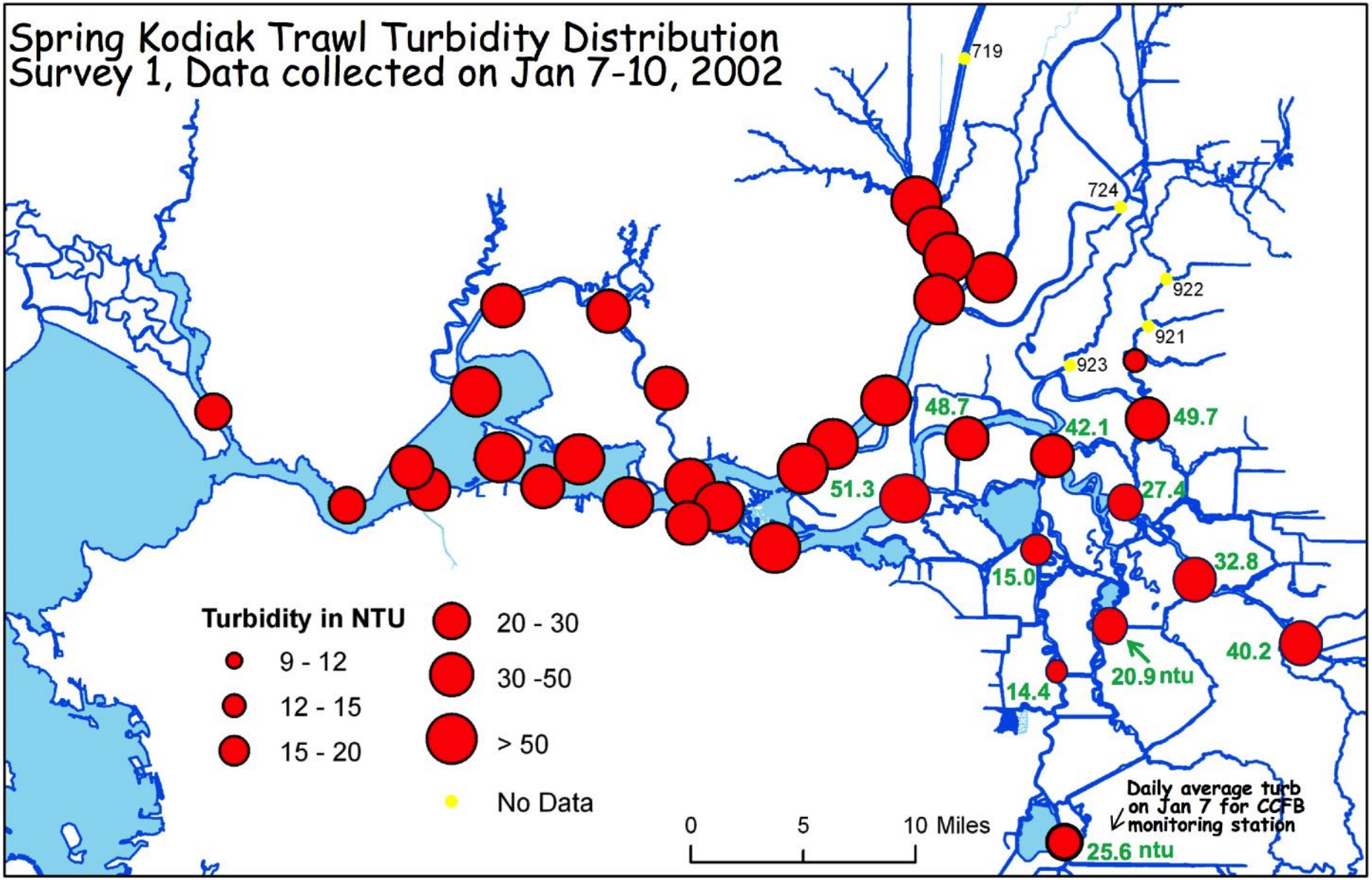

2002-01-07 12:00
0
15
30
turbidity (NTU)



SKT Secchi readings

902 – 63 cm, 915 – 65 cm, 914 – 49 cm


Secchi Depth vs Measured Turbidity
(based on FMWT data 2009-11 and SKT data 2011-12 after trimming)
Meas Turb 20% Trimmed
Power (Meas Turb 20% Trimmed)
y = 3708.2x -1.3301
R2 = 0.9439
20.9 ntu
14.4 ntu
49
65
Turbidity, in ntu
Secchi Depth, in cm
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200


Spring Kodiak Trawl Turbidity Distribution
Survey 1, Data collected on Jan 7-10, 2002
719
724
922
921
923
48.7
49.7
42.1
51.3
27.4
15.0
32.8
40.2
20.9 ntu
14.4
25.6 ntu
Daily average turb on Jan 7 for CCFB monitoring station
Turbidity in NTU
9 - 12
12 - 15
15 - 20
20 - 30
30 -50
> 50
No Data
0
5
10 Miles

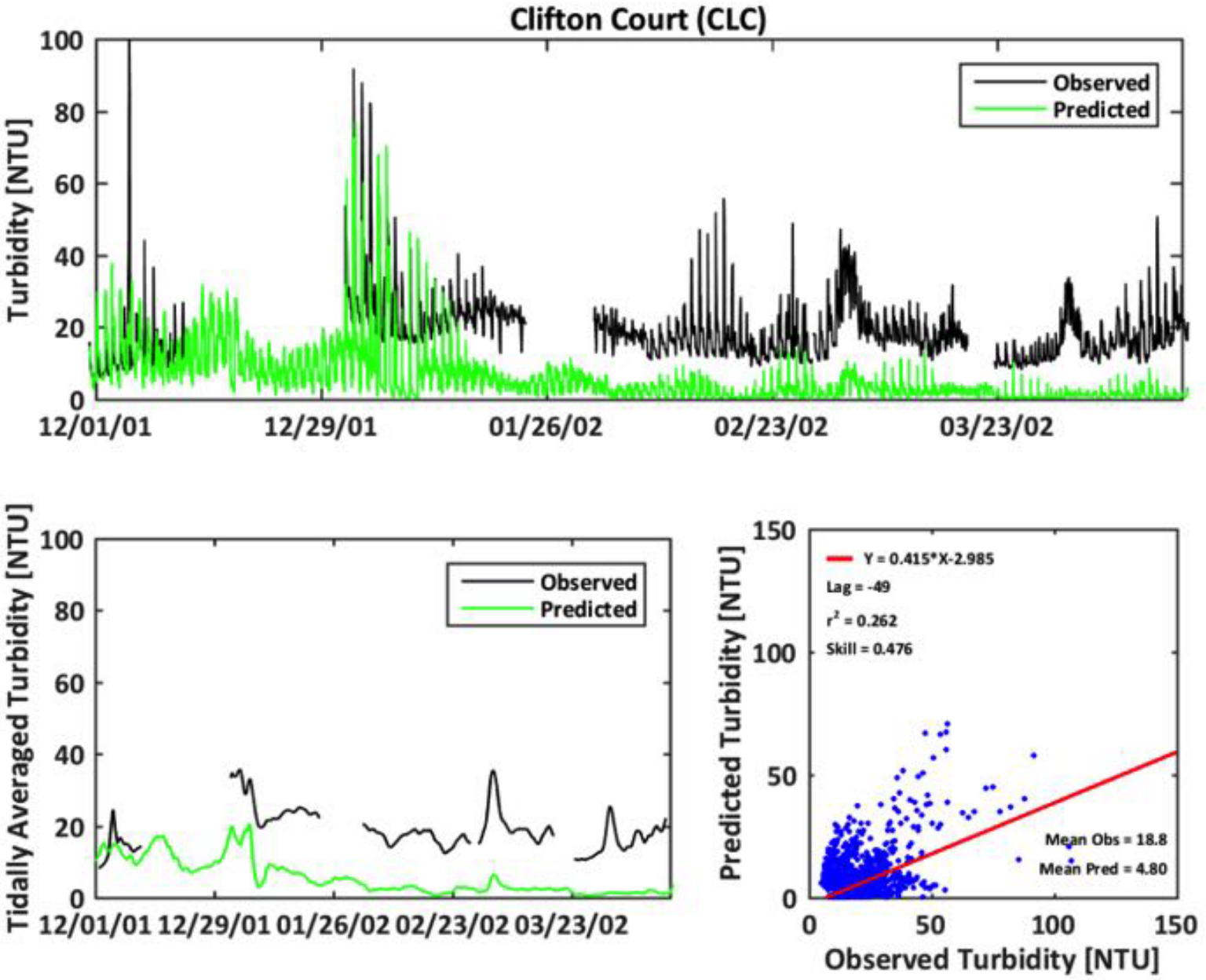


Fig 5 from 2002 Turbidity Validation Report by Bever & MacWilliams (July, 2016)

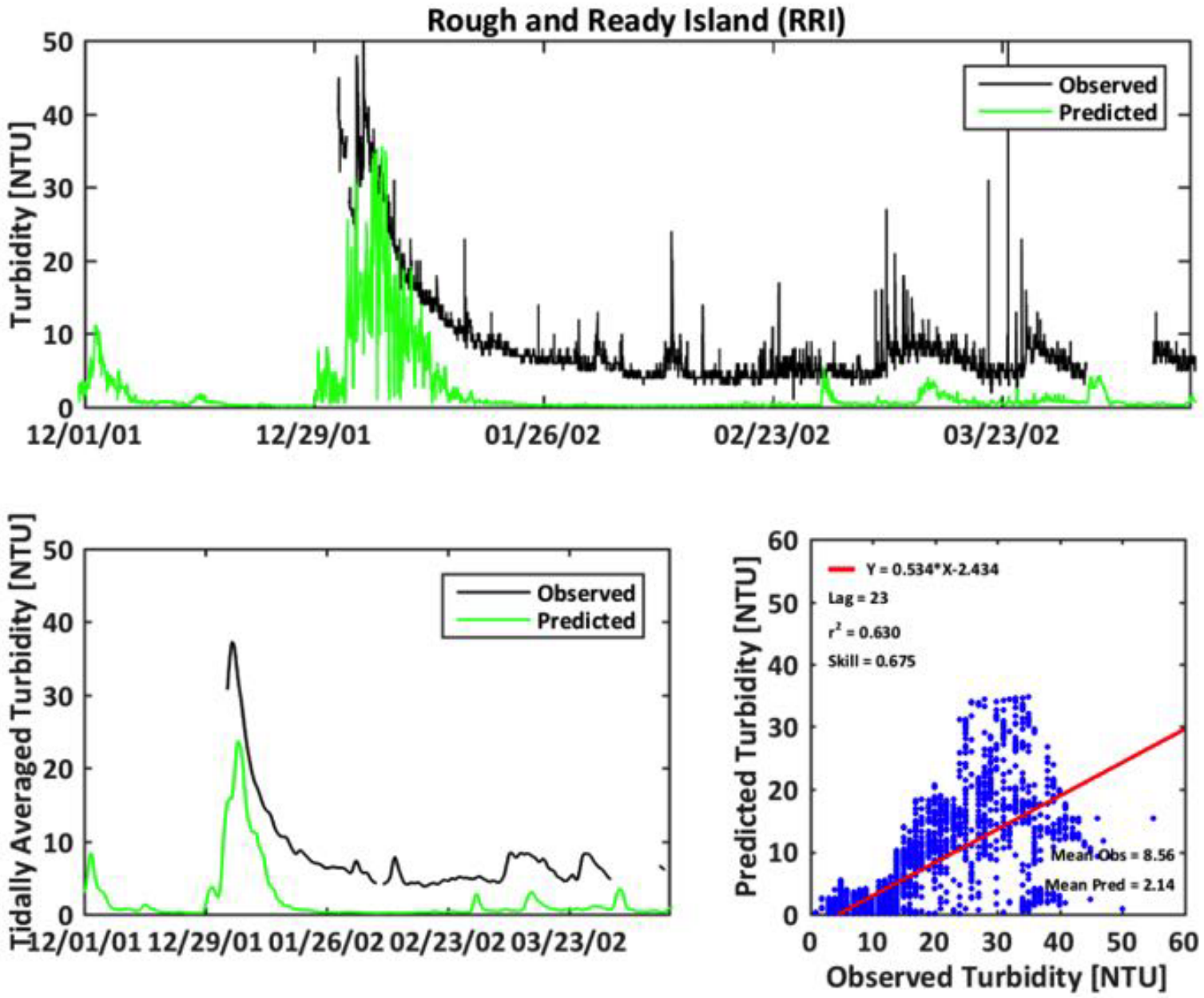
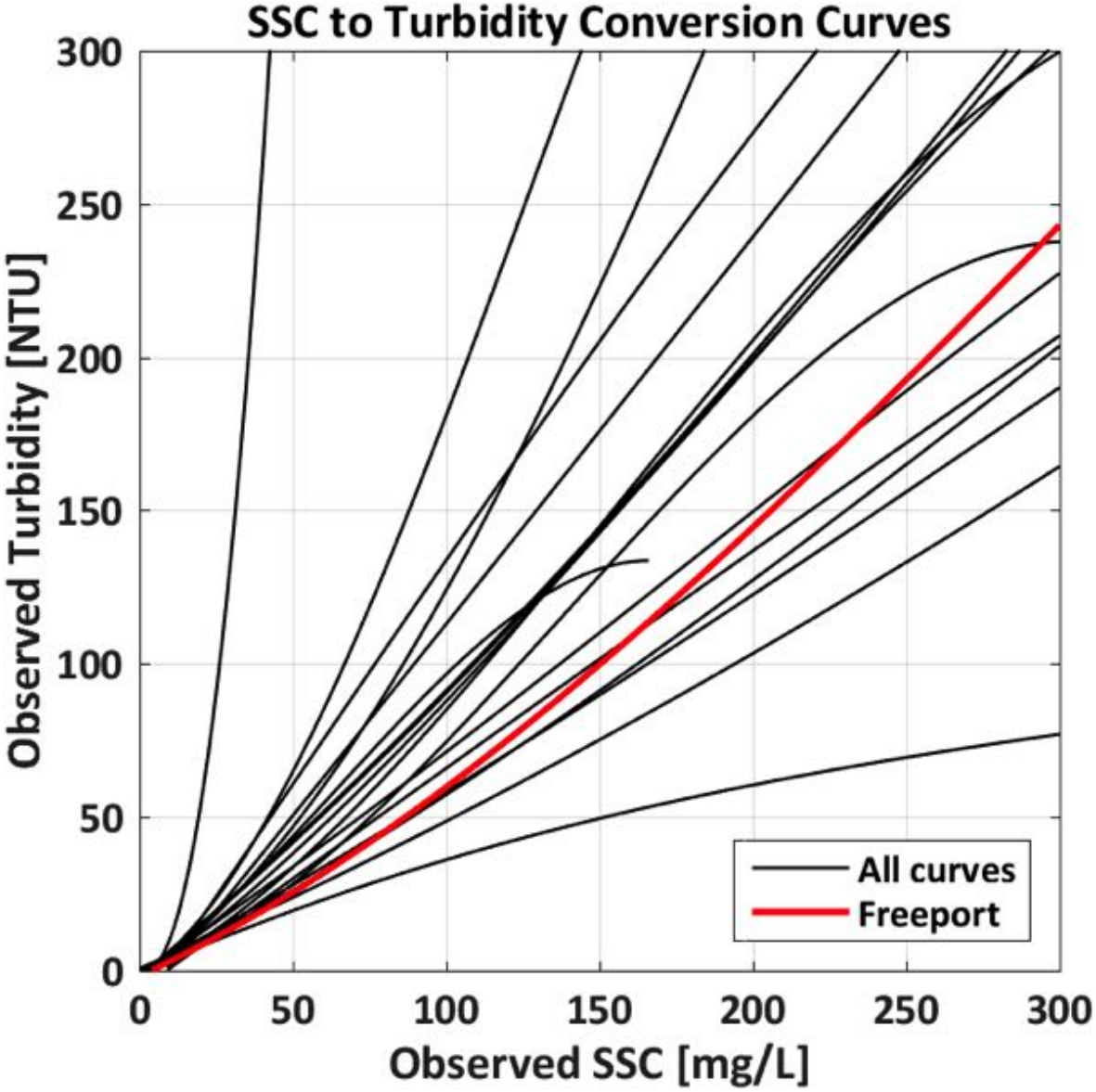


Fig 6 from 2002 Turbidity Validation Report by Bever & MacWilliams (July, 2016)



Relationship between turbidity and SSC at different locations throughout the Delta based on USGS measurements between 2010 and 2015

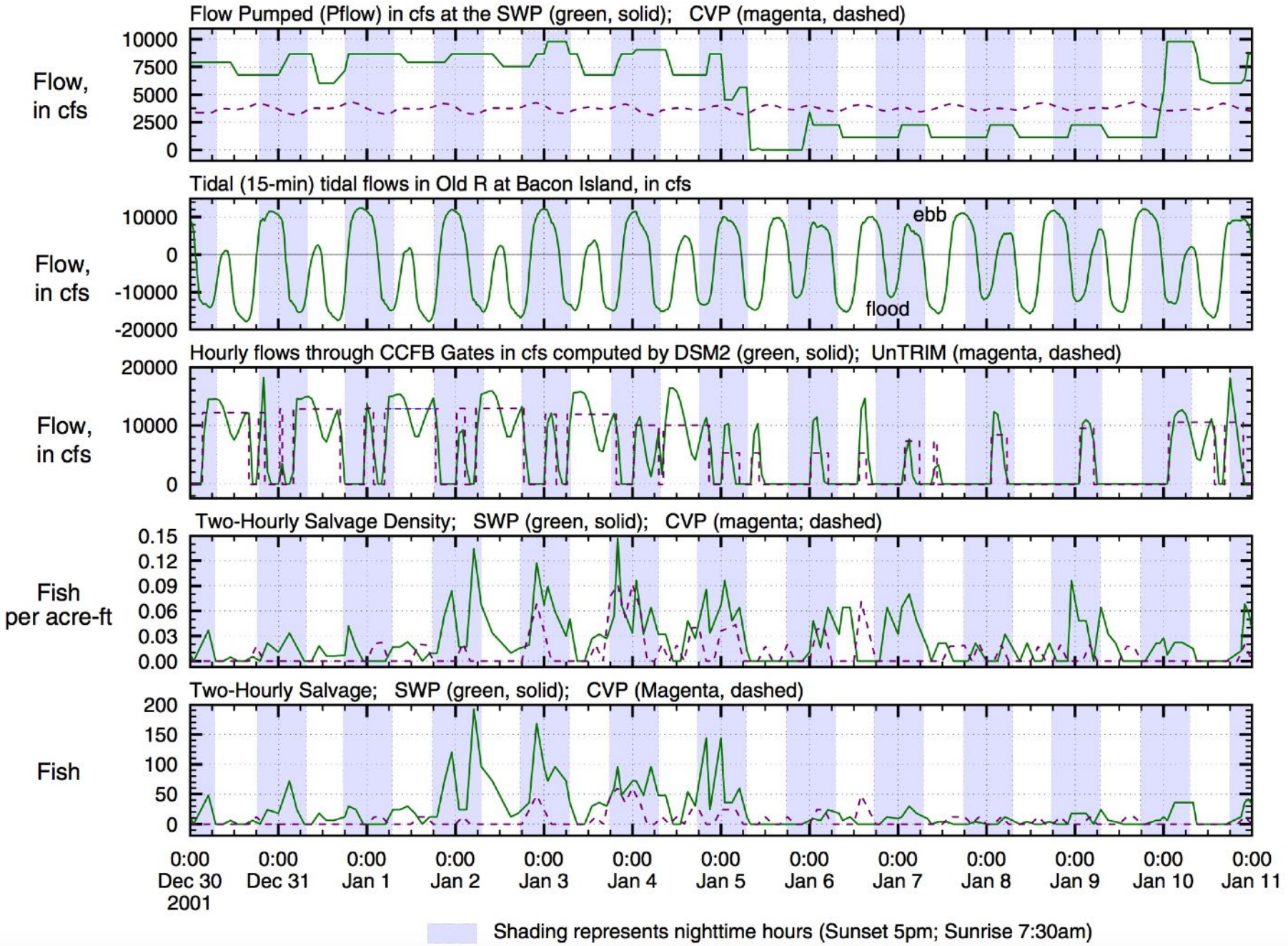
Fig 2 from 2002 Turbidity Validation Report by Bever & MacWilliams (July, 2016)

Two Issues

1. Are the turbidity predictions for water year 2002 too low in the south Delta?

2. What approach does the UnTRIM model use to estimate inflows into CCFB and how might that approach affect the ratio of Delta Smelt entrained between the CVP and SWP?

Two-Hourly Salvage Data and Flows during Water Year 2002



Preliminary Results for the CAMT Entrainment Study III, Estimating Adult Delta Smelt Proportional Losses

by P. Smith

Collaborators

John Donovan, USGS

Bernie McNamara, USGS

Ed Gross, RMA

Josh Korman, Ecometric

Presentation to CAMT Delta Smelt Scoping Team, Monday Dec 4, 2017

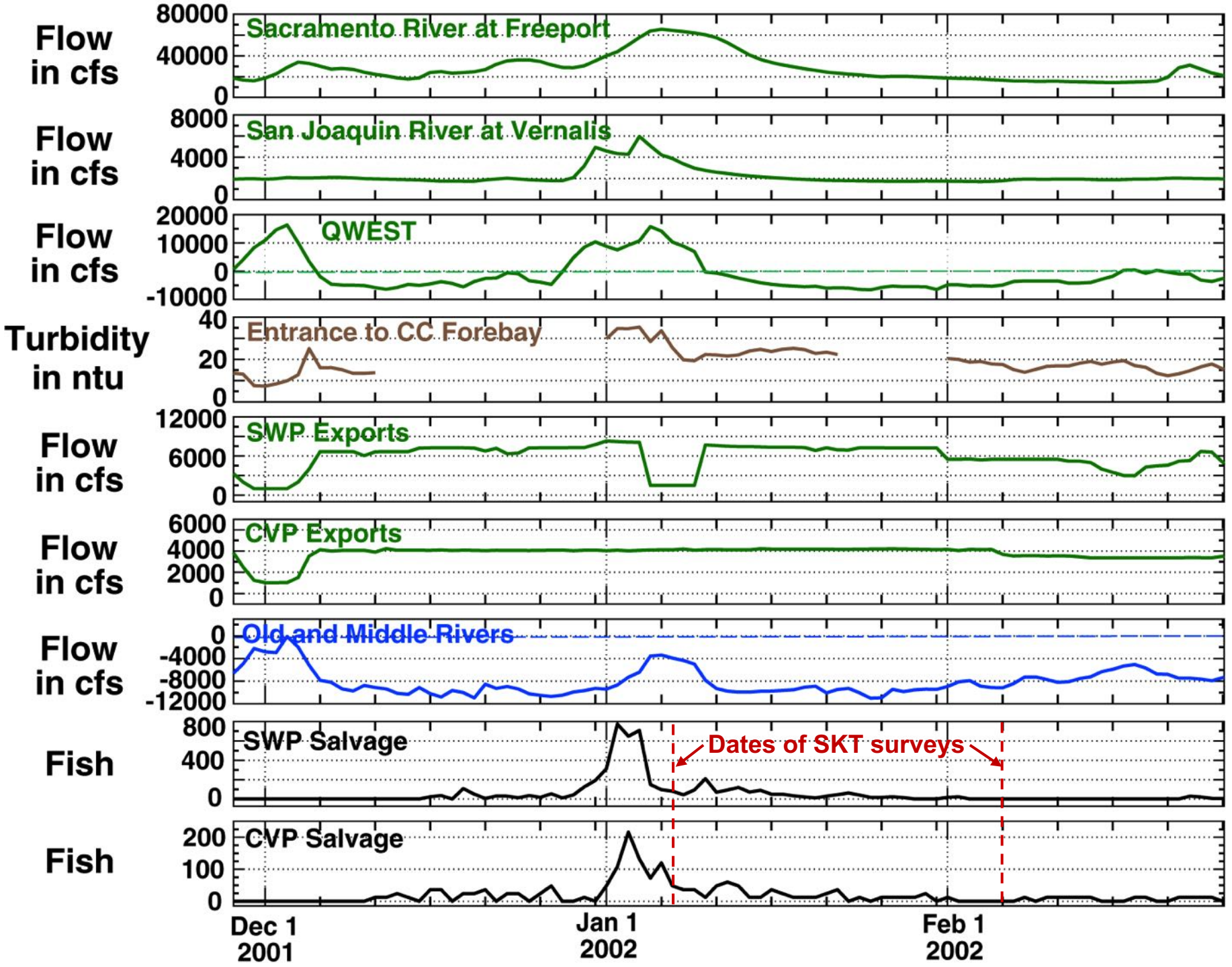
State Water Contractors Office, 1121 L Street, Suite 1050

Our assignment was to estimate adult Delta Smelt proportional entrainment losses for water years 1981-2016. The steps were:

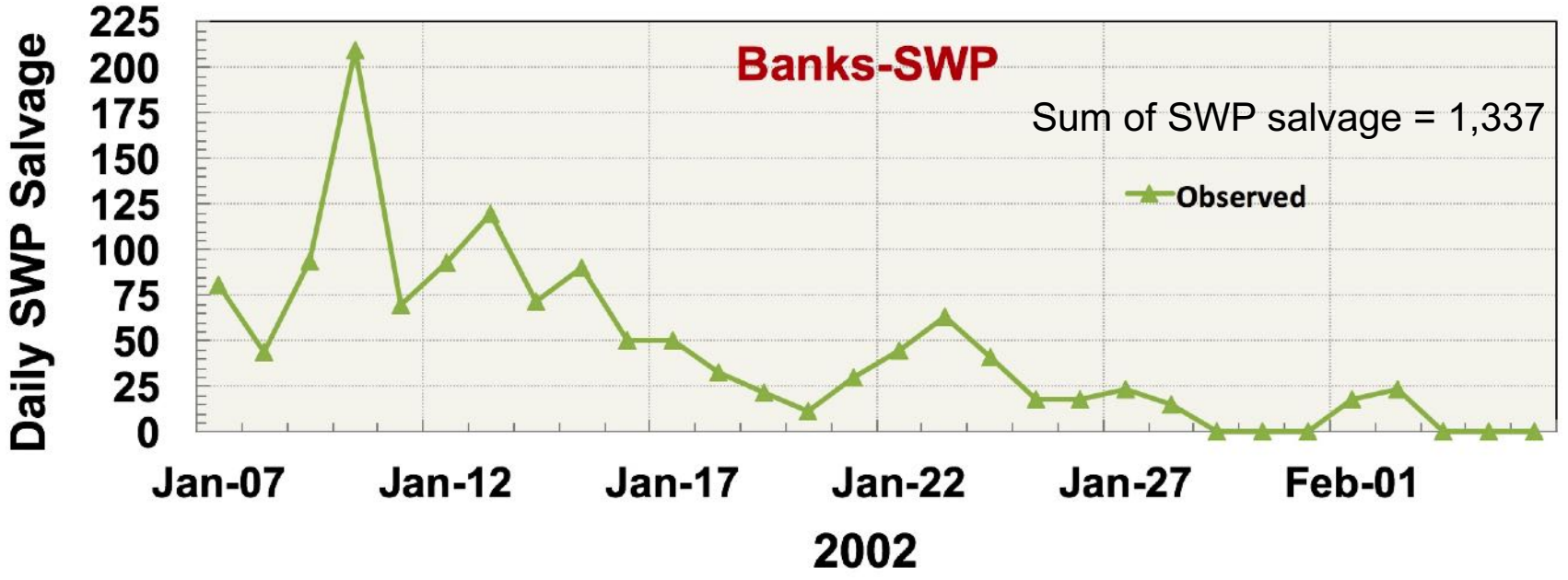
1. Estimating daily adult entrainment for 2002-2016
2. Estimating monthly adult populations from the SKTS data for 2002-2016
3. Estimating (a curve for) natural mortality, a reference population (Dec 15), and the adult proportional entrainment loss for each water year from 2002-2016
4. Estimating adult proportional entrainment losses for the pre-SKTS years (1981-2001)

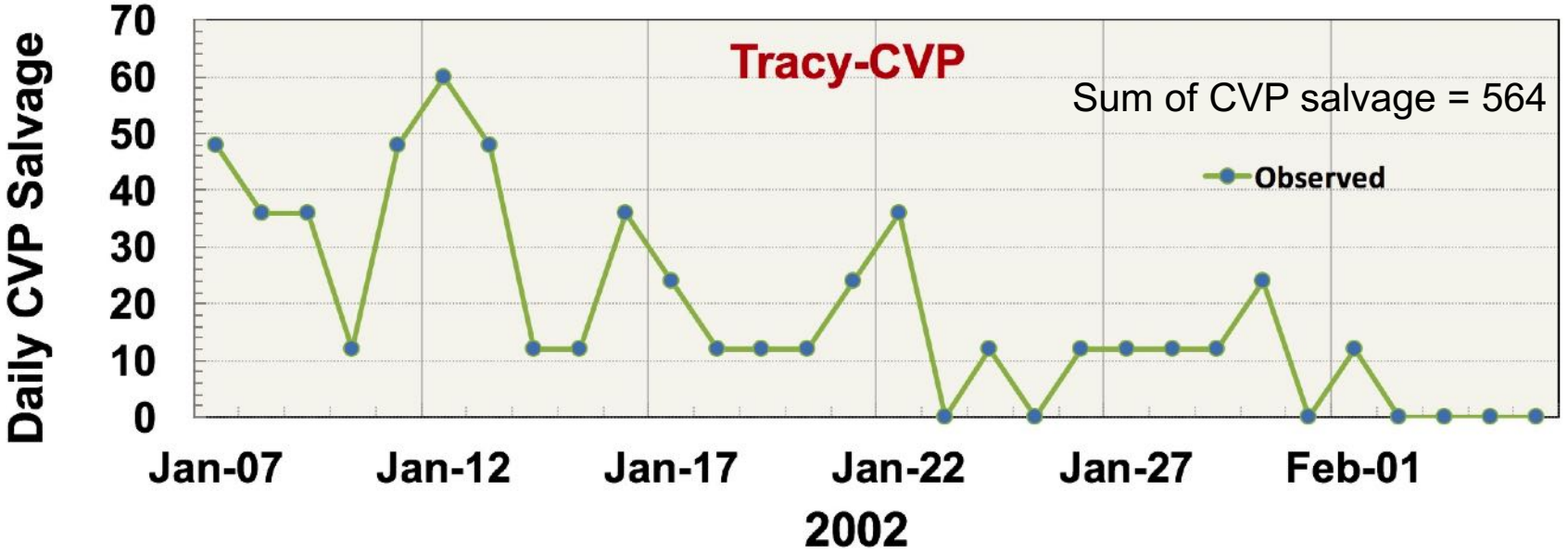
1. Estimating daily adult entrainment for water years 2002-2016

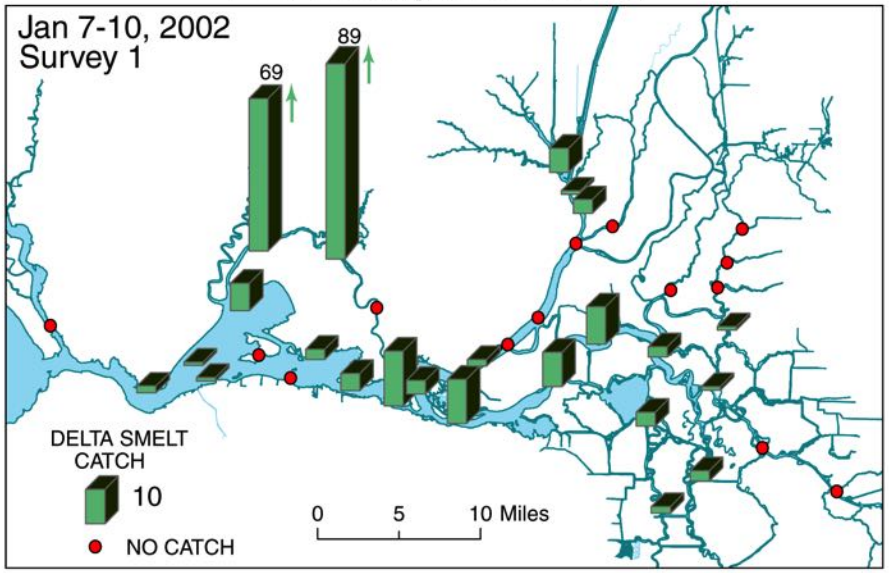
- This involves using hydrodynamic and particle-tracking modeling to derive the "expansion factors" (θ_{SWP} , θ_{CVP}) for estimating daily entrainment from the daily salvage data.
- We are using an alternative modeling approach from the full production runs. This alternative approach uses abundance data taken directly form the January SKT Survey data as the initial condition for the model and only simulates entrainment for one month.
- So far we have only done water year 2002 using this approach.

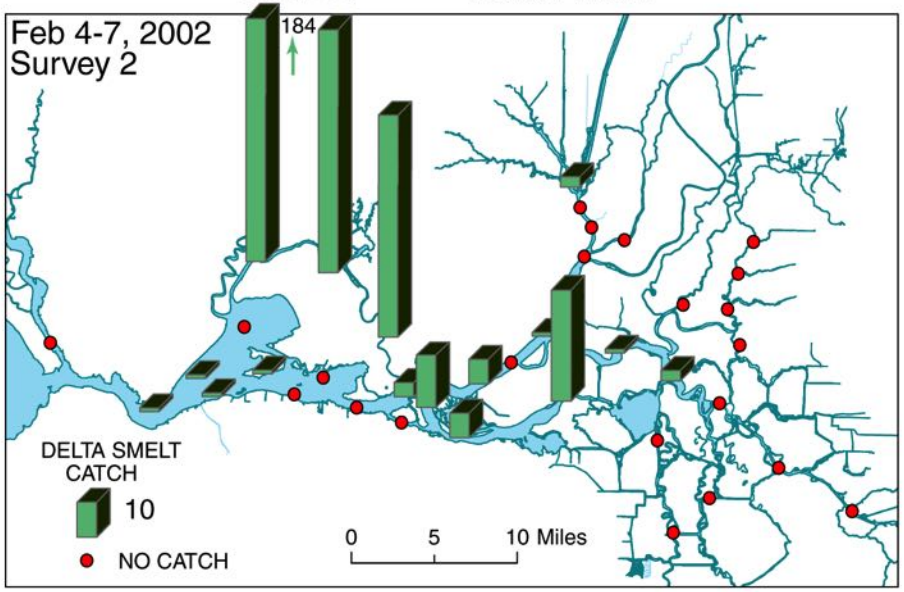

Flow in cfs
80000
40000
0
Sacramento River at Freeport
Flow in cfs
8000
4000
0
San Joaquin River at Vernalis
Flow in cfs
20000
10000
0
-10000
QWEST
Turbidity in ntu
40
20
0
Entrance to CC Forebay
Flow in cfs
12000
6000
0
SWP Exports
Flow in cfs
6000
4000
2000
0
CVP Exports
Flow in cfs
0
-4000
-8000
-12000
Old and Middle Rivers
Fish
800
400
0
SWP Salvage
Dates of SKT surveys
Fish
200
100
0
CVP Salvage
Dec 1 2001
Jan 1 2002
Feb 1 2002

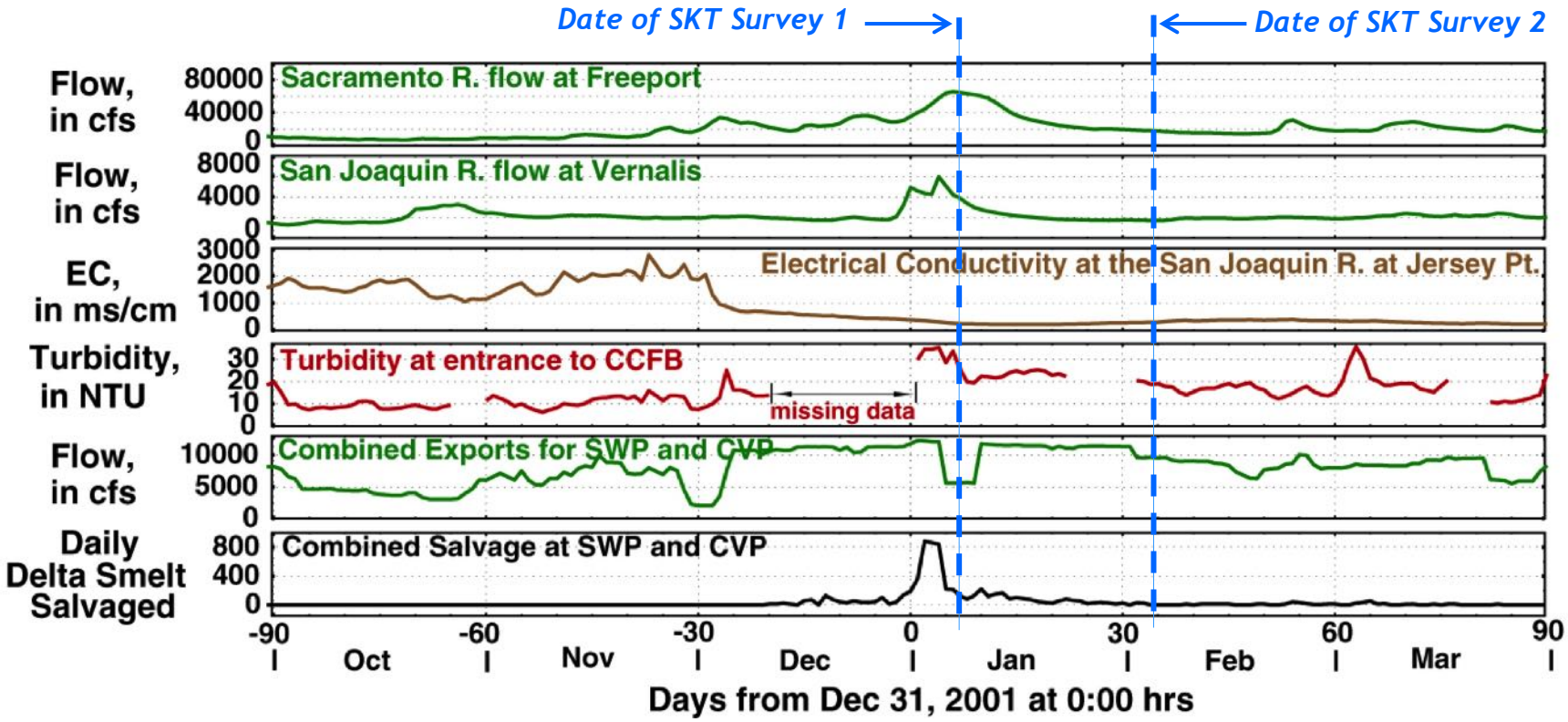
Period of Salvage Used to Estimate Theta Values

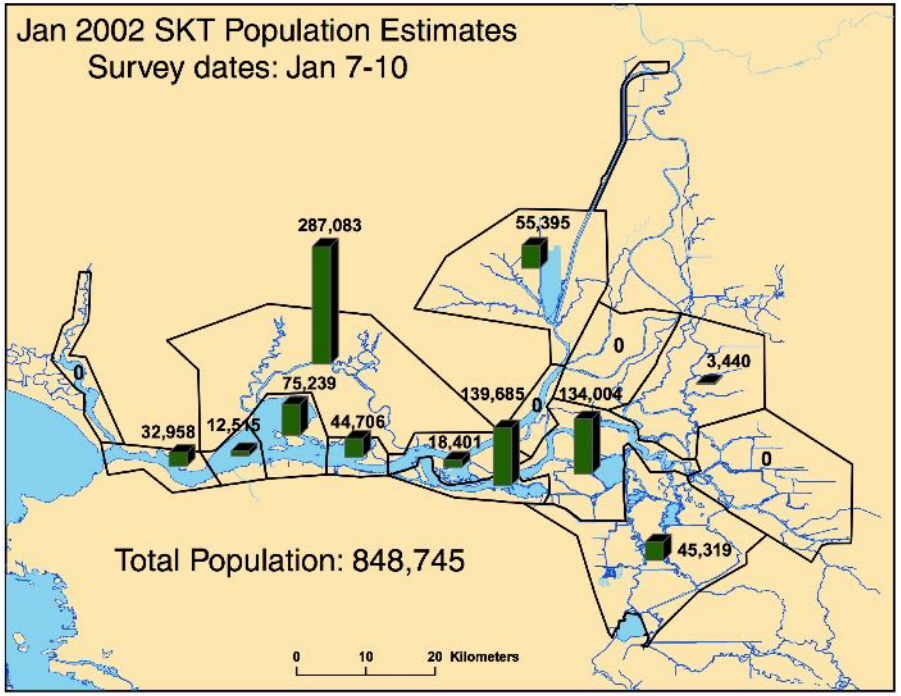


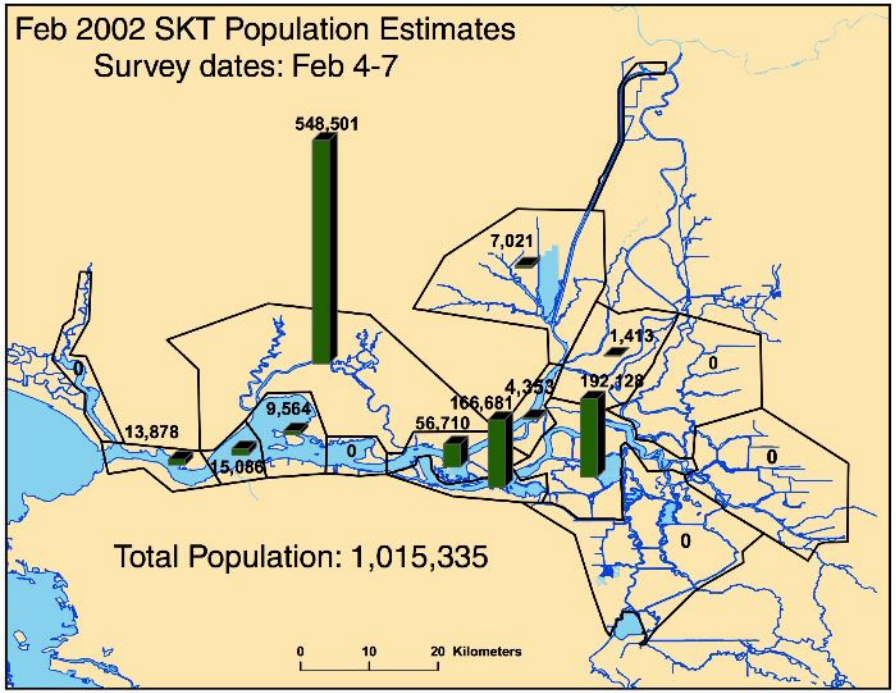


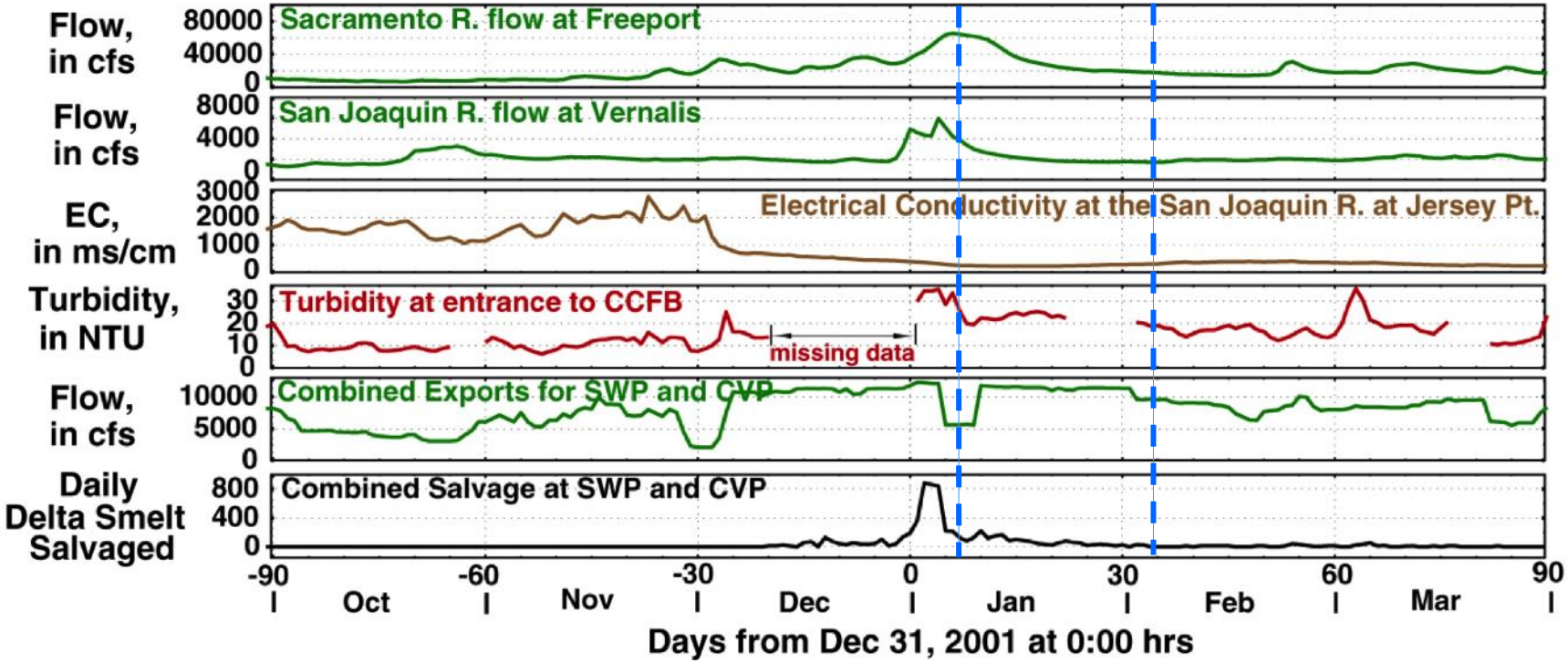

Jan 7-10, 2002
Survey 1
69
89
DELTA SMELT
CATCH
10
NO CATCH
0
5
10 Miles

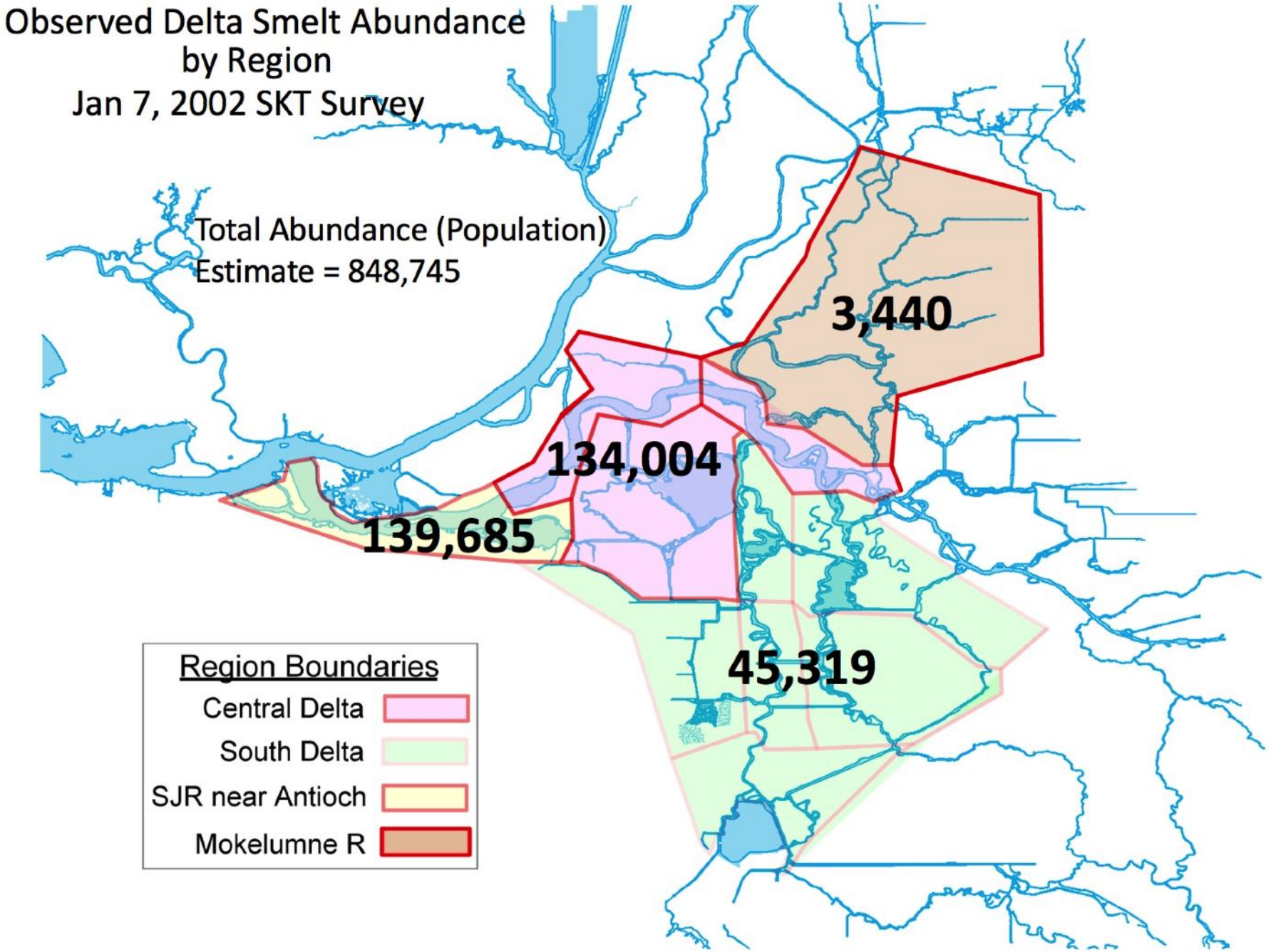

Feb 4-7, 2002
Survey 2
184
DELTA SMELT
CATCH
10
NO CATCH
0
5
10 Miles

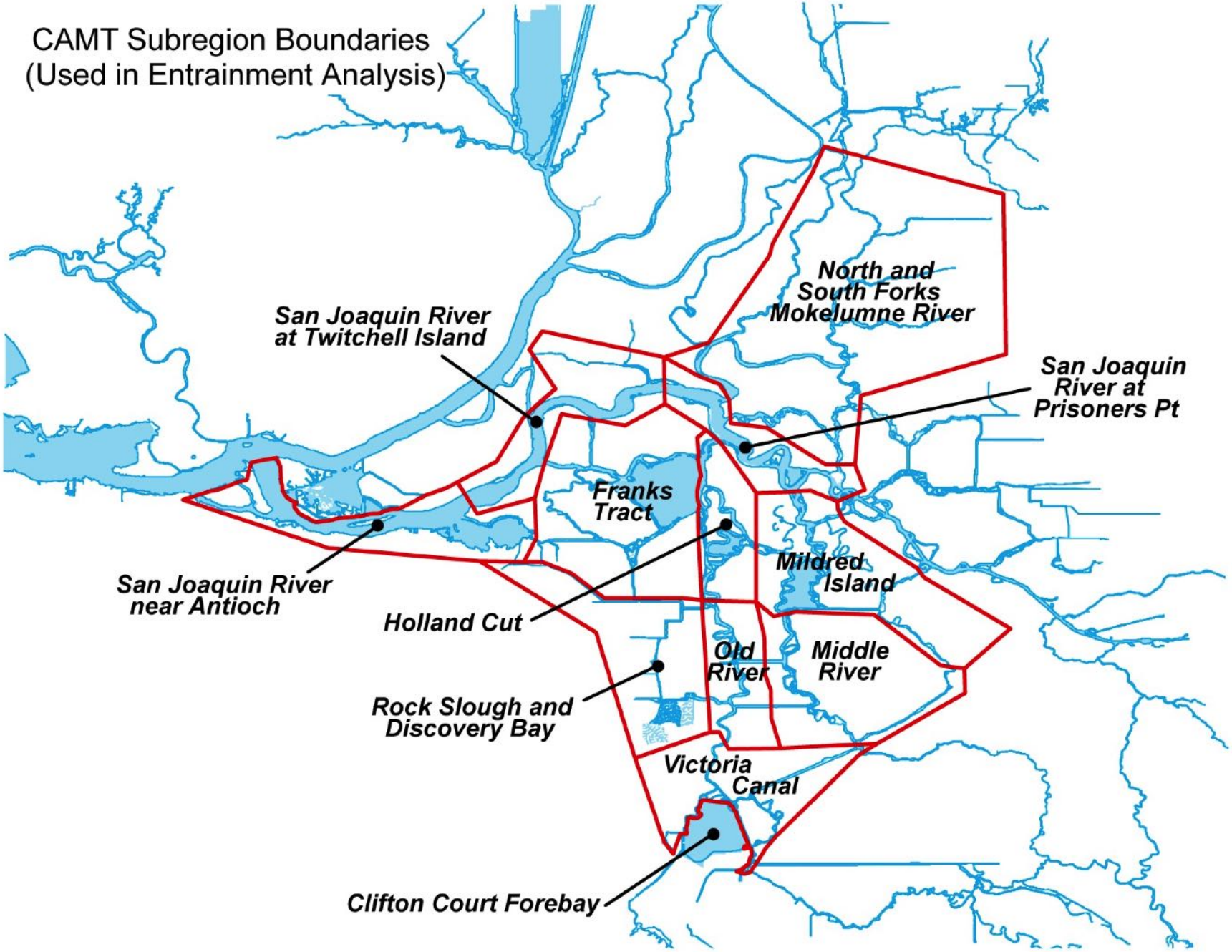

Date of SKT Survey 1
Date of SKT Survey 2
Flow, in cfs
80000
40000
0
Sacramento R. flow at Freeport
Flow, in cfs
8000
4000
0
San Joaquin R. flow at Vernalis
EC, in ms/cm
3000
2000
1000
0
Electrical Conductivity at the San Joaquin R. at Jersey Pt.
Turbidity, in NTU
30
20
10
0
Turbidity at entrance to CCFB
missing data
Flow, in cfs
10000
5000
0
Combined Exports for SWP and CVP
Daily Delta Smelt Salvaged
800
400
0
Combined Salvage at SWP and CVP
-90
-60
-30
0
30
60
90
Oct
Nov
Dec
Jan
Feb
Mar
Days from Dec 31, 2001 at 0:00 hrs


Jan 2002 SKT Population Estimates
Survey dates: Jan 7-10
287,083
55,395
0
3,440
75,239
139,685
134,004
0
32,958
12,515
44,706
18,401
0
45,319
Total Population: 848,745
0 10 20 Kilometers

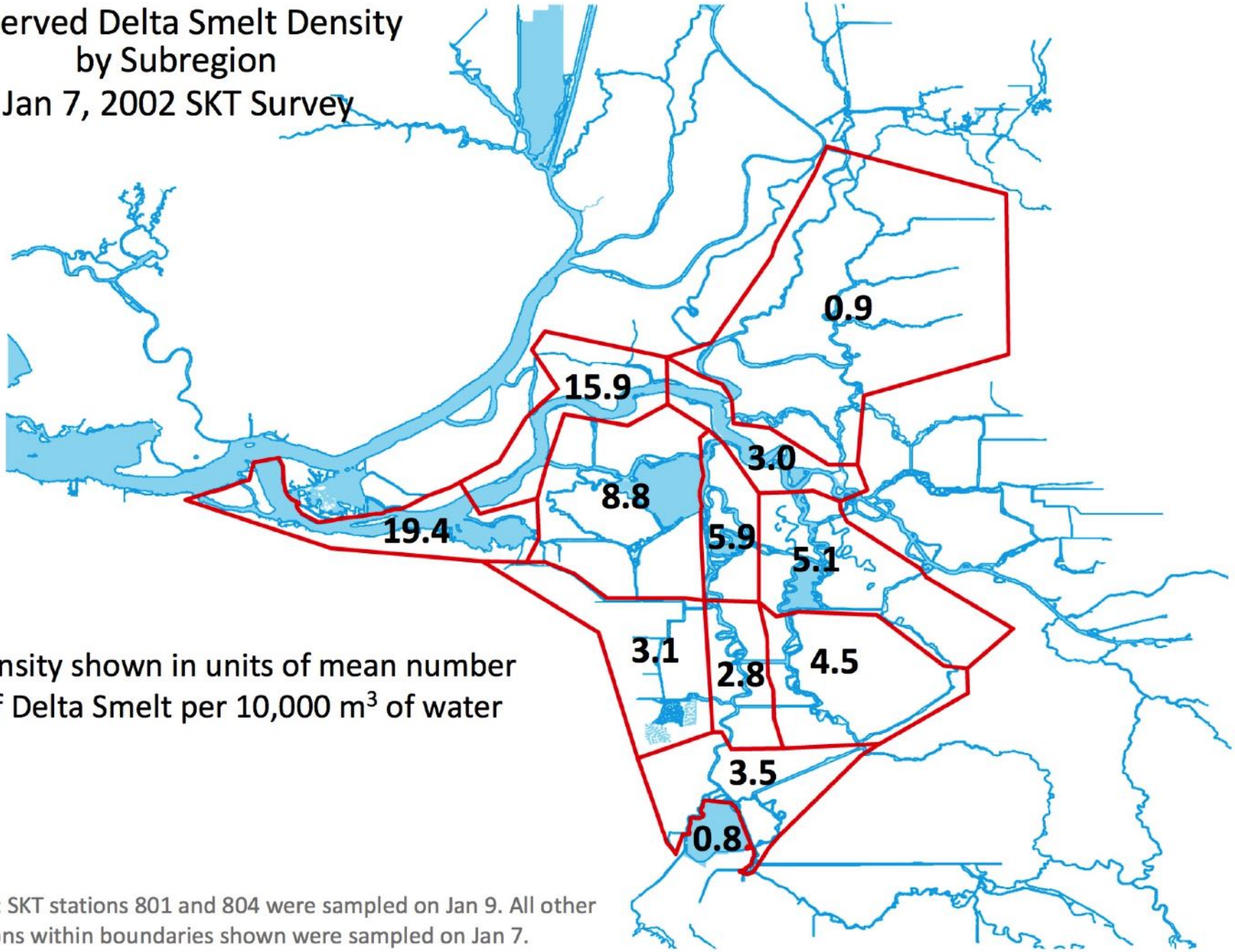

Feb 2002 SKT Population Estimates
Survey dates: Feb 4-7
548,501
7,021
1,413
0
4,353
192,128
9,564
166,681
13,878
56,710
15,086
0
0
0
Total Population: 1,015,335
0 10 20 Kilometers


Flow, in cfs
80000
40000
0
Sacramento R. flow at Freeport
Flow, in cfs
8000
4000
0
San Joaquin R. flow at Vernalis
EC, in ms/cm
3000
2000
1000
0
Electrical Conductivity at the San Joaquin R. at Jersey Pt.
Turbidity, in NTU
30
20
10
0
Turbidity at entrance to CCFB
missing data
Flow, in cfs
10000
5000
0
Combined Exports for SWP and CVP
Daily Delta Smelt Salvaged
800
400
0
Combined Salvage at SWP and CVP
-90
-60
-30
0
30
60
90
Oct
Nov
Dec
Jan
Feb
Mar
Days from Dec 31, 2001 at 0:00 hrs


Observed Delta Smelt Abundance
by Region
Jan 7, 2002 SKT Survey
Total Abundance (Population)
Estimate = 848,745
3,440
134,004
139,685
45,319
Region Boundaries
Central Delta
South Delta
SJR near Antioch
Mokelumne R

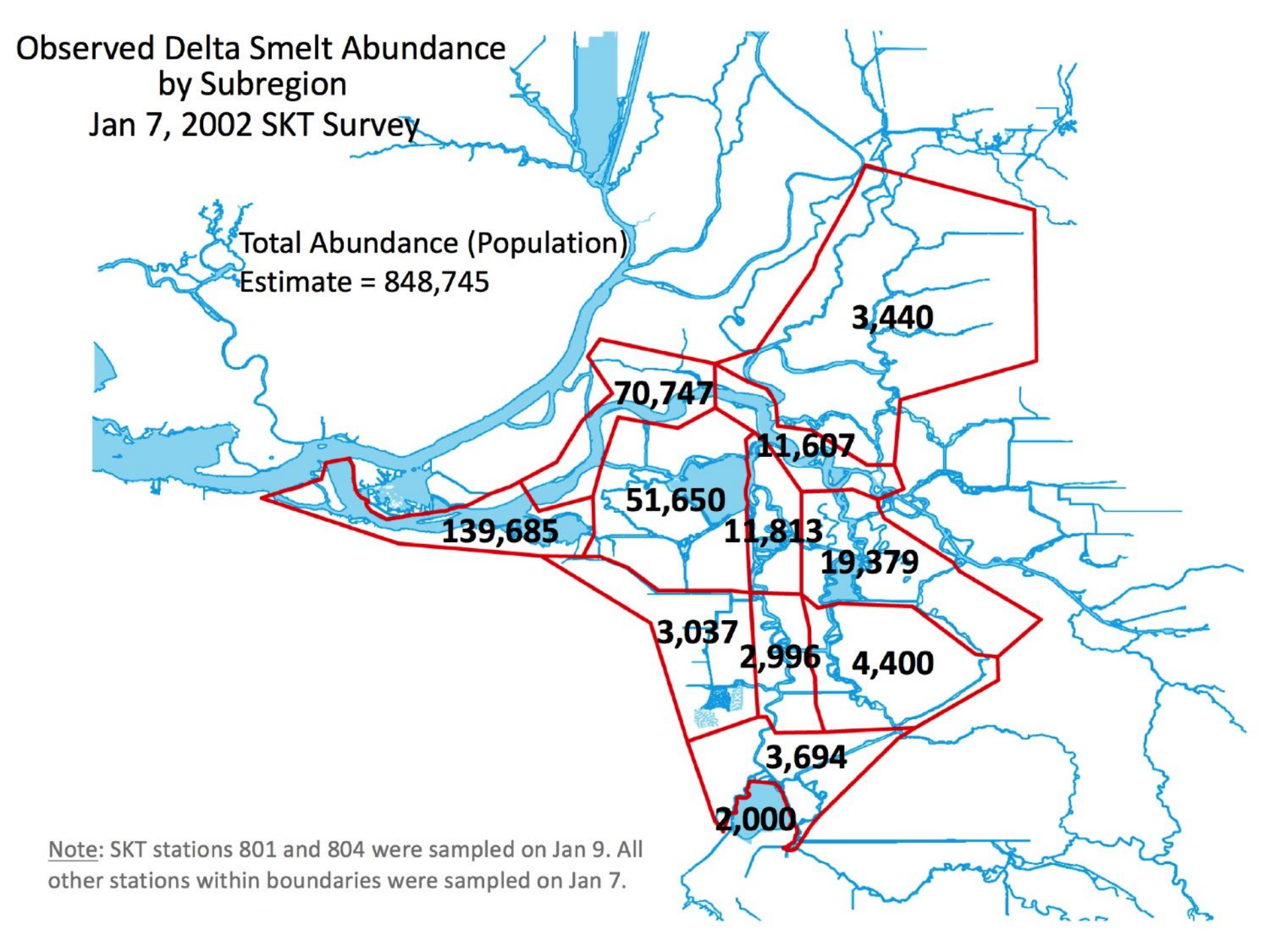

CAMT Subregion Boundaries
(Used in Entrainment Analysis)
North and South Forks Mokelumne River
San Joaquin River at Twitchell Island
San Joaquin River at Prisoners Pt
Franks Tract
Mildred Island
San Joaquin River near Antioch
Holland Cut
Old River
Middle River
Rock Slough and Discovery Bay
Victoria Canal
Clifton Court Forebay

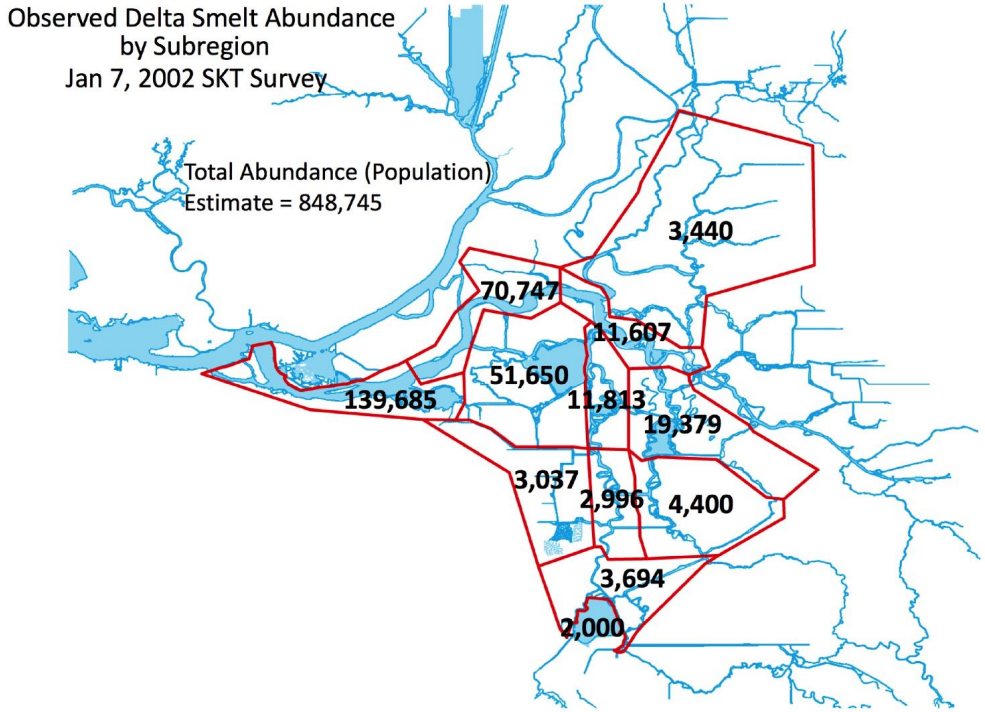
Observed Delta Smelt Density by Subregion Jan 7, 2002 SKT Survey



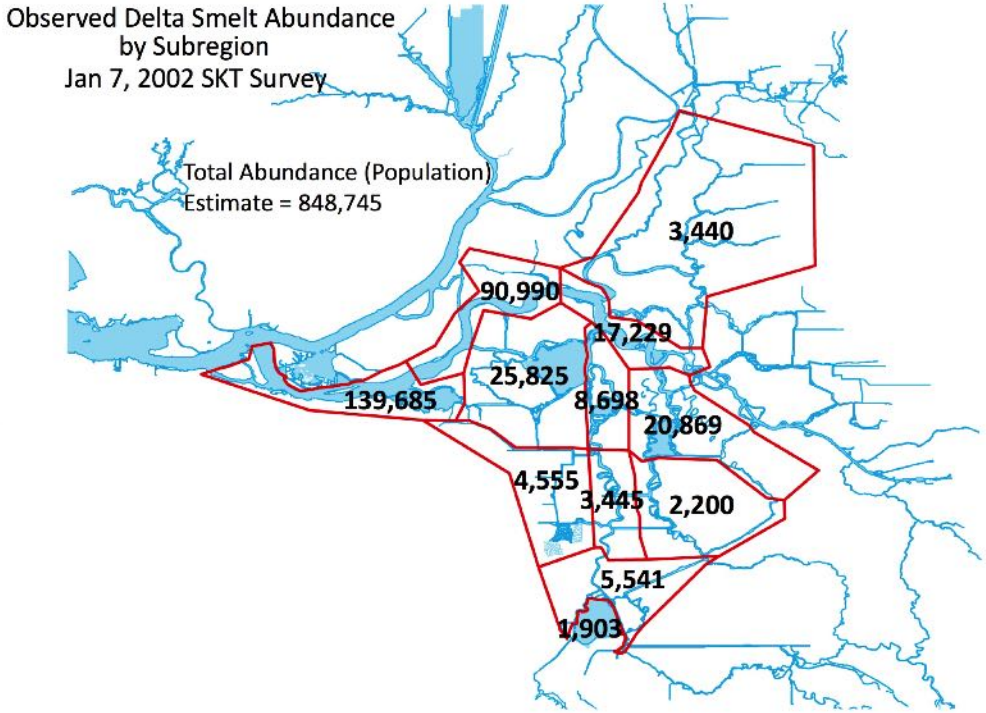
Density shown in units of mean number of Delta Smelt per 10,000 m^3 of water

Note: SKT stations 801 and 804 were sampled on Jan 9. All other stations within boundaries shown were sampled on Jan 7.

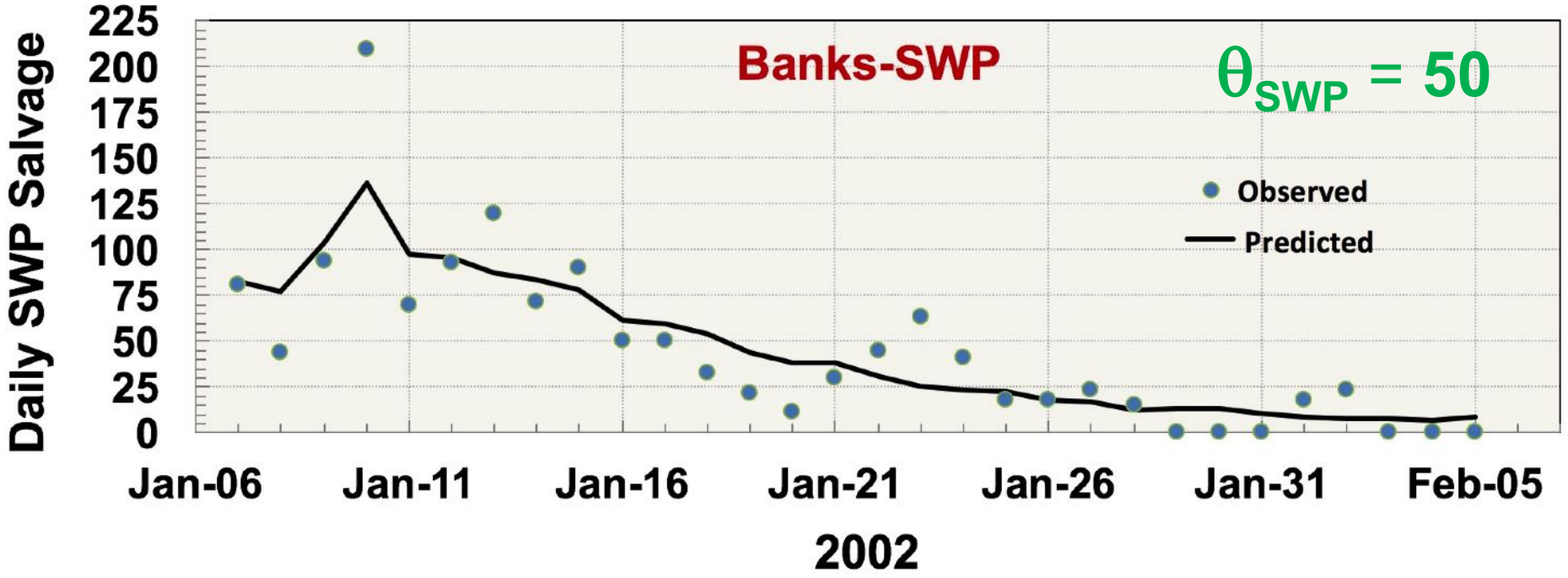

Observed Delta Smelt Abundance
by Subregion
Jan 7, 2002 SKT Survey
Total Abundance (Population)
Estimate = 848,745
3,440
70,747
11,607
51,650
139,685
11,813
19,379
3,037
2,996
4,400
3,694
2,000
Note: SKT stations 801 and 804 were sampled on Jan 9. All other stations within boundaries were sampled on Jan 7.

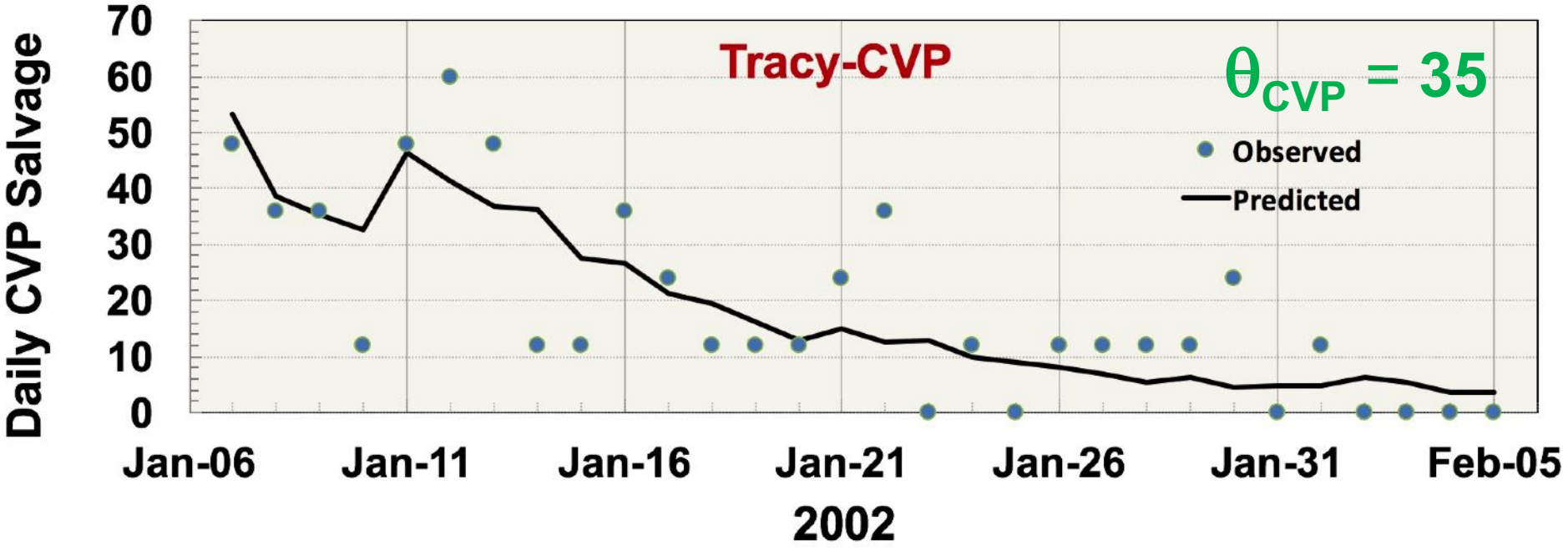


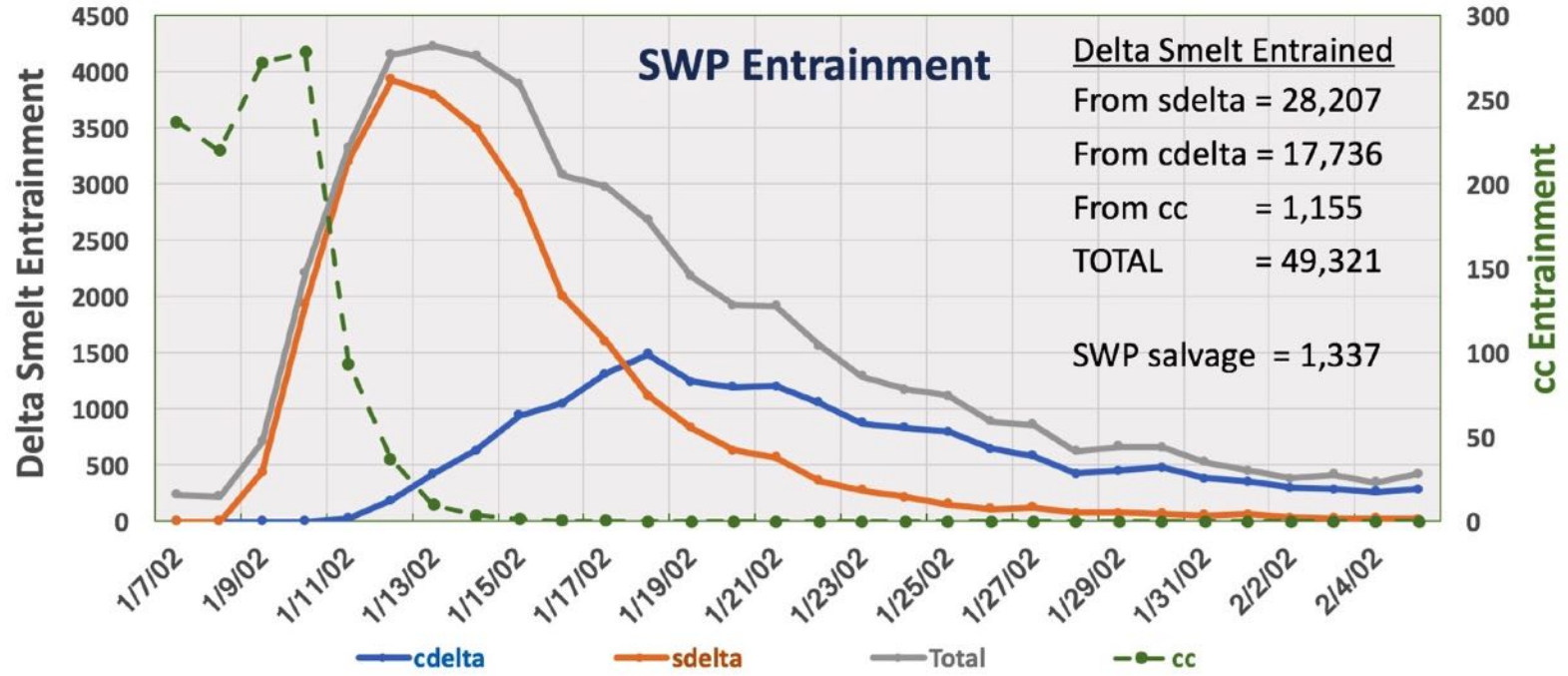
Initial estimates

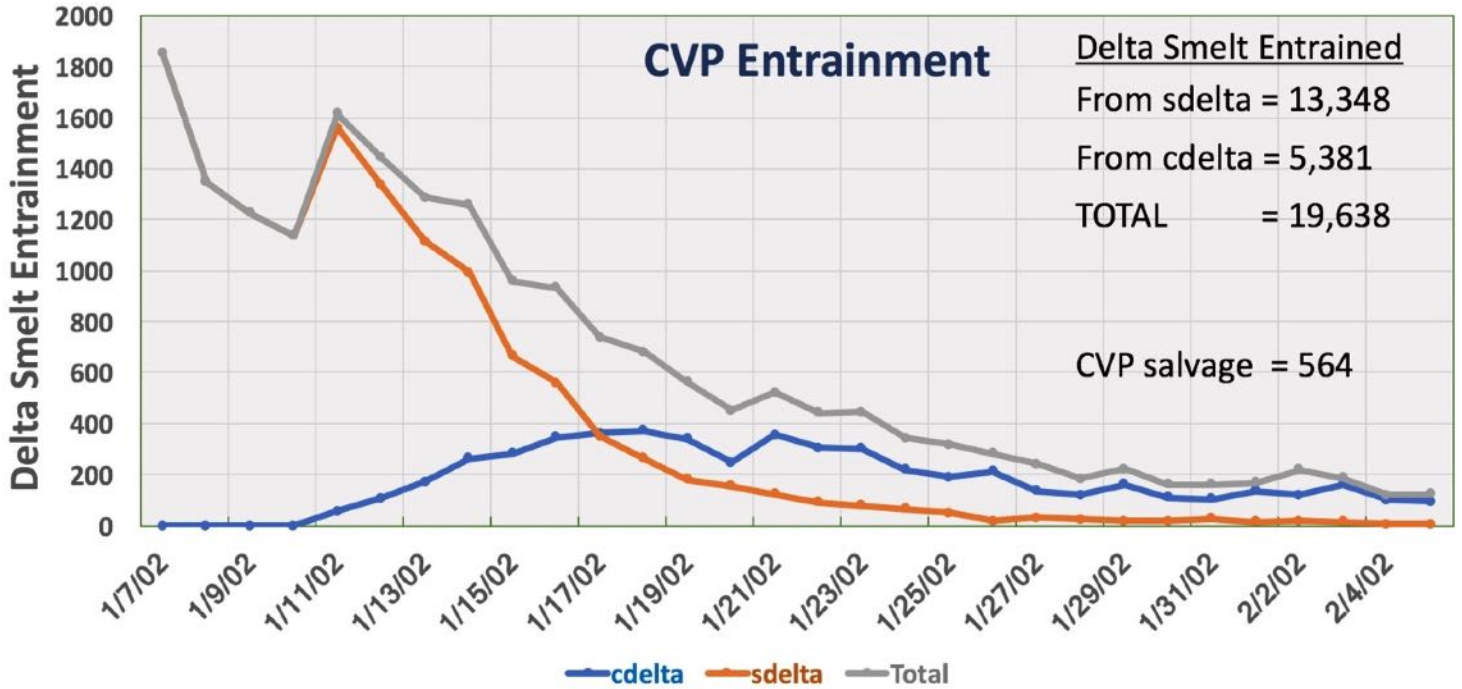


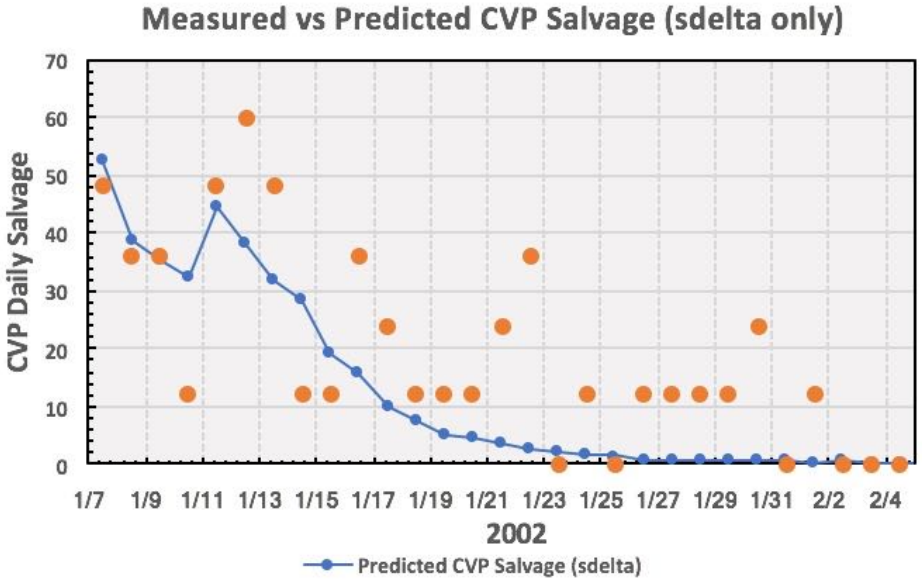
Final fitted values

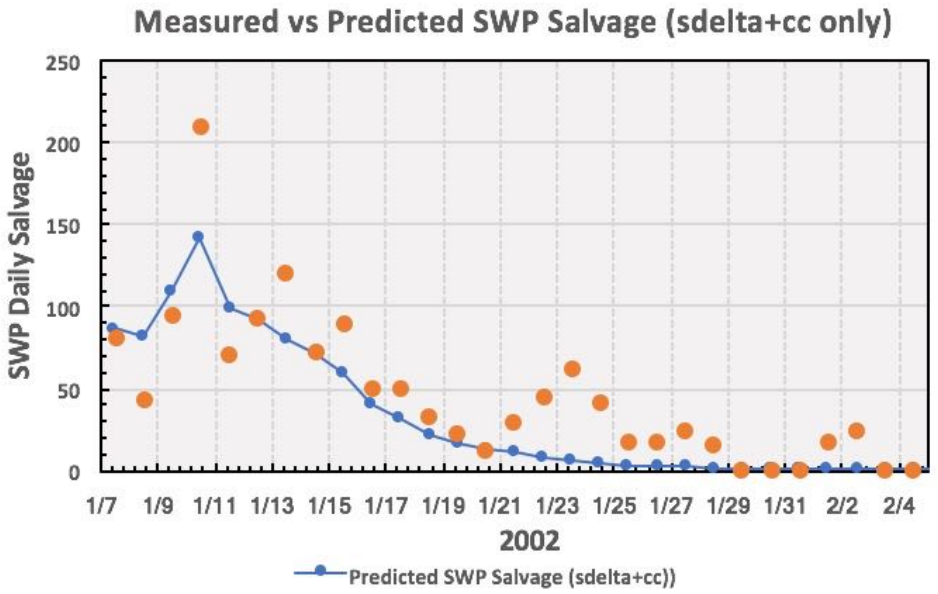

Banks-SWP
$\theta_{SWP} = 50$
Observed
Predicted
Daily SWP Salvage
225
200
175
150
125
100
75
50
25
0
Jan-06
Jan-11
Jan-16
Jan-21
Jan-26
Jan-31
Feb-05
2002

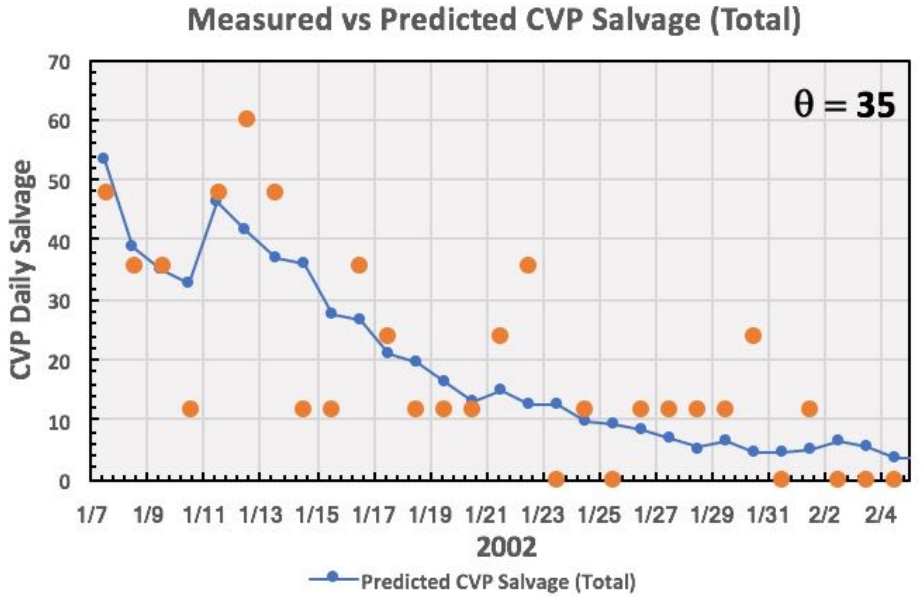

Tracy-CVP
$\theta_{CVP} = 35$
Observed
Predicted
Daily CVP Salvage
70
60
50
40
30
20
10
0
Jan-06
Jan-11
Jan-16
Jan-21
Jan-26
Jan-31
Feb-05
2002

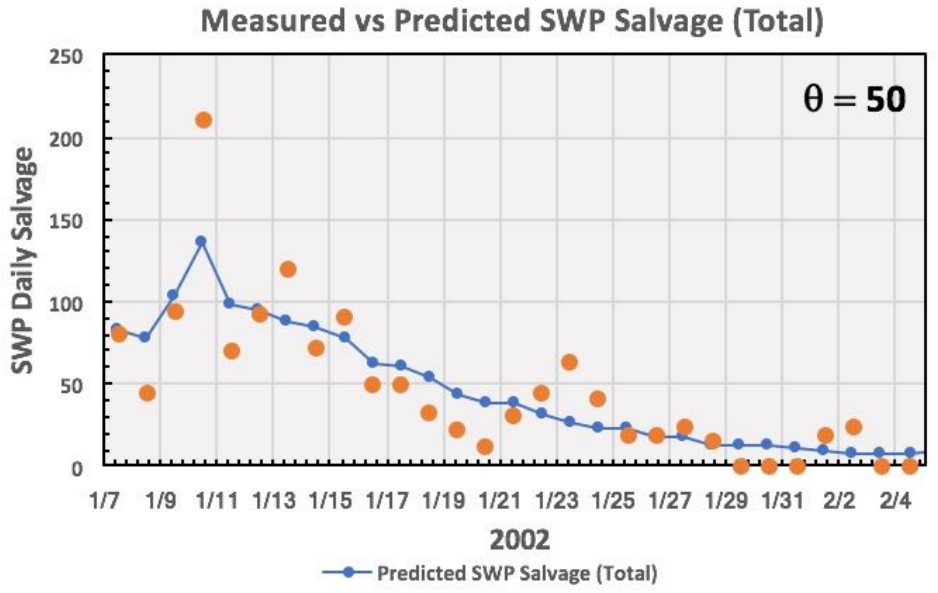

SWP Entrainment
Delta Smelt Entrained
From sdelta = 28,207
From cdelta = 17,736
From cc = 1,155
TOTAL = 49,321
SWP salvage = 1,337
Delta Smelt Entrainment
cc Entrainment
4500
4000
3500
3000
2500
2000
1500
1000
500
0
300
250
200
150
100
50
0
1/7/02
1/9/02
1/11/02
1/13/02
1/15/02
1/17/02
1/19/02
1/21/02
1/23/02
1/25/02
1/27/02
1/29/02
1/31/02
2/2/02
2/4/02
cdelta
sdelta
Total
cc


CVP Entrainment
Delta Smelt Entrained
From sdelta = 13,348
From cdelta = 5,381
TOTAL = 19,638
CVP salvage = 564
Delta Smelt Entrainment
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/7/02
1/9/02
1/11/02
1/13/02
1/15/02
1/17/02
1/19/02
1/21/02
1/23/02
1/25/02
1/27/02
1/29/02
1/31/02
2/2/02
2/4/02
cdelta
sdelta
Total


Measured vs Predicted CVP Salvage (sdelta only)
CVP Daily Salvage
70
60
50
40
30
20
10
0
1/7 1/9 1/11 1/13 1/15 1/17 1/19 1/21 1/23 1/25 1/27 1/29 1/31 2/2 2/4
2002
Predicted CVP Salvage (sdelta)

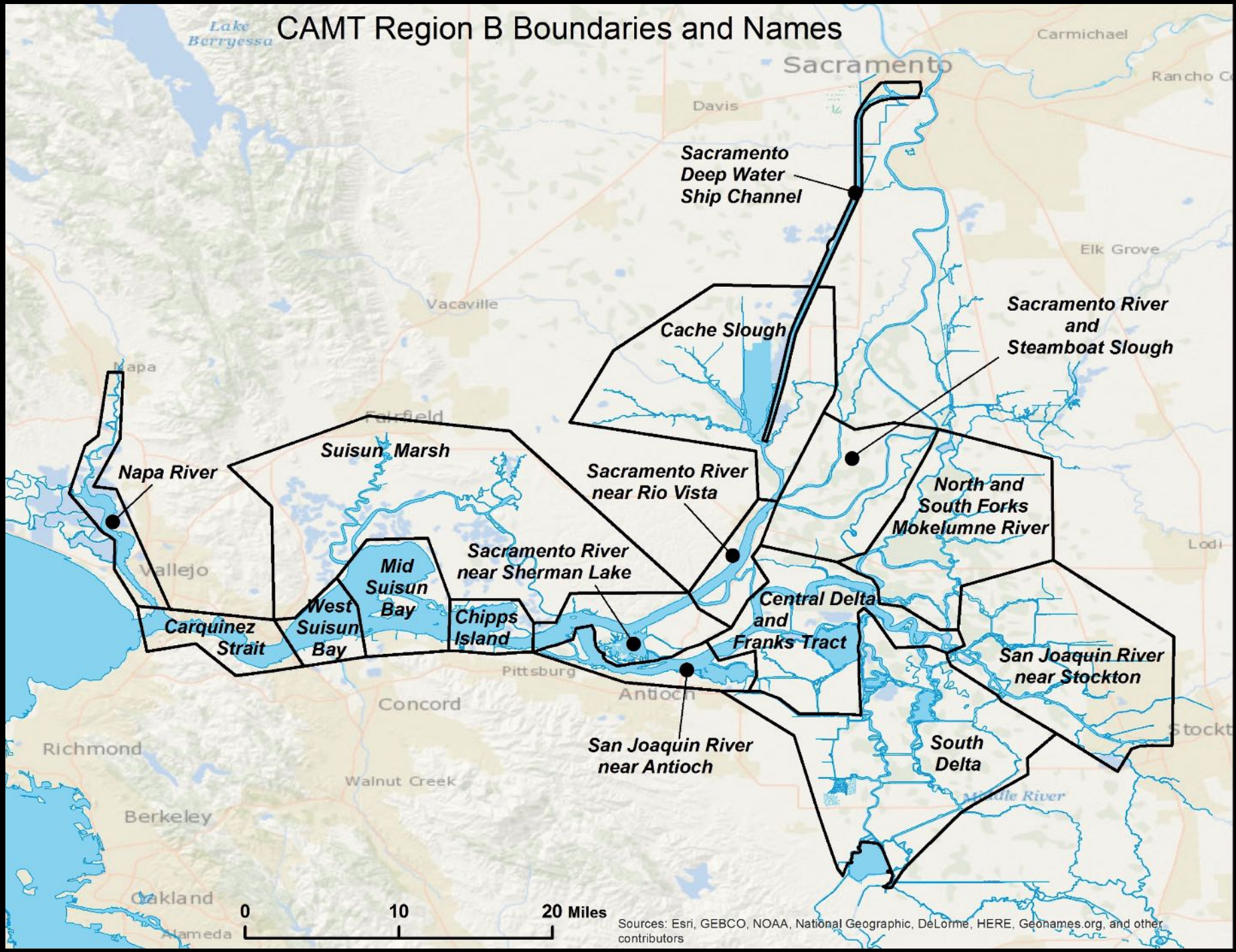

Measured vs Predicted SWP Salvage (sdelta+cc only)
SWP Daily Salvage
250
200
150
100
50
0
1/7 1/9 1/11 1/13 1/15 1/17 1/19 1/21 1/23 1/25 1/27 1/29 1/31 2/2 2/4
2002
Predicted SWP Salvage (sdelta+cc))


Measured vs Predicted CVP Salvage (Total)
θ = 35
CVP Daily Salvage
70
60
50
40
30
20
10
0
1/7 1/9 1/11 1/13 1/15 1/17 1/19 1/21 1/23 1/25 1/27 1/29 1/31 2/2 2/4
2002
Predicted CVP Salvage (Total)


Measured vs Predicted SWP Salvage (Total)
θ = 50
SWP Daily Salvage
250
200
150
100
50
0
1/7 1/9 1/11 1/13 1/15 1/17 1/19 1/21 1/23 1/25 1/27 1/29 1/31 2/2 2/4
2002
Predicted SWP Salvage (Total)

. Estimating monthly Delta Smelt populations from the SKTS data for 2002-2016

- This was relatively straightforward once Delta volumes were computed. Populations were estimated monthly during Jan-May by expanding the CPUE of Delta Smelt measured by the SKTS. A spatially stratified approach was used in which the mean CPUE per trawl for 15 or 16 strata (regions) of Delta Smelt habitat were expanded by the volume of each strata over the surface 4 meters and summed to get an index of total abundance (population) for each monthly survey.
- We have so far done no statistical processing to account for sampling error and to quantify the uncertainty in population estimates from that error.


CAMT Region B Boundaries and Names
Lake Berryessa
Sacramento
Carmichael
Davis
Elk Grove
Vacaville
Fairfield
Napa
Vallejo
Pittsburg
Antioch
Concord
Richmond
Walnut Creek
Berkeley
Oakland
Alameda
Lodi
Sacramento Deep Water Ship Channel
Cache Slough
Sacramento River and Steamboat Slough
Suisun Marsh
Napa River
Sacramento River near Rio Vista
North and South Forks Mokelumne River
Mid Suisun Bay
West Suisun Bay
Carquinez Strait
Chipps Island
Sacramento River near Sherman Lake
Central Delta and Franks Tract
San Joaquin River near Stockton
San Joaquin River near Antioch
South Delta
0
10
20 Miles
Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

SKT Summary Population Table for 15 CAMT Regions

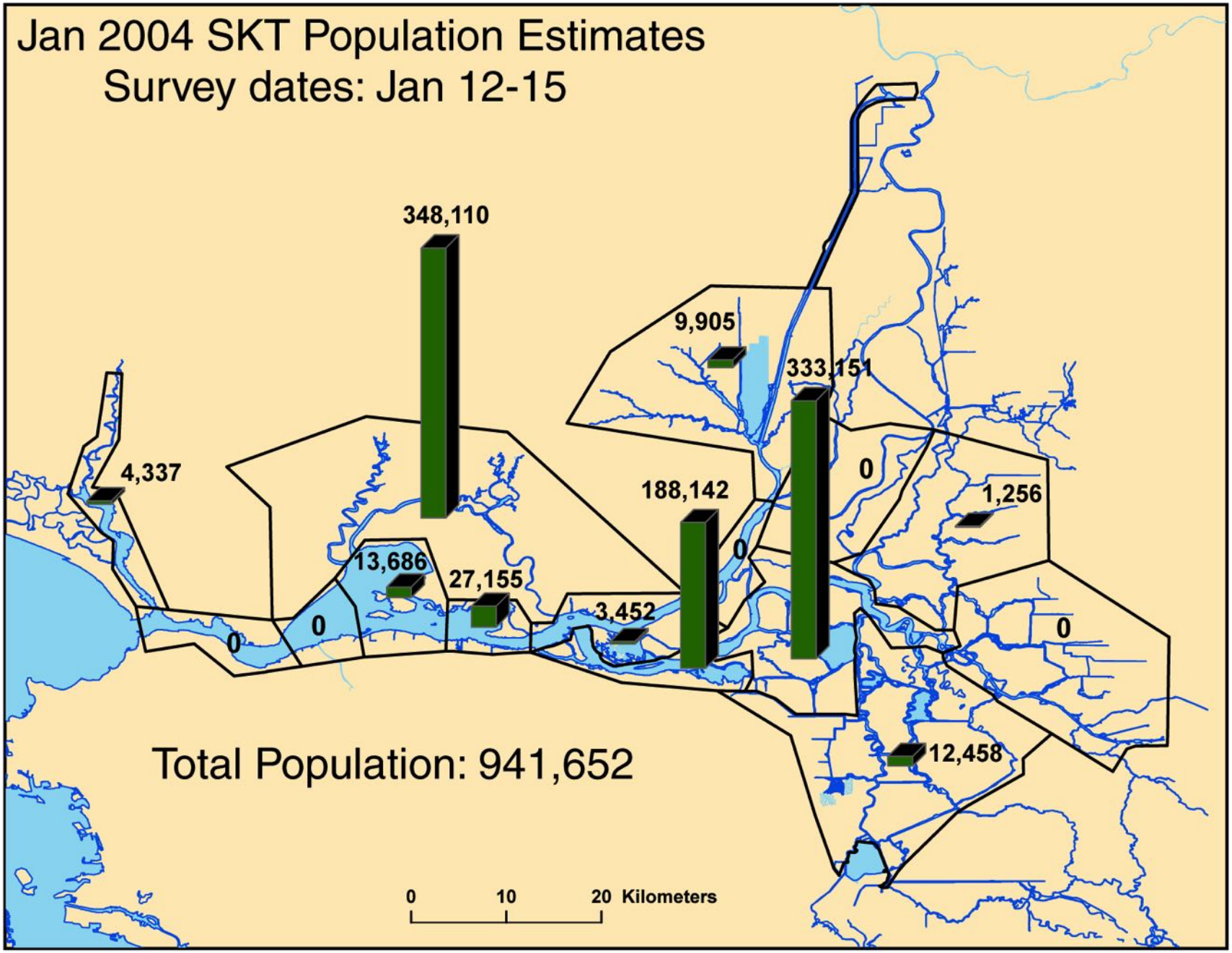
(before sampling began in the Sacramento Deep Water Ship Channel)

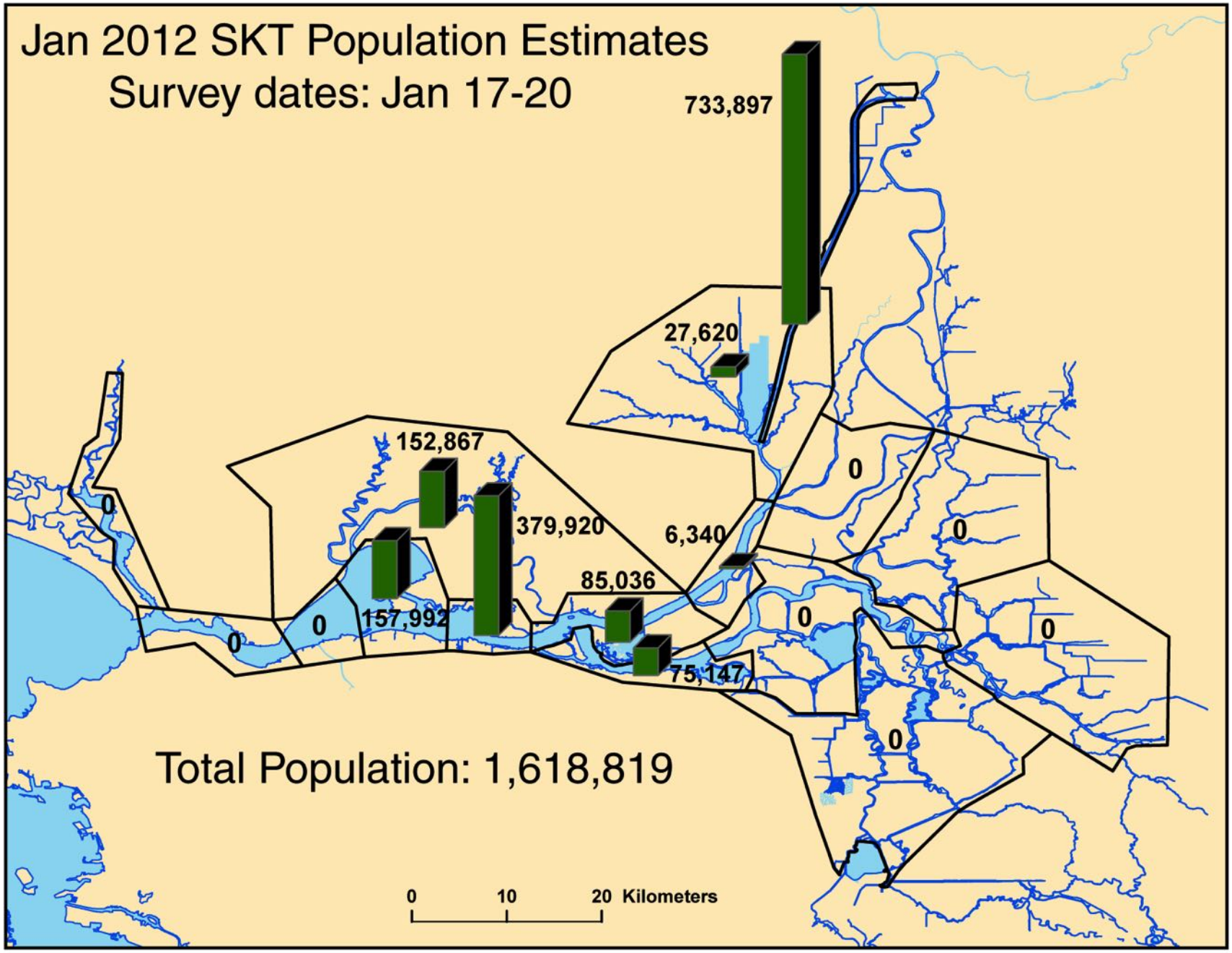
ID	Yr	Mon	mid_date	napa	carq	wsuisb	msuisb	smarsh	chipps	sac_sherm	sac_rio	cache_dwsc	sac_steam	sjr_ant	cdelta	mok	sjr_stk	sdelta	TotalPop	Comment
1	2002	Jan	8-Jan	0	32,958	12,515	75,239	287,083	44,706	18,401	0	55,395	0	139,685	134,004	3,440	0	45,319	***848,745***	
2	2002	Feb	5-Feb	0	13,878	15,086	9,564	548,501	0	56,710	4,353	7,021	1,413	166,681	192,128	0	0	0	***1,015,335***	
3	2002	Mar	5-Mar	4,146	0	5,884	0	172,266	0	160,495	168,578	97,305	1,760	8,791	52,089	5,262	0	0	***676,576***	
4	2002	Apr																		*No Survey*
5	2002	May																		*No Survey*
6	2003	Jan																		*No Survey*
7	2003	Feb	19-Feb	0	0	0	124,049	70,221	59,788	16,648	10,210	439,023	0	14,897	81,045	0	0	4,170	***820,051***	
8	2003	Mar	18-Mar	0	0	65,168	62,405	36,648	59,428	74,164	146,899	508,170	19,850	7,329	9,472	8,765	0	0	***998,298***	
9	2003	Apr	15-Apr	0	0	7,931	0	0	0	53,402	0	31,126	4,378	3,608	80,582	0	0	0	***181,027***	
10	2003	May	14-May	0	0	10,526	40,430	0	0	6,900	0	75,004	0	5,891	0	1,183	0	0	***139,934***	
11	2004	Jan	13-Jan	4,337	0	0	13,686	348,110	27,155	3,452	0	9,905	0	188,142	333,151	1,256	0	12,458	***941,652***	
12	2004	Feb	11-Feb	0	0	0	19,204	259,480	4,367	190,878	41,656	6,524	0	58,741	156,959		0	0	***737,809***	
13	2004	Mar	10-Mar	0	0	18,317	68,202	162,810	25,980	109,459	0	0	0	9,903	203,161	5,076	2,723	0	***605,631***	
14	2004	Apr	6-Apr	0	0	0	10,468	0	4,372	128,327	4,148	16,221	1,387	21,840	107,342	0	0	12,057	***306,162***	
15	2004	May	5-May	0	0	0	0	0	0	3,190	5,474	13,039	0	15,859	12,425	0	0	0	***49,987***	
16	2005	Jan	26-Jan	0	0	17,206	139,695	169,271	36,352	177,482	6,827	102,203	0	0	47,201	2,199	0	7,975	***706,411***	

SKT Summary Population Table for 16 CAMT Regions

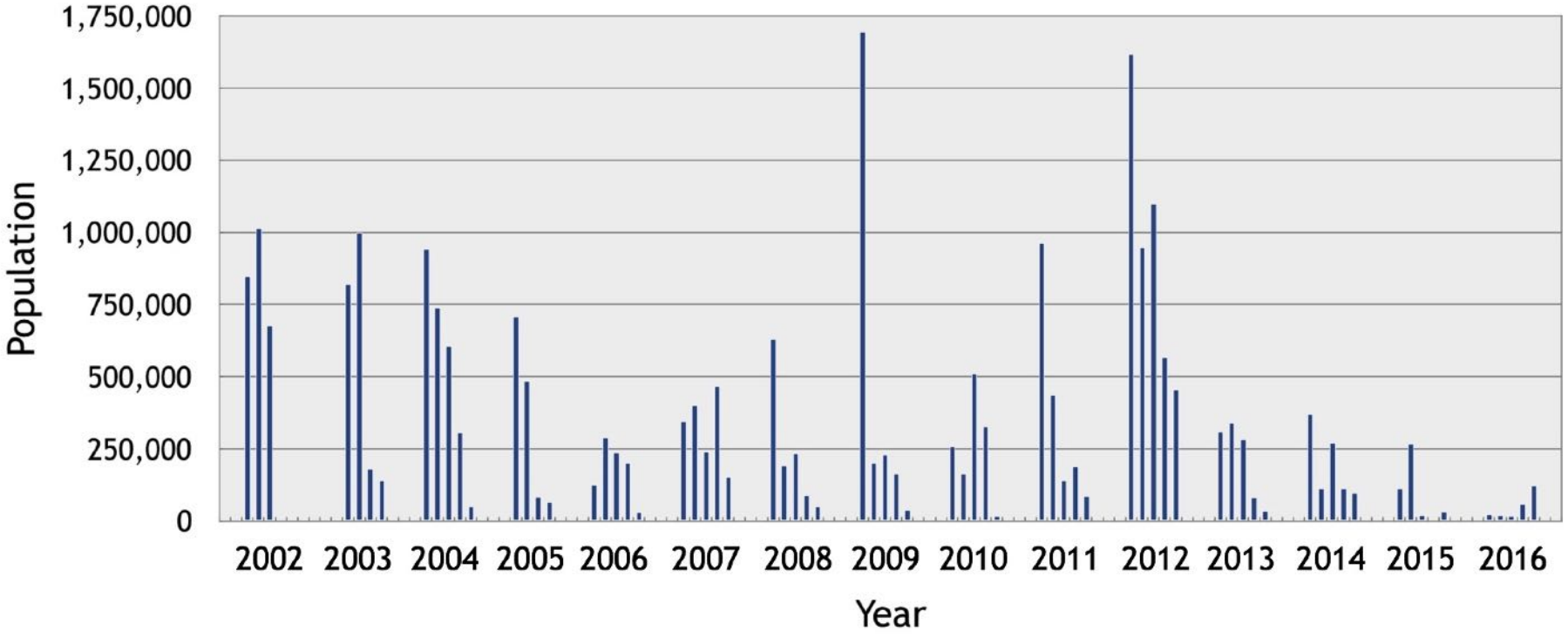
(after sampling began in the Sacramento Deep Water Ship Channel)

ID	Yr	Mon	mid_date	napa	carq	wsuisb	msuisb	smarsh	chipps	sac_sherm	sac_rio	cache	sac_steam	sjr_ant	cdelta	mok	sjr_stk	sdelta	sdwsc	TotPop	Comment
1	2005	Feb	23-Feb	13,345	0	0	16,281	207,789	9,568	39,751	0	76,930	0	3,014	0	0	0	0	117,301	***483,979***	
2	2005	Mar	23-Mar	0	0	0	7,478	6,789	12,719	21,336	0	20,087	899	0	0	0	0	0	14,233	***83,541***	
3	2005	Apr	19-Apr	0	0	5,678	0	1,890	4,315	11,383	9,057	8,303	0	0	0	0	0	0	24,939	***65,565***	
4	2005	May																			*No Survey*
5	2006	Jan	18-Jan	25,342	10,099	13,407	0	38,851	8,435	0	0	5,619	0	9,341	5,073	0	0	0	9,423	***125,590***	
6	2006	Feb	15-Feb	48,186	10,893	9,167	85,016	47,368	12,684	0	4,144	26,970	0	4,614	0	1,808	0	14,154	22,804	***287,808***	
7	2006	Mar	15-Mar	53,208	0	5,408	18,972	8,960	18,340	6,319	0	34,838	0	0	12,504	995	0	0	77,198	***236,742***	
8	2006	Apr	11-Apr	6,460	0	0	0	1,862	3,909	6,584	0	0	0	4,324	4,747	913	0	5,361	166,879	***201,039***	
9	2006	May	9-May	0	0	0	12,804	0	10,683	0	0	1,936	0	3,480	0	1,351	0	0	0	***30,254***	
10	2007	Jan	9-Jan	0	0	0	0	96,040	62,541	78,904	8,299	38,336	0	14,419	27,161	0	0	0	19,728	***345,428***	
11	2007	Feb	7-Feb		0	0	0	27,148	61,870	124,389	0	2,444	0	0	0	0	0	0	185,642	***401,493***	
12	2007	Mar	7-Mar	0	0	0	14,029	75,197	35,610	21,267	0	15,683	0	0	0	0	0	0	77,565	***239,351***	
13	2007	Apr	3-Apr	0	0	0	0	8,905	11,827	34,246	3,576	5,720	0	0	0	0	0	0	403,530	***467,804***	
14	2007	May	2-May	0	0	0	0	6,072	0	8,339	3,937	0	0	0		0			133,625	***151,973***	
15	2008	Jan	9-Jan	0	15,079	0	77,116	7,146	41,047	325,854	4,015	23,351	0	0	6,539	0	0	0	131,879	***632,026***	
16	2008	Feb	6-Feb		0	0	0	0	12,007	6,173	0	33,169	0	0	5,436	1,381	0	0	133,208	***191,374***	
17	2008	Mar	12-Mar	0	0	0	0	8,212	5,063	4,344	4,743	12,443	0	0	11,741	0	0	0	187,169	***233,715***	
18	2008	Apr	9-Apr	0	0	0	0	0	0	0	29,423	0	0	0	0	0	0	0	59,285	***88,708***	
19	2008	May	7-May	0	0	0	0	0	0	9,838	9,602	2,278	0	0	0	0	0	0	27,911	***49,629***	
20	2009	Jan	14-Jan	0	0	0	0	95,903	74,714	471,861	72,022	0	0	0	12,489	0	0	0	967,895	***1,694,884***	
21	2009	Feb	10-Feb	0	0	0	0	72,134	0	89,115	0	0	0	0	0	0	0	0	39,798	***201,047***	
22	2009	Mar	17-Mar	0	0	0	0	6,133	7,685	4,459	0	2,926	0	0	36,485	1,451	0	0	170,665	***229,804***	
23	2009	Apr	14-Apr	0	0	0	0	0	0	22,091	0	5,635	0	0	16,942	0	0	0	118,594	***163,262***	
24	2009	May	12-May	0	0	0	0	4,537	0	0	0	0	0	0	0	0	0	0	33,652	***38,189***	
25	2010	Jan	12-Jan	0	0	0	7,941	128,479	17,093	70,710	0	11,543	0	0	0	0	0	0	21,169	***256,935***	
26	2010	Feb	9-Feb	0	0	7,349	0	76,415	5,633	13,829	0	26,946	0	0	23,939	0	0	0	9,355	***163,466***	
27	2010	Mar	9-Mar	0	0	0	0	3,501	21,089	50,080	7,872	54,458	0	0	0	0	0	0	374,152	***511,152***	
28	2010	Apr	6-Apr	0	0	0	0	0	3,741	32,095	0	0	0	0	0	0	0	0	291,857	***327,693***	
29	2010	May	4-May	0	0	0	0	0	0	7,401	0	4,234	0	0	0	0	0	0	4,582	***16,217***	
30	2011	Jan	11-Jan	0	0	0	6,505	30,075	3,228	28,530	47,080	8,414	0	0	9,901	0	2,588	8,693	817,874	***962,888***	
31	2011	Feb	9-Feb	0	0	0	6,087	101,589	15,794	3,406	0	9,829	0	0	4,810	0	2,458	0	292,824	***436,797***	
32	2011	Mar	8-Mar	0	0	0	6,118	41,418	6,789	17,906	3,745	8,014	1,216	0	0	0	0	0	55,664	***140,870***	
33	2011	Apr	5-Apr	0	0	0	21,483	7,384	3,650	0	0	2,172	0	0	12,587	0	0	0	140,089	***187,365***	
34	2011	May	3-May	0	0	0	23,035	0	0	5,895	0	8,143	0	0	0	1,871	0	0	47,170	***86,114***	
35	2012	Jan	18-Jan	0	0	0	157,992	152,867	379,920	85,036	6,340	27,620	0	75,147	0	0	0	0	733,897	***1,618,819***	
36	2012	Feb	14-Feb	6,677	0	10,772	18,164	99,282	399,405	94,477	0	3,894	0	3,315	75,643	0	0	0	235,711	***947,340***	
37	2012	Mar	6-Mar						0	23,422	72,871	838,819	0	28,467	0	0	0	0	135,272	***1,098,851***	
38	2012	Apr	3-Apr	0	11,766	30,173	156,219	101,565	20,976	55,339	9,048	62,812	0	12,145	62,064	1,774	0	0	44,145	***568,026***	
39	2012	May	2-May	0	10,455	12,782	64,843	3,624	36,754	39,383	13,560	138,755	0	15,274		0			119,401	***454,831***	
40	2013	Jan	8-Jan	0	0	0	19,548	40,101	11,604	3,210	9,444	18,390	0	0	71,213	1,274	0	0	134,576	***309,360***	
41	2013	Feb	5-Feb	0	0	0	0	93,961	5,679	0	0	0	0	0	3,868	0	0	0	236,520	***340,028***	
42	2013	Mar	5-Mar	0	0	0	0	20,406	21,244	88,280	0	0	0	0	48,007	0	0	0	104,989	***282,926***	
43	2013	Apr	3-Apr	0	0	0	0	3,899	0	28,859	0	6,381	0	2,851	24,197	0	0	0	16,072	***82,259***	
44	2013	May	2-May	0	0	0	0	6,676		4,688	2,660	1,982	0						18,381	***34,387***	
45	2014	Jan	14-Jan	0	0	0	0	187,321	20,893	94,660	6,877	17,182	0	37,423	0	0	0	0	4,500	***368,856***	
46	2014	Feb	11-Feb	0	0	0	0	45,253	0	10,780	3,466	11,863	7,616	22,353	0	1,419	0	0	9,175	***111,925***	
47	2014	Mar	11-Mar	0	0	0	0	42,277	0	14,603	10,049	25,727	0	0	7,316	0	0	0	171,284	***271,256***	
48	2014	Apr	8-Apr	0	0	0	6,323	3,045	0	3,010	2,941	2,288	0	14,275	0	0	0	0	80,780	***112,662***	
49	2014	May	6-May	0	0	0	0	1,536	0	3,653	0	0	0	0	9,217	0	0	0	81,594	***96,000***	
50	2015	Jan	13-Jan	0	0	0	0	13,015	5,344	25,317	0	0	0	3,822	28,139	0	0	0	35,205	***110,842***	
51	2015	Feb	10-Feb	0	0	0	0	41,298	0	133,221	6,838	6,719	0	4,880	59,362	0	0	6,356	7,894	***266,568***	
52	2015	Mar	10-Mar	0	0	0	0	1,516	0	0	10,244	0	0	0	0	0	0	0	6,869	***18,629***	
53	2015	Apr	7-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,212	***3,212***	
54	2015	May	5-May	0	0	0	0	0	0	0	0	3,665	0	0	0	0	0	0	29,122	***32,787***	
55	2016	Jan	12-Jan	0	0	0	0	2,236	0	6,431	11,910	2,372	0	0	0	0	0	0	0	***22,949***	
56	2016	Feb	9-Feb	0	0	0	0	2,721	0	0	0	3,582	0	3,358	5,355	0	0	0	4,875	***19,891***	
57	2016	Mar	8-Mar	0	0	0	0	1,550	0	0	0	0	0	0	0	0	0	0	16,762	***18,312***	
58	2016	Apr	5-Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57,735	***57,735***	
59	2016	May	3-May		0	0	0	6,344	0	0	0	0	0	0	0	0	0	0	115,184	***121,528***	

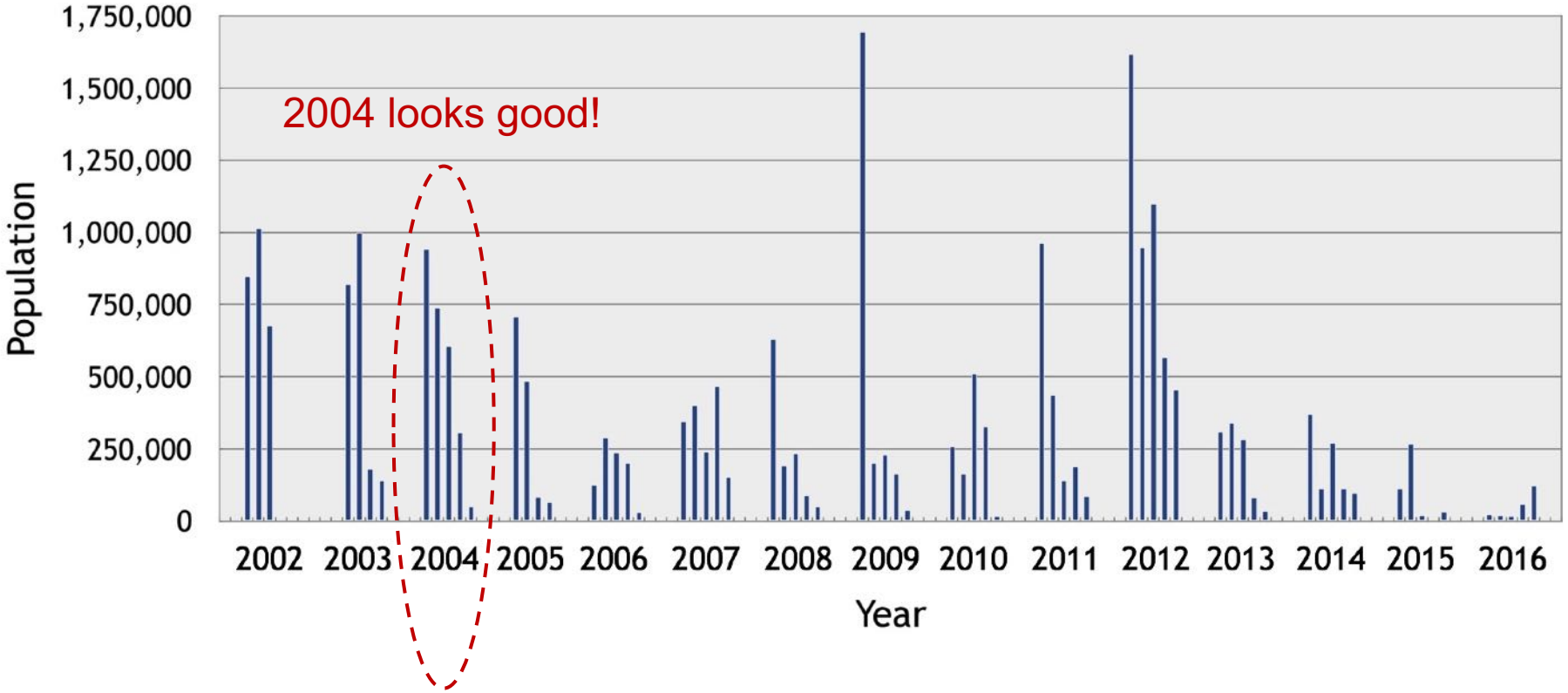

Jan 2004 SKT Population Estimates
Survey dates: Jan 12-15
348,110
9,905
333,151
4,337
188,142
0
1,256
13,686
27,155
3,452
0
0
0
0
12,458
Total Population: 941,652
0
10
20 Kilometers


Jan 2012 SKT Population Estimates
Survey dates: Jan 17-20
733,897
27,620
152,867
379,920
6,340
85,036
157,992
75,147
0
0
0
0
0
0
0
0
Total Population: 1,618,819
0
10
20 Kilometers

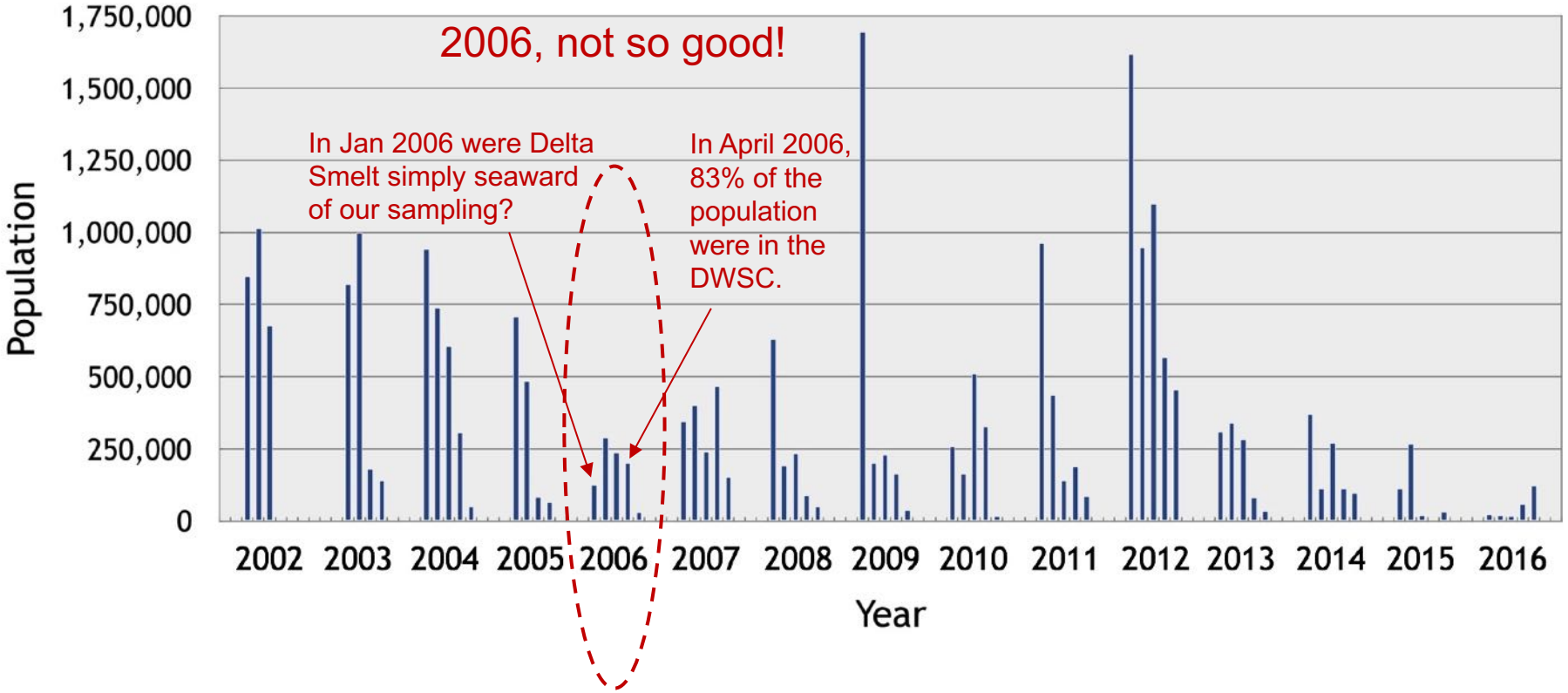
SKT Unadjusted Delta Smelt Populations by Month



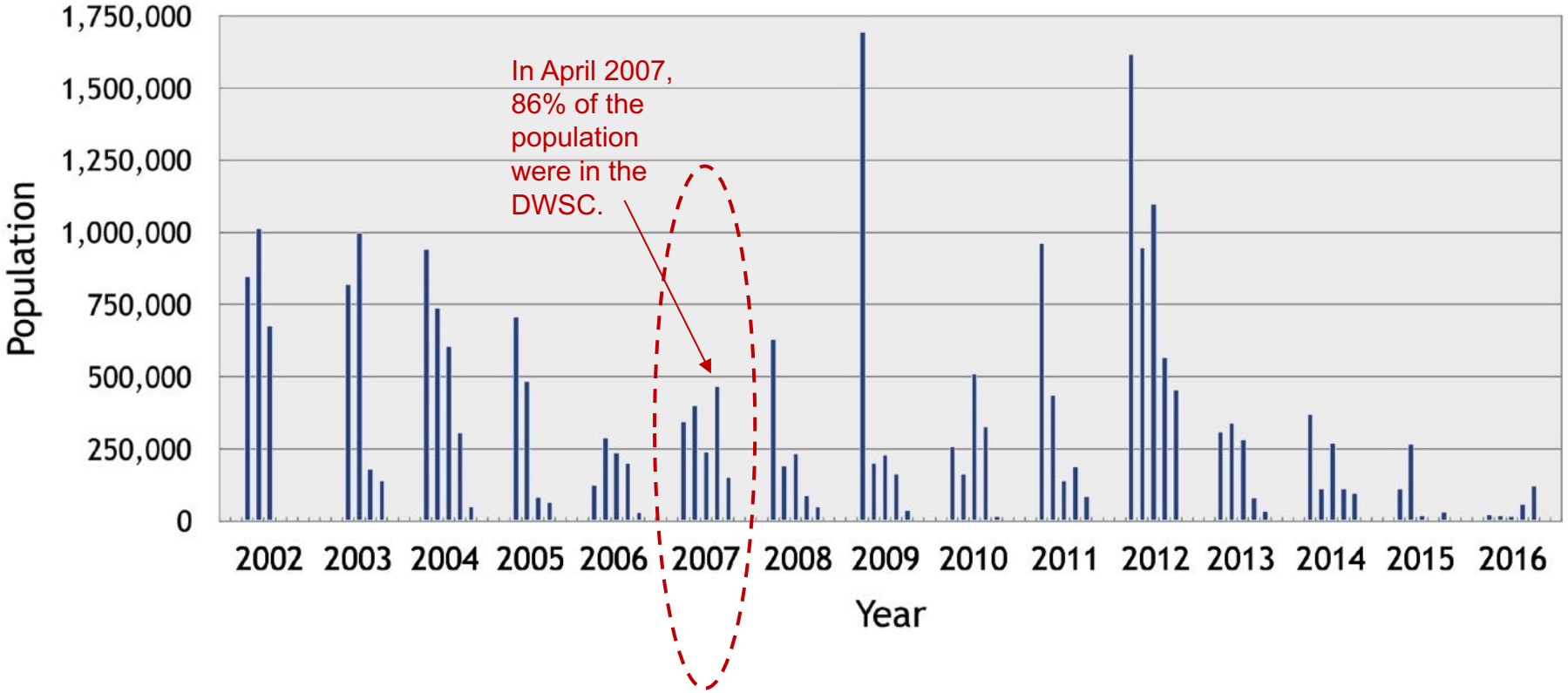
SKT Unadjusted Delta Smelt Populations by Month



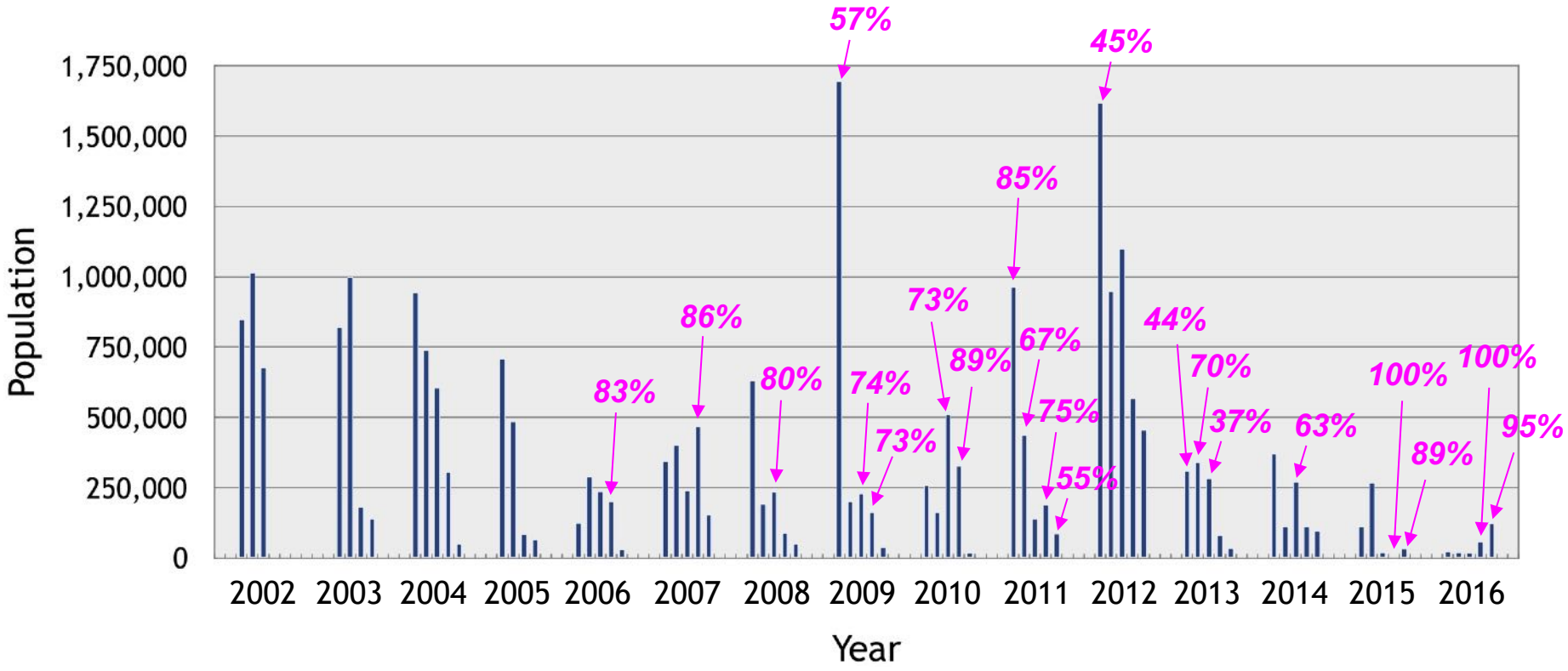
SKT Unadjusted Delta Smelt Populations by Month



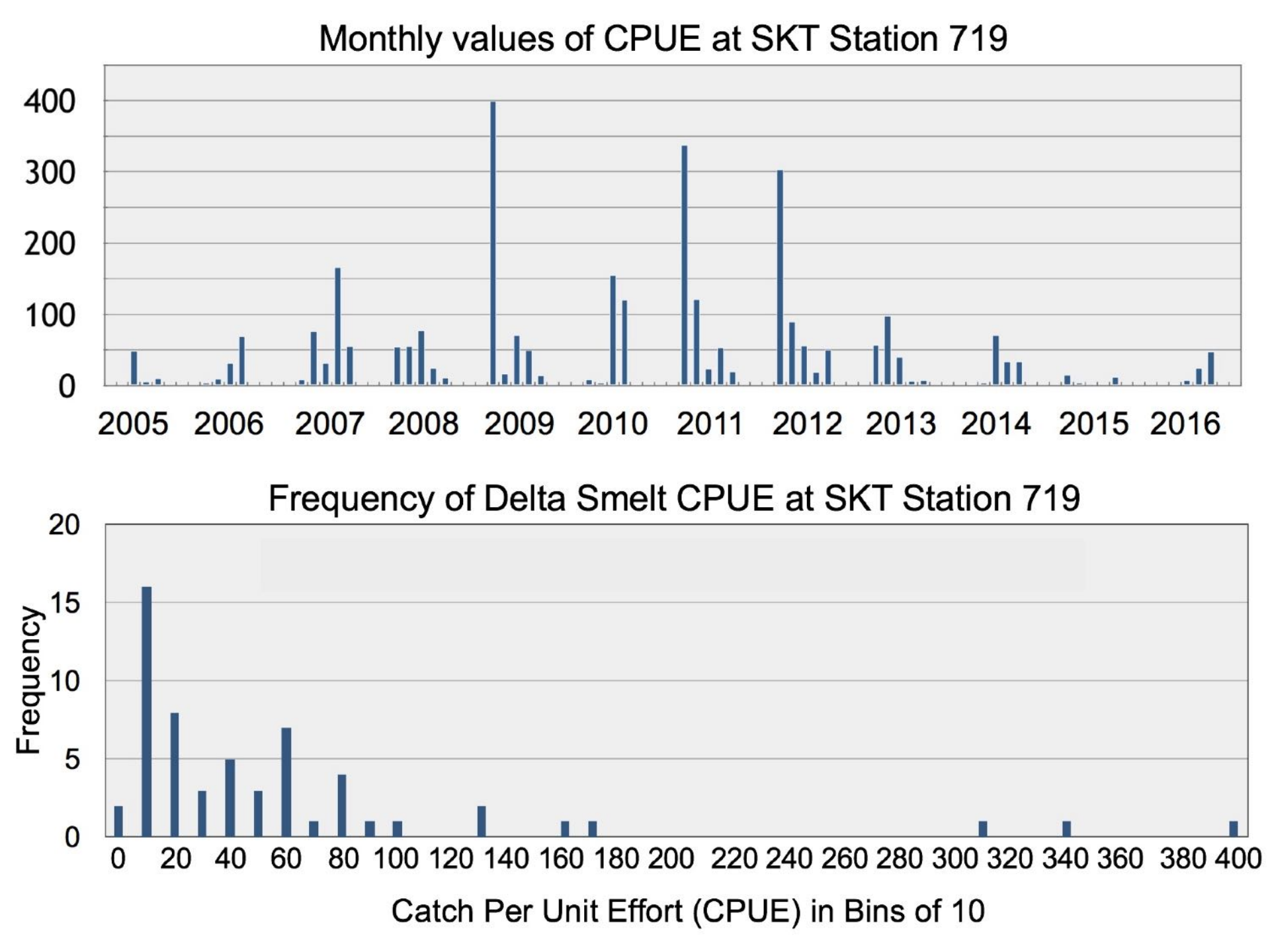
SKT Unadjusted Delta Smelt Populations by Month

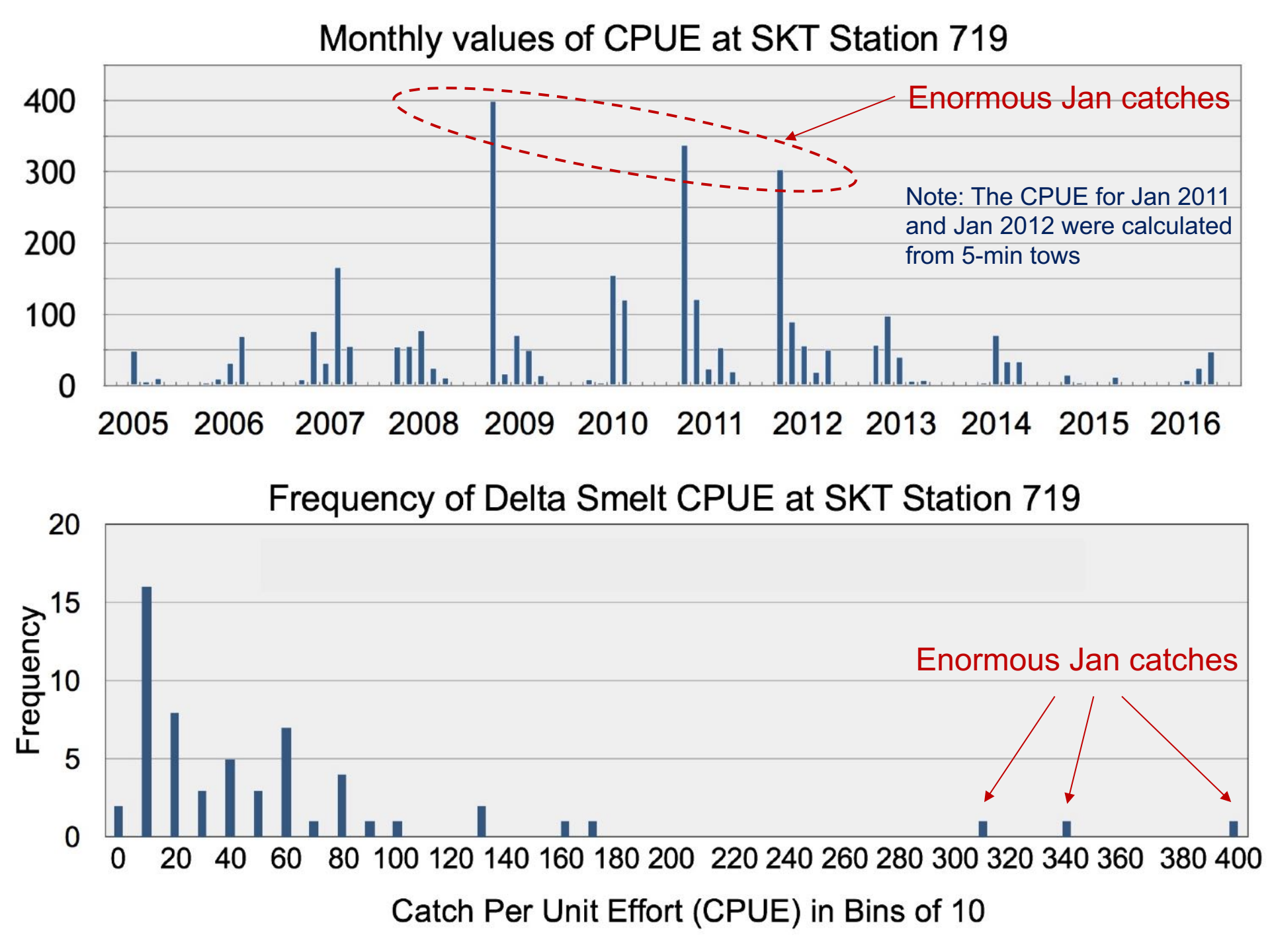


SKT Unadjusted Delta Smelt Populations by Month



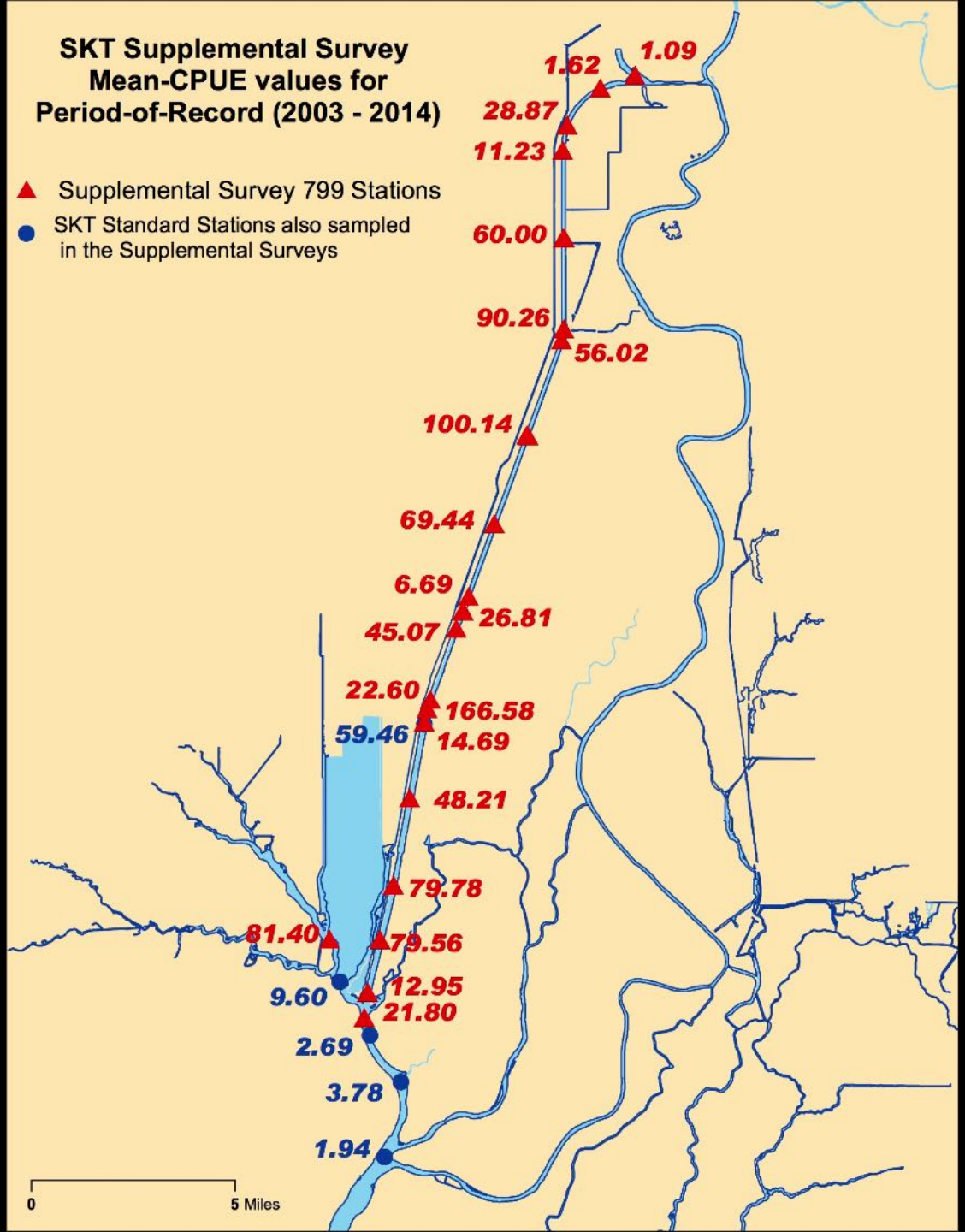
Note: The percentages shown are the percentage of the total monthly population calculated to be within the Sacramento Deep Water Ship Channel


Monthly values of CPUE at SKT Station 719
400
300
200
100
0
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Frequency of Delta Smelt CPUE at SKT Station 719
Frequency
20
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
Catch Per Unit Effort (CPUE) in Bins of 10


Monthly values of CPUE at SKT Station 719
400
300
200
100
0
Enormous Jan catches
Note: The CPUE for Jan 2011 and Jan 2012 were calculated from 5-min tows
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Frequency of Delta Smelt CPUE at SKT Station 719
Frequency
20
15
10
5
0
Enormous Jan catches
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
Catch Per Unit Effort (CPUE) in Bins of 10

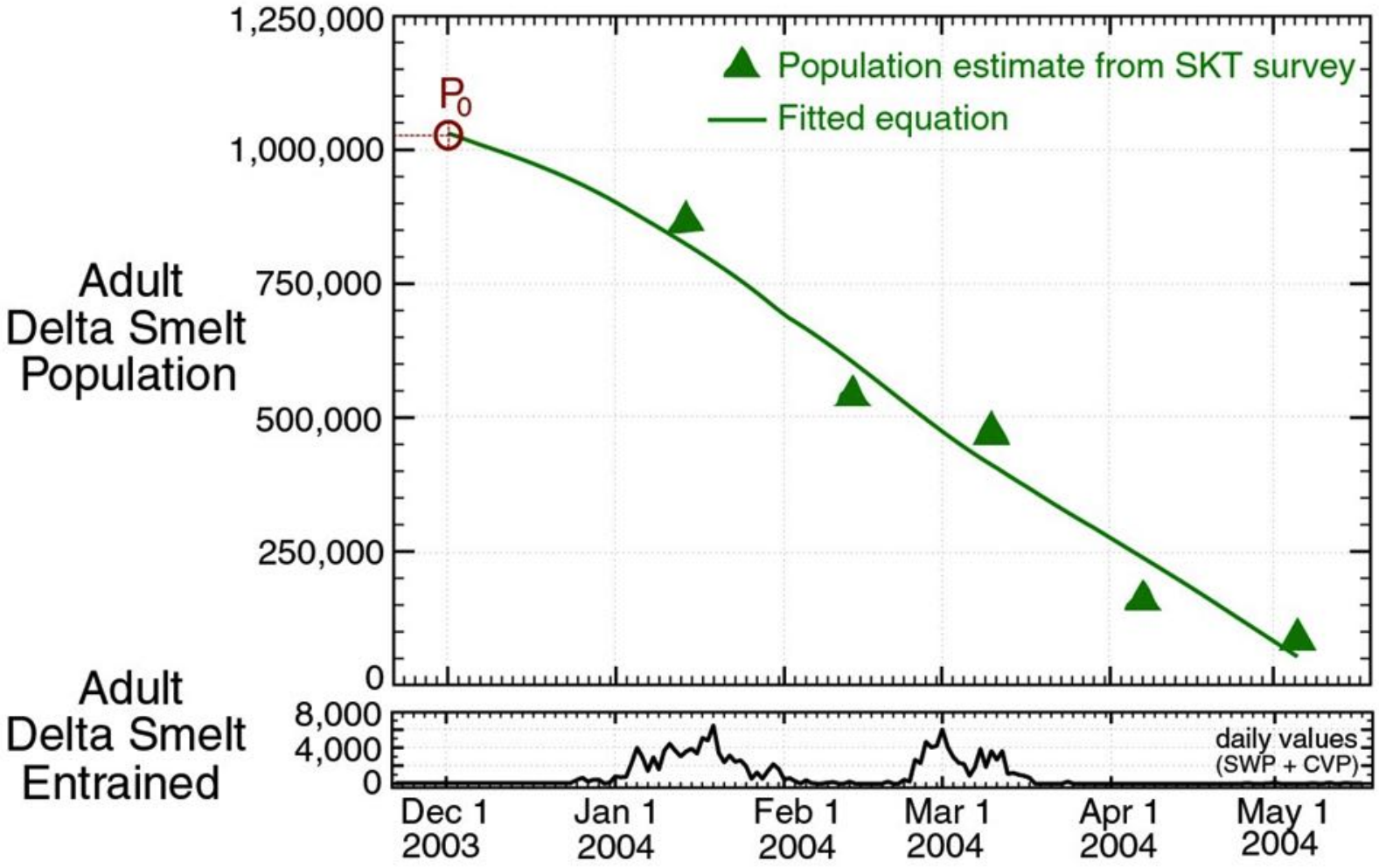
Fourteen pairs of 5-minute consecutive tows from the SKTS at Station 719 in the Sacramento Deep Water Ship Channel

Sample Date	Catch	Survey No.	Station Code	Sample Start Time	Sample End Time	Secchi	EC Top	Water Temp	Turb	Sample Volume	CPUE
18-Mar-09	29	3	719	9:35	9:40	50	50	13.3		3,572	81.2
18-Mar-09	21	3	719	9:49	9:53	50	50	13.3		3,522	59.6
12-May-09	3	5	719	10:13	10:23	43	573	18.8		2,925	10.3
12-May-09	6	5	719	10:26	10:31	43	573	18.8		3,426	17.5
13-Jan-10	3	1	719	10:17	10:23	40	511	9.5		2,908	10.3
13-Jan-10	2	1	719	10:31	10:37	40	511	9.5		2,797	7.2
10-Feb-10	1	2	719	9:26	9:31	35	505	10.7		2,616	3.8
10-Feb-10	1	2	719	9:41	9:46	35	505	10.7		2,567	3.9
5-May-10	1	5	719	9:08	9:13	33	505	18	20	5,407	1.8
5-May-10	1	5	719	9:20	9:25	33	505	18		5,178	1.9
6-Apr-11	2	4	719	10:15	10:20	46	670	14.9	18	4,836	4.1
6-Apr-11	45	4	719	10:25	10:30	46	670	14.9	18	4,037	111.5
4-May-11	8	5	719	9:56	10:01	38	537	17	25	3,979	20.1
4-May-11	7	5	719	10:08	10:13	38	537	17	25	3,720	18.8
15-Feb-12	4	2	719	11:06	11:11	36	386	10.6	31	4,136	9.7
15-Feb-12	64	2	719	11:20	11:25	36	386	10.6	31	3,463	184.8
8-Mar-12	30	3	719	11:41	11:46	25	554	11.9	40	3,667	81.8
8-Mar-12	11	3	719	11:54	11:59	25	554	11.9	40	3,689	29.8
2-May-12	21	5	719	10:30	10:35	32	646	18.8	25	3,033	69.2
2-May-12	8	5	719	10:15	10:20	32	646	18.8	25	2,731	29.3
9-Jan-13	17	1	719	11:07	11:12	22	469	8.1	74	3,465	49.1
9-Jan-13	29	1	719	11:23	11:28	22	469	8.1	74	4,678	62.0
6-Feb-13	31	2	719	9:46	9:51	30	529	9.5	42	3,738	82.9
6-Feb-13	46	2	719	9:31	9:36	30	529	9.5	42	4,098	112.2
6-Mar-13	20	3	719	9:14	9:19	70	428	12.2	17	2,929	68.3
6-Mar-13	7	3	719	9:26	9:31	70	428	12.2	17	3,815	18.3
11-Mar-15	1	3	719	10:56	11:01	49	451	15.3	16	3,597	2.8
11-Mar-15	1	3	719	11:09	11:14					3,463	2.9


SKT Supplemental Survey
Mean-CPUE values for
Period-of-Record (2003 - 2014)
Supplemental Survey 799 Stations
SKT Standard Stations also sampled
in the Supplemental Surveys
1.09
1.62
28.87
11.23
60.00
90.26
56.02
100.14
69.44
6.69
26.81
45.07
22.60
166.58
59.46
14.69
48.21
79.78
81.40
79.56
12.95
9.60
21.80
2.69
3.78
1.94
0
5 Miles

. Estimating natura mortality, a reference population (Dec 15), and the adult proportional entrainment loss for each water year from 200 - 2016

- This was accomplished by fitting a daily population model with exponential natural mortality to the five monthly population estimates for each year of the Spring Kodiak Trawl Survey.
- The model accounts for daily entrainment losses estimated from the salvage data and estimates the proportional entrainment loss (PEL).
- The fitting was done using the Java Apache Commons mathematical library.



The delta smelt population will be modeled by assuming that the population declines over time as a function of natural mortality and entrainment.

$$\Delta P = P_0\left(1 - e^{-k\Delta t}\right) + E$$

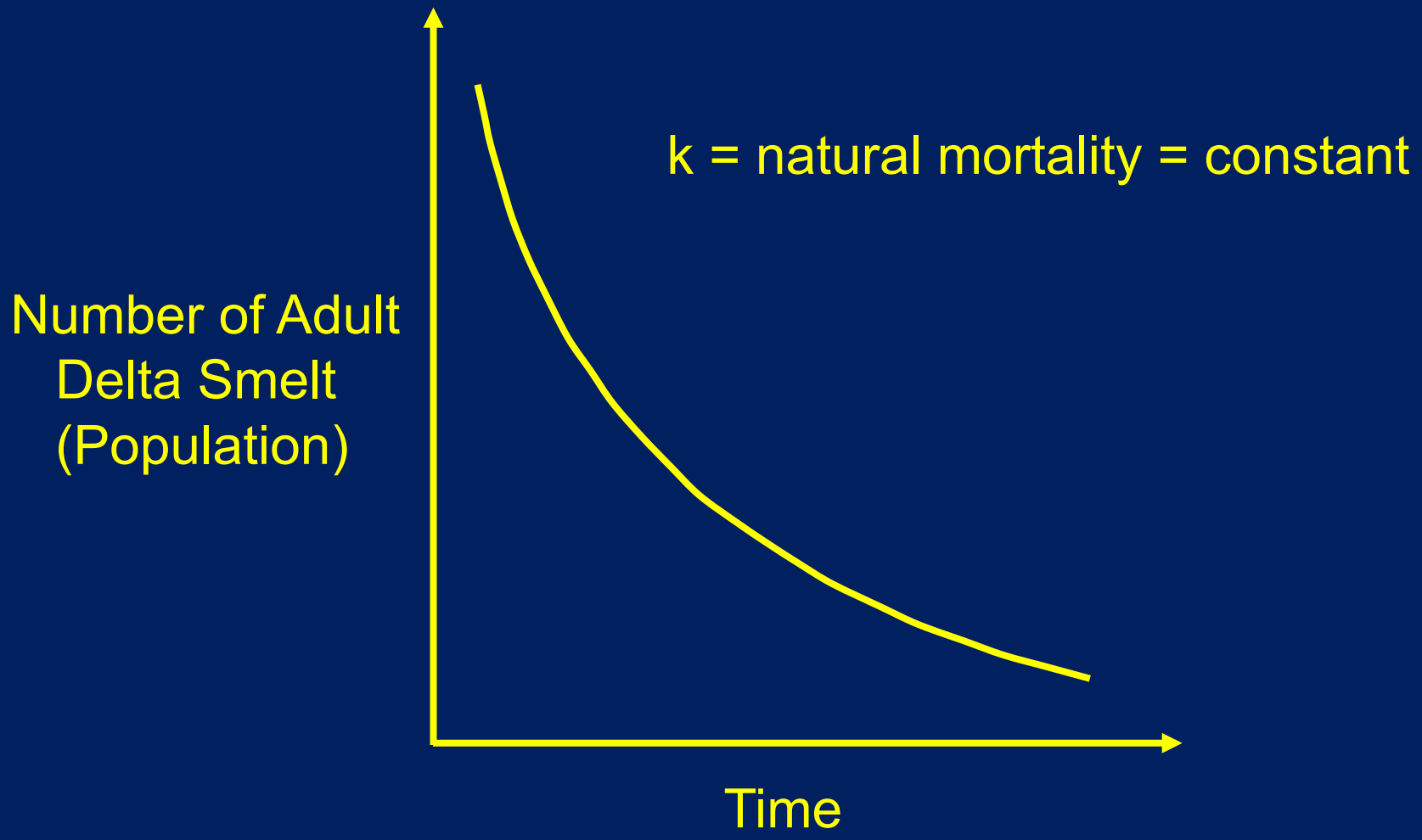
Equation to Calculate Proportional Entrainment Loss

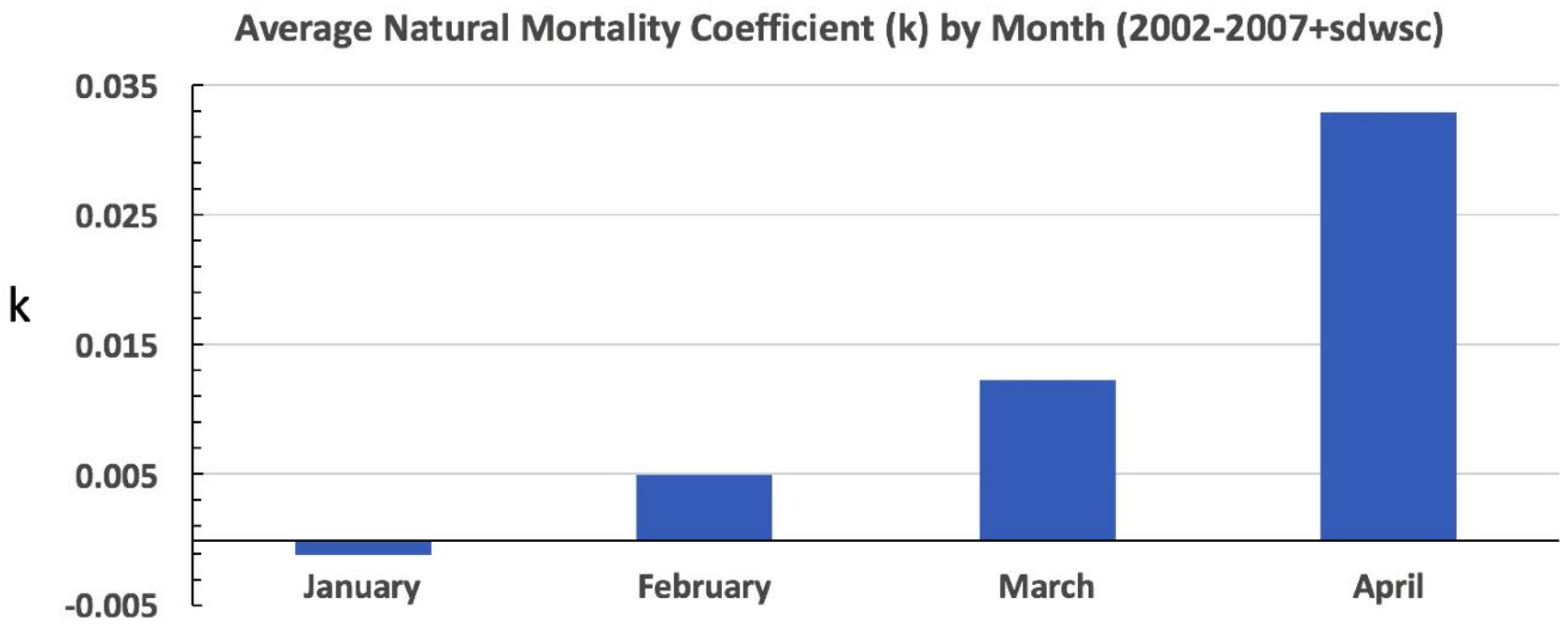
$$P_l = 1 - \prod_{d=1}^{D} \left(1 - \frac{E_d}{P_d}\right)$$

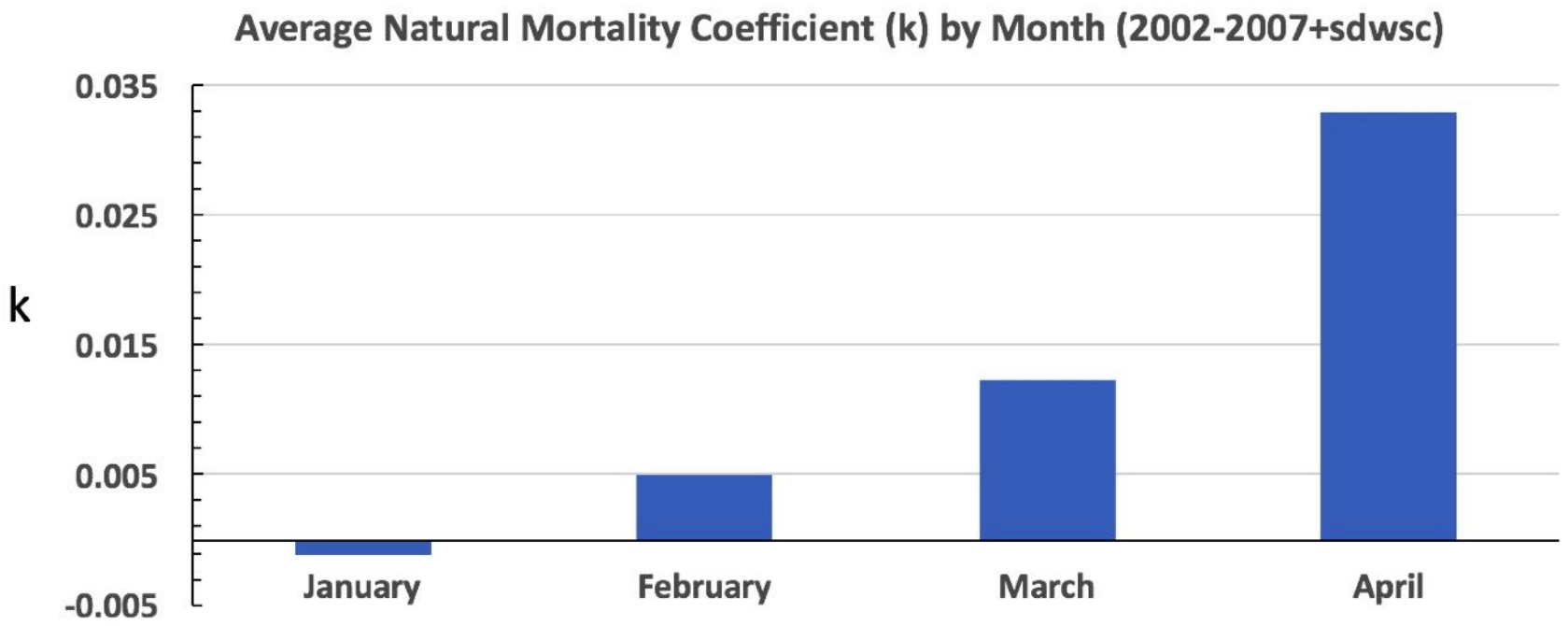
where

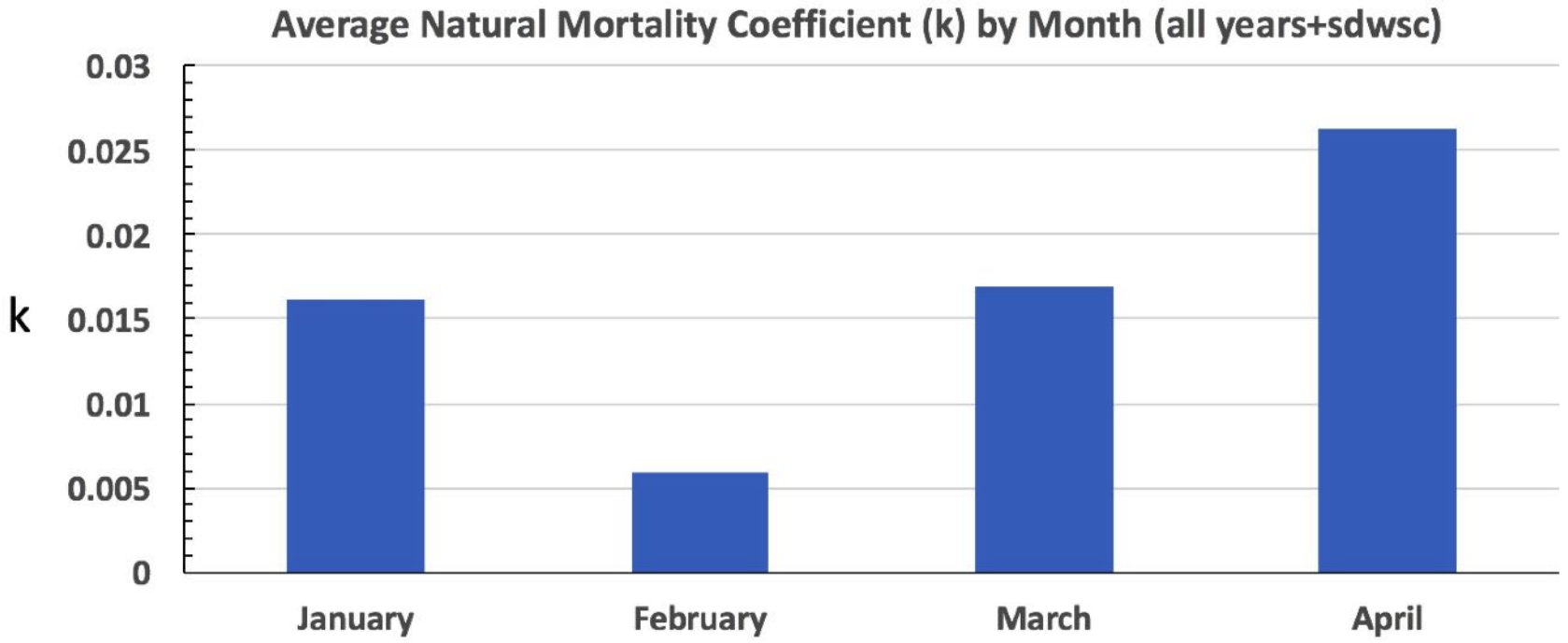
P_l = Proportional loss for the water year
d = day
D = total number of days
E_d = Number of delta smelt entrained on day d
P_d = Population on day d
$\prod(\quad)$ = Mathematical operator for the product of a sequence.
(Note: The product operator is analogous to the use of capital letter Sigma, $\sum(\quad)$, used as the summation symbol)

Relationship between the number of adult delta smelt alive and time for a population that has a constant proportion dying per unit of time




Average Natural Mortality Coefficient (k) by Month (2002-2007+sdwsc)
k
0.035
0.025
0.015
0.005
-0.005
January
February
March
April


Average Natural Mortality Coefficient (k) by Month (2002-2007+sdwsc)
k
0.035
0.025
0.015
0.005
-0.005
January
February
March
April

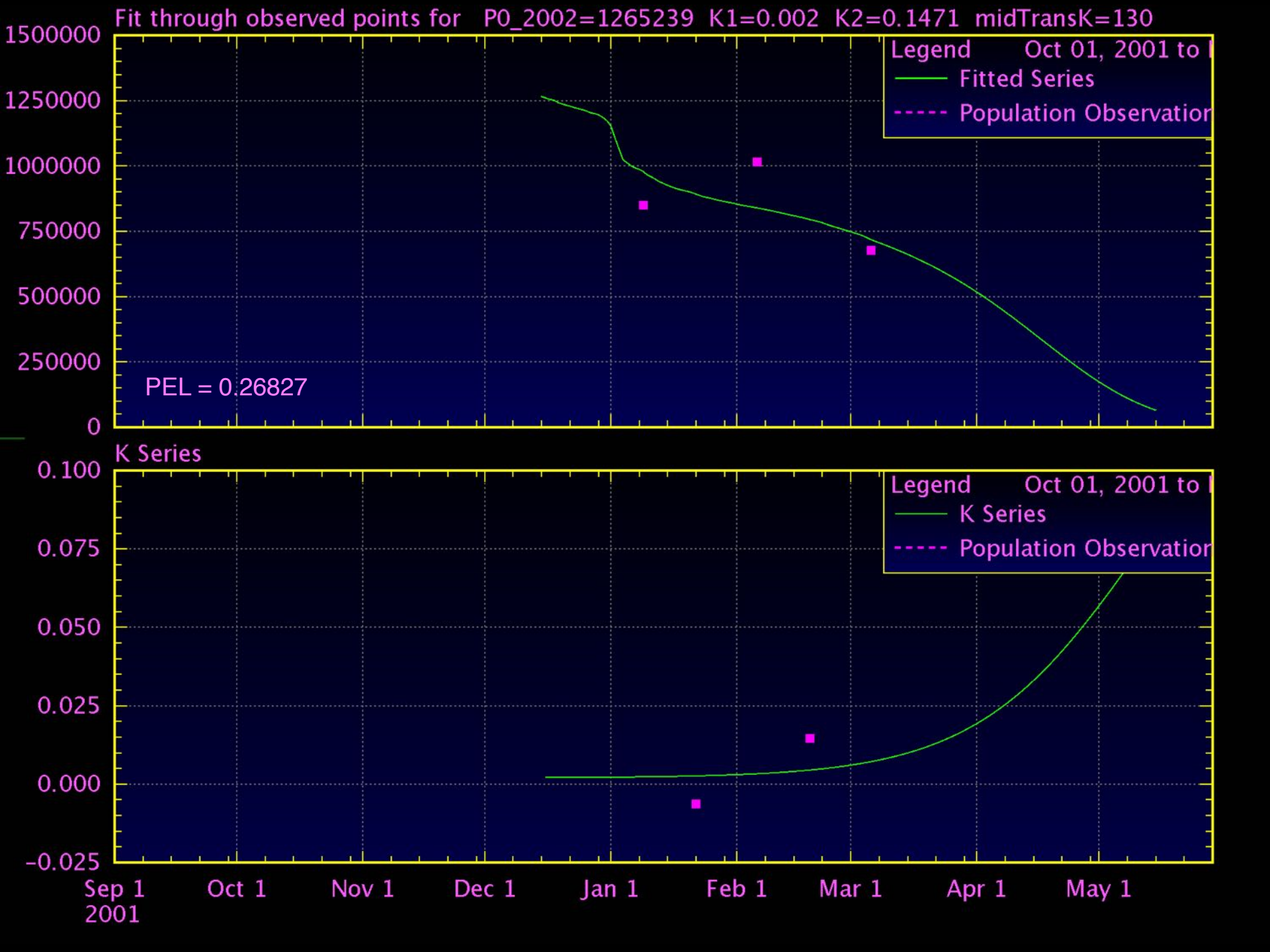

Average Natural Mortality Coefficient (k) by Month (all years+sdwsc)
k
0.03
0.025
0.02
0.015
0.01
0.005
0
January
February
March
April

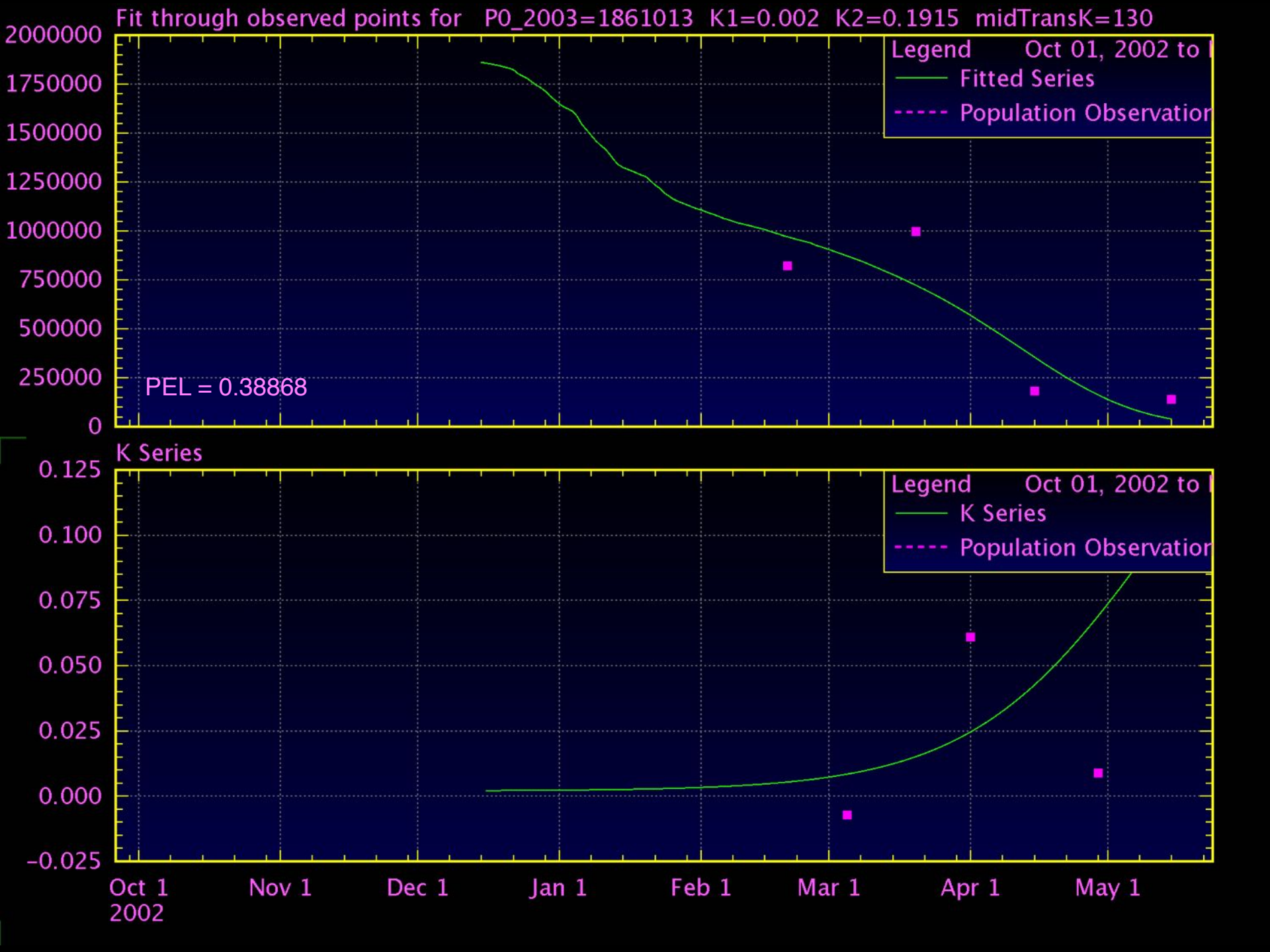
Logistic Function for Variation of Natural Mortality in Time

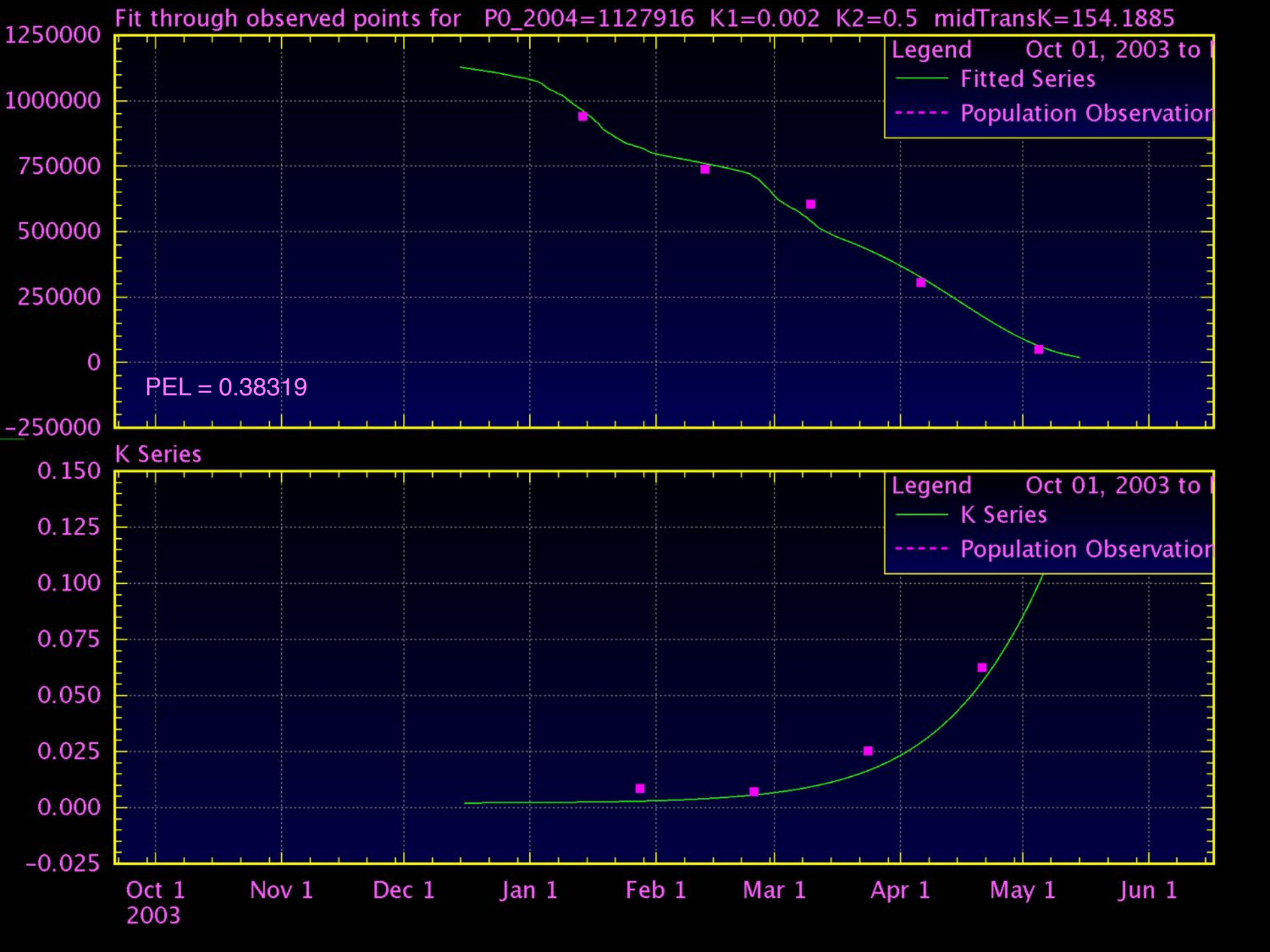
$$k(t) = k_1 + \frac{k_2 - k_1}{1 + e^{-a(t-t_0)}}$$

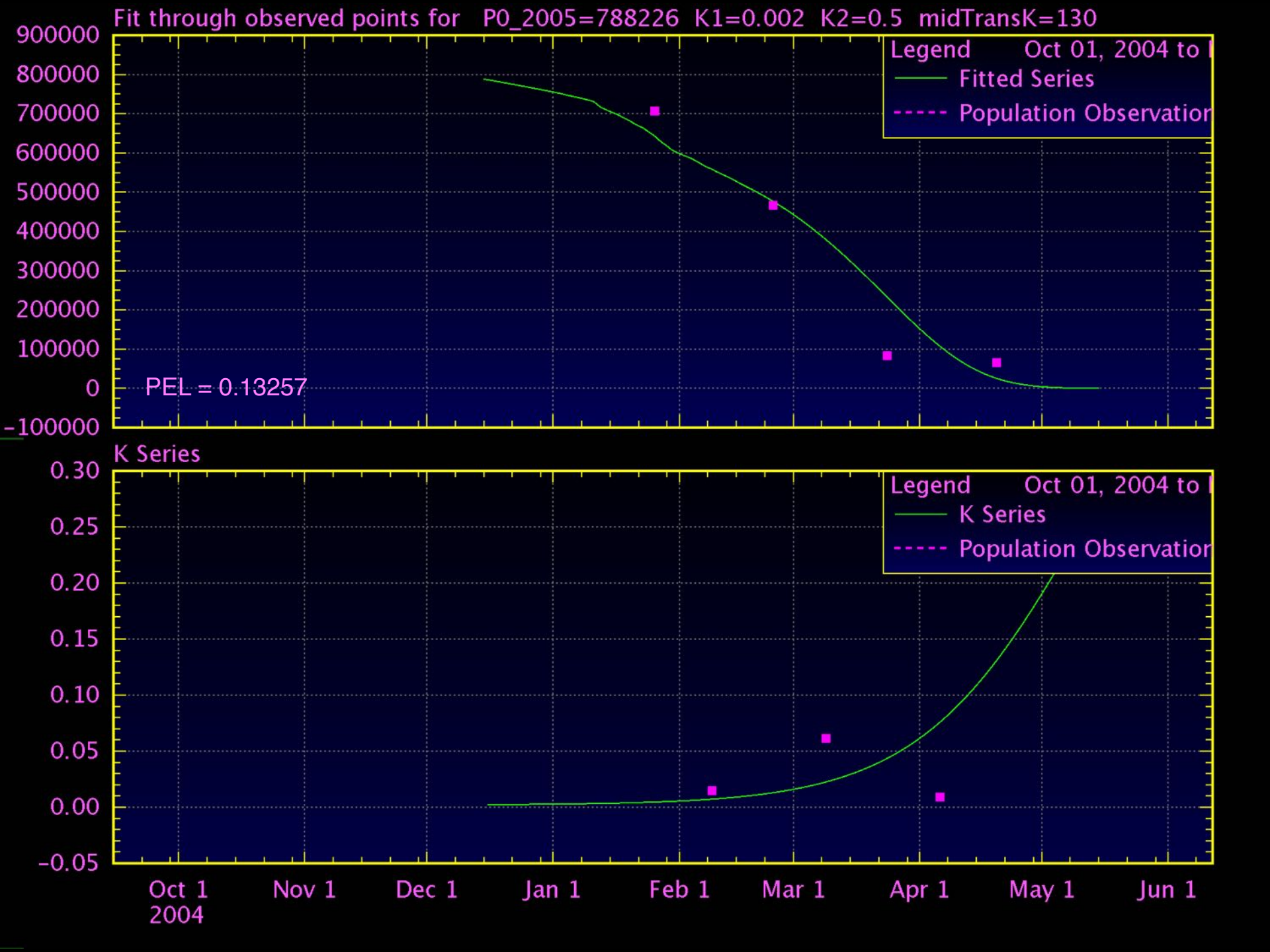
where

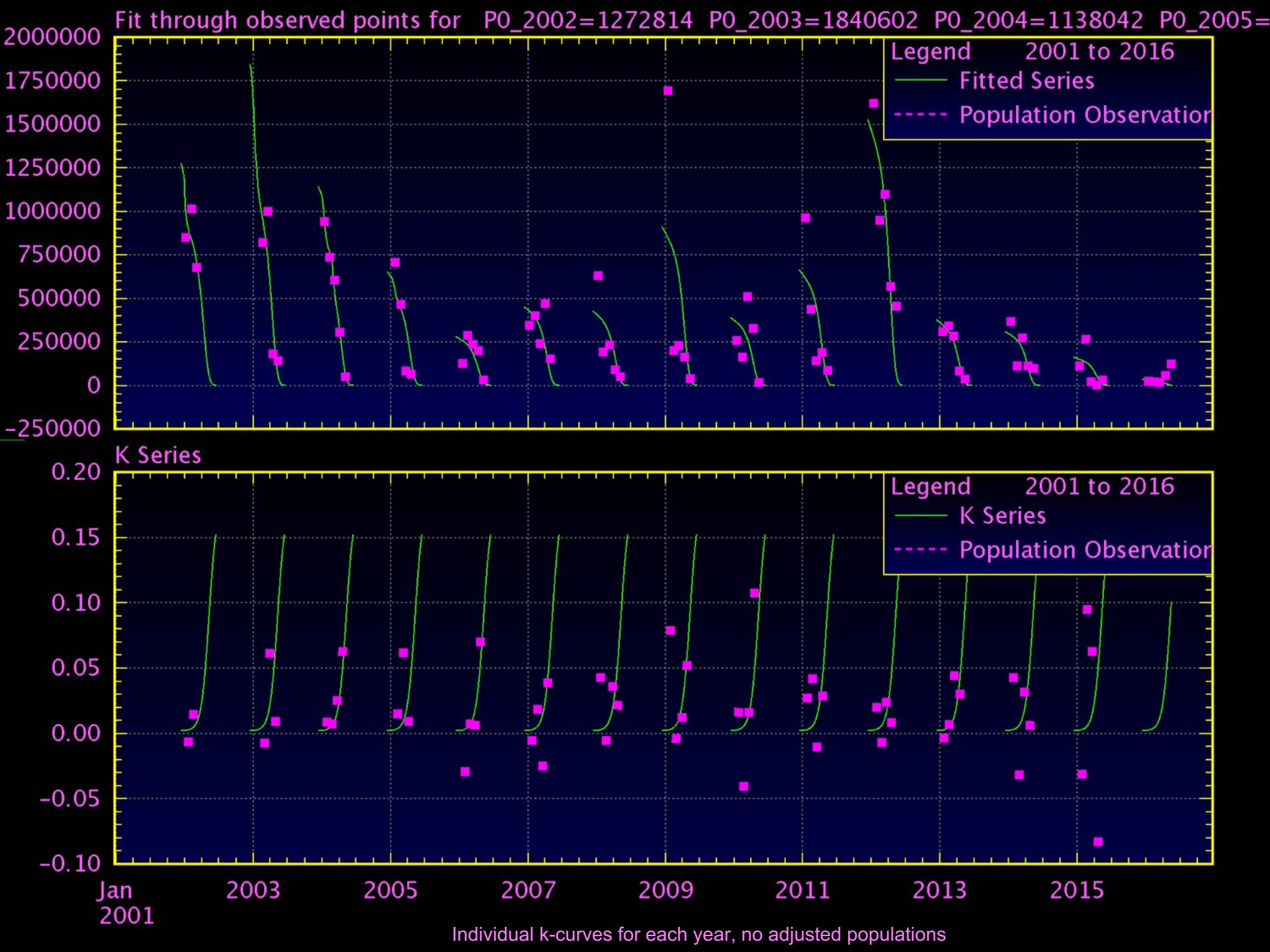
k_1 is the minimum value (lower asymptote) of $k(t)$
k_2 is the maximum value (upper asymptote) of $k(t)$
t_0 = the t-value of the sigmoid's midpoint
a = steepness parameter = 0.05

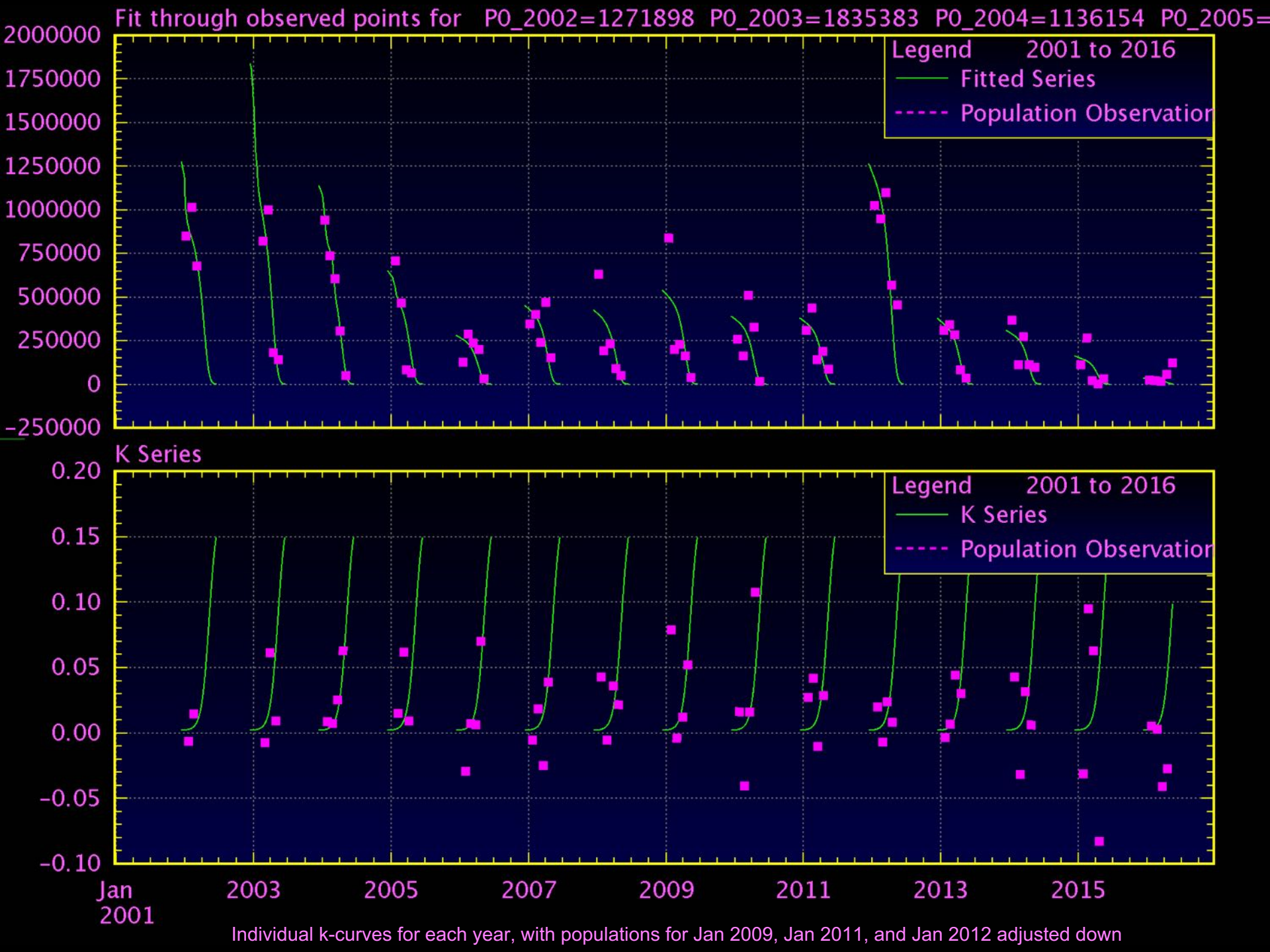

Fit through observed points for P0_2002=1265239 K1=0.002 K2=0.1471 midTransK=130
1500000
1250000
1000000
750000
500000
250000
0
Legend Oct 01, 2001 to
Fitted Series
Population Observation
PEL = 0.26827
K Series
0.100
0.075
0.050
0.025
0.000
-0.025
Legend Oct 01, 2001 to
K Series
Population Observation
Sep 1
2001
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1


Fit through observed points for P0_2003=1861013 K1=0.002 K2=0.1915 midTransK=130
2000000
1750000
1500000
1250000
1000000
750000
500000
250000
0
Legend Oct 01, 2002 to
Fitted Series
Population Observation
PEL = 0.38868
K Series
0.125
0.100
0.075
0.050
0.025
0.000
-0.025
Legend Oct 01, 2002 to
K Series
Population Observation
Oct 1
2002
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1


Fit through observed points for P0_2004=1127916 K1=0.002 K2=0.5 midTransK=154.1885
1250000
1000000
750000
500000
250000
0
-250000
Legend Oct 01, 2003 to
Fitted Series
Population Observation
PEL = 0.38319
K Series
0.150
0.125
0.100
0.075
0.050
0.025
0.000
-0.025
Legend Oct 01, 2003 to
K Series
Population Observation
Oct 1
2003
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1


Fit through observed points for P0_2005=788226 K1=0.002 K2=0.5 midTransK=130
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
-100000
Legend Oct 01, 2004 to
Fitted Series
Population Observation
PEL = 0.13257
K Series
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
Legend Oct 01, 2004 to
K Series
Population Observation
Oct 1
2004
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1


Fit through observed points for P0_2002=1272814 P0_2003=1840602 P0_2004=1138042 P0_2005=
2000000
1750000
1500000
1250000
1000000
750000
500000
250000
0
-250000
Legend 2001 to 2016
Fitted Series
Population Observation
K Series
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
Legend 2001 to 2016
K Series
Population Observation
Jan
2001
2003
2005
2007
2009
2011
2013
2015
Individual k-curves for each year, no adjusted populations



Individual k-curves for each year, with populations for Jan 2009, Jan 2011, and Jan 2012 adjusted down

P0s and PELs for model run using a single set of k-values (fit to years 2002-2007) and with the populations for Jan 2009, Jan 2011, and Jan 2012 adjusted downward (as the mean CPUE of the following three months.)

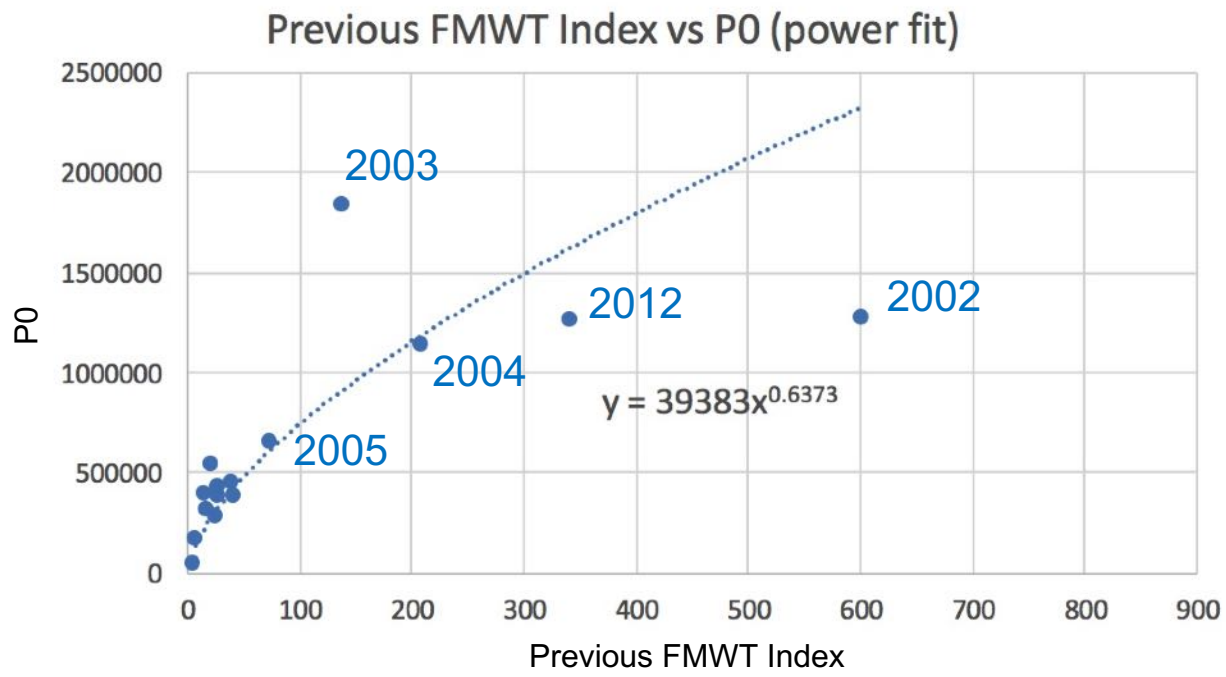
1 of 1 parameter combinations converged.
Lowest RMS = 133045.4
Parameters of Closest Fit

P0_2002 = 1,271,898	2002 Proportional Entrainment Loss = 0.268
P0_2003 = 1,835,383	2003 Proportional Entrainment Loss = 0.393
P0_2004 = 1,136,154	2004 Proportional Entrainment Loss = 0.383
P0_2005 = 648,815	2005 Proportional Entrainment Loss = 0.156
P0_2006 = 279,054	2006 Proportional Entrainment Loss = 0.061
P0_2007 = 449,575	2007 Proportional Entrainment Loss = 0.016
P0_2008 = 423,501	2008 Proportional Entrainment Loss = 0.041
P0_2009 = 537,558	2009 Proportional Entrainment Loss = 0.002
P0_2010 = 389,073	2010 Proportional Entrainment Loss = 0.011
P0_2011 = 378,360	2011 Proportional Entrainment Loss = 0.007
P0_2012 = 1,261,658	2012 Proportional Entrainment Loss = 0.009
P0_2013 = 376,409	2013 Proportional Entrainment Loss = 0.030
P0_2014 = 307,757	2014 Proportional Entrainment Loss = 0.0
P0_2015 = 160,626	2015 Proportional Entrainment Loss = 0.016
P0_2016 = 34,860	2016 Proportional Entrainment Loss = 0.016

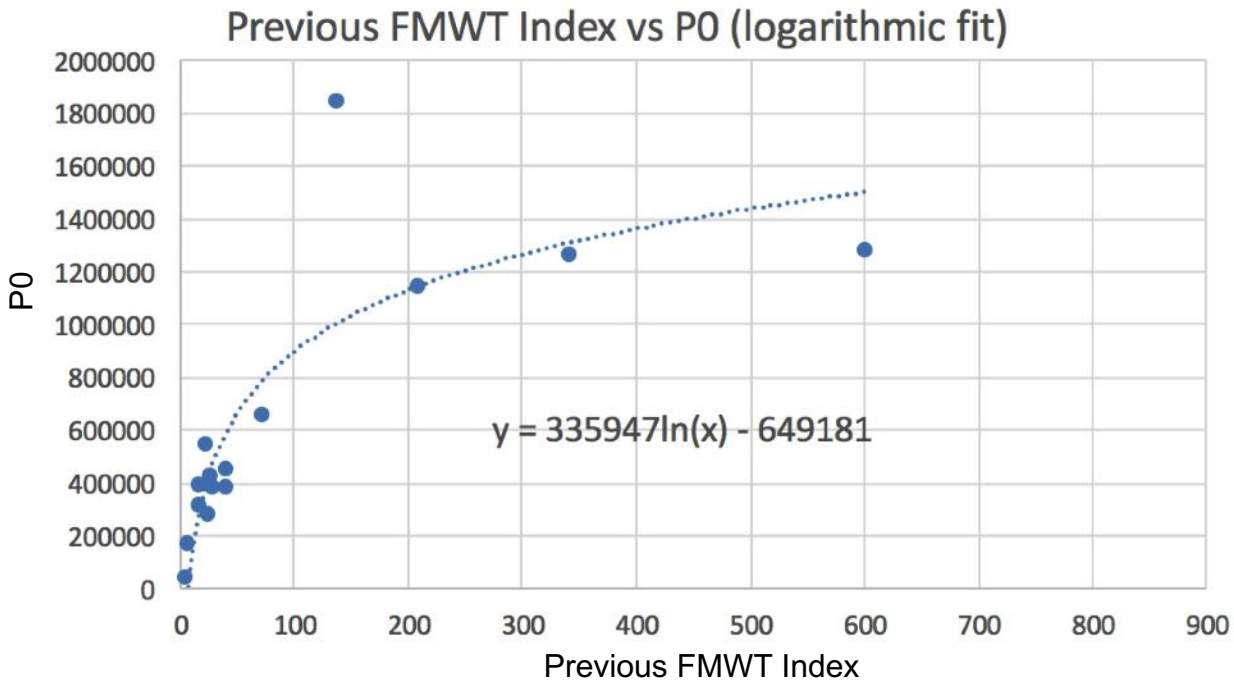
K1 = 0.002, K2 = 0.173, midTransK = 130.0 days, Theta(CVP) =35, Theta(SWP)=50

4. Estimating adult proportional entrainment losses for the pre-SKTS years (1981-2001)

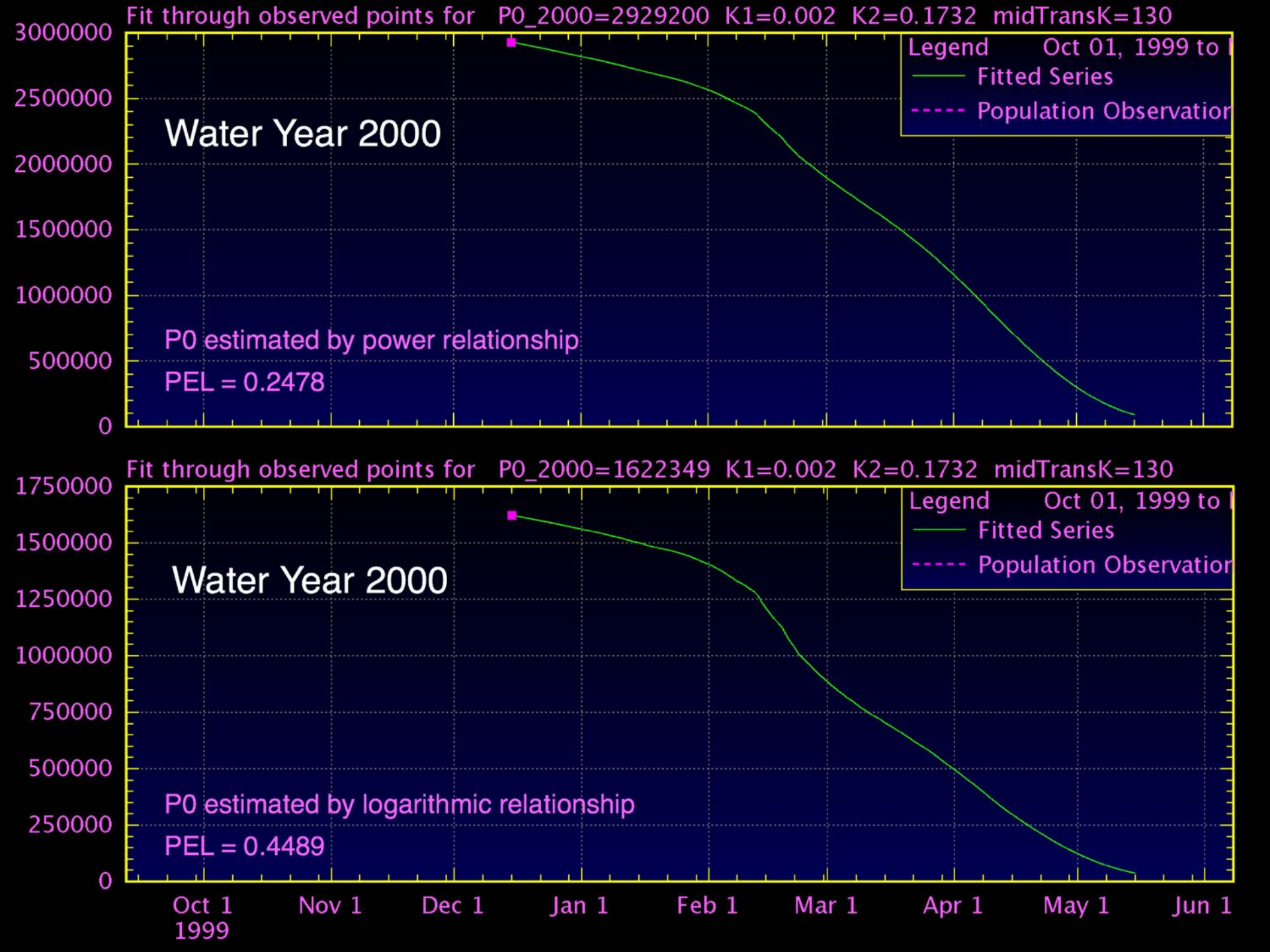
- Populations for the water years 1981-2001 must be estimated differently from those of water years 2002 -2016 because no data from the SKTS are available. For each of these water years, we will estimate a December 15th population using a regression curve relating the estimates we derived for P0 from the SKTS data to the previous FMWT index. The population model will then be used with an assigned natural mortality curve and theta values to estimate the PEL using the salvage data.

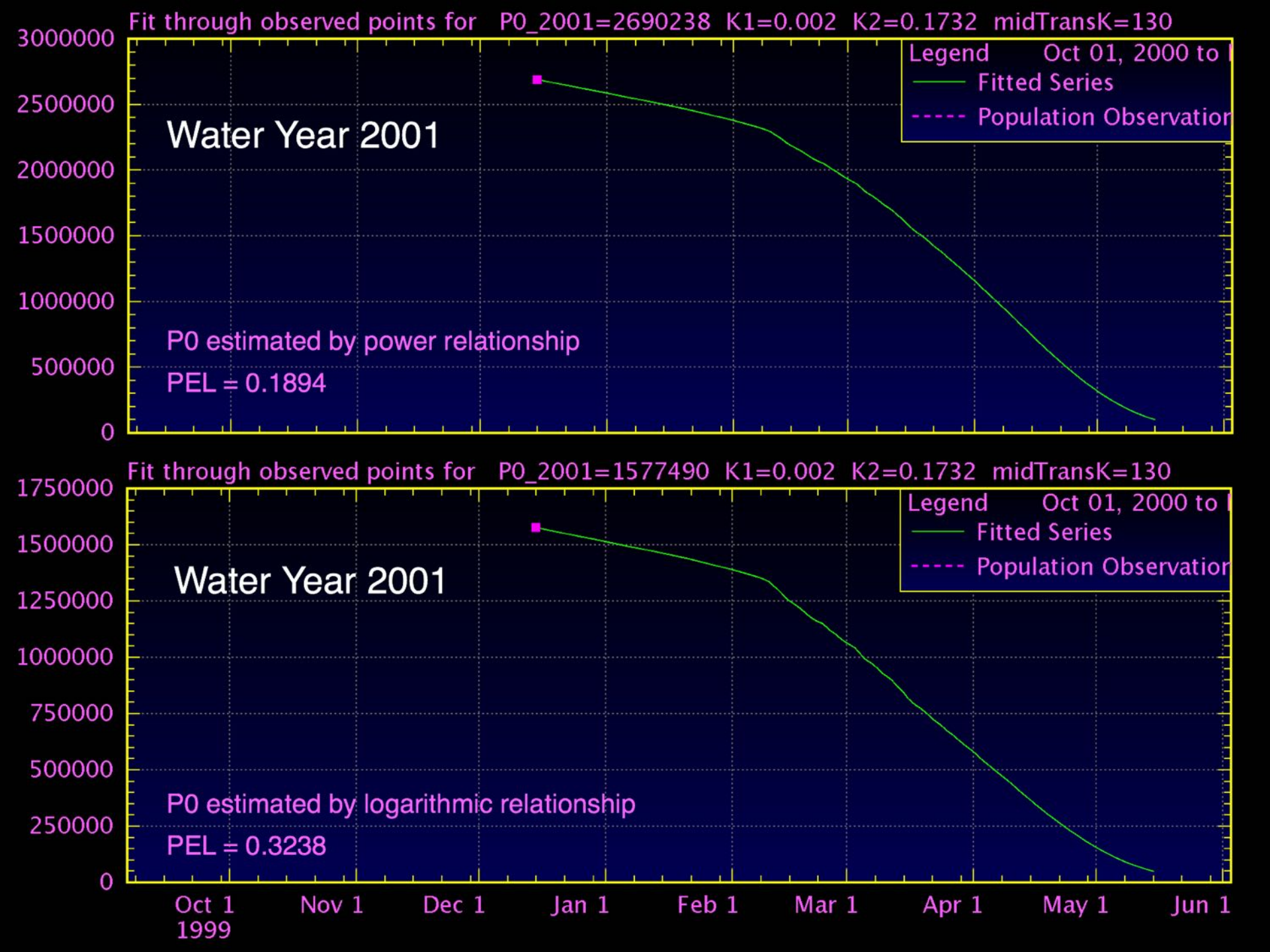


WY	PFMWT	P0
2000	864	2,929,200
2001	756	2,690,238

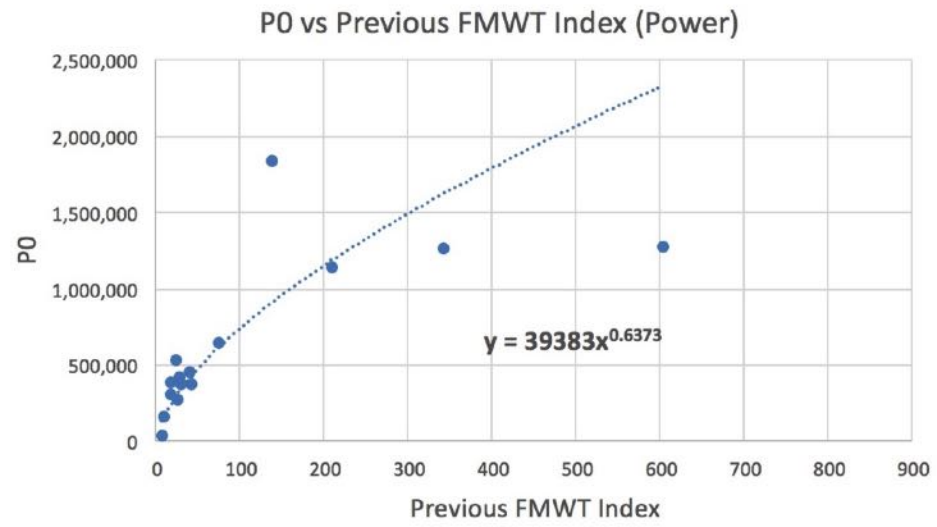


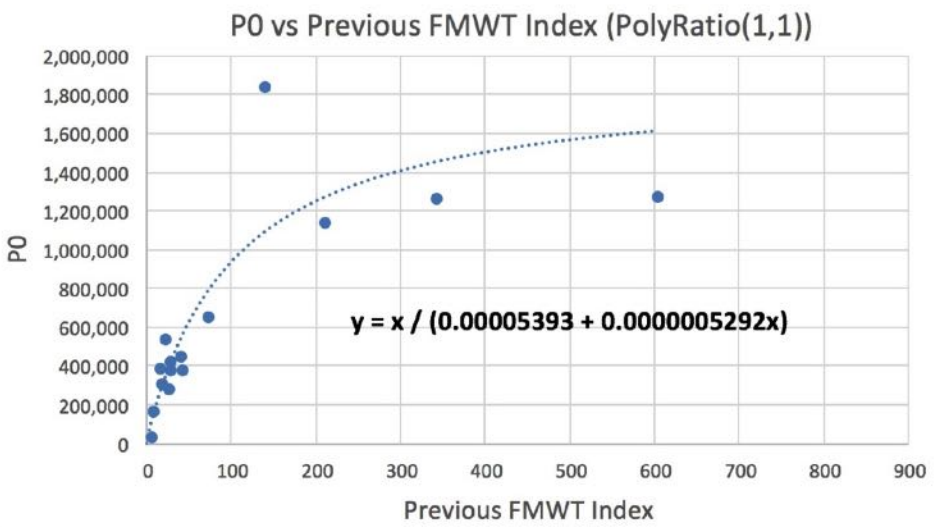
WY	PFMWT	P0
2000	864	1,622,349
2001	756	1,577,490

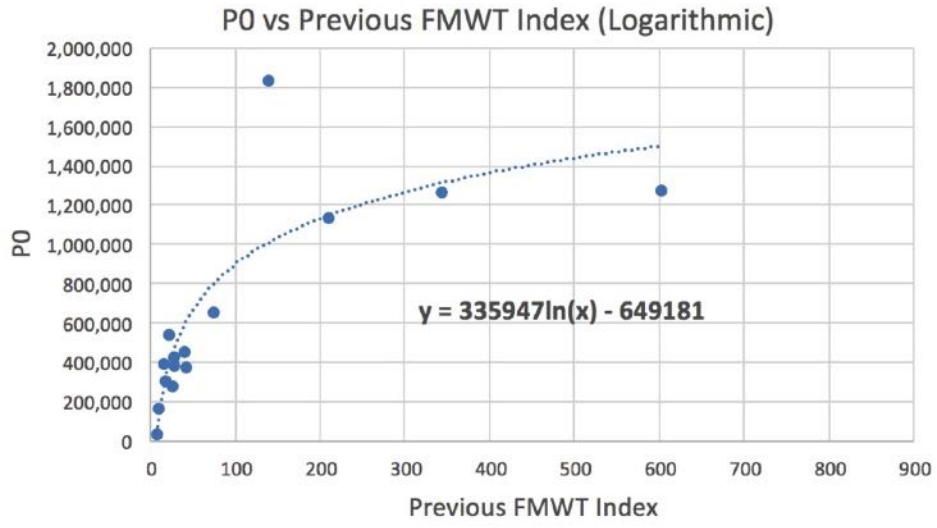

Fit through observed points for P0_2000=2929200 K1=0.002 K2=0.1732 midTransK=130
3000000
2500000
2000000
1500000
1000000
500000
0
Legend Oct 01, 1999 to
Fitted Series
Population Observation
Water Year 2000
P0 estimated by power relationship
PEL = 0.2478
Fit through observed points for P0_2000=1622349 K1=0.002 K2=0.1732 midTransK=130
1750000
1500000
1250000
1000000
750000
500000
250000
0
Legend Oct 01, 1999 to
Fitted Series
Population Observation
Water Year 2000
P0 estimated by logarithmic relationship
PEL = 0.4489
Oct 1
1999
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1

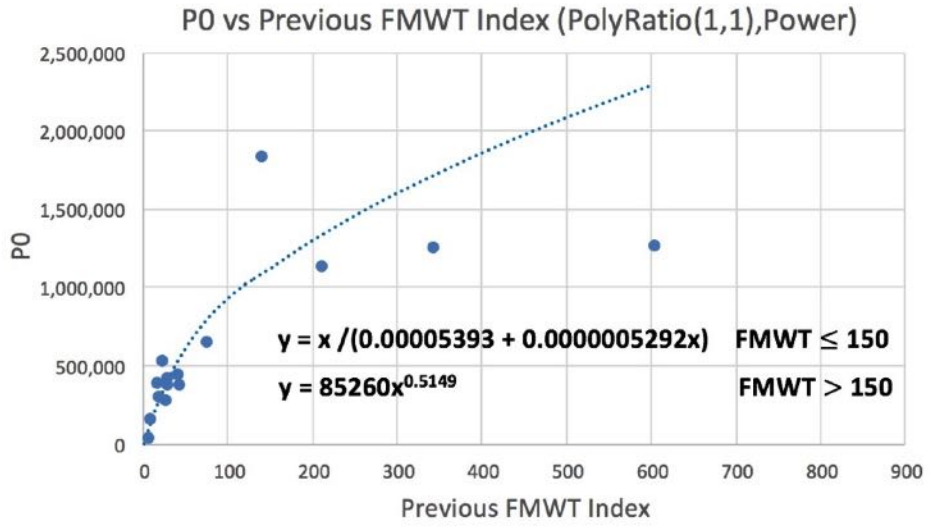

Fit through observed points for P0_2001=2690238 K1=0.002 K2=0.1732 midTransK=130
3000000
2500000
2000000
1500000
1000000
500000
0
Legend Oct 01, 2000 to
Fitted Series
Population Observation
Water Year 2001
P0 estimated by power relationship
PEL = 0.1894
Fit through observed points for P0_2001=1577490 K1=0.002 K2=0.1732 midTransK=130
1750000
1500000
1250000
1000000
750000
500000
250000
0
Legend Oct 01, 2000 to
Fitted Series
Population Observation
Water Year 2001
P0 estimated by logarithmic relationship
PEL = 0.3238
Oct 1
1999
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
May 1
Jun 1

Various Fitted Equations to Estimate Population Size (P0) from FMWT Index



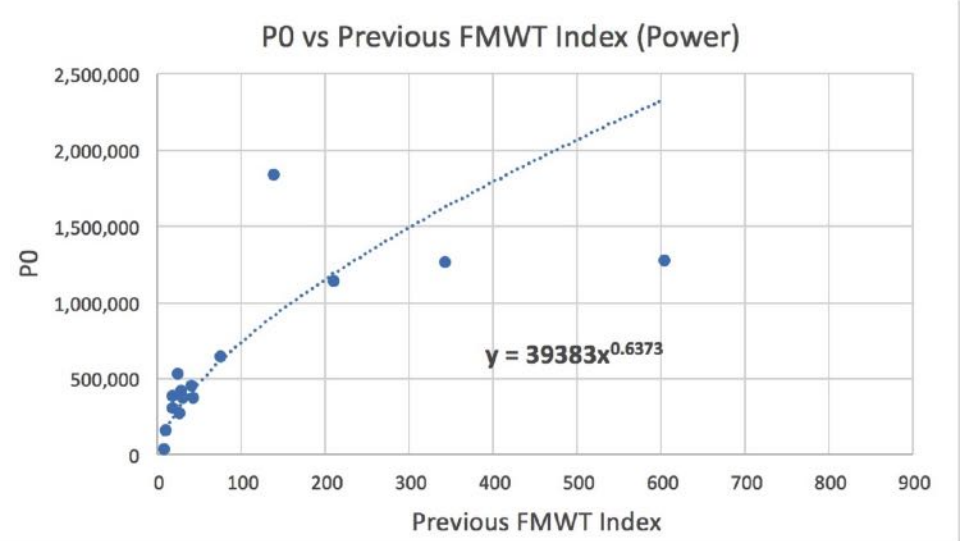


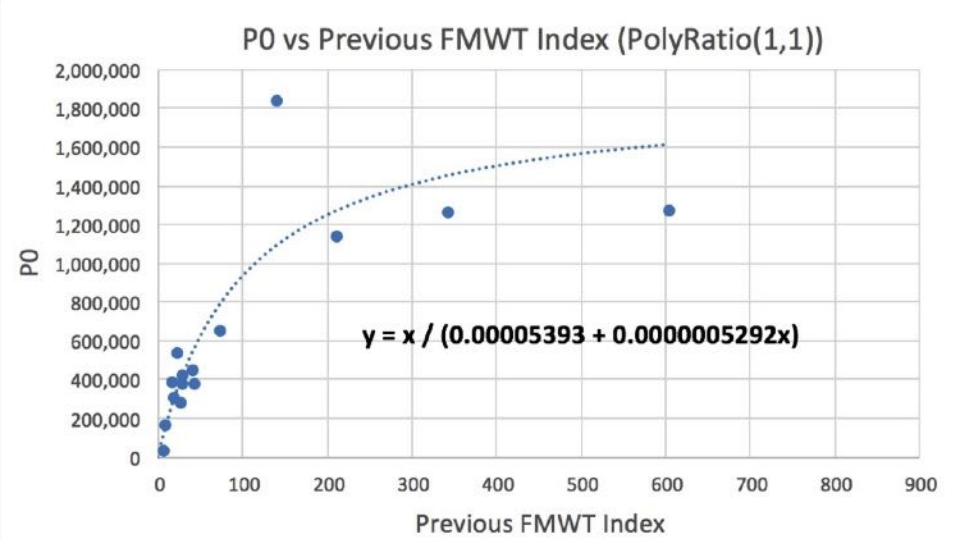


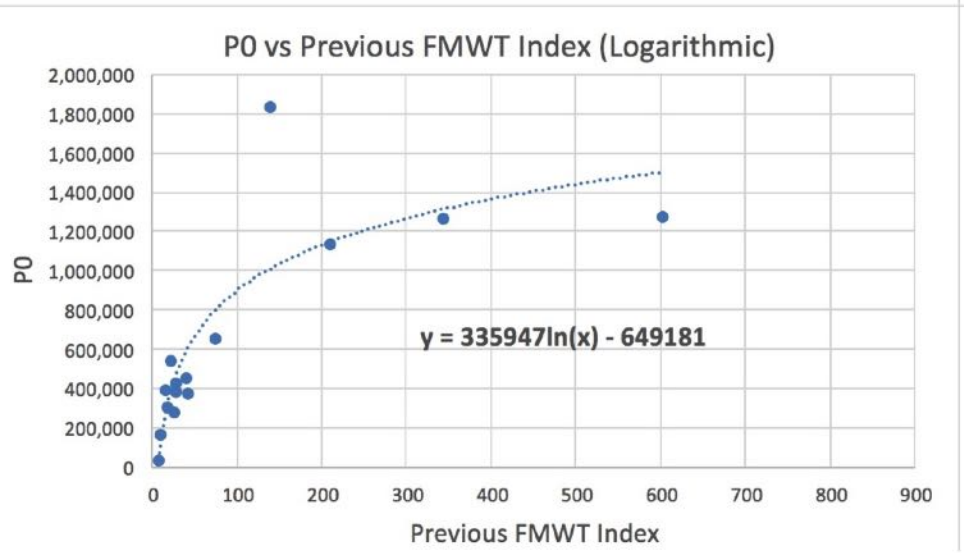


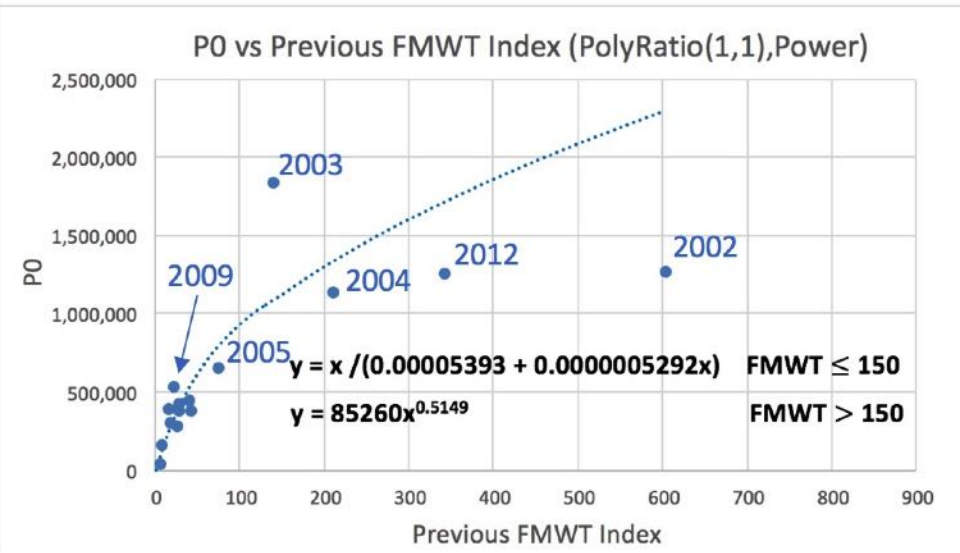
Note: P0 is population size on Dec 15th of water year

Various Fitted Equations to Estimate Population Size (P0) from FMWT Index

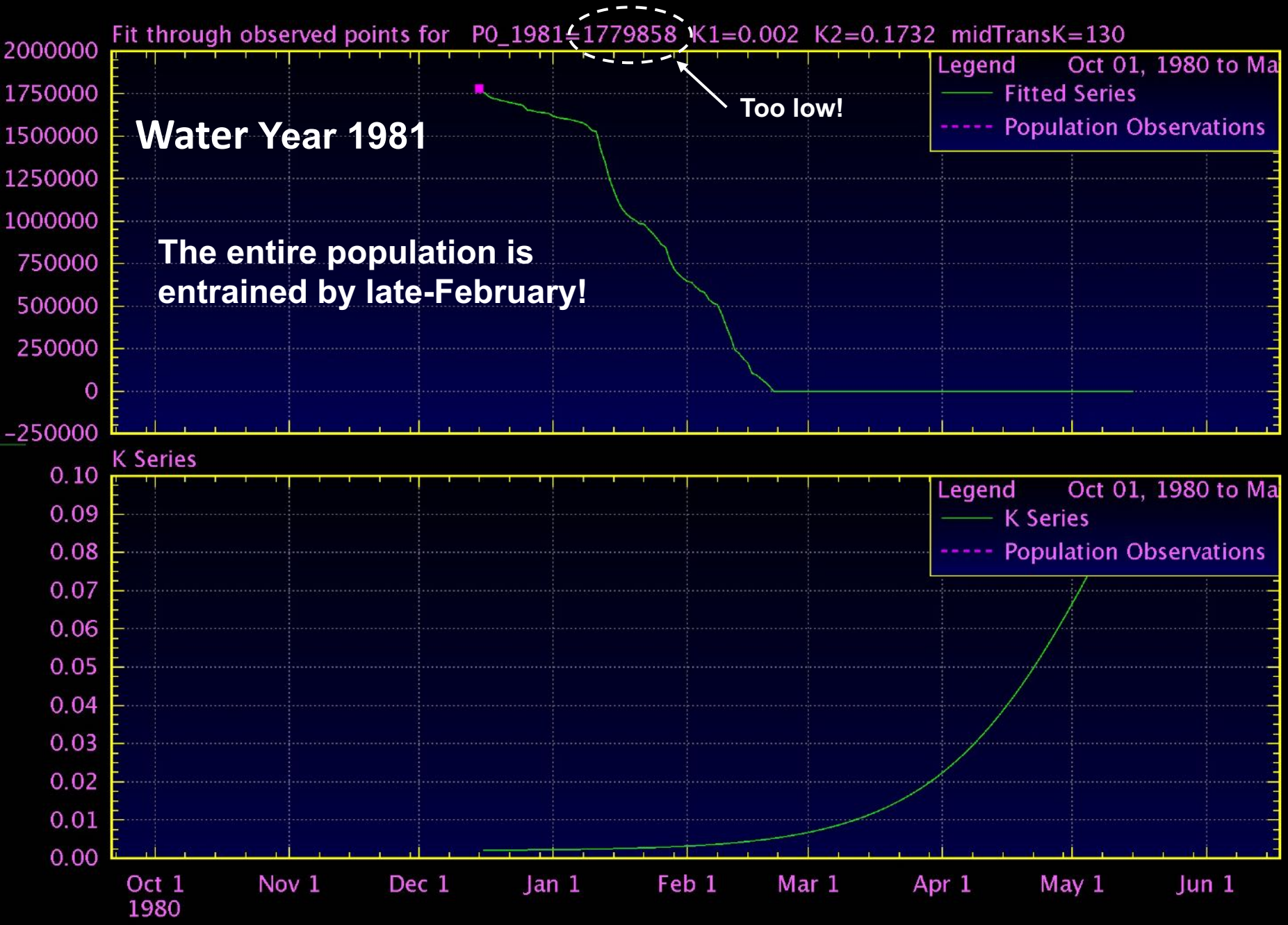




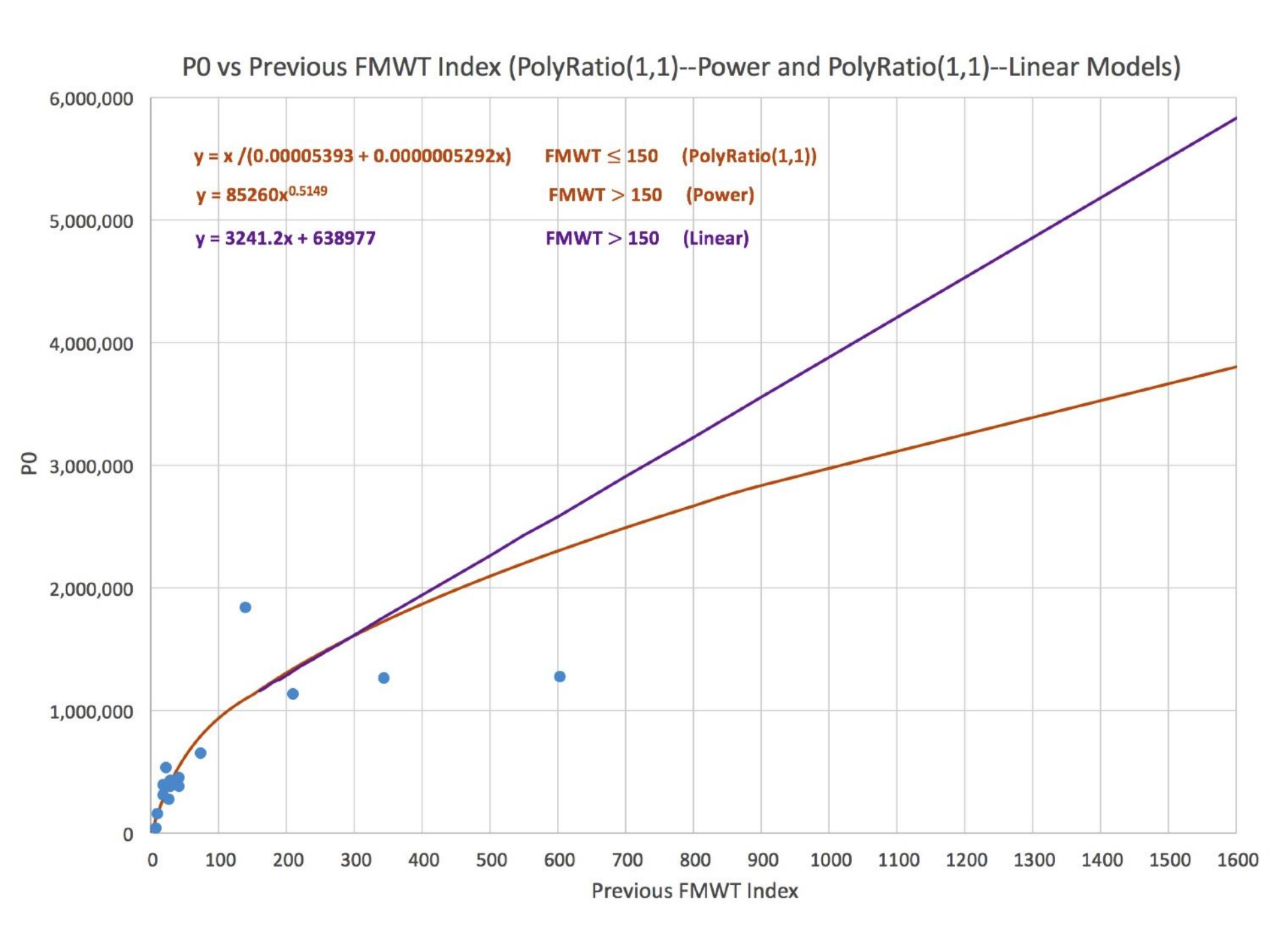




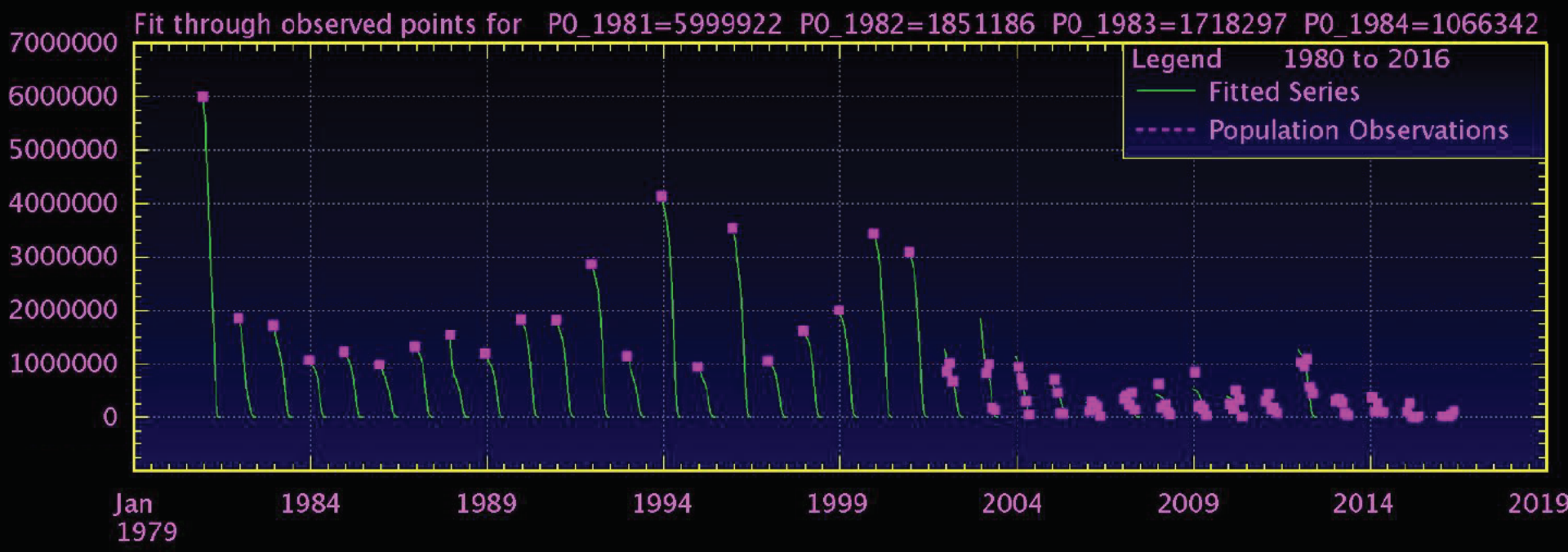
Note: P0 is population size on Dec 15th of water year



P0 determined from PolyRatio(1,1) equation


P0 vs Previous FMWT Index (PolyRatio(1,1)--Power and PolyRatio(1,1)--Linear Models)
y = x /(0.00005393 + 0.0000005292x) FMWT ≤ 150 (PolyRatio(1,1))
y = 85260x^0.5149 FMWT > 150 (Power)
y = 3241.2x + 638977 FMWT > 150 (Linear)
P0
Previous FMWT Index
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

All Years (water years 1981-2016)



Note: P0s of pre-SKT years determined with the PolyRatio(1,1),Linear equation

PEL Estimates for Early Years (1981-2001)

1981 Proportional Entrainment Loss = 0.719 ←
1982 Proportional Entrainment Loss = 0.671 ←
1983 Proportional Entrainment Loss = 0.186
1984 Proportional Entrainment Loss = 0.192
1985 Proportional Entrainment Loss = 0.158
1986 Proportional Entrainment Loss = 0.210 ←
1987 Proportional Entrainment Loss = 0.086
1988 Proportional Entrainment Loss = 0.506 ←
1989 Proportional Entrainment Loss = 0.132
1990 Proportional Entrainment Loss = 0.147
1991 Proportional Entrainment Loss = 0.134
1992 Proportional Entrainment Loss = 0.037
1993 Proportional Entrainment Loss = 0.219 ←
1994 Proportional Entrainment Loss = 0.005
1995 Proportional Entrainment Loss = 0.151
1996 Proportional Entrainment Loss = 0.088
1997 Proportional Entrainment Loss = 0.139
1998 Proportional Entrainment Loss = 0.035
1999 Proportional Entrainment Loss = 0.071
2000 Proportional Entrainment Loss = 0.211 ←
2001 Proportional Entrainment Loss = 0.165

P0s were determined with the PolyRatio(1,1),Linear equation

PEL during POD

2000 Proportional Entrainment Loss = 0.211
2001 Proportional Entrainment Loss = 0.165
2002 Proportional Entrainment Loss = 0.268
2003 Proportional Entrainment Loss = 0.393
2004 Proportional Entrainment Loss = 0.383
2005 Proportional Entrainment Loss = 0.156
2006 Proportional Entrainment Loss = 0.061

PEL Estimates for Early Years (1981-2001)

1981 Proportional Entrainment Loss = 0.719, 0.440
1982 Proportional Entrainment Loss = 0.671, 0.627
1983 Proportional Entrainment Loss = 0.186
1984 Proportional Entrainment Loss = 0.192, 0.117
1985 Proportional Entrainment Loss = 0.158, 0.069
1986 Proportional Entrainment Loss = 0.210
1987 Proportional Entrainment Loss = 0.086, 0.050
1988 Proportional Entrainment Loss = 0.506, 0.479
1989 Proportional Entrainment Loss = 0.132, 0.090
1990 Proportional Entrainment Loss = 0.147, 0.042
1991 Proportional Entrainment Loss = 0.134, 0.080
1992 Proportional Entrainment Loss = 0.037
1993 Proportional Entrainment Loss = 0.219
1994 Proportional Entrainment Loss = 0.005
1995 Proportional Entrainment Loss = 0.151
1996 Proportional Entrainment Loss = 0.088
1997 Proportional Entrainment Loss = 0.139, 0.092
1998 Proportional Entrainment Loss = 0.035
1999 Proportional Entrainment Loss = 0.071, 0.049
2000 Proportional Entrainment Loss = 0.211, 0.187
2001 Proportional Entrainment Loss = 0.165, 0.148

Second number is if salvage after March 31 is neglected

Summary of PELs for Pre-SKT Years

Water Year	Calendar Year of FMWT Survey	FMWT Index	Results using combined PolyRatio(1,1), Linear Model	
			P0	PEL
1981	1980	1654	5,999,922	0.719069847
1982	1981	374	1,851,186	0.671448442
1983	1982	333	1,718,297	0.186122349
1984	1983	132	1,066,343	0.192398068
1985	1984	182	1,228,875	0.157707487
1986	1985	110	980,879	0.210133919
1987	1986	212	1,326,111	0.085772276
1988	1987	280	1,546,513	0.506156117
1989	1988	174	1,202,946	0.132223919
1990	1989	366	1,825,256	0.147403616
1991	1990	364	1,818,774	0.133623527
1992	1991	689	2,872,164	0.036645003
1993	1992	156	1,144,604	0.217467475
1994	1993	1078	4,132,991	0.005160228
1995	1994	102	945,228	0.151450042
1996	1995	899	3,552,816	0.088357325
1997	1996	127	1,048,362	0.139372723
1998	1997	303	1,621,061	0.035109473
1999	1998	420	2,000,281	0.070610048
2000	1999	864	3,439,374	0.210900677
2001	2000	756	3,089,324	0.164826773

Summary of PELs for SKT Years

Water Year	Calendar Year of FMWT Survey	FMWT Index	P0	PEL
2002	2001	603	1,271,898	0.267645296
2003	2002	139	1,835,383	0.392969774
2004	2003	210	1,136,154	0.38327923
2005	2004	74	648,815	0.155955782
2006	2005	26	279,054	0.061253572
2007	2006	41	449,575	0.015580888
2008	2007	28	423,501	0.04068937
2009	2008	23	537,558	0.002434561
2010	2009	17	389,073	0.010787269
2011	2010	29	378,360	0.006972808
2012	2011	343	1,261,658	0.008687318
2013	2012	42	376,409	0.030349895
2014	2013	18	307,757	0
2015	2014	9	160,627	0.016420609
2016	2015	7	34,860	0.016309839

End