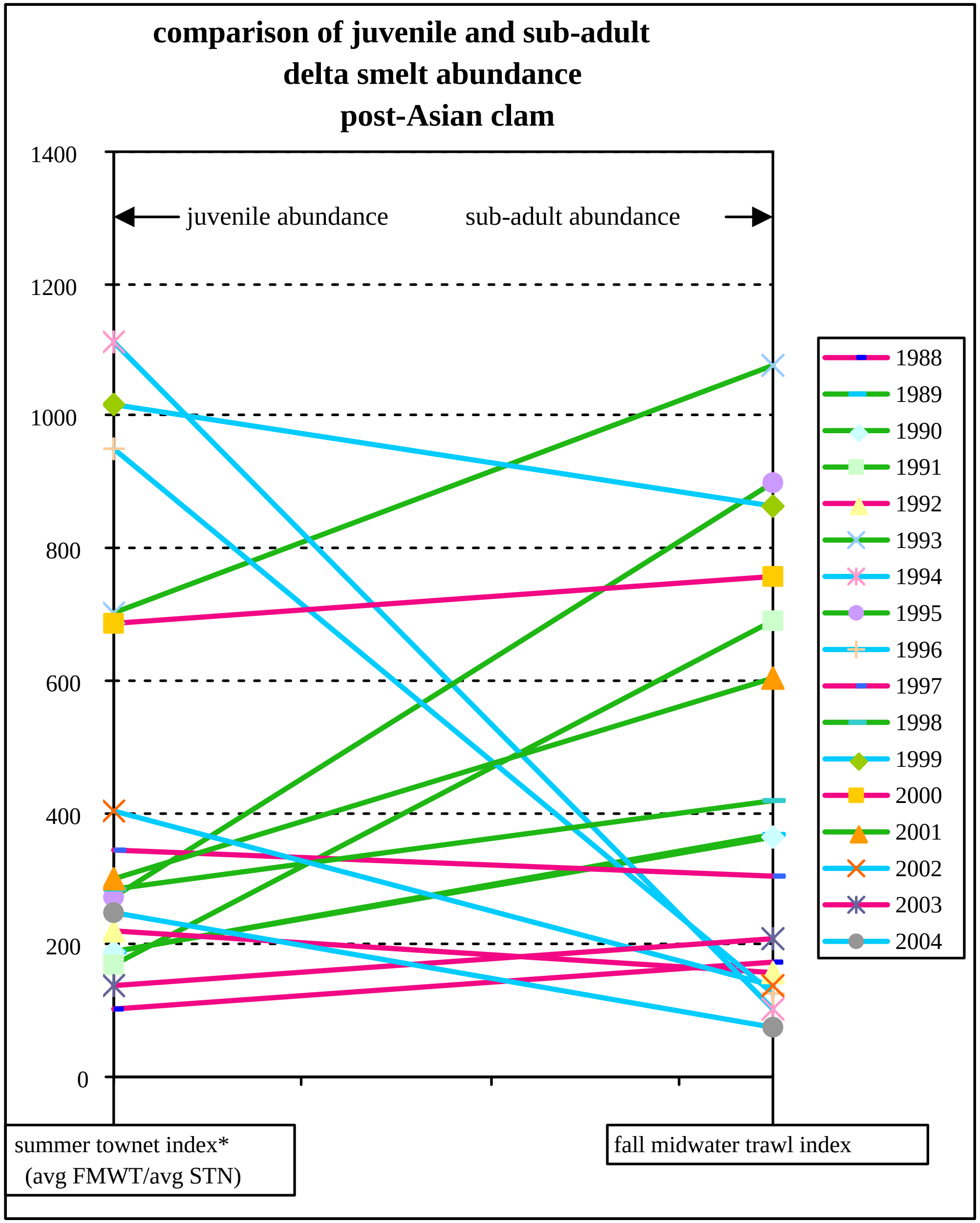
Delta Smelt

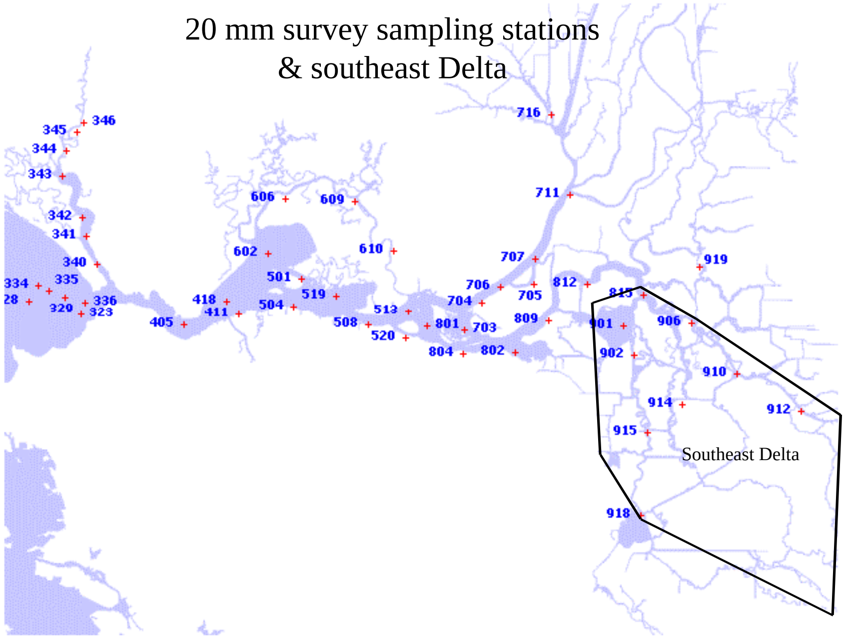
Managing juvenile entrainment

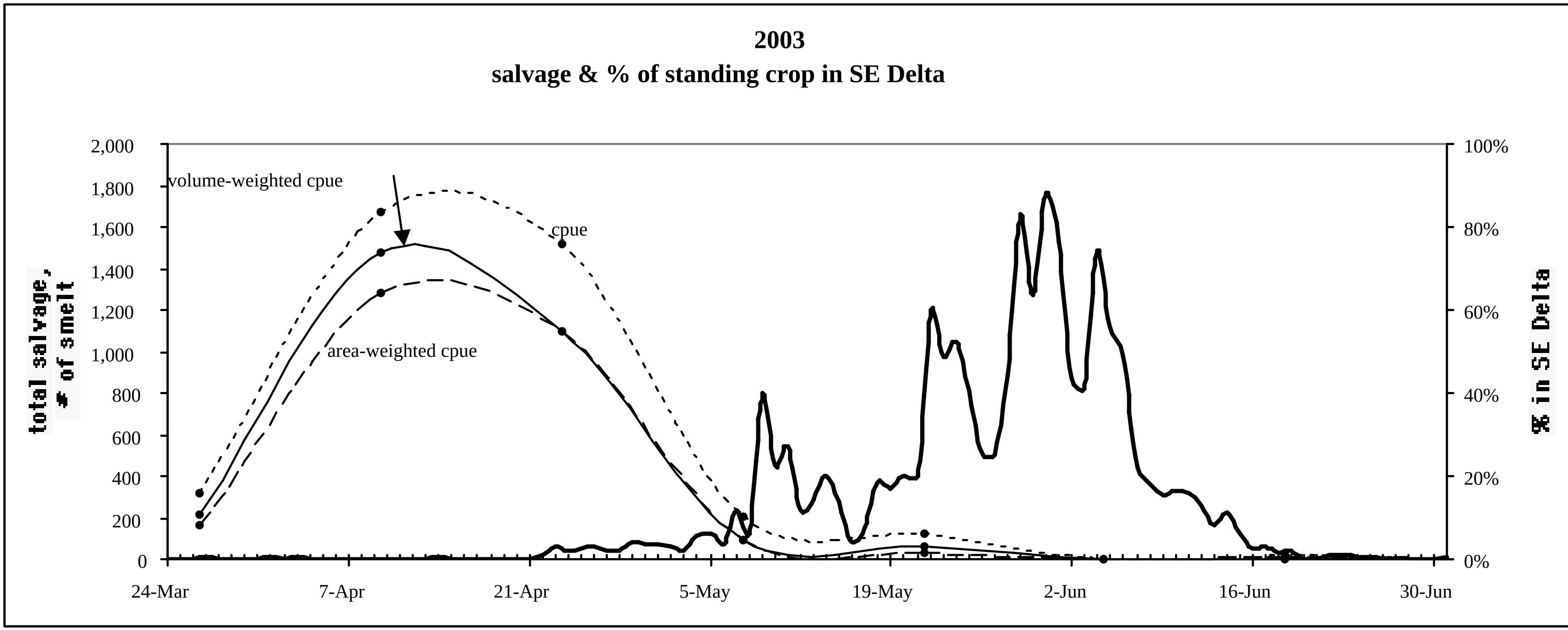
The "so what" question

- Relationship between STN and FMWT is tenuous
- Within limits, juvenile popn may not be important to adult popn
- Therefore, within limits, juvenile entrainment may not be important to adult popn

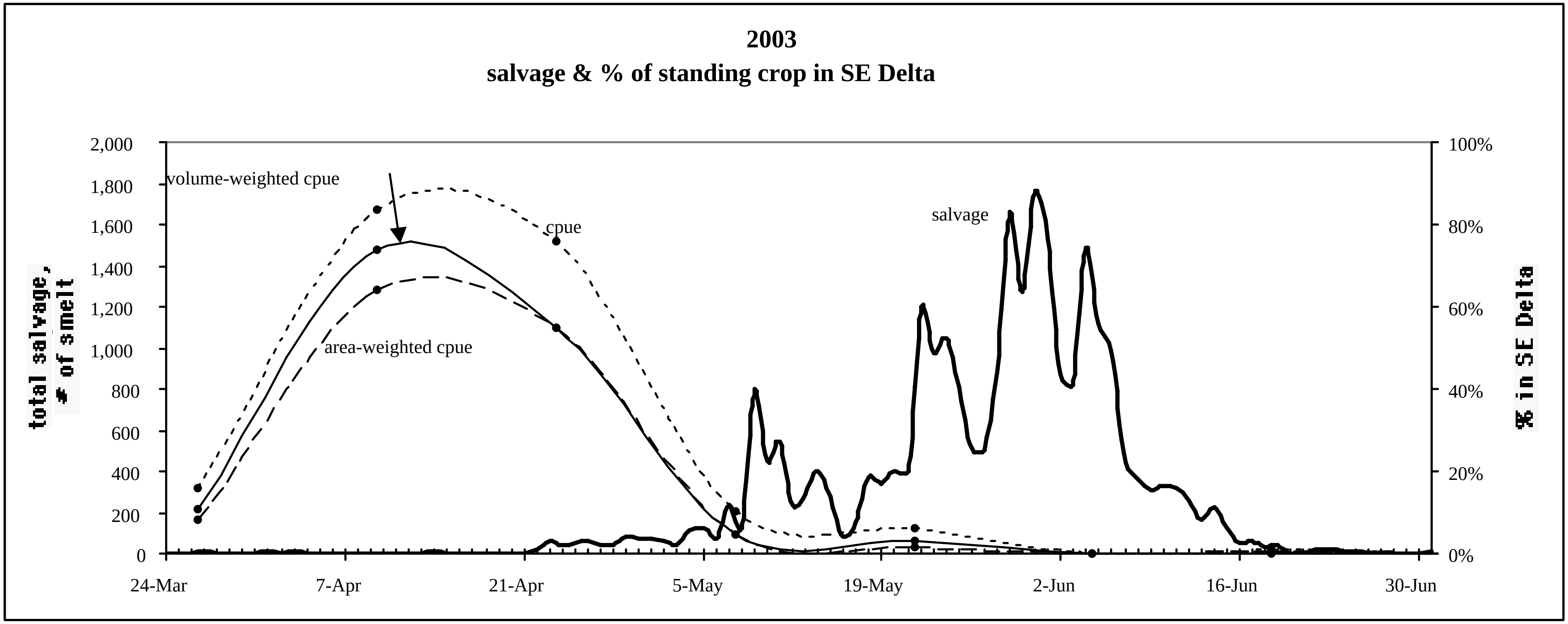

comparison of juvenile and sub-adult
delta smelt abundance
post-Asian clam
1400
1200
1000
800
600
400
200
0
juvenile abundance
sub-adult abundance
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
summer townet index*
(avg FMWT/avg STN)
fall midwater trawl index

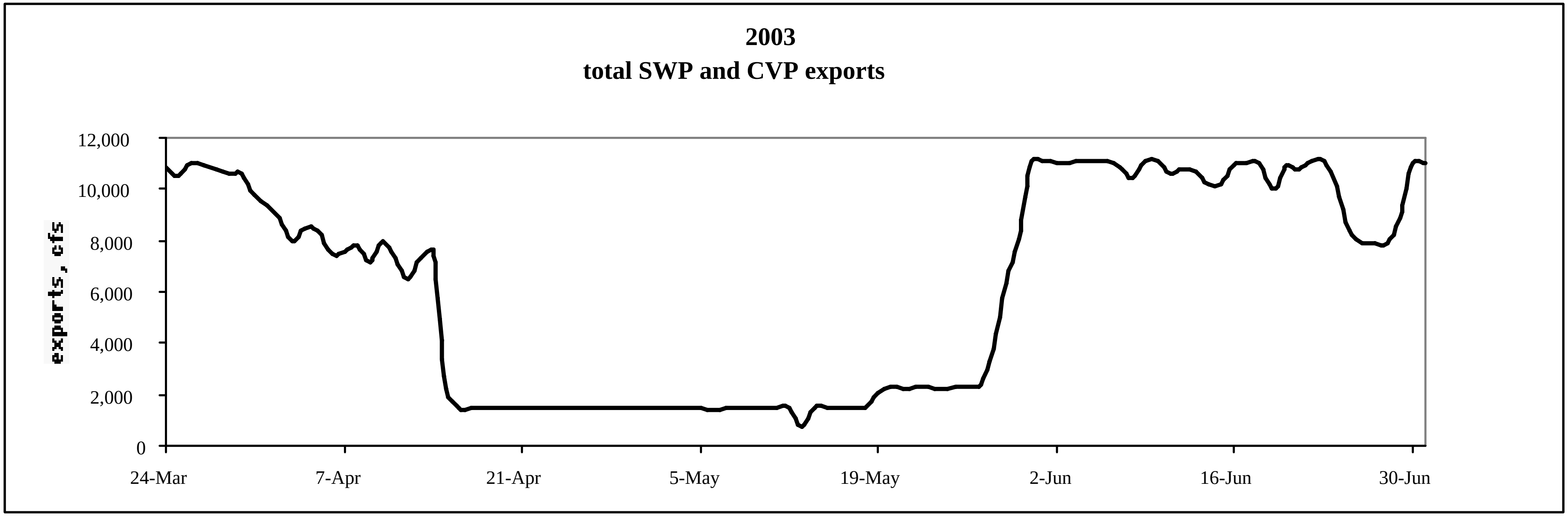
20 mm survey sampling stations
& southeast Delta



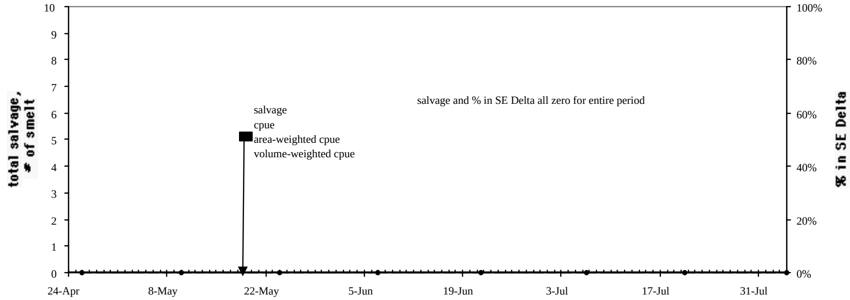


2003
salvage & % of standing crop in SE Delta
total salvage, # of smelt
% in SE Delta
volume-weighted cpue
cpue
area-weighted cpue
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
100%
80%
60%
40%
20%
0%
24-Mar
7-Apr
21-Apr
5-May
19-May
2-Jun
16-Jun
30-Jun

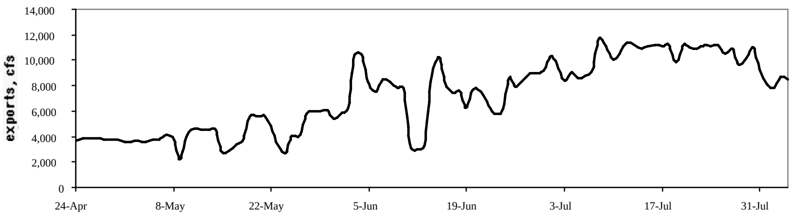

2003
salvage & % of standing crop in SE Delta
total salvage, # of smelt
% in SE Delta
volume-weighted cpue
cpue
area-weighted cpue
salvage
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
100%
80%
60%
40%
20%
0%
24-Mar
7-Apr
21-Apr
5-May
19-May
2-Jun
16-Jun
30-Jun


2003
total SWP and CVP exports
exports, cfs
12,000
10,000
8,000
6,000
4,000
2,000
0
24-Mar
7-Apr
21-Apr
5-May
19-May
2-Jun
16-Jun
30-Jun

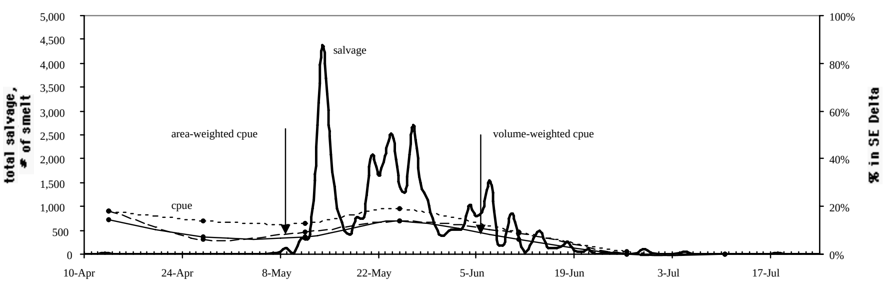
1995
salvage & % of standing crop in SE Delta



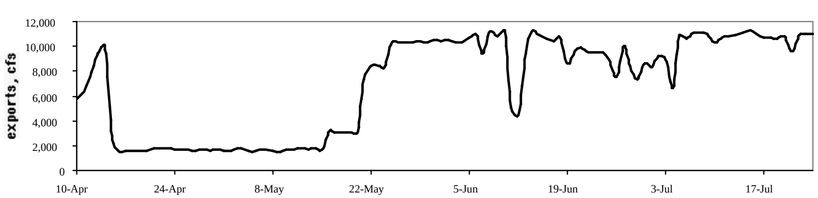
1995
total SWP and CVP exports



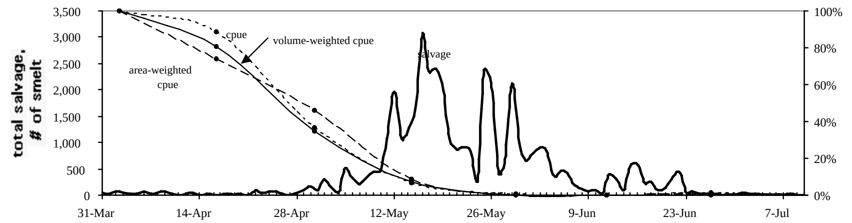
1996
salvage & % of standing crop in SE Delta



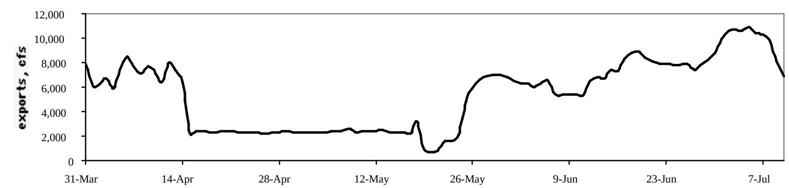
1996
total SWP and CVP exports



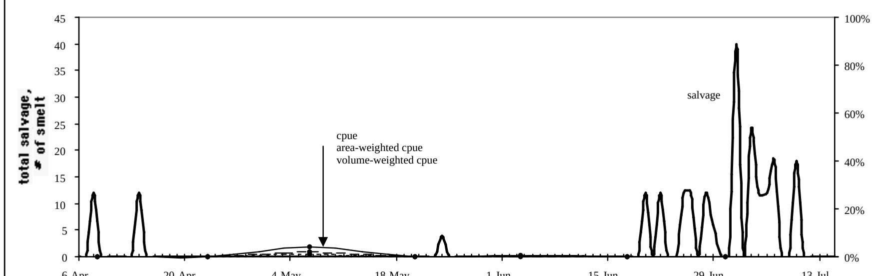
1997
salvage & % of standing crop in SE Delta



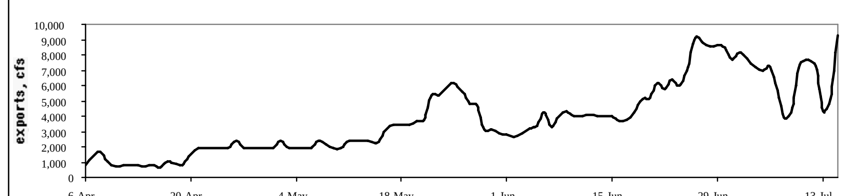
1997
total SWP and CVP exports



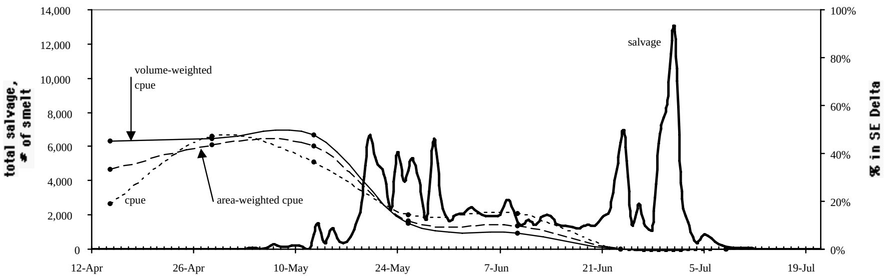
1998
salvage & % of standing crop in SE Delta



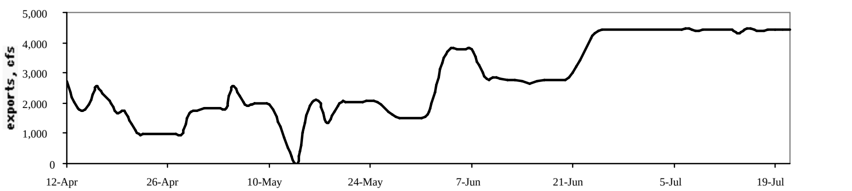
1998
total SWP and CVP exports



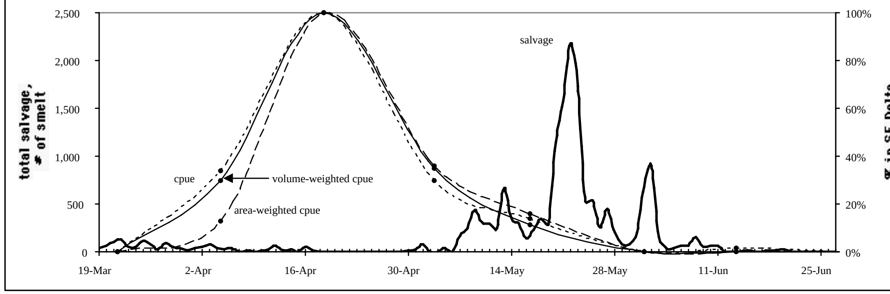
1999
salvage & % of standing crop in SE Delta



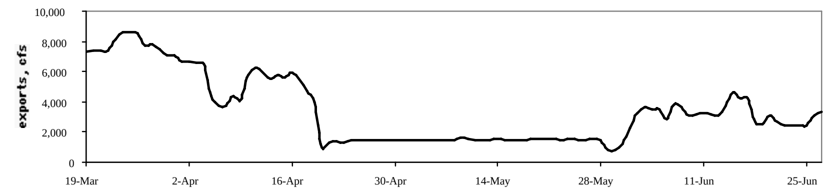
1999
total SWP and CVP exports



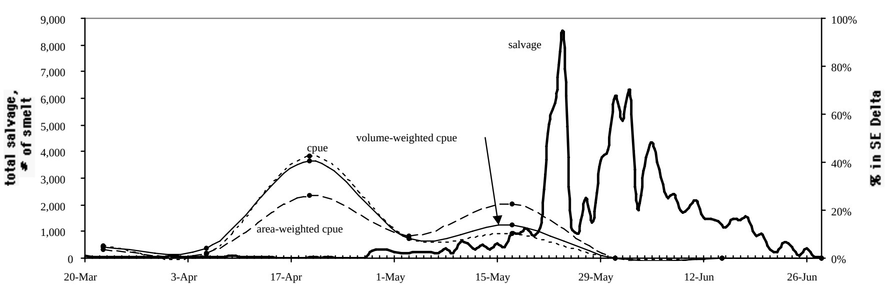
2001
salvage & % of standing crop in SE Delta



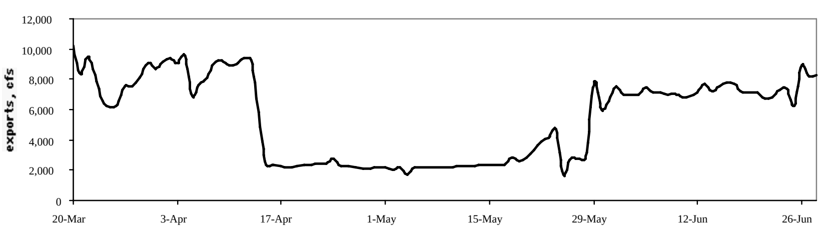
2001
total SWP and CVP exports



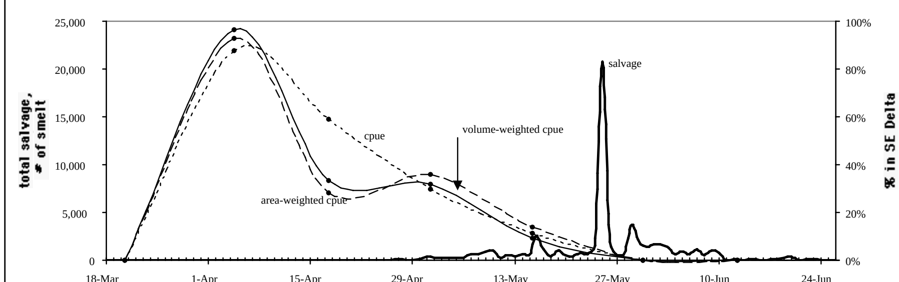
2000
salvage & % of standing crop in SE Delta



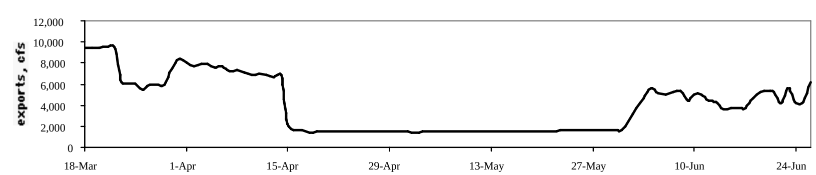
2000
total SWP and CVP exports



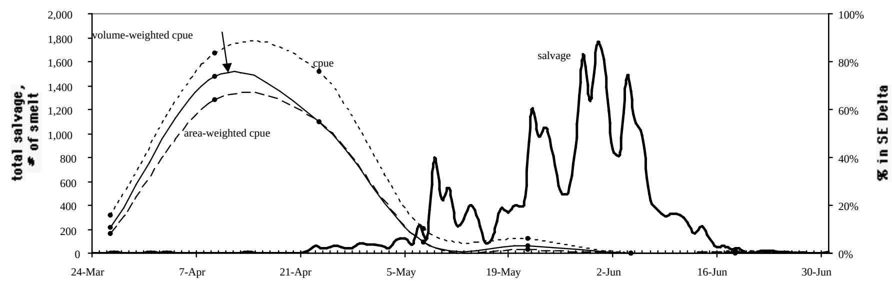
2002
salvage & % of standing crop in SE Delta



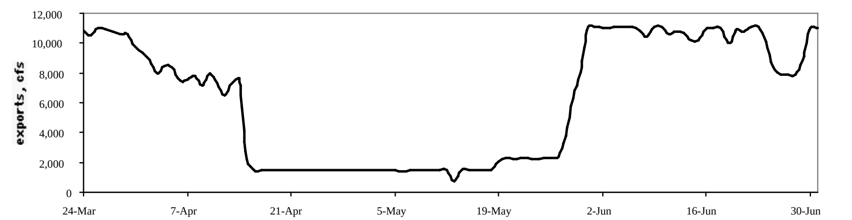
2002
total SWP and CVP exports



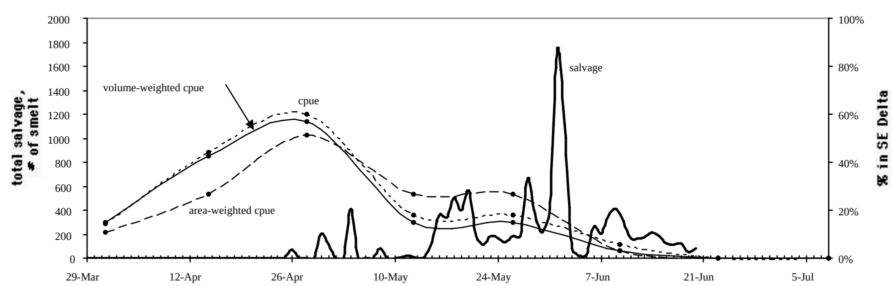
2003
salvage & % of standing crop in SE Delta



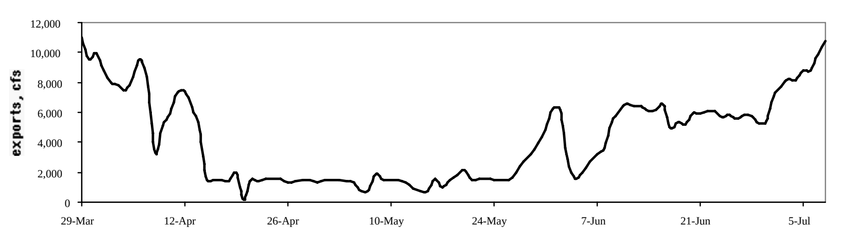
2003
total SWP and CVP exports



2004
salvage & % of standing crop in SE Delta



2004
total SWP and CVP exports



Conclusion

- Salvage occurring after most smelt had left the SE Delta
- High exports were sometimes occurring when significant fraction of smelt in SE Delta (& smelt < 20 mm)
- Salvage a poor basis for measuring entrainment and managing exports

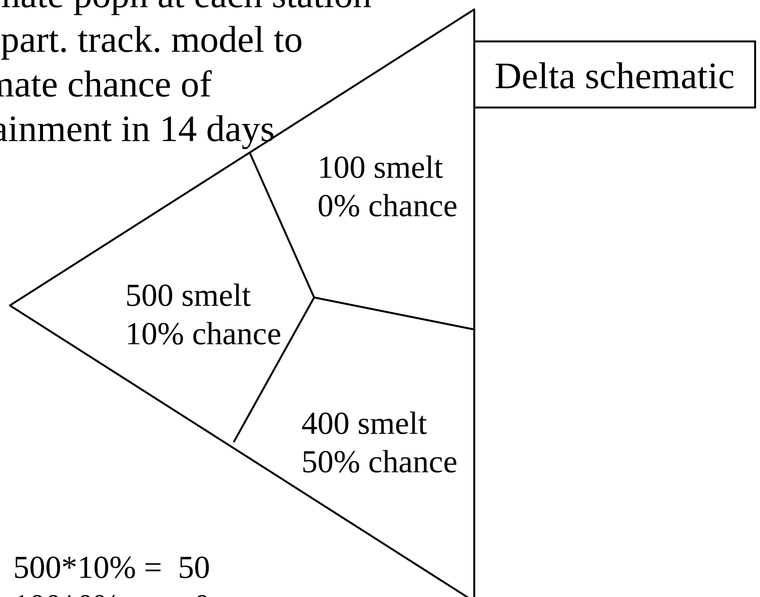
Better method estimate % juveniles entrained

- Estimate fraction of hatched popn at each 20 mm station
- Use Particle Tracking Model to extimate chance of being entrained from each station
- Sum results from all surveys

Estimating % entrained without knowing population

knowing population

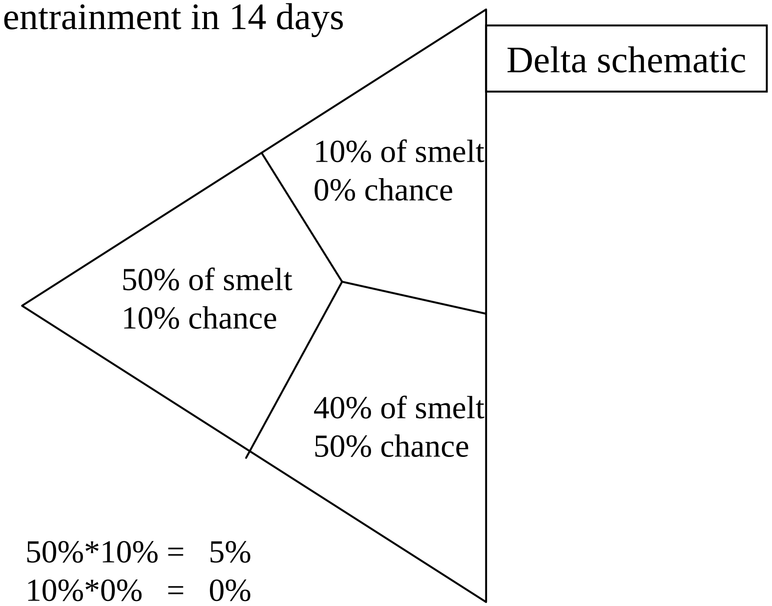
Estimate popn at each station
Use part. track. model to
estimate chance of
entrainment in 14 days



500*10% = 50
100*0% = 0
400*50% = 200
total = 250
250/1000 = 25%

knowing distribution
(based on cpue from
20 mm survey)

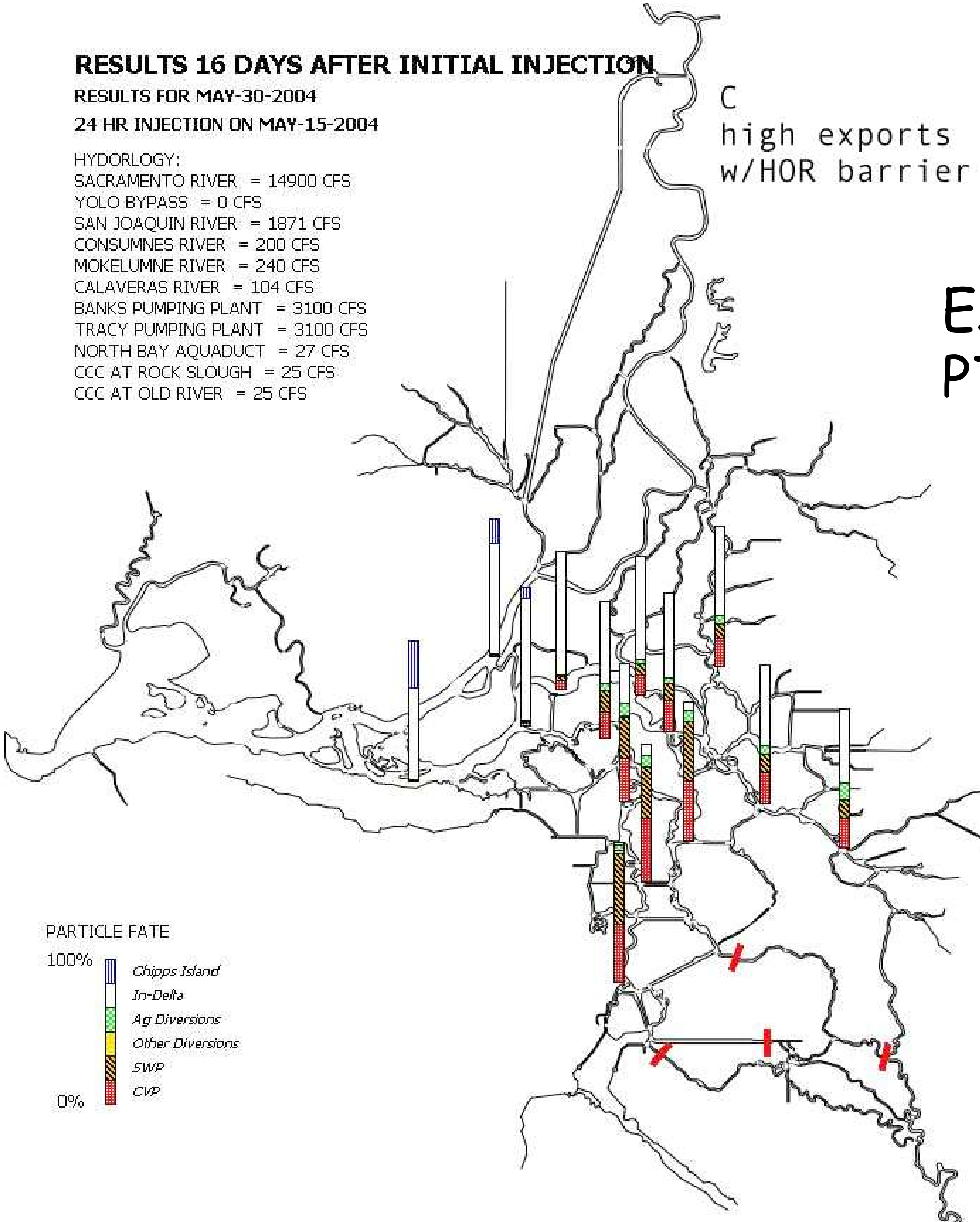
Use relative cpue (or weighted
cpue) to estimate % smelt at each
station.Use PTM to estimate
chance of entrainment in 14 days



50%*10% = 5%
10%*0% = 0%
40%*50% = 20%
total = 25%

Conclusion: with an estimate of the %-age of smelt at each Station and PTM results, can estimate % entrained. Do not need an estimate of the population

Example of PTM results



using all So. Delta EIR VAMP PTM runs

PTM node	percentage of particles entrained in 14 days. X = exports/Delta outflow	R2 and p values
6	%=10.97-23.58*HOR+0.00155*SJR+0.00858*CVP+0.00292*SWP	R2=0.95, p(HOR)=2E-9, p(SJR)=0.02, p(CVP)=8E-11, p(SWP)=7E-7
26	%=-8.316+12.82*HOR-0.00160*SJR+0.0132*CVP+0.00262*SWP	R2=0.95, p(HOR)=0.0002, p(SJR)=0.02, p(CVP)=3E-15, p(SWP)=9E-6
37	%=1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP	R2=0.97, p(SJR)=9E-8, p(CVP)=6E-9, p(SWP)=5E-18
44	%=1.474-0.00140*SJR+0.00361*SWP	R2=0.96, p(SJR)=9E-7, p(SWP)=4E-24
52	%=23.96-59.19*HOR+0.00567*SJR+0.00814*CVP	R2=0.30, p(HOR)=1.6E-10, p(SJR)=0.0004, p(CVP)=1.1E-5
194	%=3.200+29.93*HOR+0.0205*CVP	R2=0.87, p(HOR)=3E-6, p(CVP)=7E-17
285	%=0.975-0.00257*SJR+0.00259*CVP+0.00672*SWP	R2=0.98, p(SJR)=7E-8, p(CVP)=5E-5, p(SWP)=5E-22
335	%=1.324-0.00138*SJR+0.000622*CVP+0.00319*SWP	R2=0.98, p(SJR)=7E-9, p(CVP)=0.028, p(SWP)=10E-22
350	%=3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP	R2=0.94, p(SAC)=0.015, p(SJR)=0.0002, p(SWP)=1.1E-15
356	%=-0.0910+0.355*(exp/outflow)	R2=0.85, p(E/I)=1E-16

20 mm stations	corresponding PTM nodes	equations relating % entrainment to Delta hydrology
323	0	0
340	0	0
342	0	0
343	0	0
344	0	0
345	0	0
346	0	0
405	0	0
411	0	0
418	0	0
501	0	0
504	0	0
508	0	-0.091+0.355*(exp/outflow)
513	0	-0.091+0.355*(exp/outflow)
519	0	0
520	0	-0.091+0.355*(exp/outflow)
602	0	0
606	0	0
609	0	0
610	0	0
703	1/2 node 44	(1.474-0.00140*SJR+0.00361*SWP)/2
704	1/2 node 350	(3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP)/2
705	avg nodes 44 & 350	((1.474-0.00140*SJR+0.00361*SWP)+(3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP))/2
706	1/2 node 350	(3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP)/2
707	avg nodes 44 & 350	((1.474-0.00140*SJR+0.00361*SWP)+(3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP))/2
711	node 350	3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP
716	node 350	3.82-0.000275*SAC-0.000585*SJR+0.00201*SWP
801	1/2 node 44	(1.474-0.00140*SJR+0.00361*SWP)/2
804	1/2 node 44	(1.474-0.00140*SJR+0.00361*SWP)/2
809	node 44	1.474-0.00140*SJR+0.00361*SWP
812	avg nodes 37 & 44	((1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP)+(1.474-0.00140*SJR+0.00361*SWP))/2
815	node 37	1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP
901	node 37	1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP
902	(2*node 37 + 1*node 194)/3	(2*(1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP)+(3.200+29.93*HOR+0.0205*CVP))/3
906	avg nodes 26 & 37	((-8.316+12.82*HOR-0.00160*SJR+0.0132*CVP+0.00262*SWP)+(1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP))/2
910	node 26	-8.316+12.82*HOR-0.00160*SJR+0.0132*CVP+0.00262*SWP
912	node 26	-8.316+12.82*HOR-0.00160*SJR+0.0132*CVP+0.00262*SWP
914	avg node 26 & node 194	((-8.316+12.82*HOR-0.00160*SJR+0.0132*CVP+0.00262*SWP)+(3.200+29.93*HOR+0.0205*CVP))/2
915	node 194	3.200+29.93*HOR+0.0205*CVP
918	100	IF(SWP+CVP>0,100,0)
919	avg node 37 & node 285	((1.533-0.00343*SJR+0.00582*CVP+0.00678*SWP)+(0.975-0.00257*SJR+0.00259*CVP+0.00672*SWP))/2

Instructions: Insert data from a 20 mm survey into the red cells. Use a separate worksheet to arrange the data so the rows exactly correspond to the station numbers in Column B. Then paste the data into this worksheet. Insert Delta hydrology data for the period from the 20 mm survey in question to the next 20 mm survey in the green cells. The spreadsheet will calculate the percentage of smelt in the southeastern Delta (stations 815-918) and the chances of being entrained in 14 days from each 20 mm station (i.e., from all stations, not just those in the SE Delt a). Then, use the graph on the next worksheet to estimate the fraction of smelt hatched in the survey in question. Multiply this fraction by the % smelt entrained to estimate the % of the entire population entrained from the survey in question to the next survey.

survey description		
	Species:	Delta smelt
	Year:	
	Type of Survey:	
	Survey number:	

Particle Tracking Model data										
Sac R	15,000	Mokel. R.		No. Bay Aq.		days after release		net Delta out	15,000
Yolo Bypass		Calav. R.		CCC Rock Sl.				exp/out	0.40
SJ R.	6,000	Banks PP	2,000	CCC Old R.		HOR barrier	0		
Cosum. R.		Tracy PP	4,000						

STATION	survey data					weighting factors			percentage of particles entrained in two weeks			cpue and weighted cpue			fraction of smelt at each station			(fraction at each station)*(%-age entrained from that station)			STATION
	STATION	surface temp	surface ec	number of tows	avg cpue	volumetric weighting factor	station depth feet	area weighting factor	CVP %	SWP %	SWP + CVP %	avg cpue	avg cpue*vol wtg factor	avg cpue* area wtg factor	avg cpue	avg cpue*vol wtg factor	avg cpue* area wtg factor	avg cpue %	avg cpue*vol wtg factor %	avg cpue* area wtg factor %	
323	323	15	11,430	3	0	213	20	10.65			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	323
340	328	15	14,000	3	0	10	10	1.00			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	340
342	329	15	12,320	3	0	4	10	0.40			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	342
343	334	15	13,790	3	0	2	10	0.20			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	343
344	335	15	12,980	3	0	1	10	0.10			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	344
345	336	15	10,390	3	4	1	10	0.10			0.000	3.6	4	0	0.0115	0.0004	0.0010	0.0000	0.0000	0.0000	345
346	340	16	8,140	3	15	1	10	0.10			0.000	14.7	15	1	0.0466	0.0016	0.0039	0.0000	0.0000	0.0000	346
405	405	16	543	3	0	13	10	1.30			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	405
411	411	16	464	3	0	46	10	4.60			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	411
418	418	19	668	3	0	70	35	2.00			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	418
501	501	16	327	3	0	49	22	2.23			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	501
504	504	16	170	3	0	60	22	2.73			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	504
508	508	16.4	158	3	31.54	31	55	0.56			0.051	31.5	978	18	0.1001	0.1051	0.0478	0.0051	0.0054	0.0024	508
513	513	15.7	146	3	7.26	43	30	1.43			0.051	7.3	312	10	0.0230	0.0335	0.0280	0.0012	0.0017	0.0014	513
519	519	16	172	3	0	15	9	1.67			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	519
520	520	16.3	163	3	31.93	9	38	0.24			0.051	31.9	287	8	0.1013	0.0309	0.0203	0.0052	0.0016	0.0010	520
602	602	17.6	208	3	0	44	4	11.00			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	602
606	606	17.6	512	3	0	20	25	0.80			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	606
609	609	16.8	814	3	8.02	15	33	0.45			0.000	8.0	120	4	0.0255	0.0129	0.0098	0.0000	0.0000	0.0000	609
610	610	15.7	212	3	0	4	13	0.31			0.000	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	610
703	703	15.3	150	3	19.04	4	15	0.27			0.147	19.0	76	5	0.0604	0.0082	0.0137	0.0089	0.0012	0.0020	703
704	704	15	133	3	36.75	53	26	2.04			0.103	36.8	1,948	75	0.1166	0.2093	0.2014	0.0120	0.0215	0.0206	704
705	705	15.6	142	3	0	1	20	0.05			0.250	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	705
706	706	15	140	3	11.1	27	22	1.23			0.103	11.1	300	14	0.0352	0.0322	0.0366	0.0036	0.0033	0.0038	706
707	707	15.9	151	3	7.1	35	24	1.46			0.250	7.1	249	10	0.0225	0.0267	0.0278	0.0056	0.0067	0.0069	707
711	711	15.7	104	3	0	32	13	2.46			0.205	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	711
716	716	16.8	245	3	3.51	5	30	0.17			0.205	3.5	18	1	0.0111	0.0019	0.0016	0.0023	0.0004	0.0003	716
801	801	15.2	165	3	7.62	26	30	0.87			0.147	7.6	198	7	0.0242	0.0213	0.0178	0.0036	0.0031	0.0026	801
804	804	15.7	167	3	56.72	52	22	2.36			0.147	56.7	2,949	134	0.1800	0.3169	0.3605	0.0265	0.0466	0.0530	804
809	809	15.1	159	3	3.61	56	42	1.33			0.294	3.6	202	5	0.0115	0.0217	0.0129	0.0034	0.0064	0.0038	809
812	812	15.9	147	3	11.39	22	20	1.10			**9.044**	11.4	251	13	0.0362	0.0269	0.0337	0.3269	0.2435	0.3047	812
815	815	15.9	151	3	18.4	40	17	2.35			17.793	18.4	736	43	0.0584	0.0791	0.1164	1.0391	1.4072	2.0714	815
901	901	15.7	171	3	7.65	5	20	0.25			17.793	7.7	38	2	0.0243	0.0041	0.0051	0.4320	0.0731	0.0915	901
902	902	16.5	204	3	13.73	23	26	0.88			40.262	13.7	316	12	0.0436	0.0339	0.0327	1.7546	1.3663	1.3149	902
906	906	16.3	233	3	3.54	21	38	0.55			**28.959**	3.5	74	2	0.0112	0.0080	0.0053	0.3254	0.2313	0.1523	906
910	910	17.8	316	3	0	11	38	0.29			40.124	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	910
912	912	17.6	351	3	0	8	40	0.20			40.124	0.0	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	912
914	914	17.9	281	3	7.18	15	31	0.48			62.662	7.2	108	3	0.0228	0.0116	0.0093	1.4280	0.7252	0.5854	914
915	915	18.1	263	3	3.58	15	30	0.50			**85.200**	3.6	54	2	0.0114	0.0058	0.0048	0.9681	0.4916	0.4101	915
918	918	18.2	328	3	3.29	11	20	0.55			100.000	3.3	36	2	0.0104	0.0039	0.0049	1.0442	0.3889	0.4866	918
919	919	14.8	119	3	3.81	10	22	0.45			13.574	3.8	38	2	0.0121	0.0041	0.0047	0.1641	0.0556	0.0632	919
	ZofE temp	17.0										315	9,306	372	**18%**	**15%**	**18%**	**8%**	**5%**	**6%**	
												totals			% smelt, zone of entrainment			% smelt entrained			

Percentage of hatched juvenile delta smelt entrained

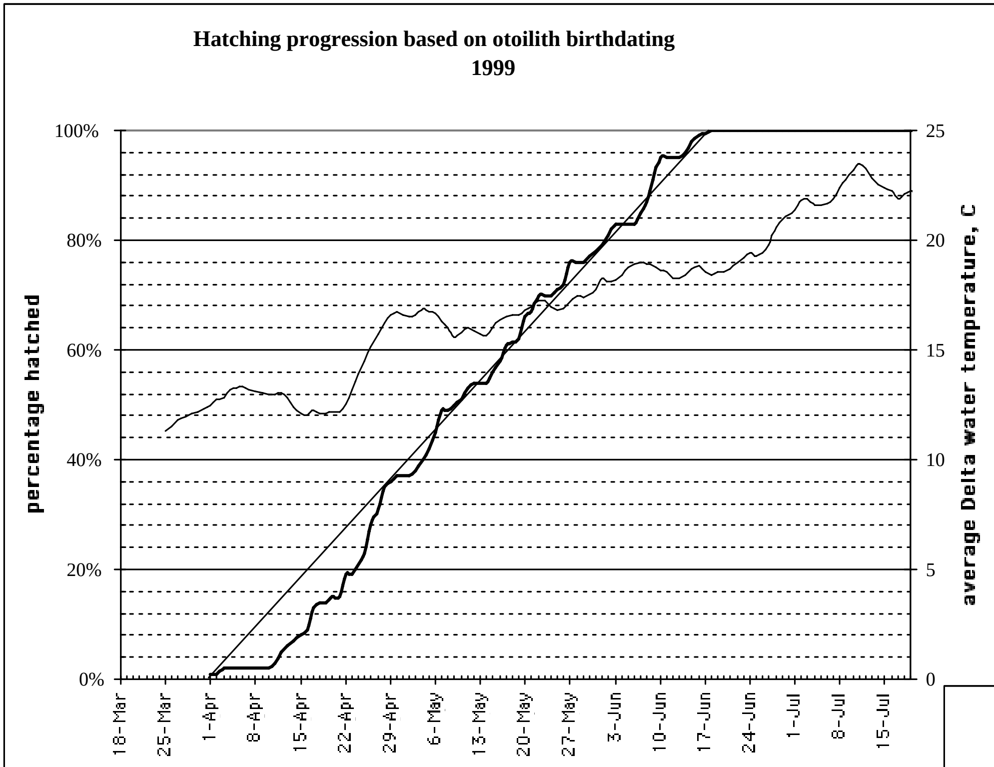
survey number	mid-date	% entrained per particle tracking model: avg cpue	avg cpue*vol wtg factor	avg cpue* area wtg factor	survey number	mid-date	% entrained per particle tracking model: avg cpue	avg cpue*vol wtg factor	avg cpue* area wtg factor
1	4/26/95	0%	0%	0%	1	3/22/00	5%	4%	3%
2	5/10/95	0%	0%	0%	2	4/5/00	1%	3%	1%
3	5/24/95	0%	0%	0%	3	4/19/00	3%	3%	2%
4	6/7/95	0%	0%	0%	4	5/3/00	0%	0%	0%
5	6/21/95	0%	0%	0%	5	5/17/00	2%	3%	3%
6	7/6/95	0%	0%	0%	6	5/31/00	0%	0%	0%
7	7/20/95	0%	0%	0%	7	6/14/00	0%	0%	0%
8	8/4/95	0%	0%	0%	8	6/28/00	0%	0%	0%
1	4/13/96	2%	1%	1%	1	3/21/01	3%	4%	2%
2	4/27/96	0%	0%	0%	2	4/4/01	14%	12%	6%
3	5/11/96	1%	0%	1%	3	4/18/01	28%	20%	22%
4	5/25/96	14%	12%	12%	4	5/3/01	1%	1%	0%
5	6/11/96	9%	6%	9%	5	5/16/01	0%	0%	0%
6	6/26/96	0%	0%	0%	6	6/1/01	0%	0%	0%
7	7/10/96	0%	0%	0%	7	6/13/01	0%	0%	0%
8	7/24/96	0%	0%	0%	8	6/27/01	0%	0%	0%
1	4/2/97	45%	39%	36%	1	3/20/02	0%	0%	0%
2	4/16/97	11%	8%	7%	2	4/4/02	52%	54%	57%
3	4/30/97	2%	1%	1%	3	4/17/02	15%	7%	7%
4	5/14/97	1%	1%	1%	4	5/1/02	0%	0%	0%
5	5/29/97	0%	0%	0%	5	5/15/02	1%	1%	1%
6	6/11/97	0%	0%	0%	6	5/30/02	0%	0%	0%
7	6/26/97	0%	0%	0%	7	6/12/02	0%	0%	0%
8	7/10/97	0%	0%	0%	8	6/26/02	0%	0%	0%
1	4/8/98	0%	0%	0%	1	3/26/03	15%	11%	10%
2	4/23/98	0%	0%	0%	2	4/9/03	20%	18%	17%
3	5/6/98	0%	0%	0%	3	4/23/03	12%	7%	9%
4	5/20/98	0%	0%	0%	4	5/7/03	0%	0%	0%
5	6/3/98	0%	0%	0%	5	5/21/03	6%	3%	2%
6	6/17/98	0%	0%	0%	6	6/4/03	0%	0%	0%
7	6/30/98	0%	0%	0%	7	6/18/03	0%	0%	0%
8	7/15/98	0%	0%	0%	8	7/1/03	0%	0%	0%
1	4/14/99	6%	13%	11%	1	3/31/04	9%	9%	7%
2	4/28/99	2%	1%	1%	2	4/14/04	1%	1%	1%
3	5/12/99	7%	7%	7%	3	4/28/04	0%	0%	0%
4	5/25/99	4%	3%	3%	4	5/12/04	1%	1%	1%
5	6/9/99	2%	1%	1%	5	5/26/04	6%	5%	7%
6	6/23/99	0%	0%	0%	6	6/9/04	6%	3%	3%
7	7/8/99	0%	0%	0%	7	6/23/04	0%	0%	0%
8	7/21/99	0%	0%	0%	8	7/8/04	0%	0%	0%

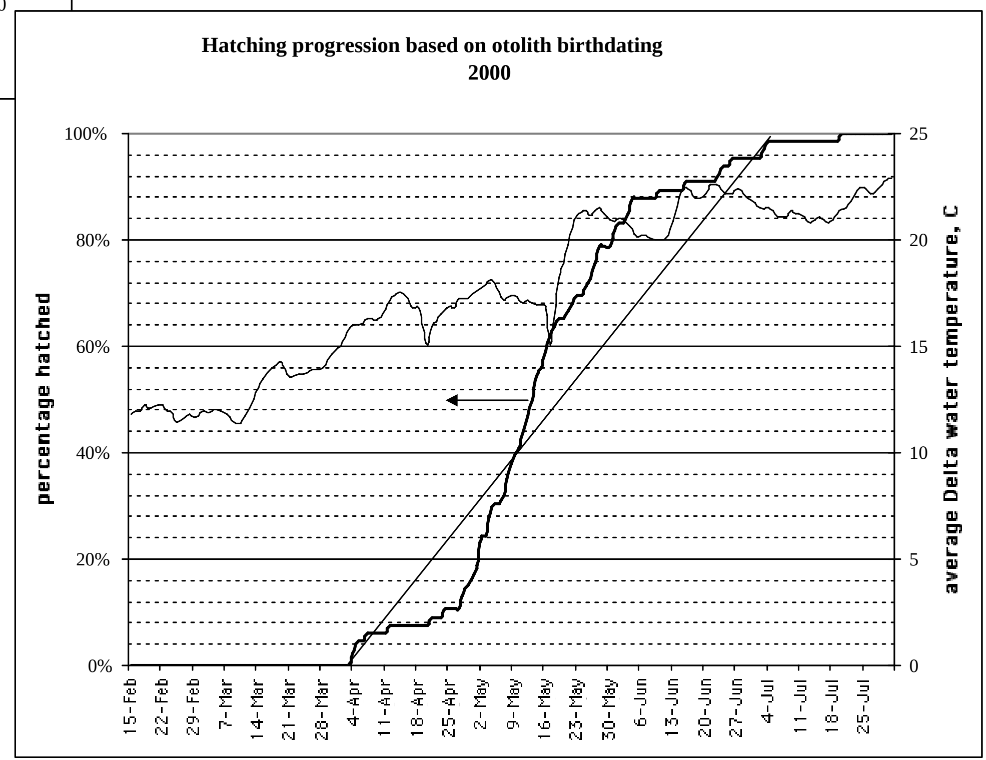
Estimating annual juvenile entrainment from estimates for each survey

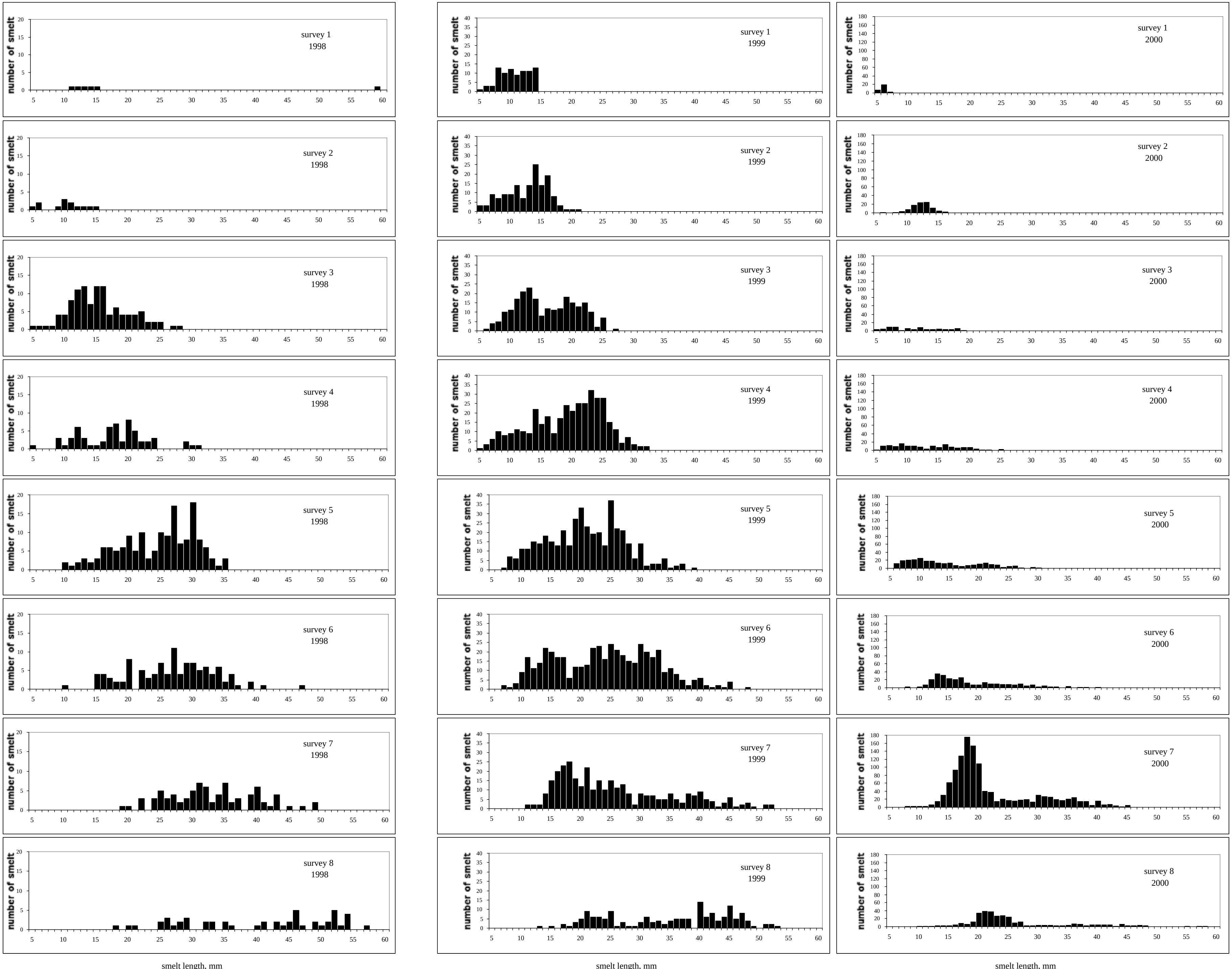
- Must account for possibility that only a fraction have hatched in early surveys
- Must account for fact that each survey's percentage entrainment is only occurring to population not entrained in previous surveys (i.e., can't double count)

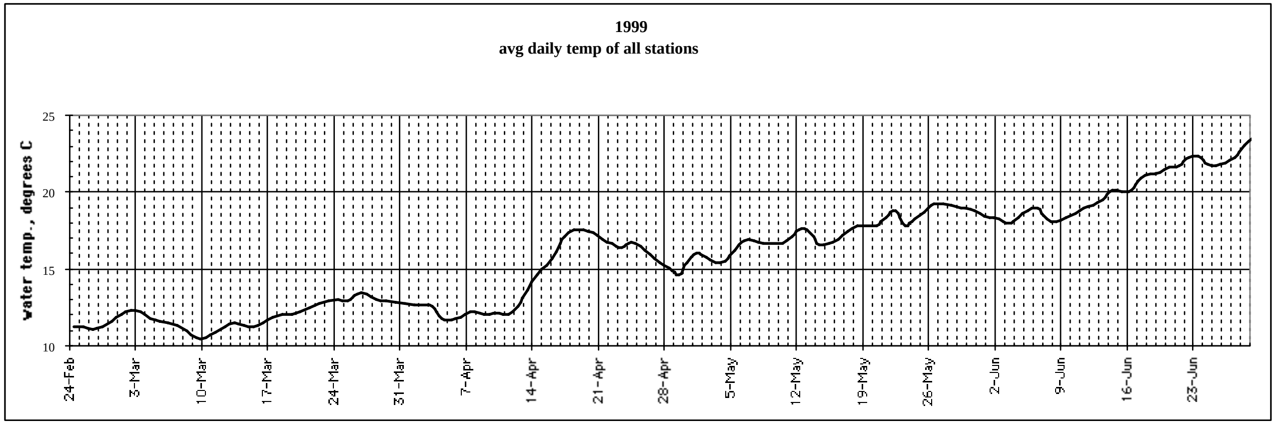
Estimating fraction hatched for each survey

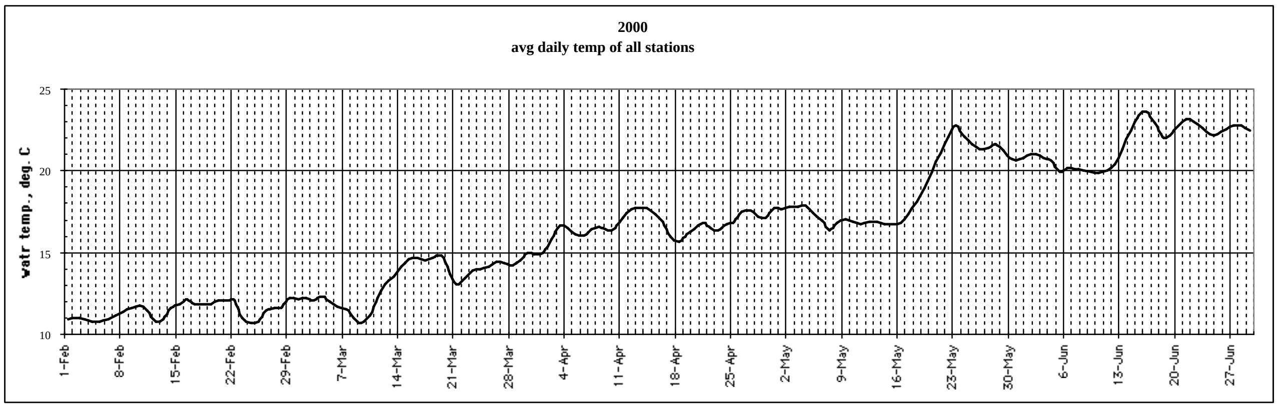
- Various methods
  - Bennett's otolith-age birthdating
  - 20 mm survey, presence of 5-6 mm smelt
  - Dates when water temp reaches 15 and 20 degrees
- Bennett's otolith birthdating
  - indicates that cumulative percentage hatched is approx. straight line relationship with time(?)
- Combined data: 15-20 deg. reasonable, conservative = 10 days earlier

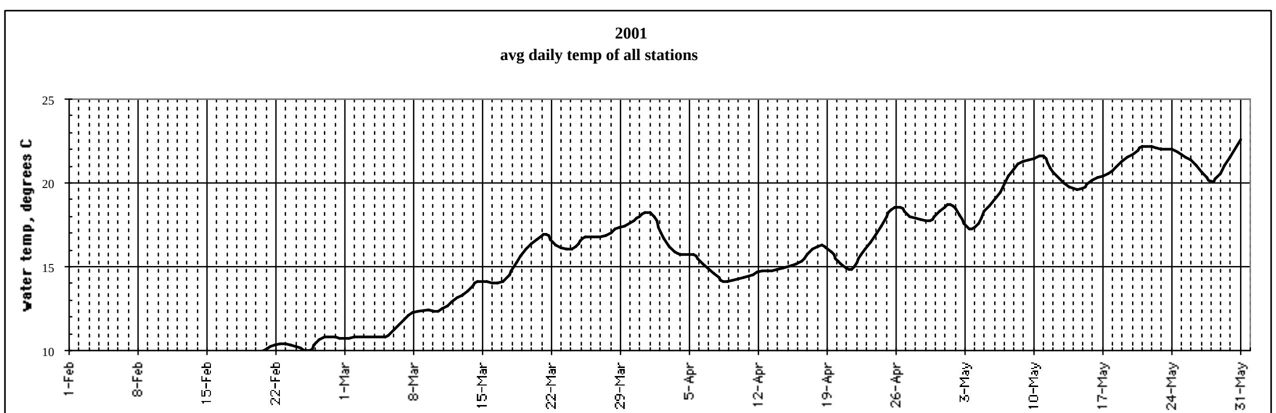

Hatching progression based on otolith birthdating
1999
100%
80%
60%
40%
20%
0%
percentage hatched
25
20
15
10
5
0
average Delta water temperature, C
18-Mar
25-Mar
1-Apr
8-Apr
15-Apr
22-Apr
29-Apr
6-May
13-May
20-May
27-May
3-Jun
10-Jun
17-Jun
24-Jun
1-Jul
8-Jul
15-Jul


Hatching progression based on otolith birthdating
2000
100%
80%
60%
40%
20%
0%
percentage hatched
25
20
15
10
5
0
average Delta water temperature, C
15-Feb
22-Feb
29-Feb
7-Mar
14-Mar
21-Mar
28-Mar
4-Apr
11-Apr
18-Apr
25-Apr
2-May
9-May
16-May
23-May
30-May
6-Jun
13-Jun
20-Jun
27-Jun
4-Jul
11-Jul
18-Jul
25-Jul


survey 1
1998
survey 2
1998
survey 3
1998
survey 4
1998
survey 5
1998
survey 6
1998
survey 7
1998
survey 8
1998
survey 1
1999
survey 2
1999
survey 3
1999
survey 4
1999
survey 5
1999
survey 6
1999
survey 7
1999
survey 8
1999
survey 1
2000
survey 2
2000
survey 3
2000
survey 4
2000
survey 5
2000
survey 6
2000
survey 7
2000
survey 8
2000
number of smelt
smelt length, mm
smelt length, mm
smelt length, mm


1999
avg daily temp of all stations
water temp., degrees C
25
20
15
10
24-Feb
3-Mar
10-Mar
17-Mar
24-Mar
31-Mar
7-Apr
14-Apr
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun


2000
avg daily temp of all stations
watr temp., deg. C
25
20
15
10
1-Feb
8-Feb
15-Feb
22-Feb
29-Feb
7-Mar
14-Mar
21-Mar
28-Mar
4-Apr
11-Apr
18-Apr
25-Apr
2-May
9-May
16-May
23-May
30-May
6-Jun
13-Jun
20-Jun
27-Jun


2001
avg daily temp of all stations
water temp, degrees C
25
20
15
10
1-Feb
8-Feb
15-Feb
22-Feb
1-Mar
8-Mar
15-Mar
22-Mar
29-Mar
5-Apr
12-Apr
19-Apr
26-Apr
3-May
10-May
17-May
24-May
31-May

Data on beginning and end of delta smelt hatching

		histograms 5 and 6 mm smelt		bennett dates of 15 & 20 degrees	bennett otolith birthdating	bj-cdec avg. Delta temp	zooplankton survey temp data	20 mm survey avg temp
year	beginning date	before 26-Apr-1995		5-Apr-95			24-Apr-95	before 4/26
1995	ending date	before 26-Apr-1995		6-Jun-95			16-Jun-95	6/21-7/6
year	beginning date	before 13-Apr-1996		11-Apr-96			27-Mar-96	before 4/13
1996	ending date	25-May-96	11-Jun-96	12-Jun-96			8-May-96	5/25-6/11
year	beginning date	before 2-Apr-97		12-Apr-97			29-Mar-97	before 4/2
1997	ending date	14-May-97	29-May-97	14-May-97			10-May-97	4/30-5/14
year	beginning date	before 8-Apr-98		18-Apr-98			6-Apr-98	4/8-4/23
1998	ending date	20-May-98	3-Jun-98	15-Jun-98			16-Jun-98	6/3-6/17
year	beginning date	before 14-Apr-99		16-Apr-99	1-Apr-99	15-Apr-99	30-Apr-99	4/14-4/28
1999	ending date	14-Jun-99	23-Jun-99	18-Jun-99	18-Jun-99	14-Jun-99	19-Jun-99	6/9-6/23
year	beginning date	before 22-Mar-00		1-Apr-00	3-Apr-00	30-Mar-00	27-Mar-00	3/22-4/5
2000	ending date	6-Jun-00	14-Jun-00	28-May-00	21-Jun-00	20-May-00	11-Jun-00	5/17-5/31
year	beginning date	before 21-Mar-01		19-Mar-01		18-Mar-01	16-Apr-01	about 3/21
2001	ending date	16-May-01	1-Jun-01	21-May-01		7-May-01	18-May-01	5/3-5/16
year	beginning date	4-Apr-02		5-Apr-02		29-Mar-02	25-Mar-02	3/20-4/4
2002	ending date	1-May-02	15-May-02	2-Jun-02		29-May-02	25-May-02	5/15-5/30
year	beginning date	before 26-Mar-03				1-May-03	24-Mar-03	about 5/26
2003	ending date	7-May-03	21-May-03			22-May-03	9-Jun-03	5/21-6/4
year	beginning date	before 31-Mar-04				11-Mar-04	9-Mar-04	before 3/31
2004	ending date	28-Apr-04	12-May-04			2-May-04	20-May-04	4/28-5/12

(blue shading) indicates agreement on temperature and/or beginning/end of hatching

conclusions:

Hatching begins at or somewhat before water temp reaches 15 deg.

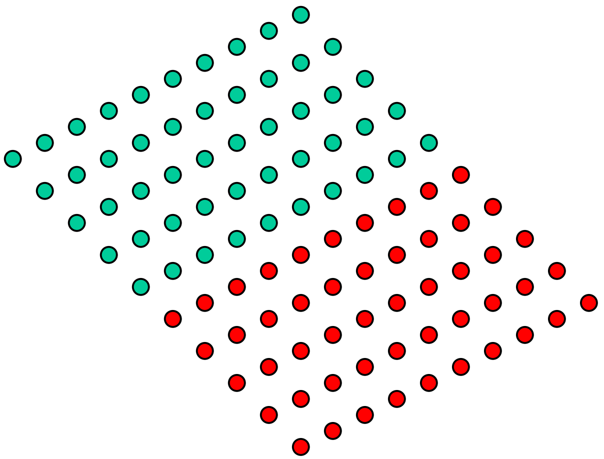
Hatching ends when water temp is about 20 degrees (within 2-3 weeks).

Estimates of fraction hatched

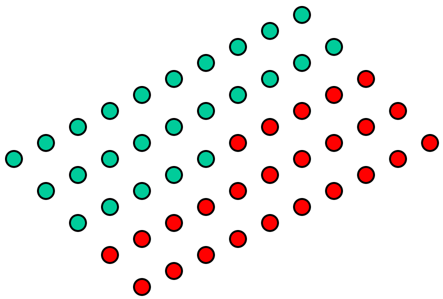
year	survey number	mid-date	fraction hatched
1995	1	26-Apr-95	0.50
	2	10-May-95	0.73
	3	24-May-95	0.95
	4	7-Jun-95	1.00
	5	21-Jun-95	1.00
	6	6-Jul-95	1.00
	7	20-Jul-95	1.00
	8	4-Aug-95	1.00
1996	1	13-Apr-96	0.20
	2	27-Apr-96	0.42
	3	11-May-96	0.65
	4	25-May-96	0.87
	5	11-Jun-96	1.00
	6	26-Jun-96	1.00
	7	10-Jul-96	1.00
	8	24-Jul-96	1.00
1997	1	2-Apr-97	0.02
	2	16-Apr-97	0.45
	3	30-Apr-97	0.89
	4	14-May-97	1.00
	5	29-May-97	1.00
	6	11-Jun-97	1.00
	7	26-Jun-97	1.00
	8	10-Jul-97	1.00
1998	1	8-Apr-98	0.01
	2	23-Apr-98	0.26
	3	6-May-98	0.49
	4	20-May-98	0.73
	5	3-Jun-98	0.97
	6	17-Jun-98	1.00
	7	30-Jun-98	1.00
	8	15-Jul-98	1.00
1999	1	14-Apr-99	0.13
	2	28-Apr-99	0.36
	3	12-May-99	0.58
	4	25-May-99	0.79
	5	9-Jun-99	1.00
	6	23-Jun-99	1.00
	7	8-Jul-99	1.00
	8	21-Jul-99	1.00

year	survey number	mid-date	fraction hatched
2000	1	22-Mar-00	0.01
	2	5-Apr-00	0.25
	3	19-Apr-00	0.50
	4	3-May-00	0.74
	5	17-May-00	0.98
	6	31-May-00	1.00
	7	14-Jun-00	1.00
	8	28-Jun-00	1.00
2001	1	21-Mar-01	0.20
	2	4-Apr-01	0.42
	3	18-Apr-01	0.64
	4	3-May-01	0.88
	5	16-May-01	1.00
	6	1-Jun-01	1.00
	7	13-Jun-01	1.00
	8	27-Jun-01	1.00
2002	1	20-Mar-02	0.00
	2	4-Apr-02	0.16
	3	17-Apr-02	0.39
	4	1-May-02	0.63
	5	15-May-02	0.87
	6	30-May-02	1.00
	7	12-Jun-02	1.00
	8	26-Jun-02	1.00
2003	1	26-Mar-03	0.23
	2	9-Apr-03	0.46
	3	23-Apr-03	0.69
	4	7-May-03	0.93
	5	21-May-03	1.00
	6	4-Jun-03	1.00
	7	18-Jun-03	1.00
	8	1-Jul-03	1.00
2004	1	31-Mar-04	0.59
	2	14-Apr-04	0.86
	3	28-Apr-04	1.00
	4	12-May-04	1.00
	5	26-May-04	1.00
	6	9-Jun-04	1.00
	7	23-Jun-04	1.00
	8	8-Jul-04	1.00

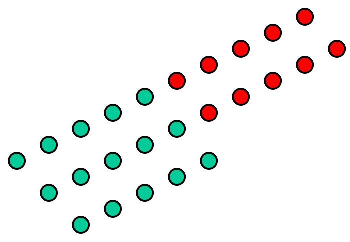
Cumulative entrainment is not
50% + 50% +40% = 140%
It is only 85% ((100-15)/100



3rd survey
50% entrained



4th survey
50% entrained

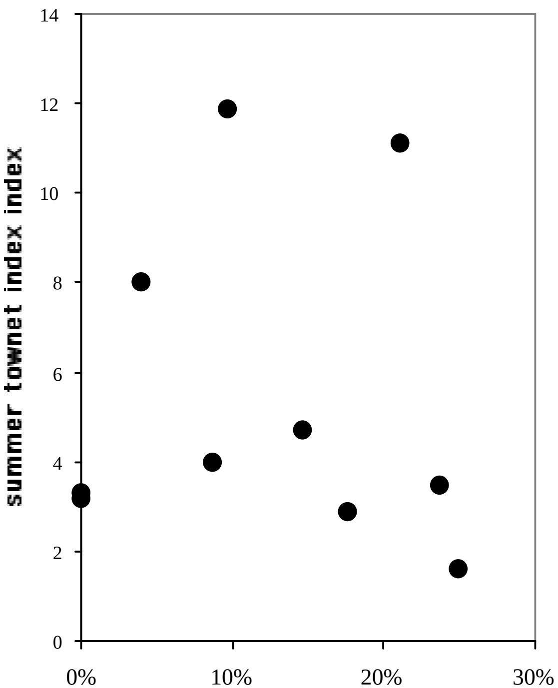


5th survey
40% entrained

annual juvenile delta smelt entrainment

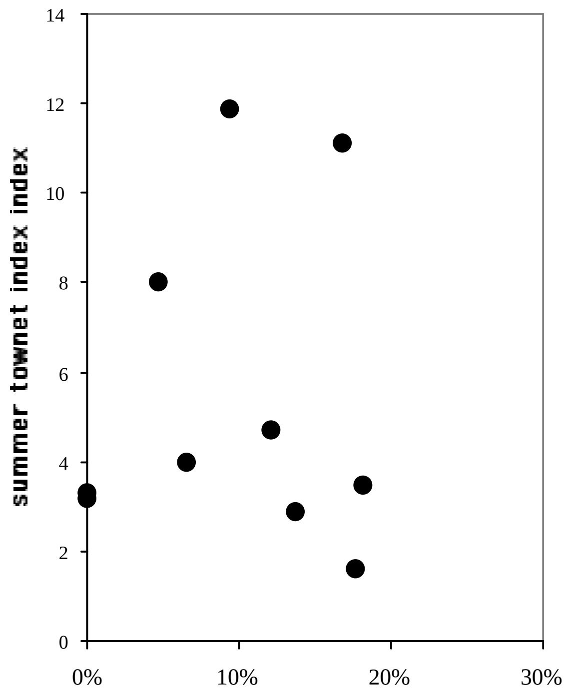
year	% population entrained		
	avg cpue	avg cpue*vol wtg factor	avg cpue* area wtg factor
1995	0%	0%	0%
1996	21%	17%	18%
1997	9%	7%	6%
1998	0%	0%	0%
1999	10%	9%	9%
2000	4%	5%	5%
2001	24%	18%	17%
2002	15%	12%	13%
2003	25%	18%	17%
2004	18%	14%	15%

summer townet index
vs.
previous annual % juvenile entrainment



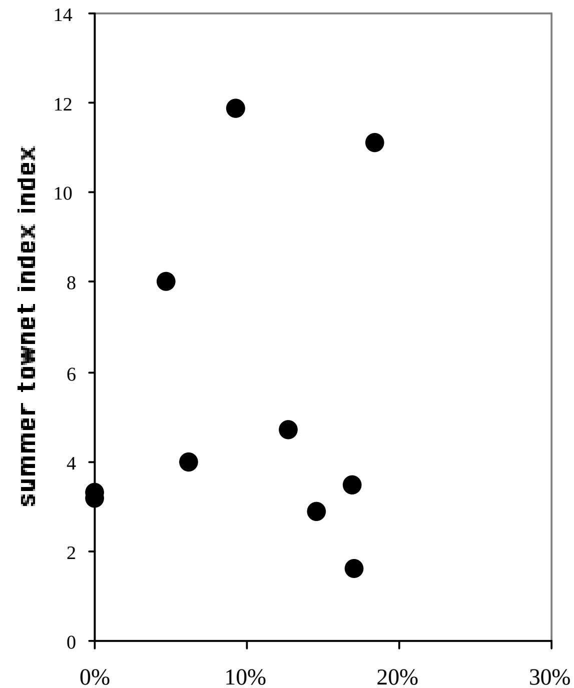
annual juvenile entrainment
CPUE

summer townet index
vs.
previous annual % juvenile entrainment

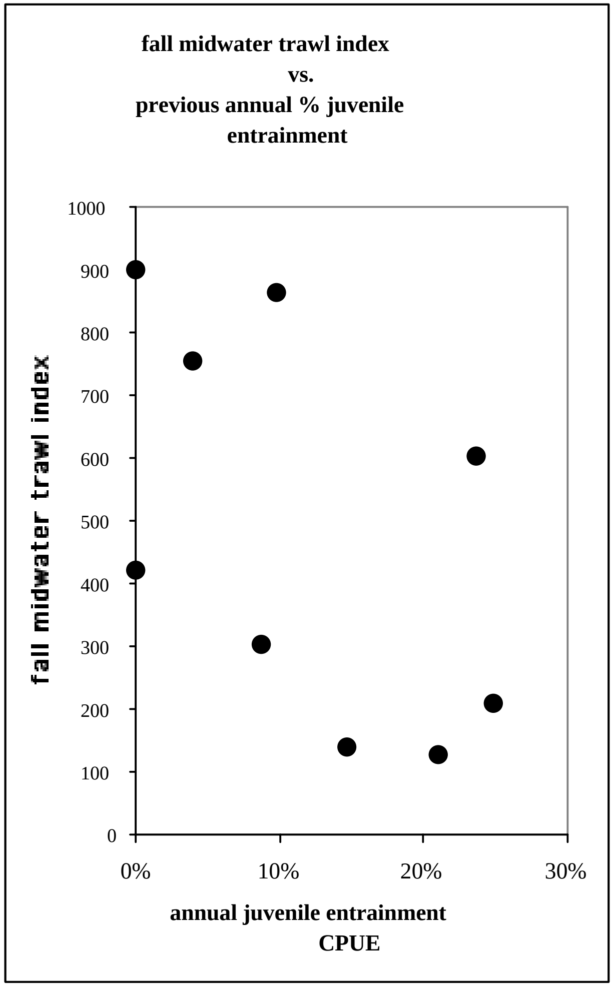


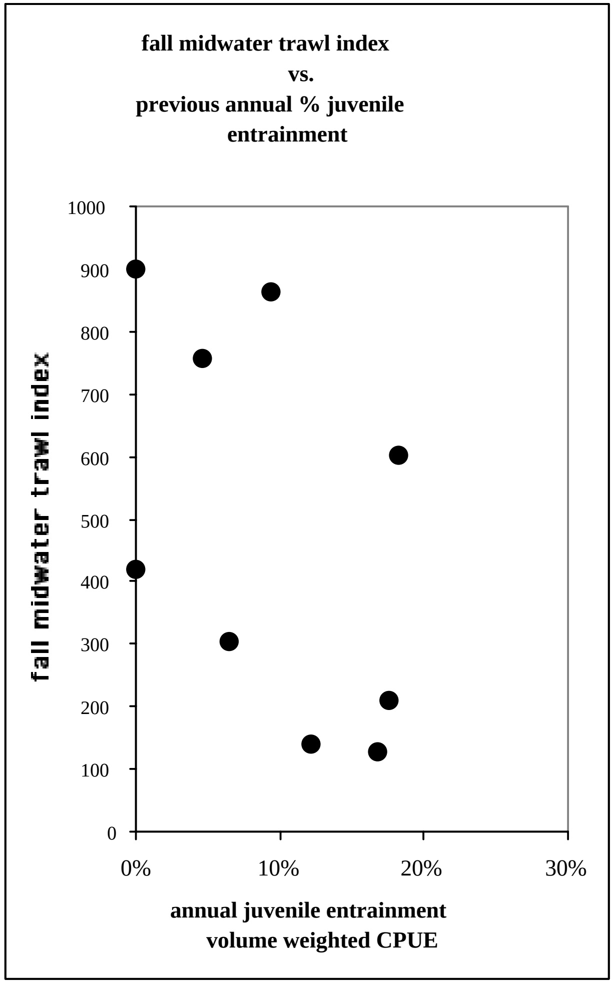
annual juvenile entrainment
volume weighted CPUE

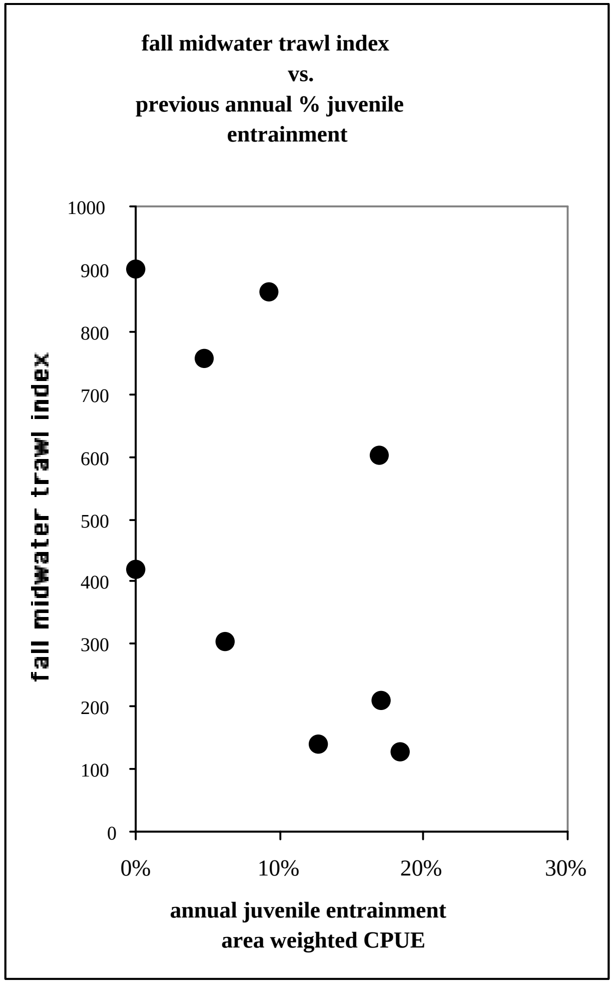
summer townet index
vs.
previous annual % juvenile entrainment



annual juvenile entrainment
area weighted CPUE


fall midwater trawl index
vs.
previous annual % juvenile entrainment
fall midwater trawl index
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
annual juvenile entrainment
CPUE

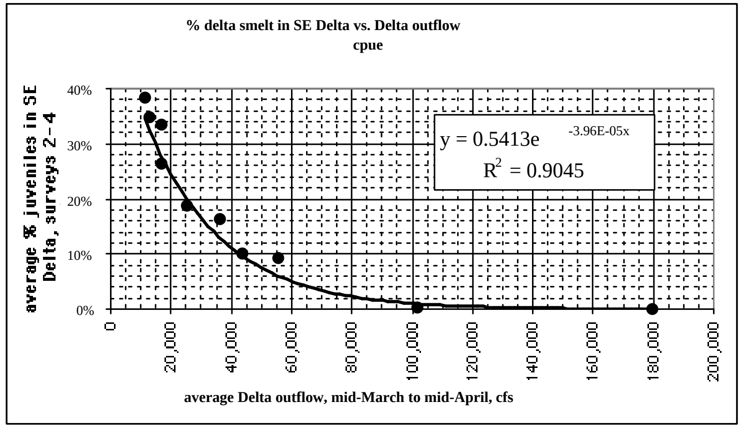

fall midwater trawl index
vs.
previous annual % juvenile entrainment
fall midwater trawl index
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
annual juvenile entrainment
volume weighted CPUE

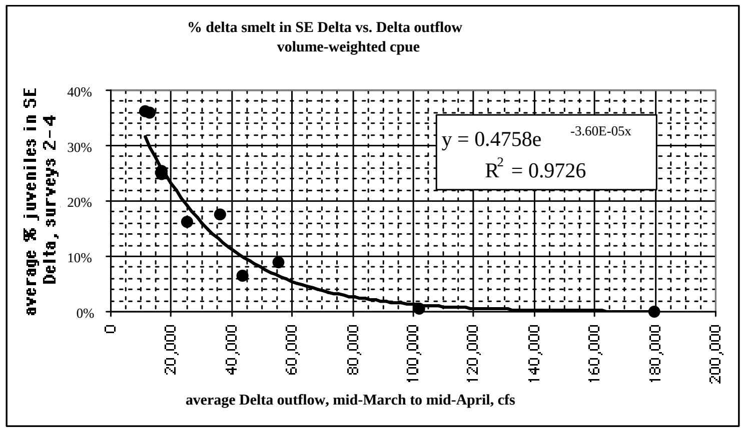

fall midwater trawl index
vs.
previous annual % juvenile entrainment
fall midwater trawl index
1000
900
800
700
600
500
400
300
200
100
0
0%
10%
20%
30%
annual juvenile entrainment
area weighted CPUE

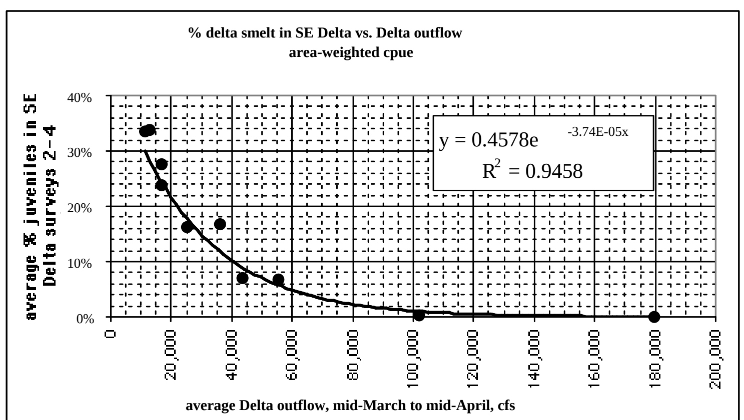
Managing exports to limit juvenile entrainment

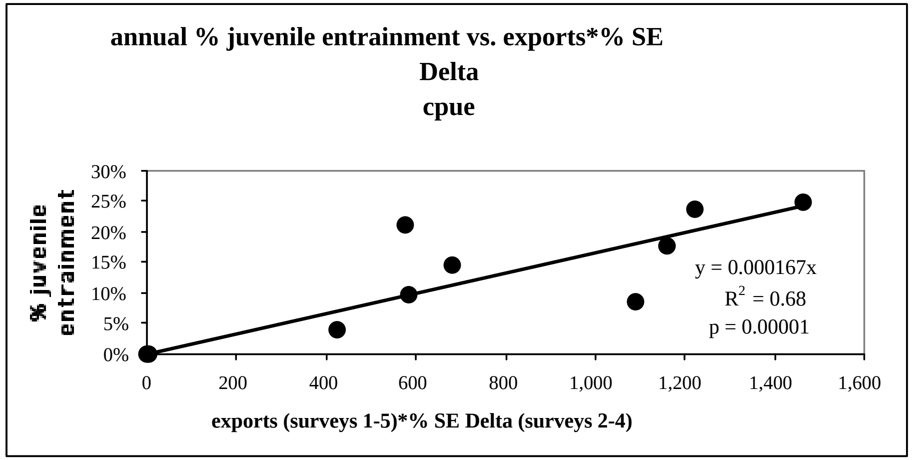
- Choose target % juvenile entrainment
- Compute target % entrainment per survey
- Predict % SE Delta from mid-March-mid-Apr Delta outflow
- Use relationship of % entrain vs. (% SE Delta)*(exports surveys 1-5) to choose exports
- Adjust exports to manage each survey's % entrainment

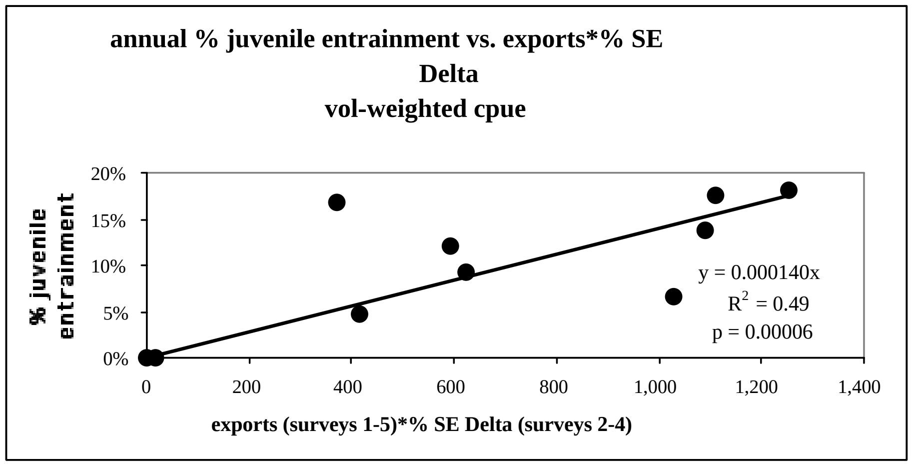
Percentage of total delta smelt in the southeastern Delta vs. export rate

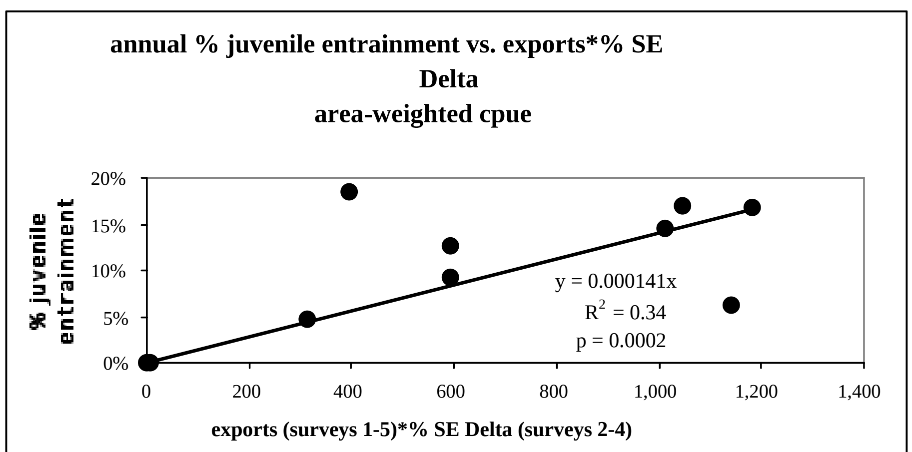







annual % juvenile entrainment vs. exports*% SE Delta
cpue
% juvenile entrainment
30%
25%
20%
15%
10%
5%
0%
0
200
400
600
800
1,000
1,200
1,400
1,600
exports (surveys 1-5)*% SE Delta (surveys 2-4)
y = 0.000167x
R2 = 0.68
p = 0.00001

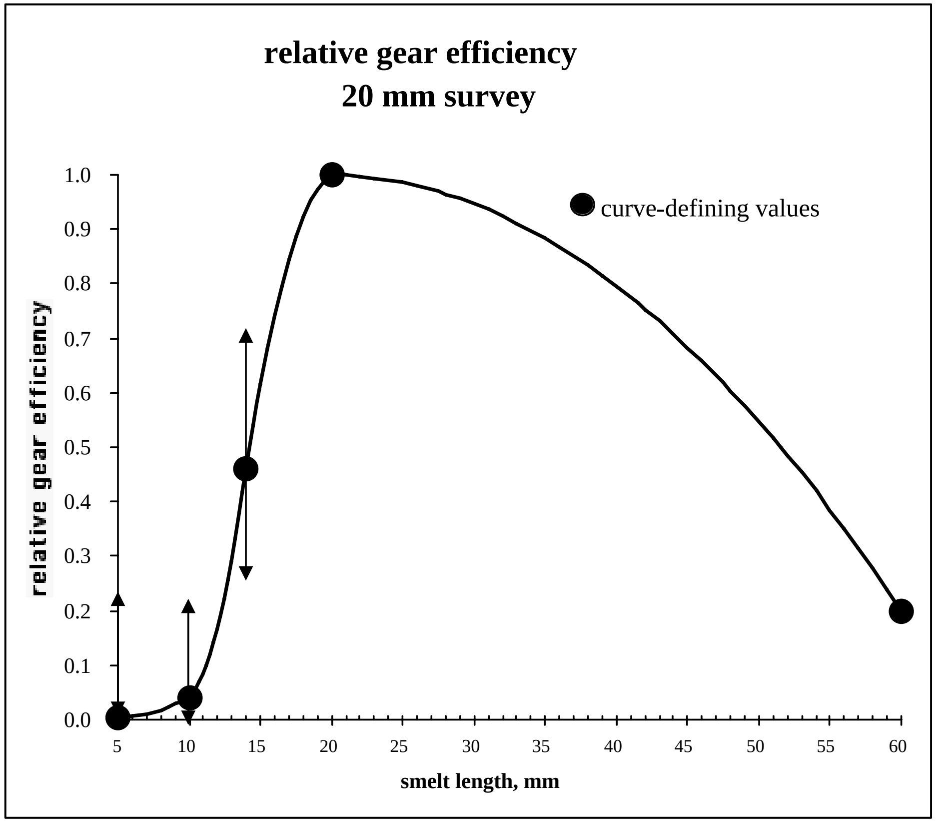

annual % juvenile entrainment vs. exports*% SE Delta
vol-weighted cpue
% juvenile entrainment
20%
15%
10%
5%
0%
0
200
400
600
800
1,000
1,200
1,400
exports (surveys 1-5)*% SE Delta (surveys 2-4)
y = 0.000140x
R2 = 0.49
p = 0.00006


annual % juvenile entrainment vs. exports*% SE Delta
area-weighted cpue
% juvenile entrainment
20%
15%
10%
5%
0%
0
200
400
600
800
1,000
1,200
1,400
exports (surveys 1-5)*% SE Delta (surveys 2-4)
y = 0.000141x
R2 = 0.34
p = 0.0002

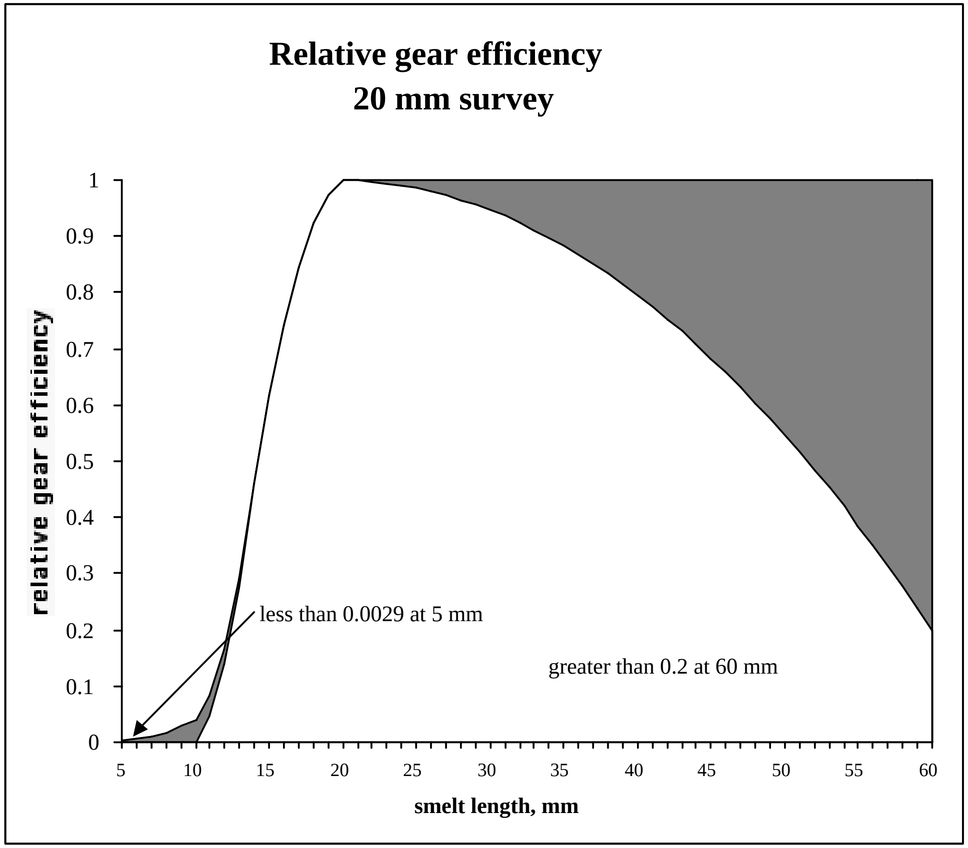
year	change in exports, 1st 5 surveys, AF			
	target entrainment			
	10%	15%	20%	25%
1995	600,000	600,000	600,000	600,000
1996	625,000	650,000	650,000	650,000
1997	-200,000	-25,000	150,000	325,000
1998	1,050,000	1,050,000	1,050,000	1,050,000
1999	500,000	900,000	925,000	925,000
2000	100,000	475,000	750,000	800,000
2001	200,000	-50,000	100,000	250,000
2002	200,000	-25,000	125,000	275,000
2003	-250,000	-75,000	125,000	300,000
2004	75,000	325,000	575,000	825,000
average	290,000	375,000	500,000	600,000

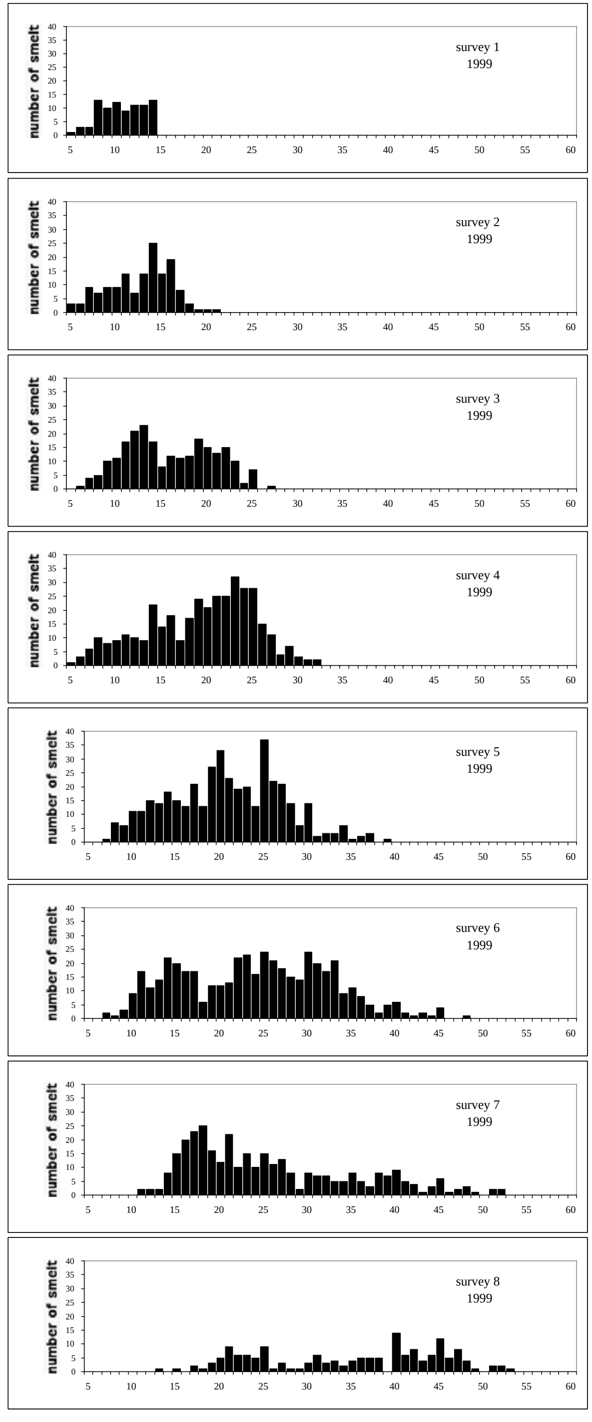
Relative gear efficiency 20 mm survey

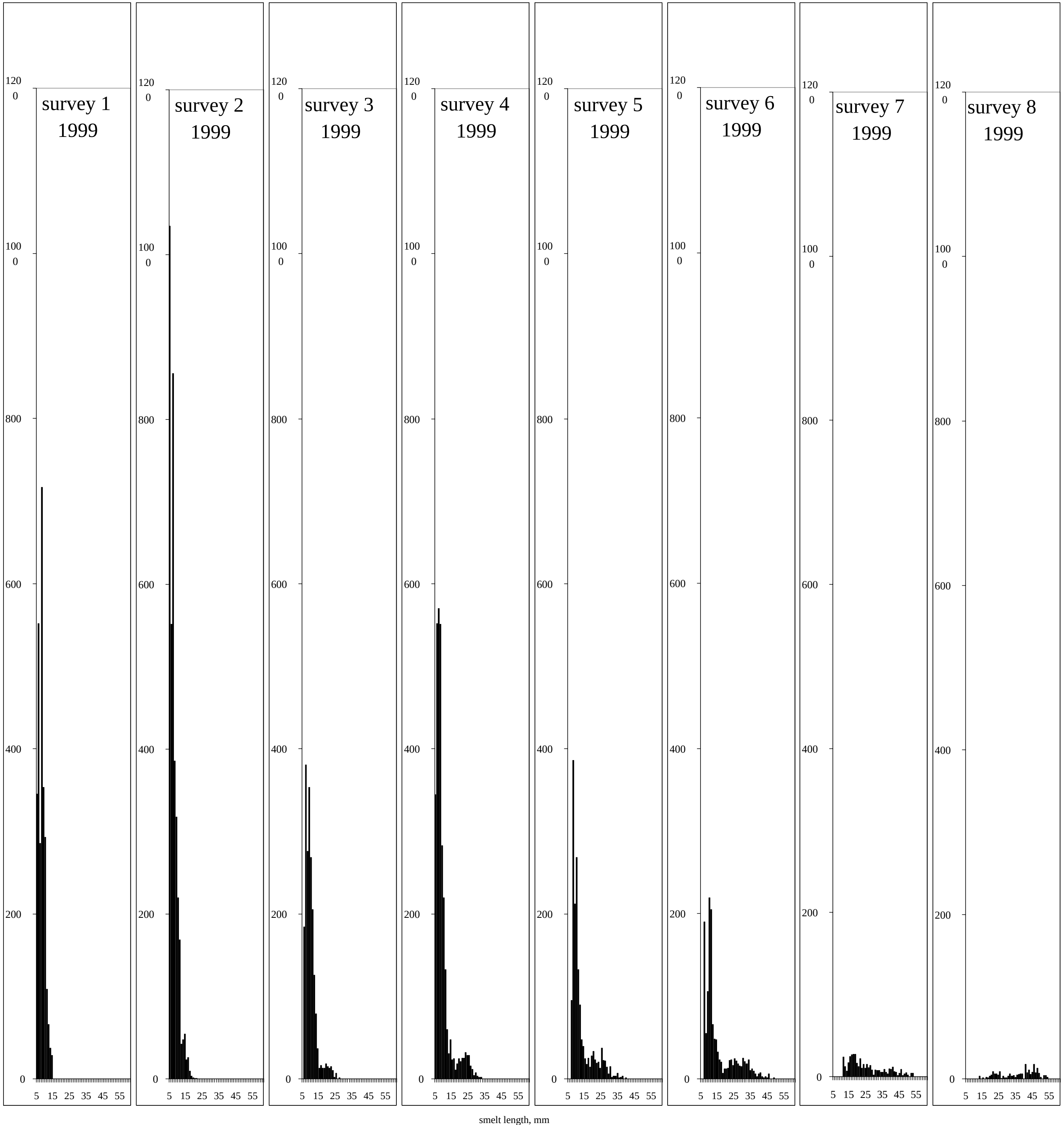
- Assume a relative efficiency curve
  - Smooth, no discontinuities
  - Very inefficient at 5 mm
  - Relative efficiency = 1.0 at 20 mm
  - Efficiency at 60 mm <1.0
- Adjust histograms using that curve
- Find curve that causes decrease in all successive populations after all smelt have hatched

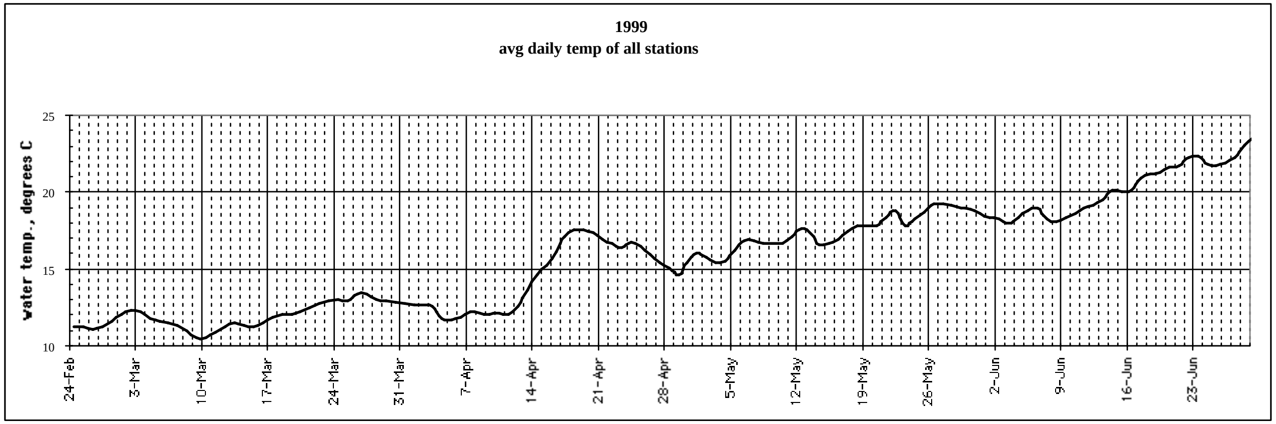


Test: For all “normal” surveys after hatching complete, each survey’s population should be less than previous survey’s

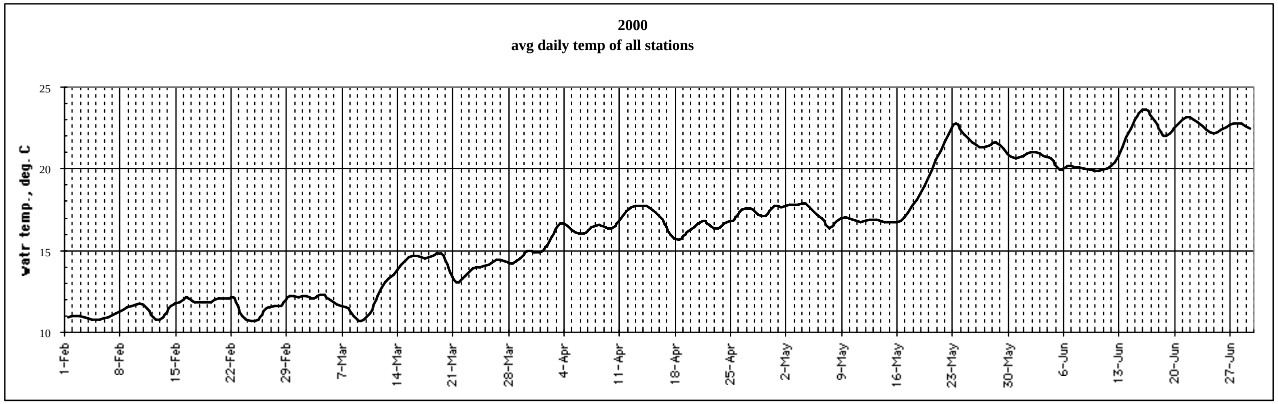



number of smelt
survey 1
1999
survey 2
1999
survey 3
1999
survey 4
1999
survey 5
1999
survey 6
1999
survey 7
1999
survey 8
1999
0 5 10 15 20 25 30 35 40
5 10 15 20 25 30 35 40 45 50 55 60
smelt length, mm

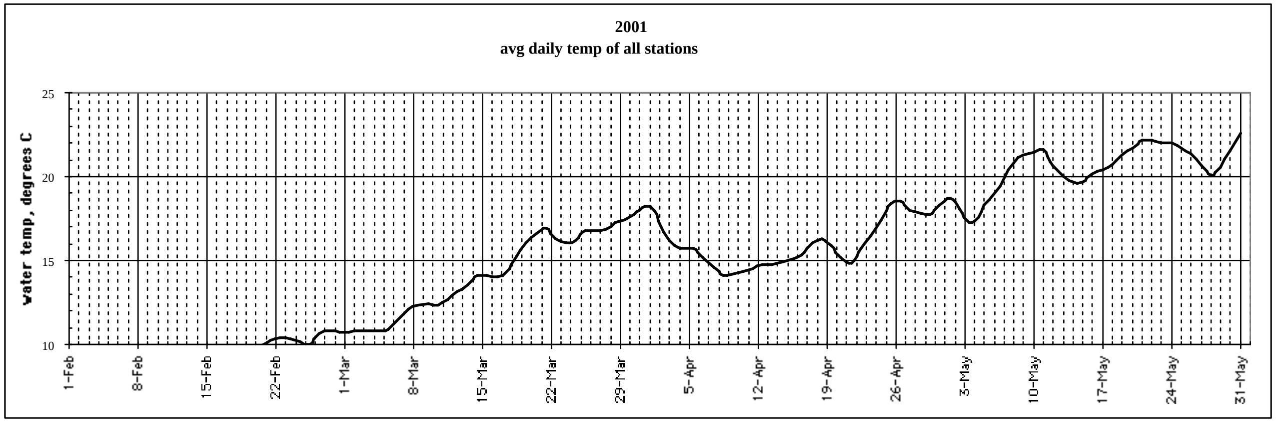

survey 1 1999
survey 2 1999
survey 3 1999
survey 4 1999
survey 5 1999
survey 6 1999
survey 7 1999
survey 8 1999
1200
1000
800
600
400
200
0
5 15 25 35 45 55
smelt length, mm



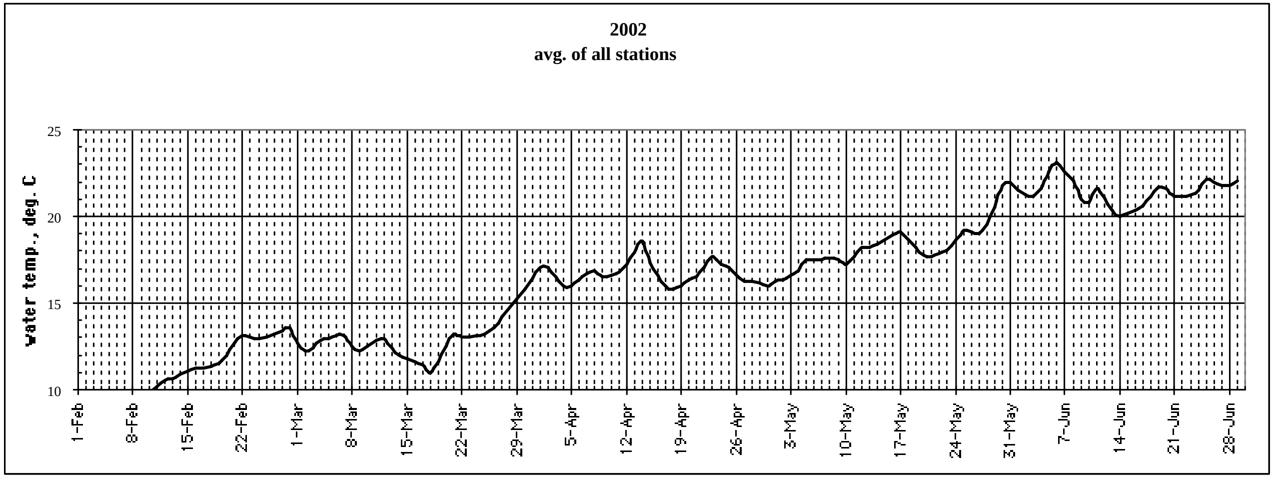
1999
avg daily temp of all stations
water temp., degrees C
25
20
15
10
24-Feb
3-Mar
10-Mar
17-Mar
24-Mar
31-Mar
7-Apr
14-Apr
21-Apr
28-Apr
5-May
12-May
19-May
26-May
2-Jun
9-Jun
16-Jun
23-Jun

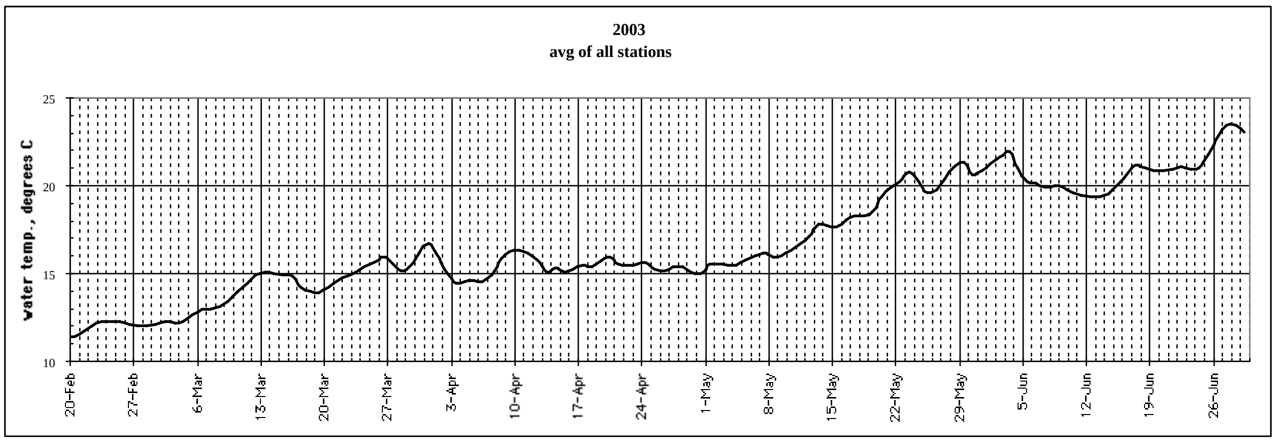


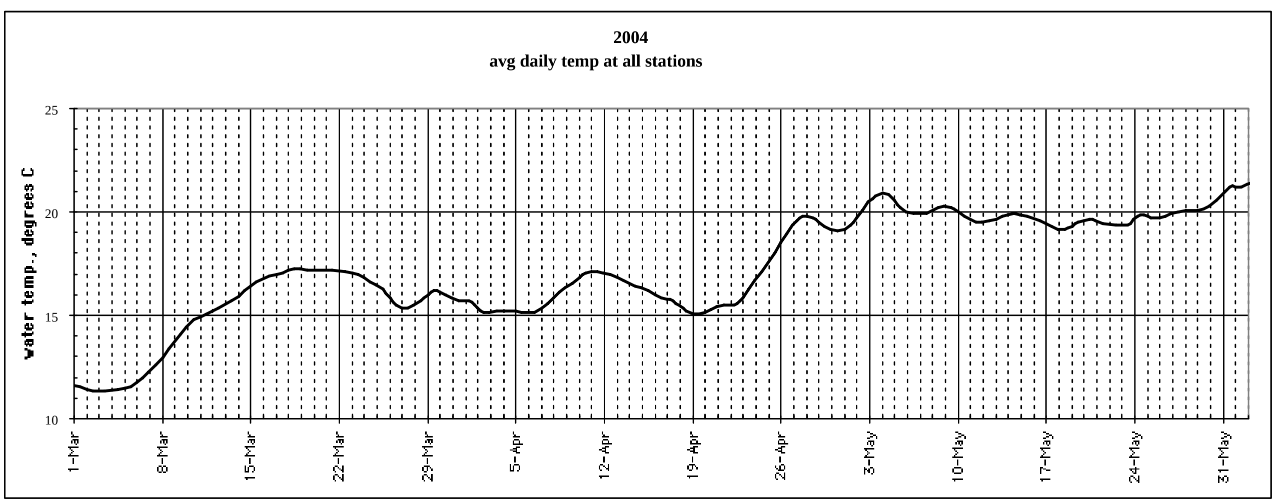
2000
avg daily temp of all stations
watr temp., deg. C
25
20
15
10
1-Feb
8-Feb
15-Feb
22-Feb
29-Feb
7-Mar
14-Mar
21-Mar
28-Mar
4-Apr
11-Apr
18-Apr
25-Apr
2-May
9-May
16-May
23-May
30-May
6-Jun
13-Jun
20-Jun
27-Jun

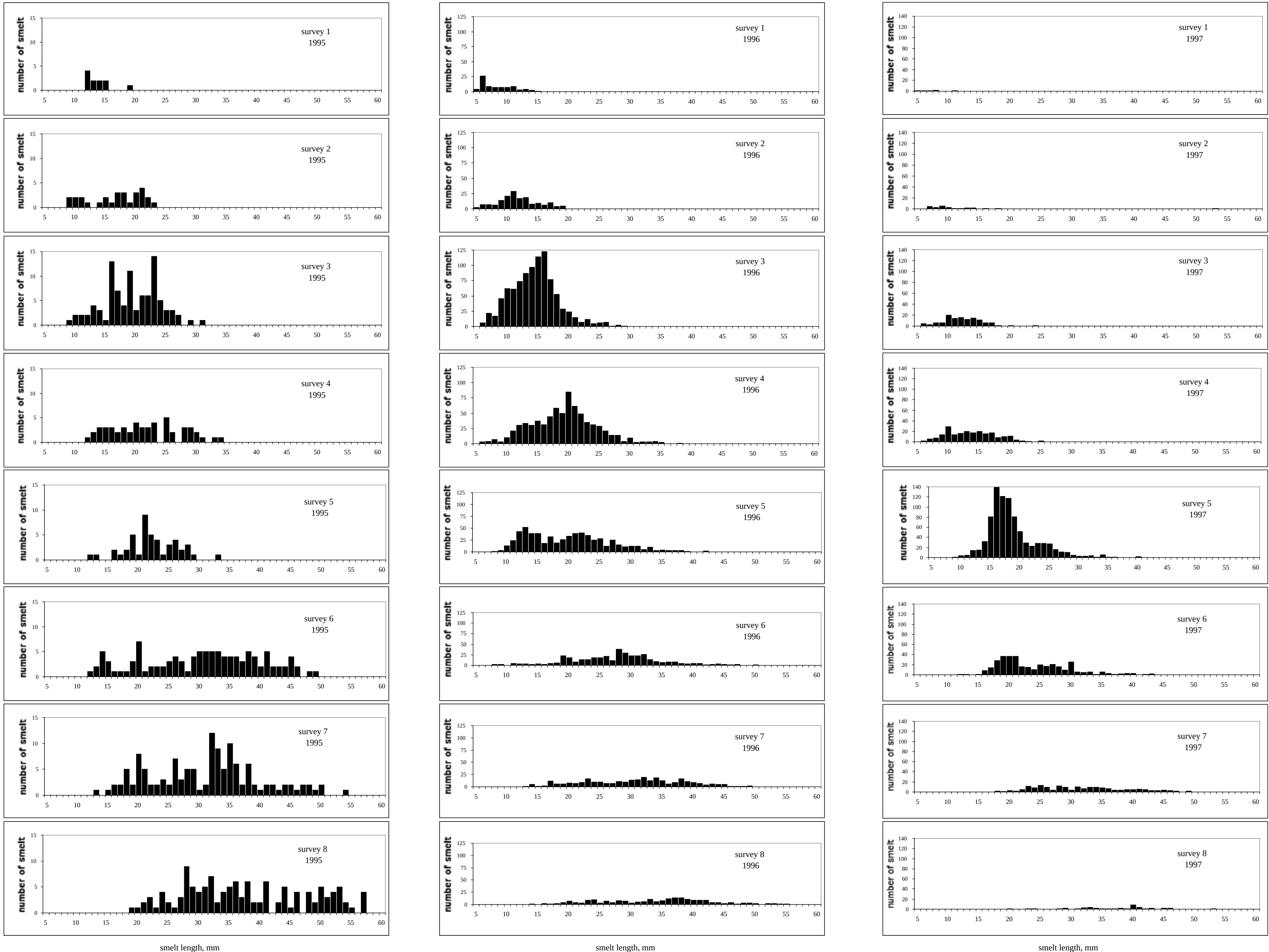


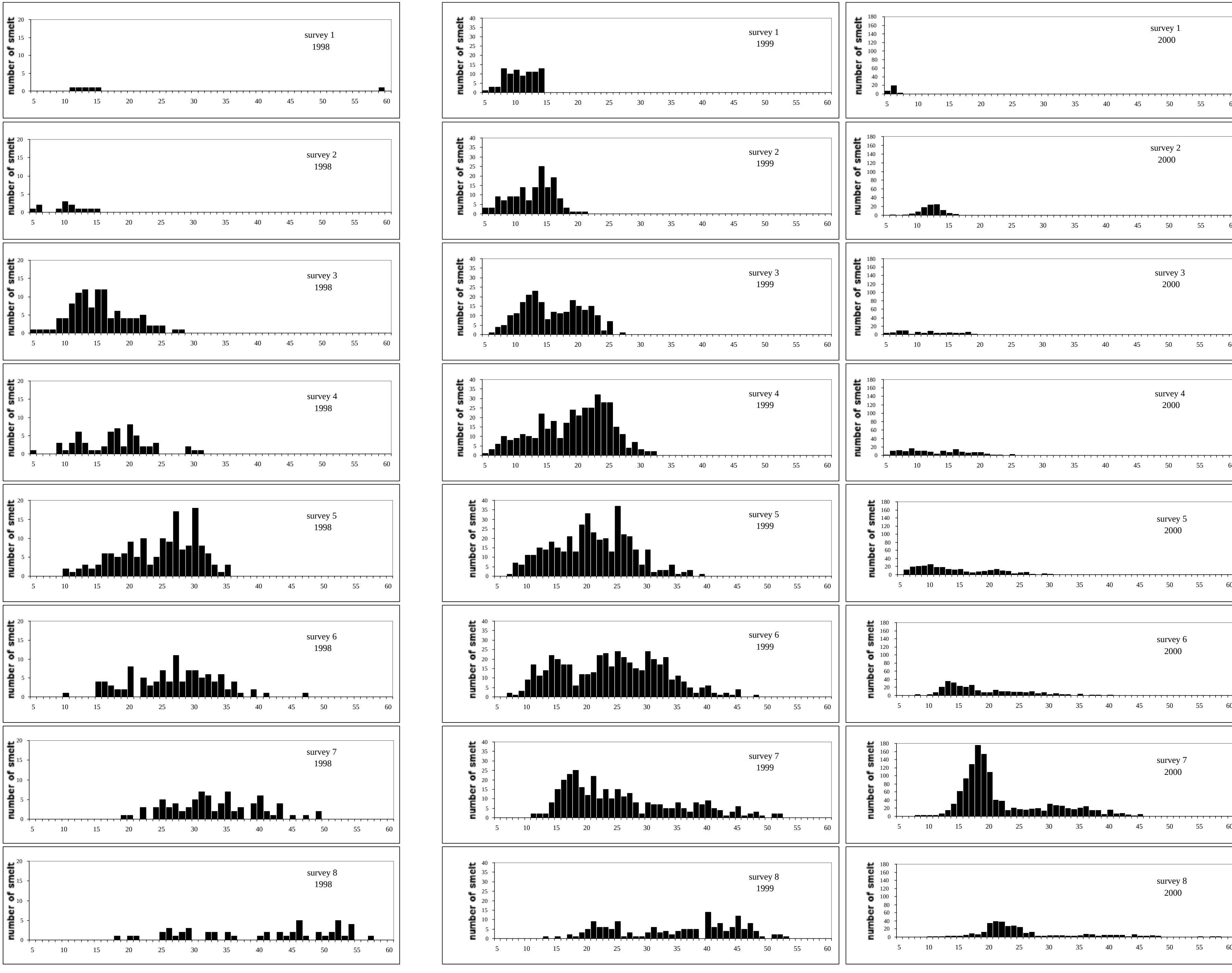
2001
avg daily temp of all stations
water temp, degrees C
25
20
15
10
1-Feb
8-Feb
15-Feb
22-Feb
1-Mar
8-Mar
15-Mar
22-Mar
29-Mar
5-Apr
12-Apr
19-Apr
26-Apr
3-May
10-May
17-May
24-May
31-May

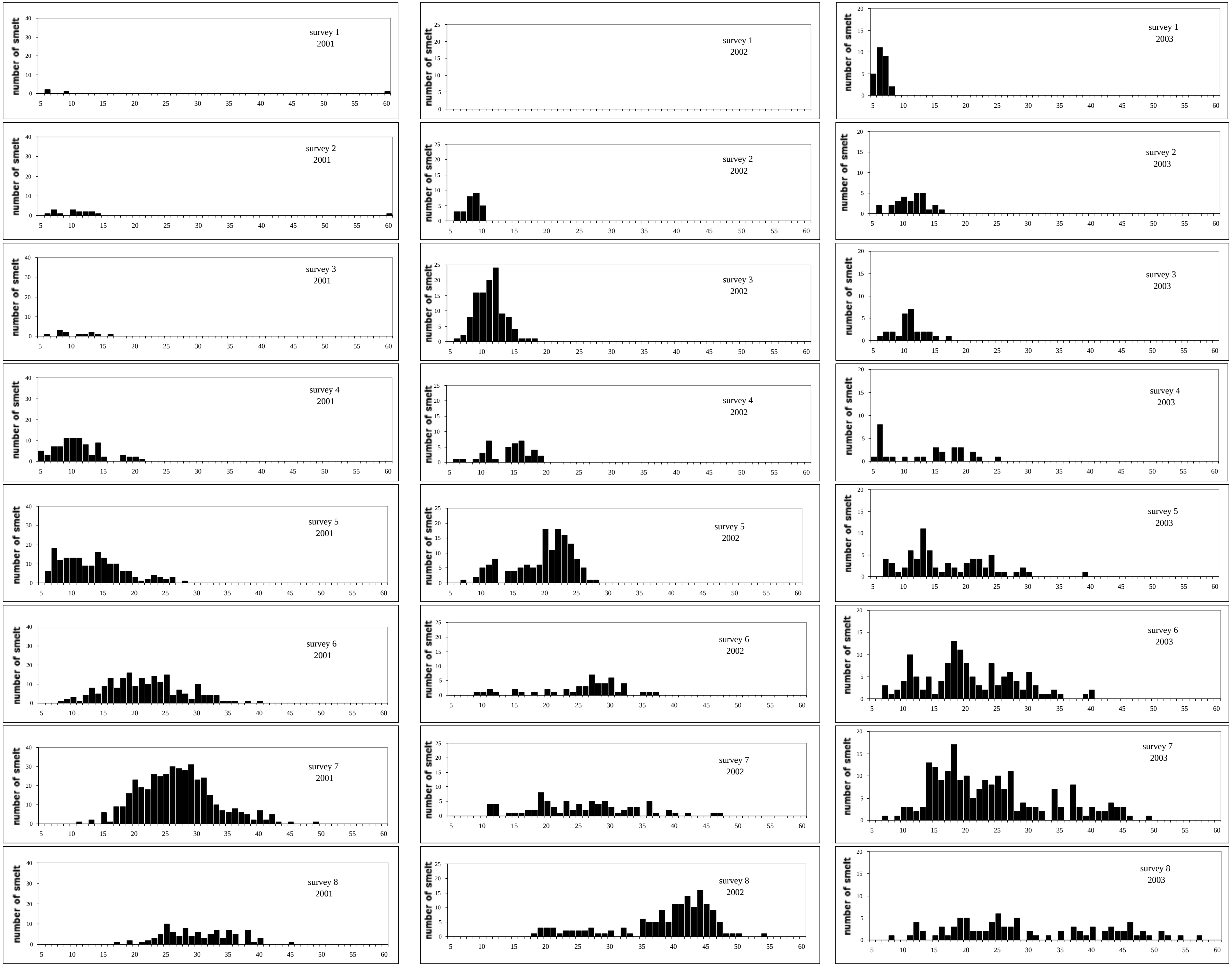

2002
avg. of all stations
water temp., deg. C
25
20
15
10
1-Feb
8-Feb
15-Feb
22-Feb
1-Mar
8-Mar
15-Mar
22-Mar
29-Mar
5-Apr
12-Apr
19-Apr
26-Apr
3-May
10-May
17-May
24-May
31-May
7-Jun
14-Jun
21-Jun
28-Jun


2003
avg of all stations
water temp., degrees C
25
20
15
10
20-Feb
27-Feb
6-Mar
13-Mar
20-Mar
27-Mar
3-Apr
10-Apr
17-Apr
24-Apr
1-May
8-May
15-May
22-May
29-May
5-Jun
12-Jun
19-Jun
26-Jun

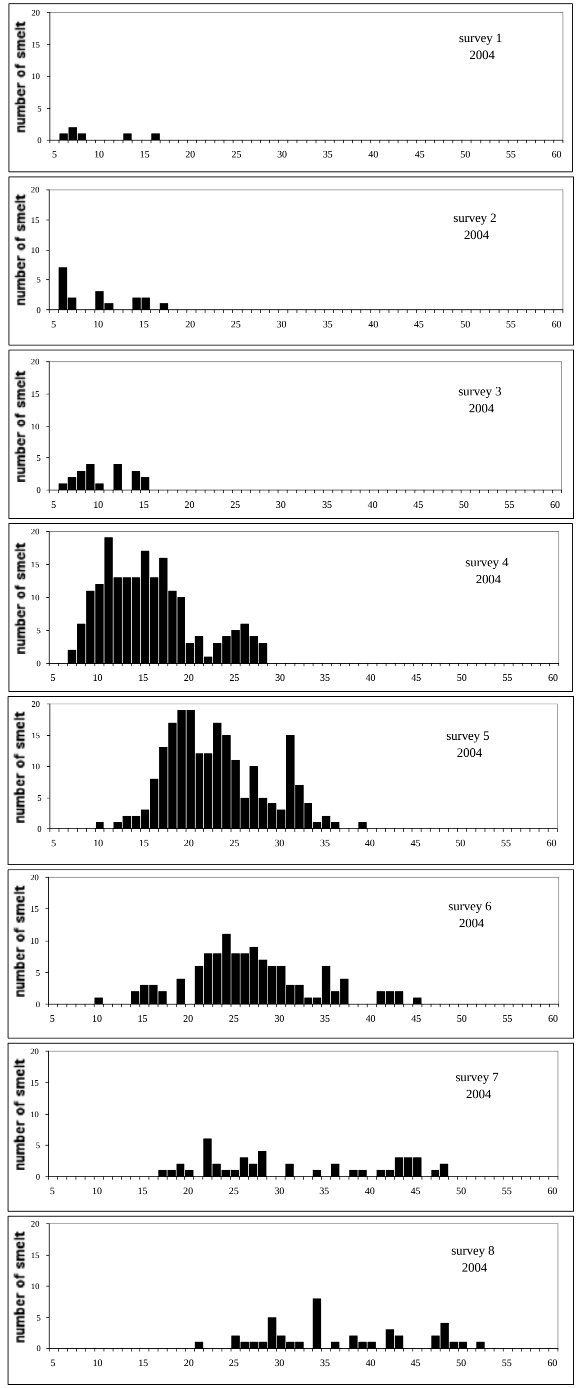

2004
avg daily temp at all stations
water temp., degrees C
25
20
15
10
1-Mar
8-Mar
15-Mar
22-Mar
29-Mar
5-Apr
12-Apr
19-Apr
26-Apr
3-May
10-May
17-May
24-May
31-May


survey 1
1995
survey 2
1995
survey 3
1995
survey 4
1995
survey 5
1995
survey 6
1995
survey 7
1995
survey 8
1995
survey 1
1996
survey 2
1996
survey 3
1996
survey 4
1996
survey 5
1996
survey 6
1996
survey 7
1996
survey 8
1996
survey 1
1997
survey 2
1997
survey 3
1997
survey 4
1997
survey 5
1997
survey 6
1997
survey 7
1997
survey 8
1997
number of smelt
smelt length, mm
smelt length, mm
smelt length, mm


survey 1
1998
survey 2
1998
survey 3
1998
survey 4
1998
survey 5
1998
survey 6
1998
survey 7
1998
survey 8
1998
survey 1
1999
survey 2
1999
survey 3
1999
survey 4
1999
survey 5
1999
survey 6
1999
survey 7
1999
survey 8
1999
survey 1
2000
survey 2
2000
survey 3
2000
survey 4
2000
survey 5
2000
survey 6
2000
survey 7
2000
survey 8
2000
number of smelt
smelt length, mm
smelt length, mm
smelt length, mm



survey 1 2001
survey 2 2001
survey 3 2001
survey 4 2001
survey 5 2001
survey 6 2001
survey 7 2001
survey 8 2001
survey 1 2002
survey 2 2002
survey 3 2002
survey 4 2002
survey 5 2002
survey 6 2002
survey 7 2002
survey 8 2002
survey 1 2003
survey 2 2003
survey 3 2003
survey 4 2003
survey 5 2003
survey 6 2003
survey 7 2003
survey 8 2003
number of smelt
smelt length, mm



smelt length, mm