Relative Exposure of Bay-Delta Fish Species to CVP/SWP Entrainment Loss and Evidence of Population-level Effects

- Focused on direct loss effects
- Focused on non-salmonids
- Plus, thoughts on estimating population level effects (B. J. Miller)

Pat Coulston
California Dept. of Fish and Game

Presentation Topics

- Review salvage rates
- Discuss relative levels of exposure to direct loss
- For key species
  - Brief life history review
  - Degree and nature of direct loss exposure
  - Factors (including direct loss) affecting abundance
  - Uncertainties and information needs
- Role of density dependence/compensation
- Thoughts on improving measures of population level effects

Conclusions

- Salvage does not equal loss
- Direct loss does not equal export impact
- Other factors may mask DL effects
- Assuming density dependence is risky
- Beware of the delta smelt nightmare
- Disconnect between past and recent SB investigations needs to be resolved
- Delta smelt and striped bass have very high exposure
- Longfin smelt have high exposure in dry years
- A multifactor analysis, incorporating fractional loss, is needed for delta smelt

Species	1993-2002 Annual Average	% Total Salvage
Threadfin Shad	4,837,028	42.074
Striped Bass	3,027,198	26.332
American Shad	1,312,787	11.419
Splittail	893,847	7.775
White Catfish	442,697	3.851
Yellowfin Goby	322,131	2.802
Prickly Sculpin	130,556	1.136
Bluegill	97,209	0.846
Chinook Salmon	80,771	0.703
Inland Silverside	75,099	0.653
Channel Catfish	60,873	0.529
Delta Smelt	52,992	0.461
Largemouth Bass	50,647	0.441
Common Carp	29,642	0.258
Black Crappie	13,484	0.117
Longfin Smelt	11,647	0.101
Chameleon Goby	11,039	0.096
Sacramento Blackfish	8,982	0.078
Bigscale Logperch	8,649	0.075
Golden Shiner	6,973	0.061
Steelhead Trout	5,856	0.051
Lamprey Spp.	5,144	0.045
Redear Sunfish	1,949	0.017
Shimofuri Goby	1,723	0.015
Brown Bullhead	1,093	0.010
Western Mosquitofish	1,033	0.009
Warmouth	763	0.007
Tule Perch	755	0.007
Sacramento Sucker	480	0.004
Green Sunfish	363	0.003
Wakasagi	330	0.003
Pacific Staghorn Sculpin	309	0.003
Starry Flounder	298	0.003
White Sturgeon	262	0.002
White Crappie	224	0.002
Riffle Sculpin	212	0.002
Threespine Stickleback	205	0.002
Sacramento Pikeminnow	165	0.001
Goldfish	161	0.001
Black Bullhead	151	0.001
Rainwater Killifish	115	0.001
Smallmouth Bass	103	0.001
Blue Catfish	80	0.001
Hardhead	75	0.001
Green Sturgeon	72	0.001

“Biases”

- Hydrologic/hydrodynamic conditions affect salvage composition (93-02=wet)
- “Salvage” is not a very good index of direct loss
- Fish smaller than 20mm not screened well or enumerated
- Pre-screen loss rates vary by species and lifestage
- Screen efficiency varies by species and life stage

SWP/CVP DIRECT LOSS MATRIX

Exposure (population/species)

Interest	LOW	MODERATE	HIGH
LOW	green sunfish mosquito fish goldfish	yellowfin goby inland silversides	shimofuri goby
MODERATE	smallmouth bass P. staghorn sculpin riffle sculpin	starry flounder Sac. blackfish tule perch	threadfin shad American shad
HIGH	northern anchovy Pacific herring Cal. halibut white sturgeon	longfin smelt Sac. River Chinook green sturgeon splittail	striped bass delta smelt S.J. fall-run Chinook

FOCUS SPECIES

SPECIES	NATIVE	CHARACTERISTICS
Threadfin shad	NO	Small, freshwater, pelagic, forage fish
American shad	NO	Anadromous, secondary sport fish
Longfin smelt	YES	Small, estuarine/anadromous, pelagic
Sac. River Chinook salmon	YES[1]	Anadromous, major sport fish
Green sturgeon	YES	Anadromous, demersal, minor sport fish
Sacramento splittail	YES[2]	Estuarine, shallow-water, minor sport fish
S.J. River Chinook salmon	YES	Anadromous, major sport fish
Striped bass	NO	Estuarine/anadromous, major sport fish
Delta smelt	YES[1]	Euryhaline, pelagic

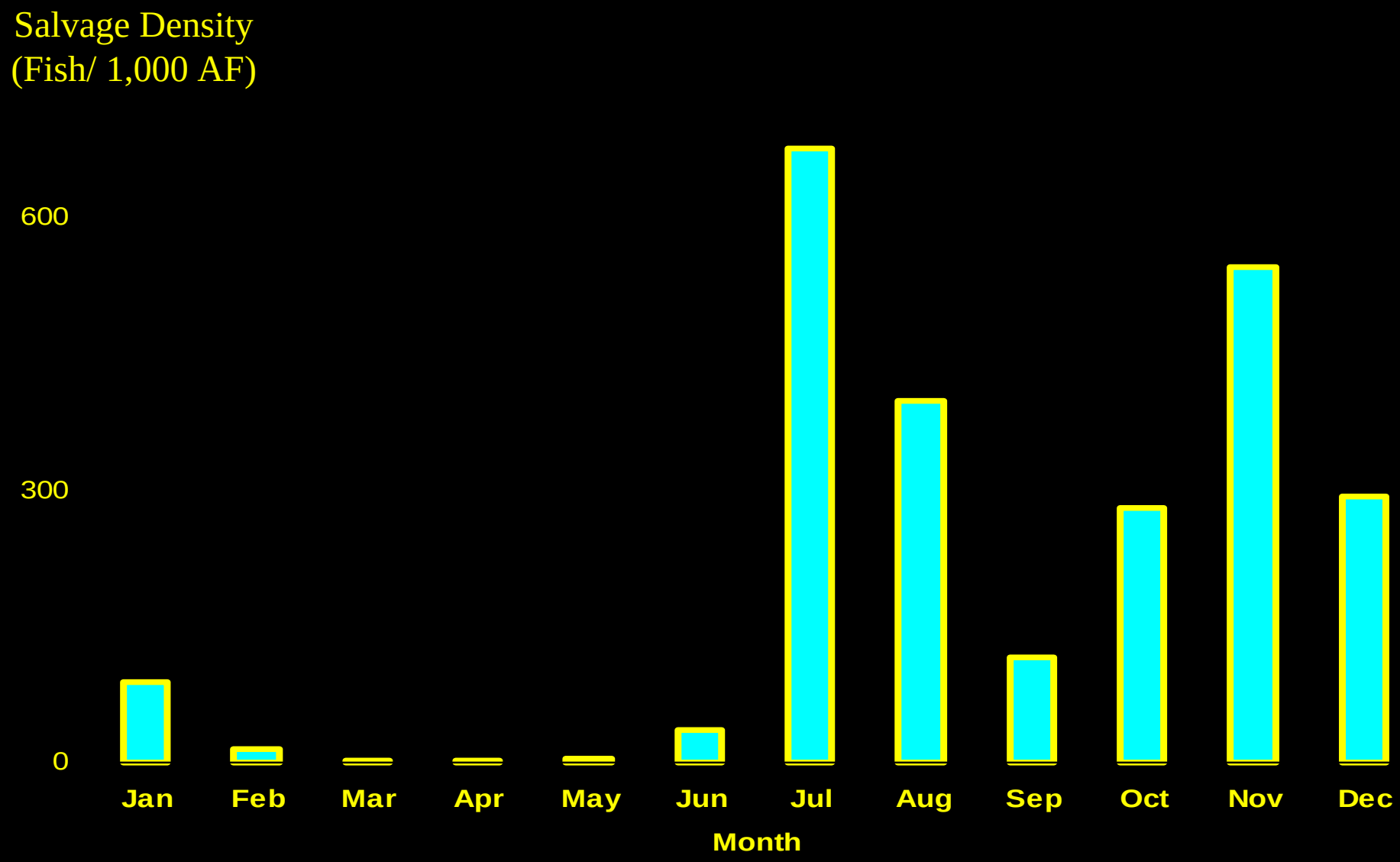
1/ Endemic, listed
2/ Endemic, not listed

DIRECT LOSS EFFECTS SUMMARY

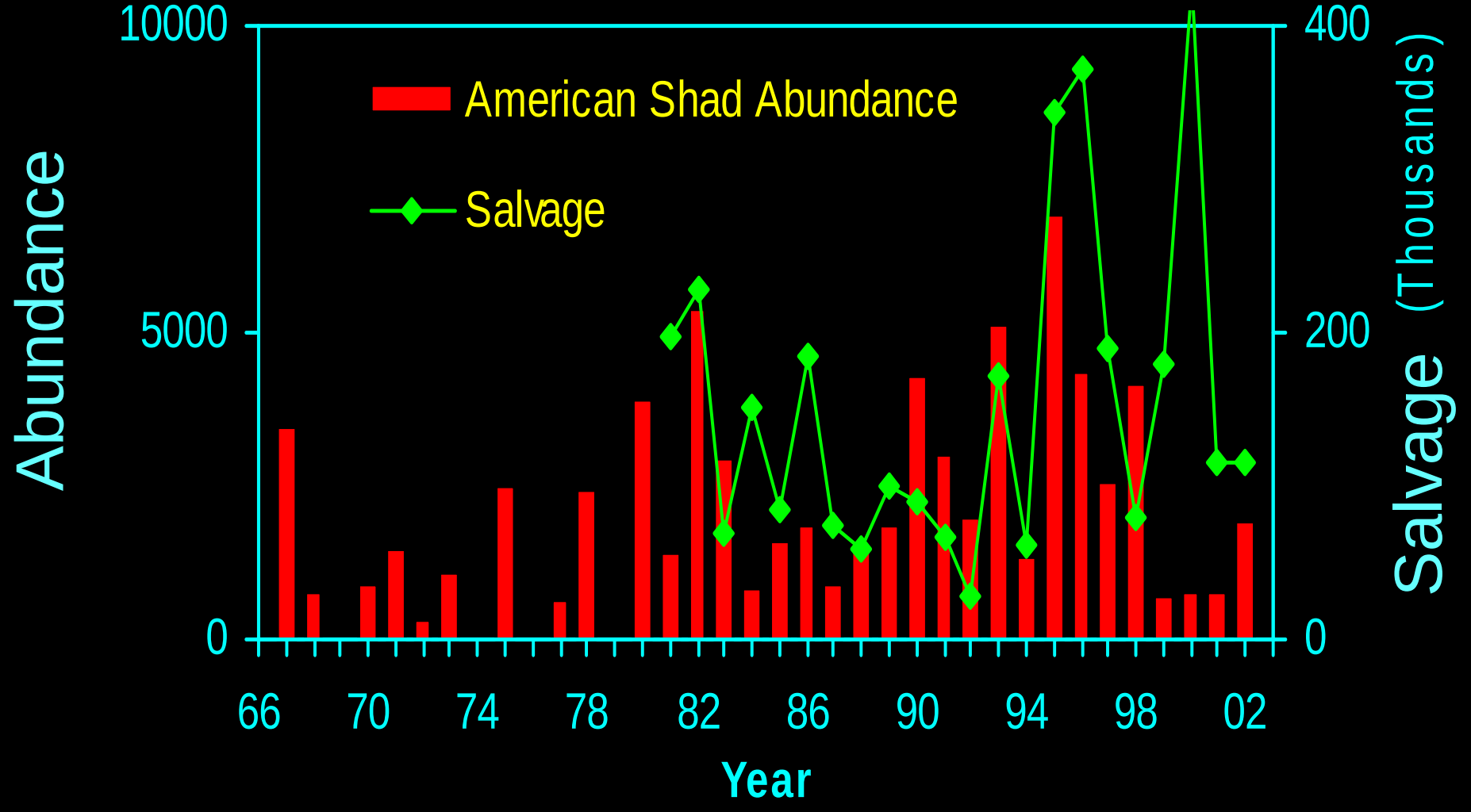
AMERICAN SHAD

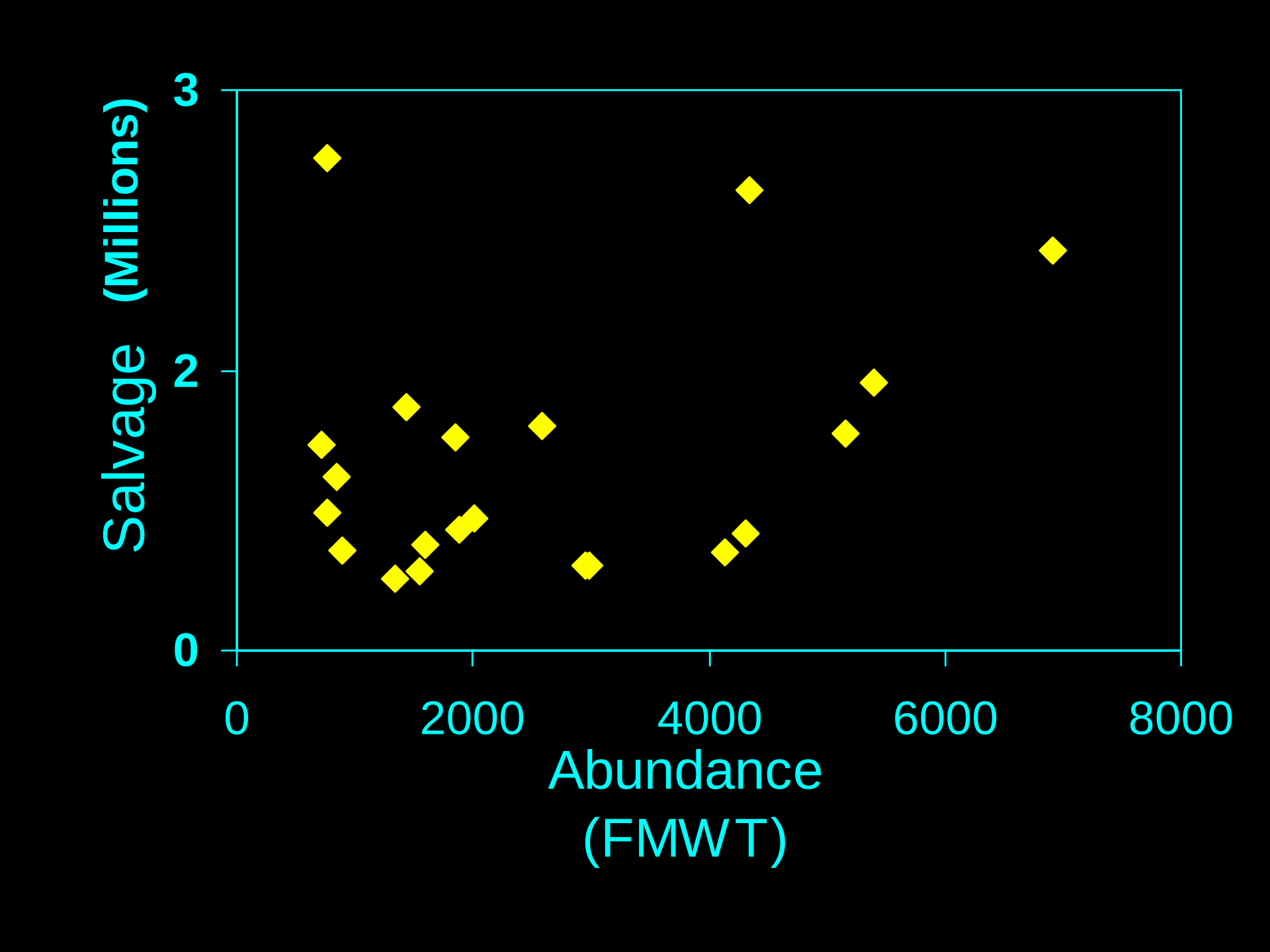
- **Effects have not been thoroughly investigated**
- **Salvage ”high”, but loss exposure moderate**
- **WYSIWYG (comparably)**
- **No clearly demonstrated direct loss effect**
- **Former flow/abundance relationship has weakened**

Monthly American Shad Salvage Density (SWP+CVP) 1993-2002



American Shad Abundance (FMWT) and Combined Mean Jul-Dec Salvage per AF by Year



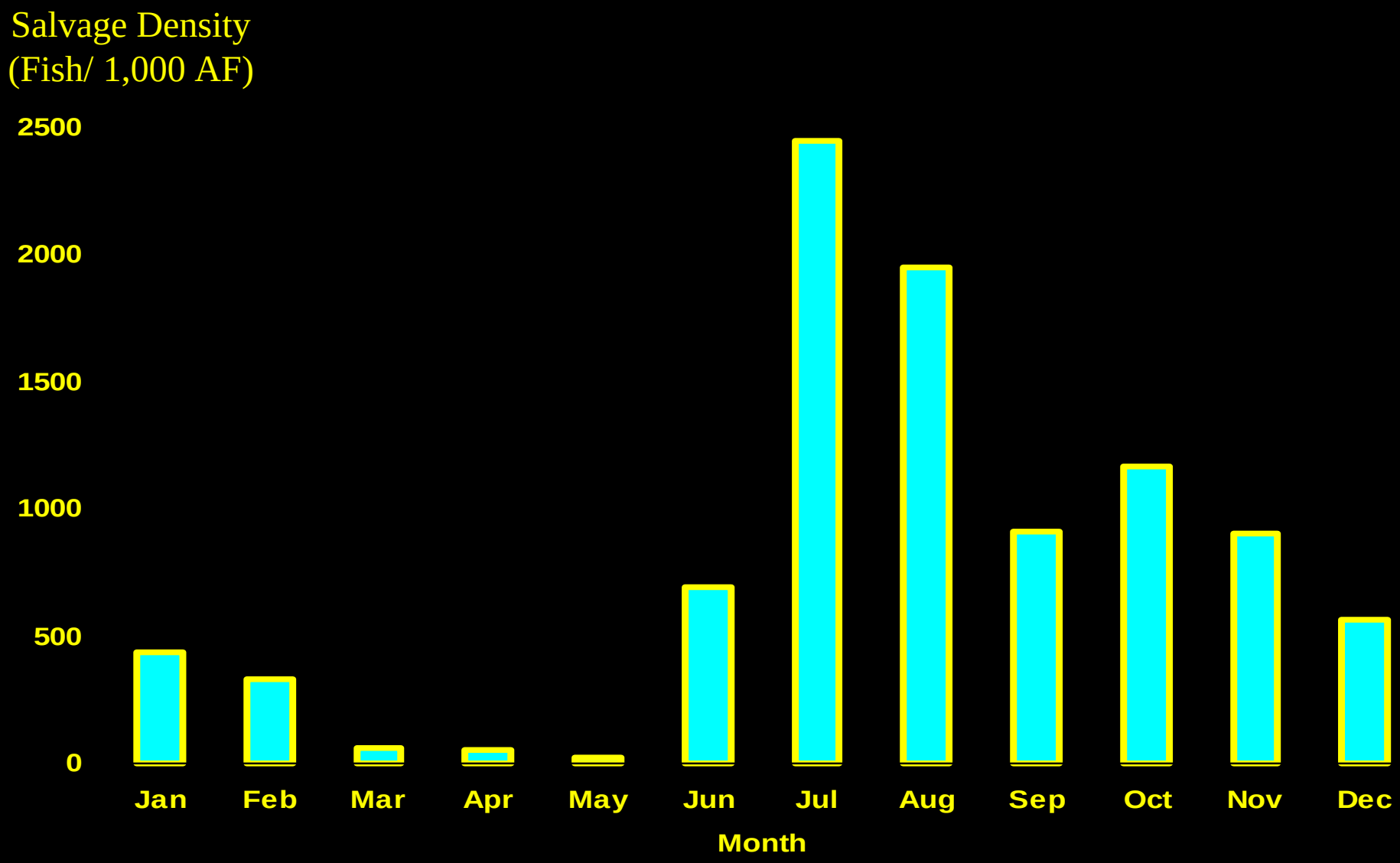

Salvage (Millions)
3
2
0
0
2000
4000
6000
8000
Abundance
(FMWT)

DIRECT LOSS EFFECTS SUMMARY

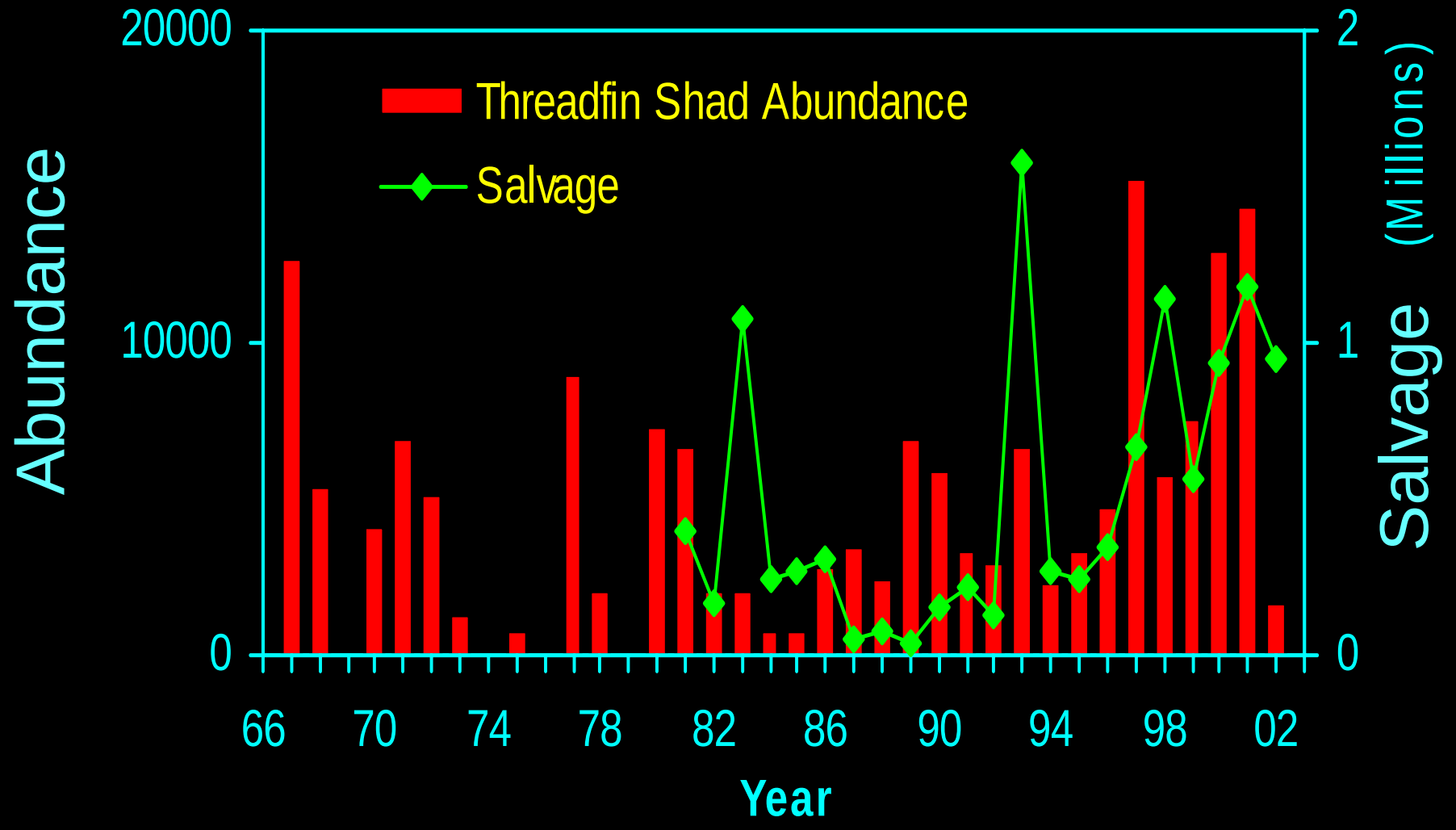
THREADFIN SHAD

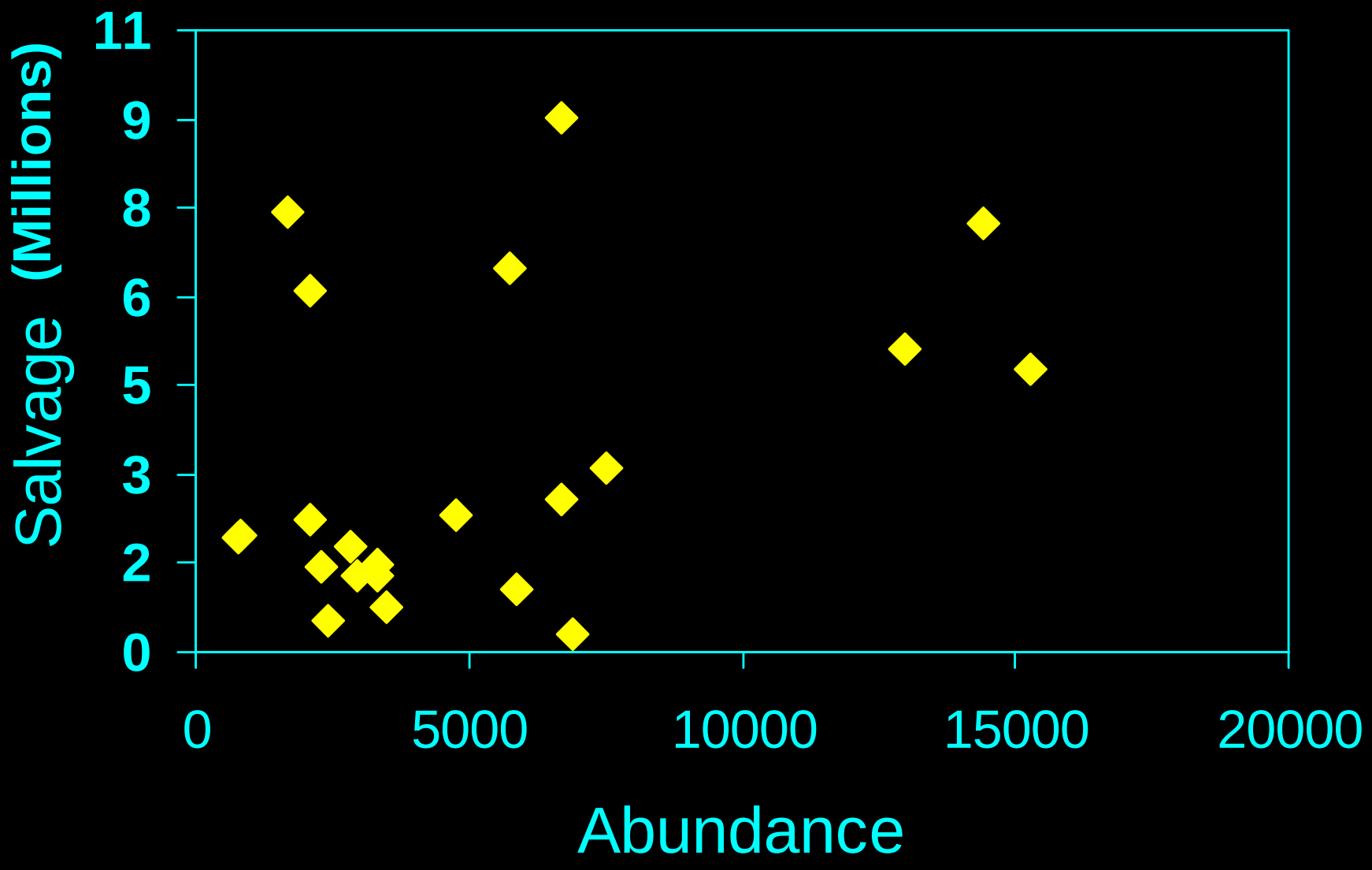
- Effects have not been investigated
- Salvage has tended to track abundance
- Recent moderate increases in abundance
- Freshwater species, perhaps responding to extent of freshwater habitat in the Delta
- Important food source for striped bass

Monthly Threadfin Shad Salvage Density (SWP+CVP) 1993-2002



Threadfin Shad Abundance (FMWT) and Combined Mean Jul-Nov Salvage per AF by Year



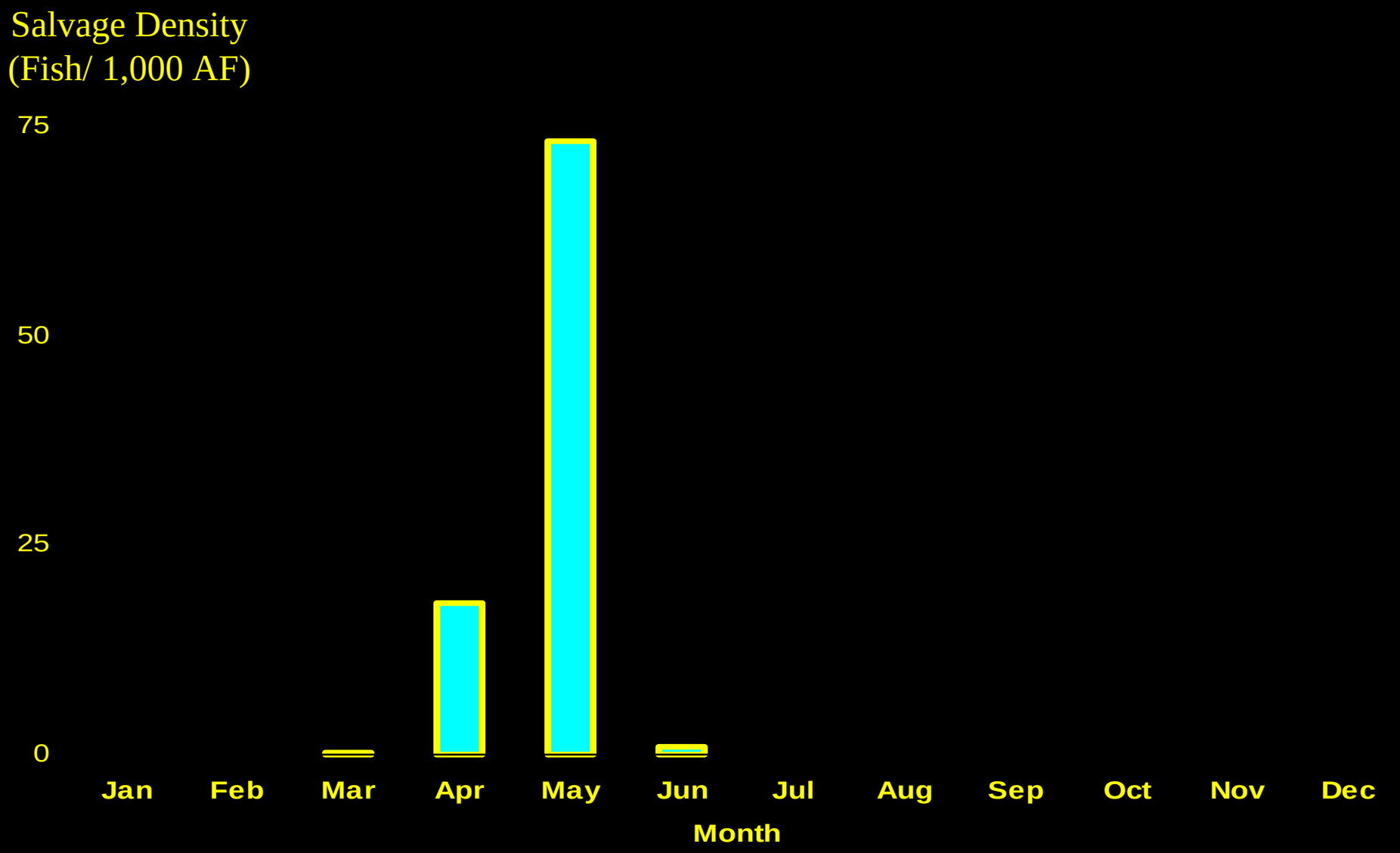

Salvage (Millions)
11
9
8
6
5
3
2
0
0
5000
10000
15000
20000
Abundance

DIRECT LOSS EFFECTS SUMMARY

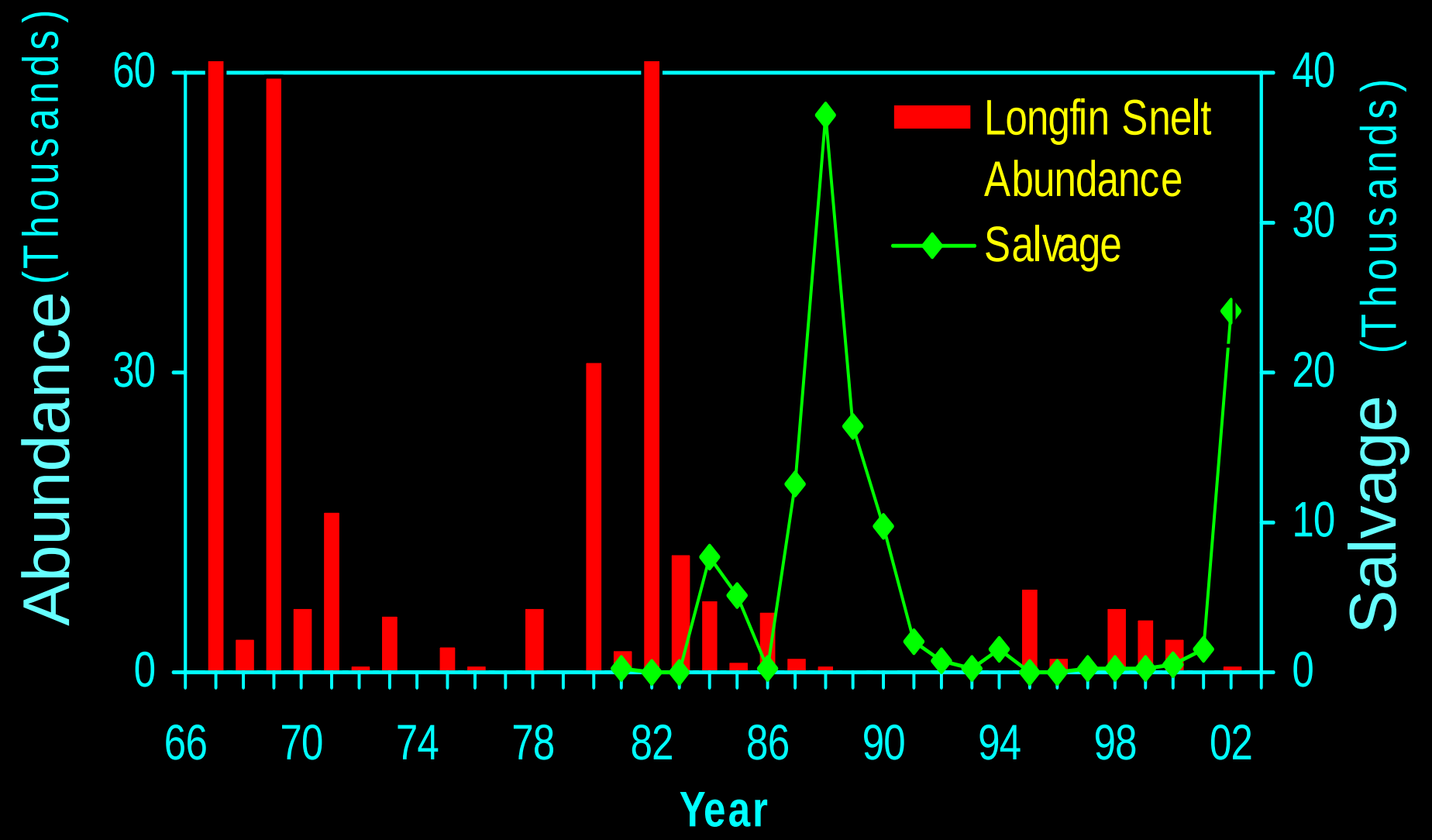
LONGFIN SMELT

- **LFS production apparently, largely driven by outflow levels (X2)**
- **Direct losses “kick them while they are down, possibly exacerbating poor production in dry years**
- **Shift to lower flow/abundance relationship in recent years**

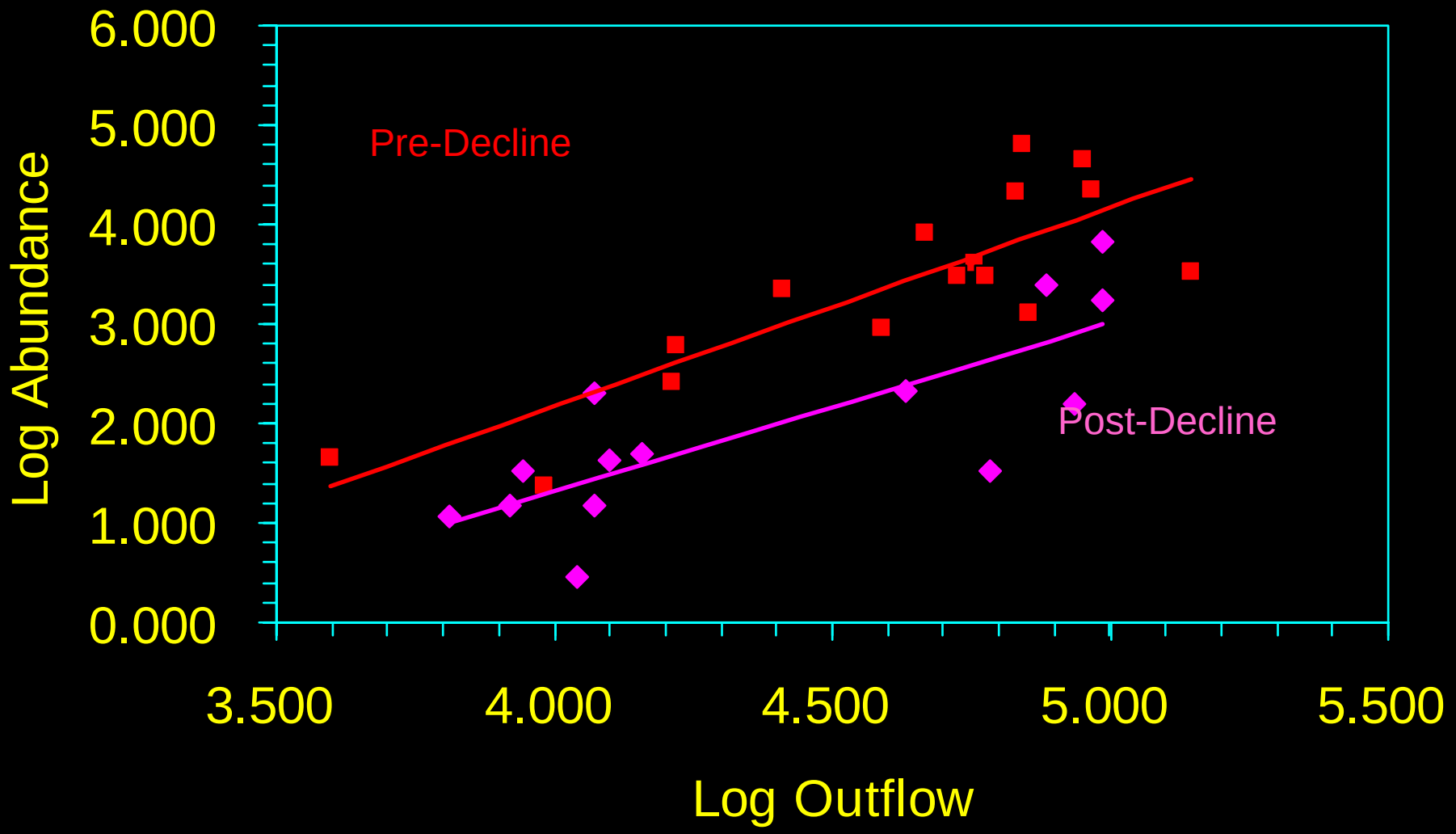
Monthly Longfin Smelt Salvage Density (SWP+CVP) 1993-2002



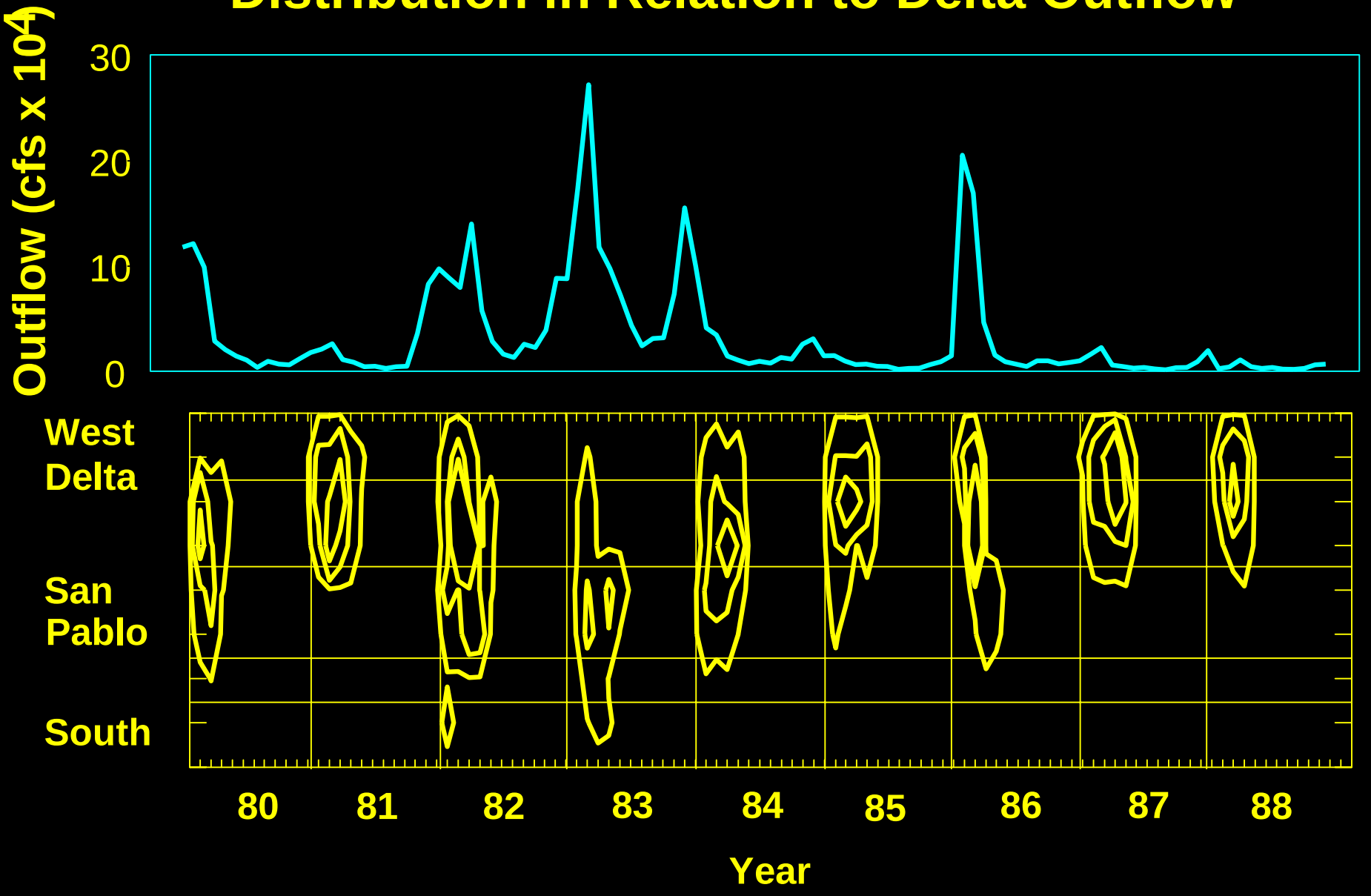
Longfin Smelt Abundance (FMWT) and Combined Mean Apr-Jul Salvage per AF by Year



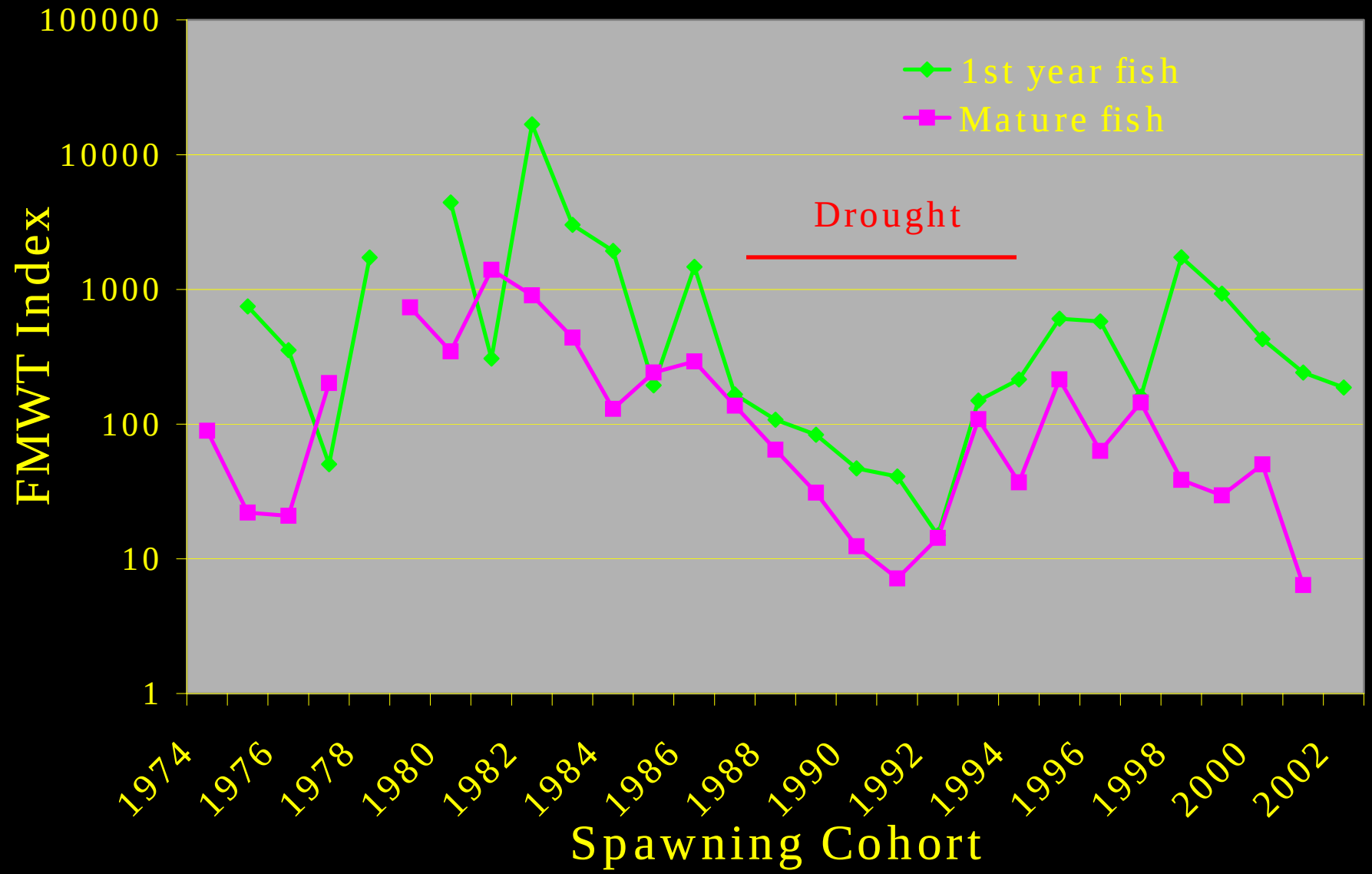
Longfin smelt abundance vs Delta Outflow Pre- and Post-decline (Fall Midwater Trawl)



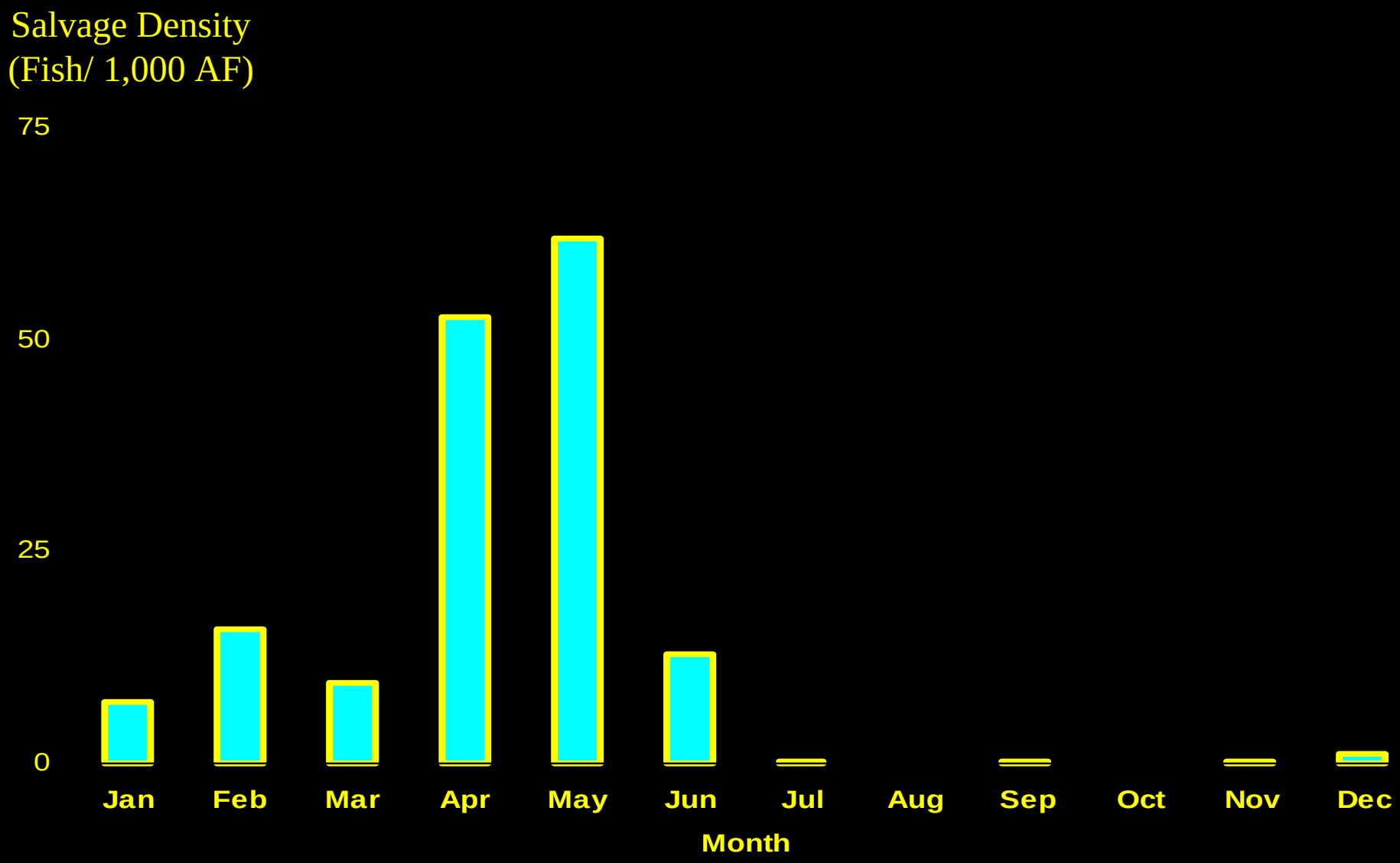
Larval Longfin Smelt Geographic and Temporal Distribution in Relation to Delta Outflow

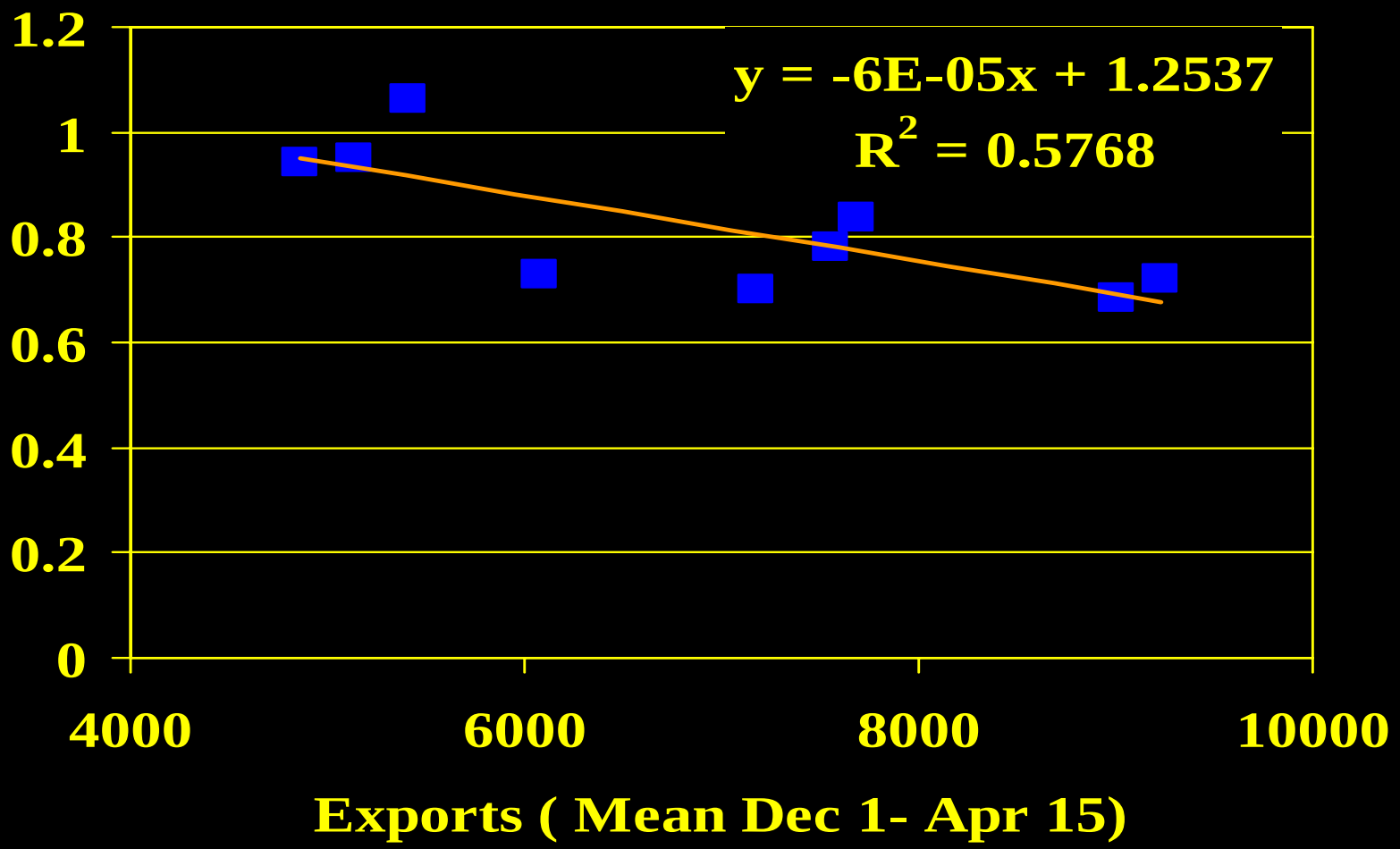


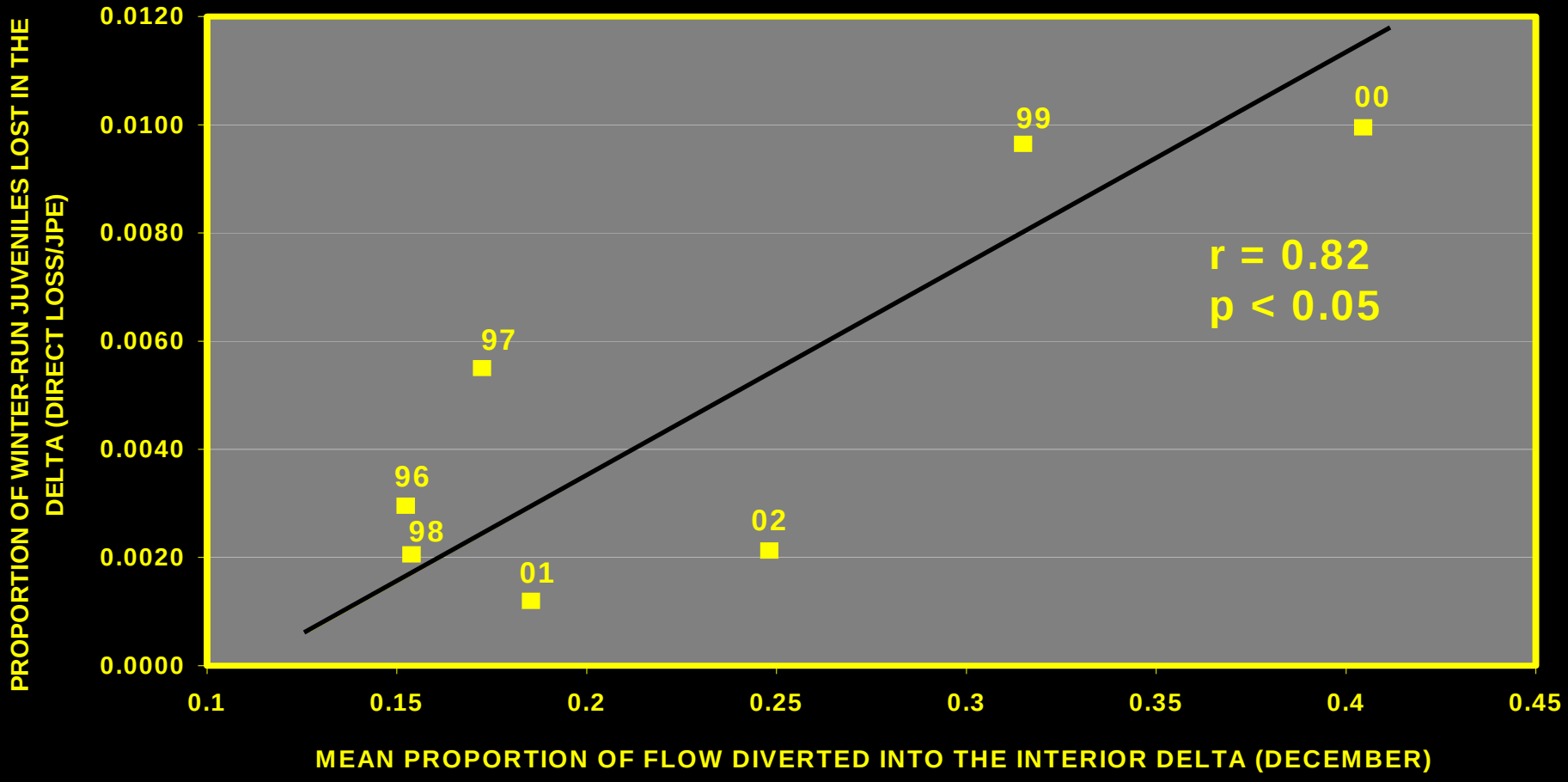
Longfin Smelt Demography



Monthly Chinook Salmon Salvage Density (SWP+CVP) 1993-2002




y = -6E-05x + 1.2537
R2 = 0.5768
1.2
1
0.8
0.6
0.4
0.2
0
4000
6000
8000
10000
Exports (Mean Dec 1- Apr 15)

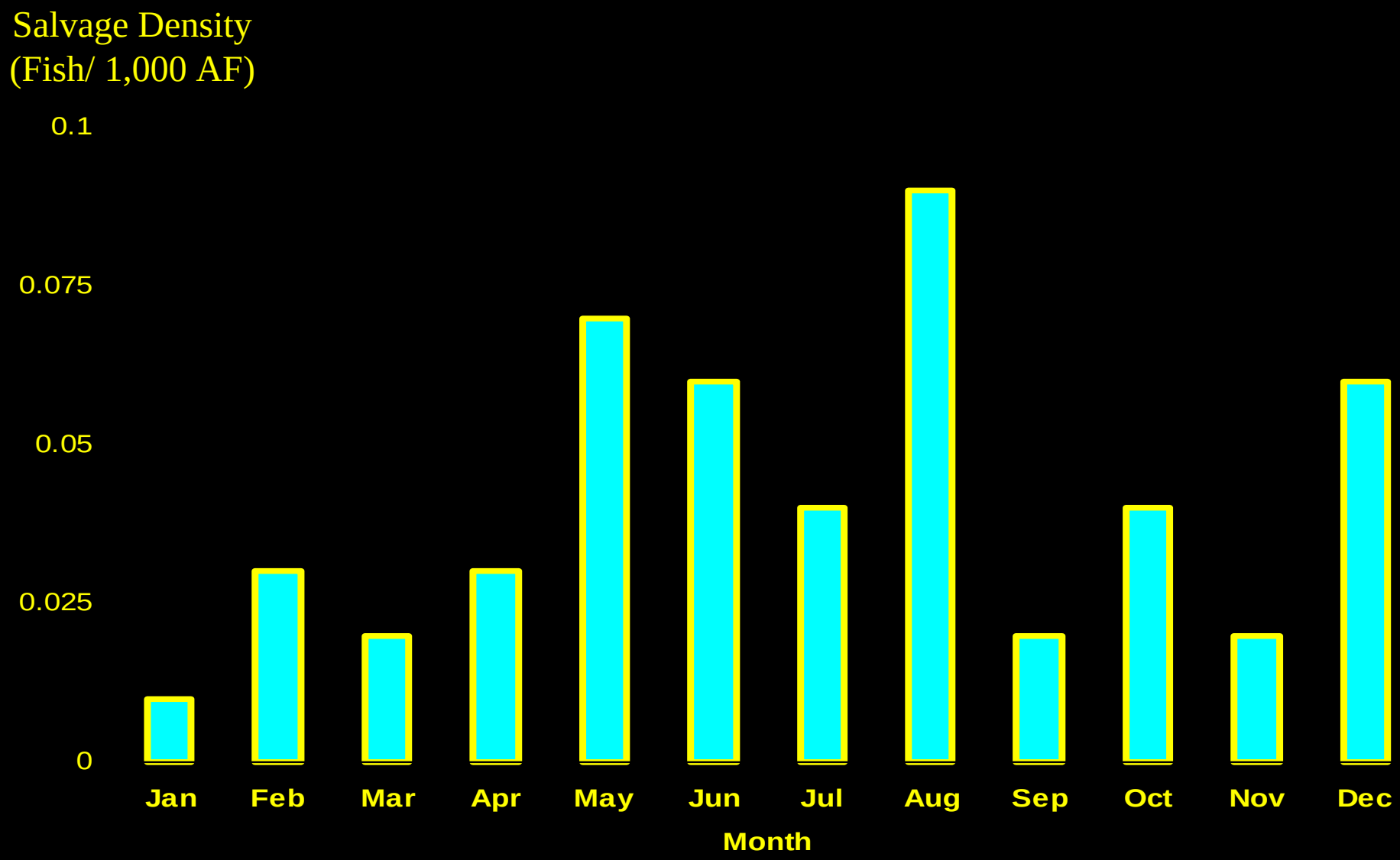

PROPORTION OF WINTER-RUN JUVENILES LOST IN THE DELTA (DIRECT LOSS/JPE)
0.0120
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
MEAN PROPORTION OF FLOW DIVERTED INTO THE INTERIOR DELTA (DECEMBER)
96
97
98
99
00
01
02
r = 0.82
p < 0.05

DIRECT LOSS EFFECTS SUMMARY

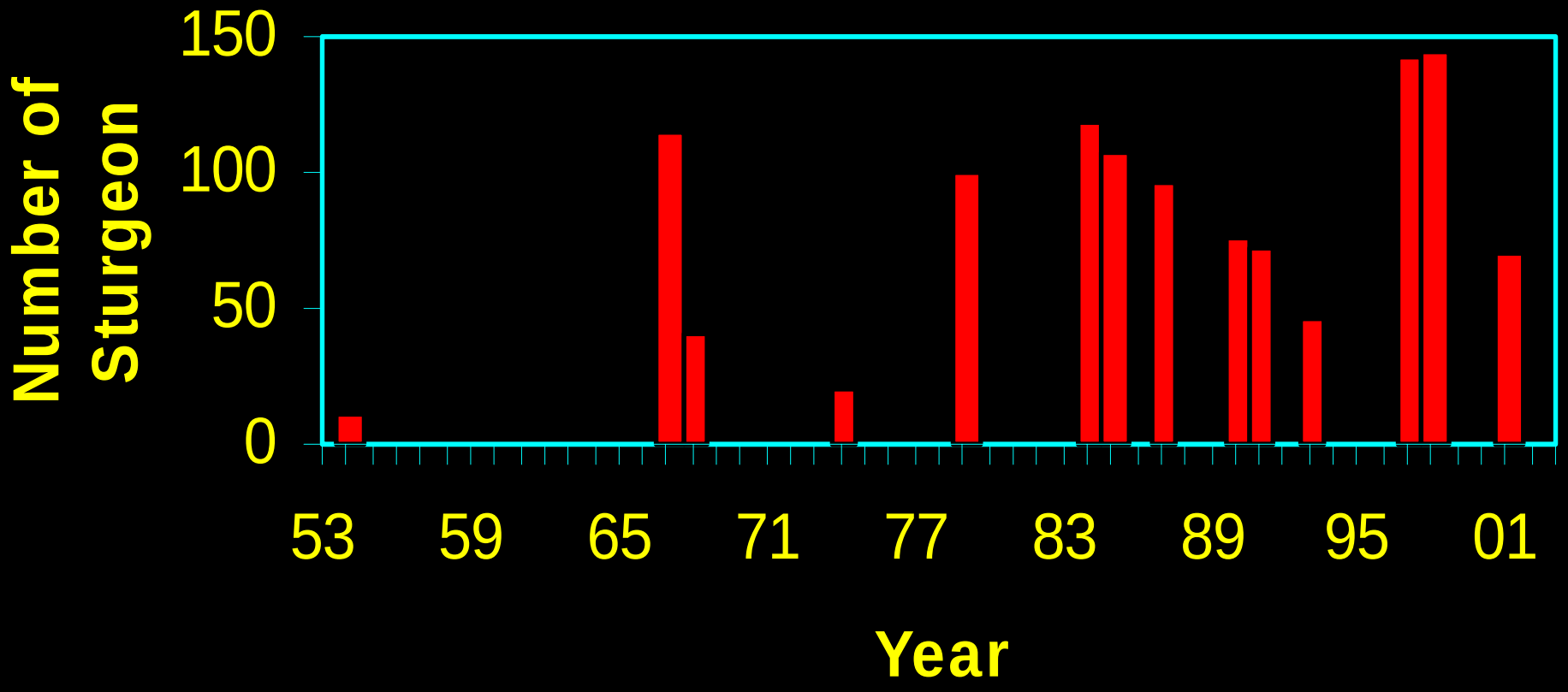
STURGEON

- Generally low vulnerability due to origin (upper Sac R.) and demersal habits
- Populations have been relatively stable for many years
- Production is river flow-driven and dominant year classes have lowest vulnerability

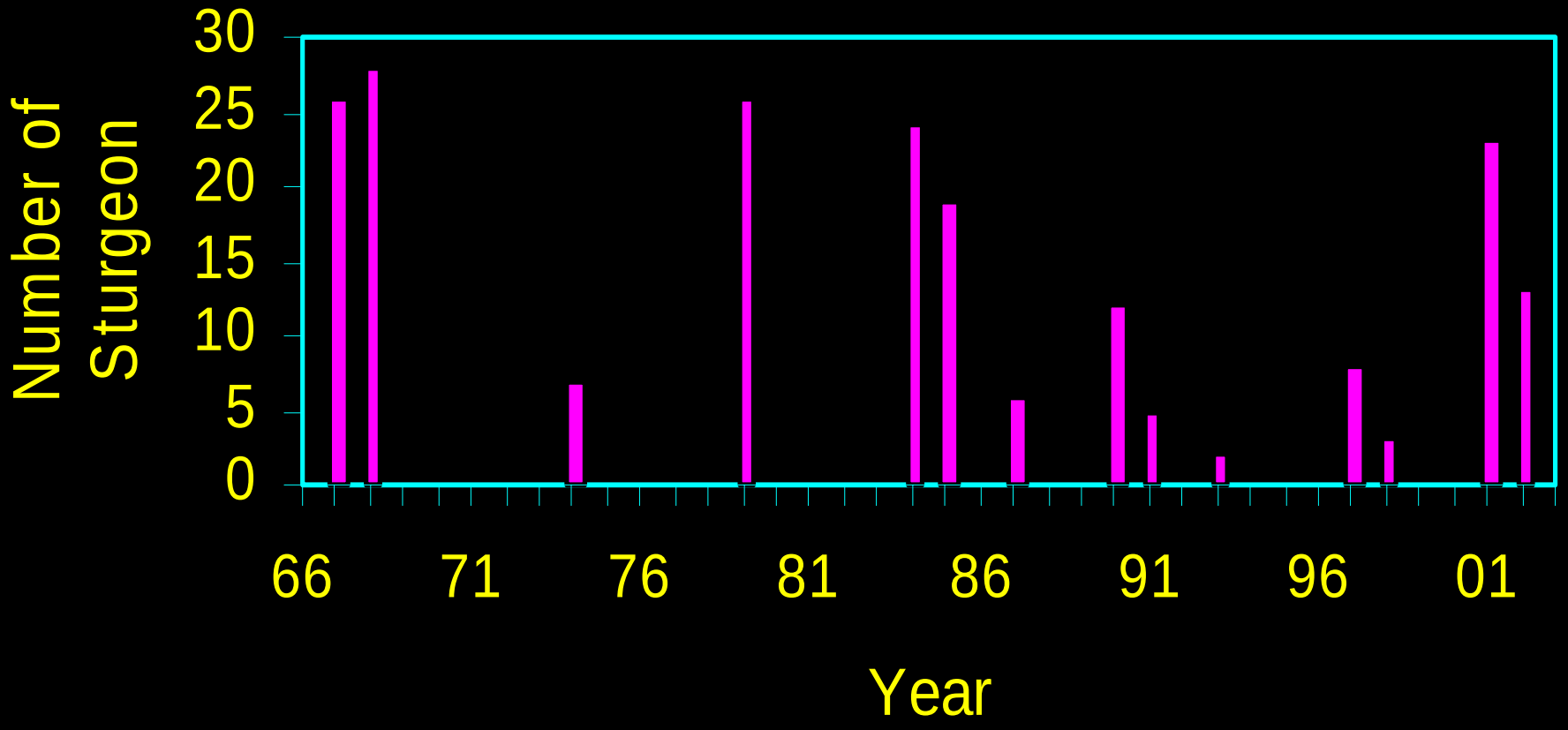
Monthly Green Sturgeon Salvage Density (SWP+CVP) 1993-2002



Population of White Sturgeon >=102cm (40 inches) in Thousands



Total Catch Green Sturgeon >102cm TL

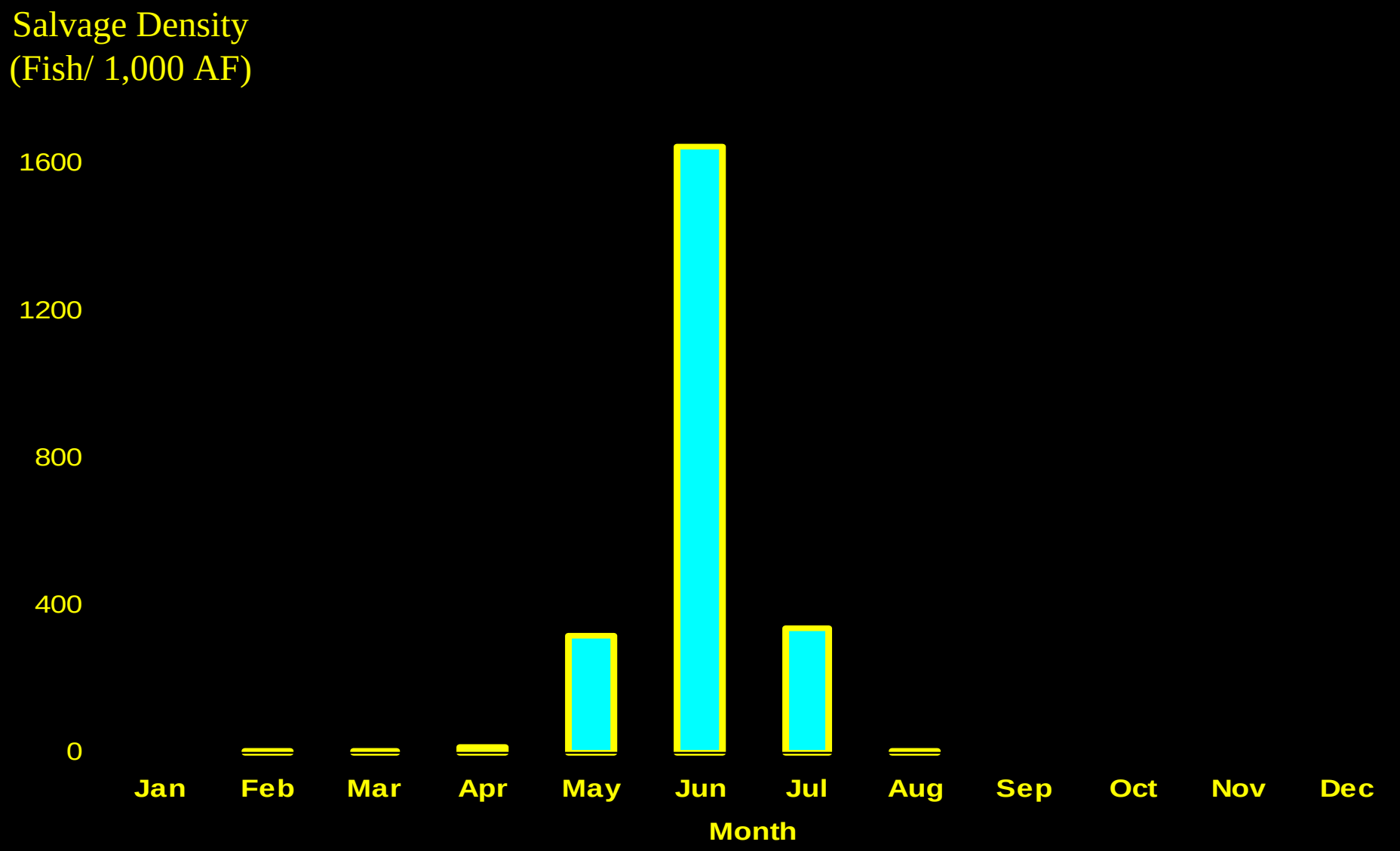


DIRECT LOSS EFFECTS SUMMARY

SPLITTAIL

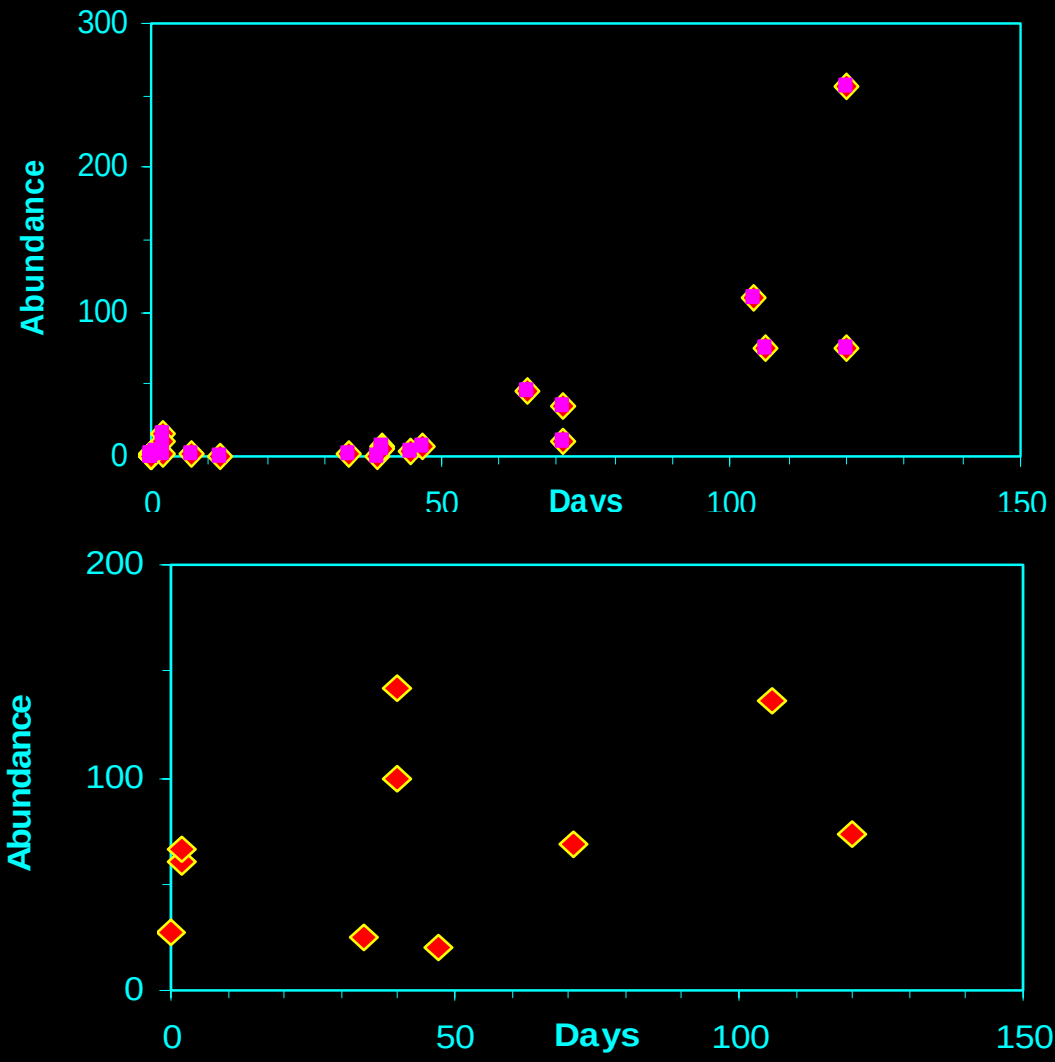
- Production largely driven by floodplain inundation
- Production appears higher in Sacramento River than San Joaquin River
- High salvage associated with strong year classes
- Exposure appears to be opposite of longfin smelt

Monthly Splittail Salvage Density (SWP+CVP) 1993-2002

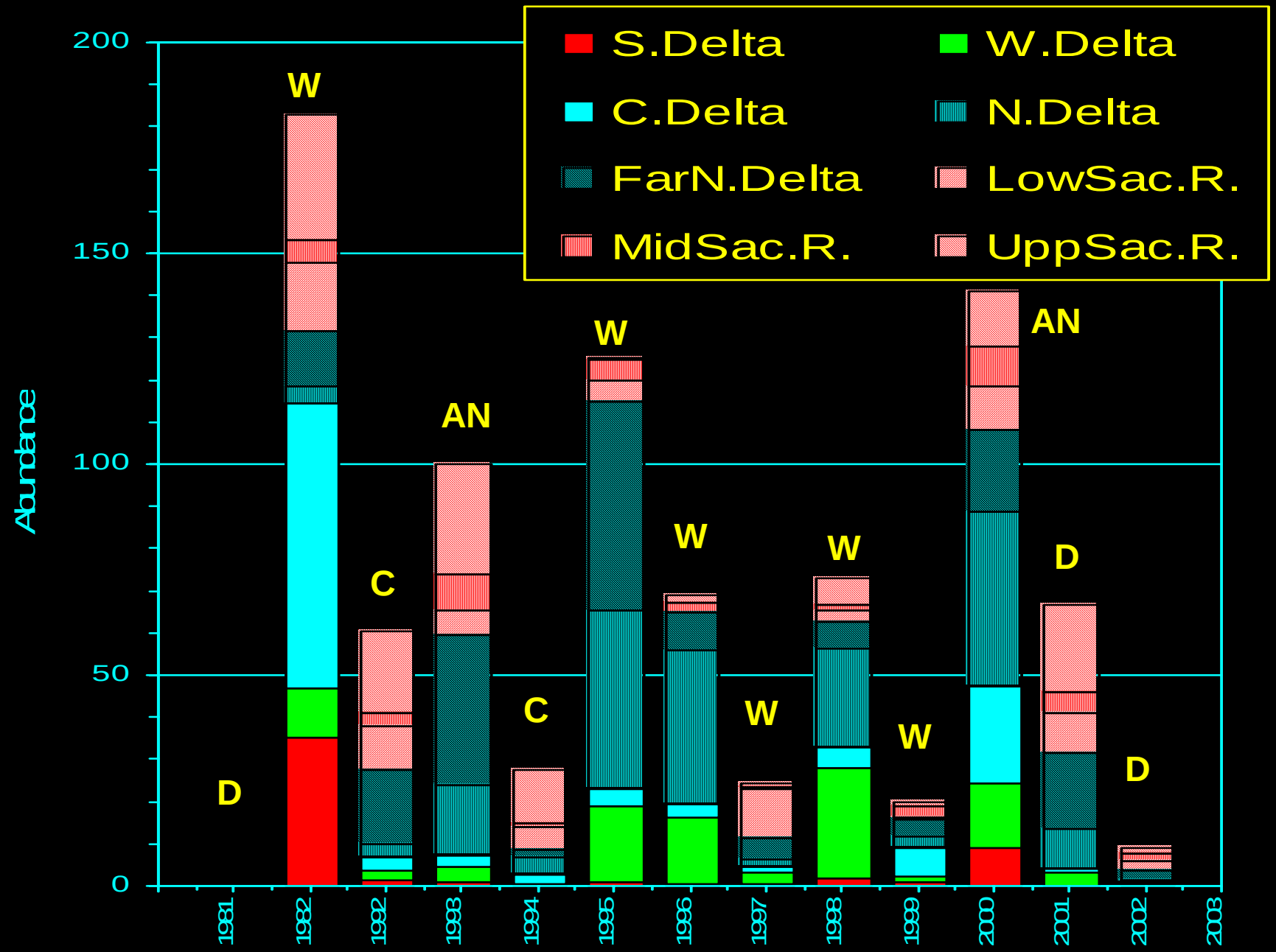


Splittail Abundance (FMWT) and Combined Mean Apr-Jul Salvage per AF by Year

Days of floodplain inundating flow vs FMWT Splittail Age-0 Abundance (Top) and Beach Seine Abundance (Bottom)



Splittail Abundance (USFWS Beach Seine)

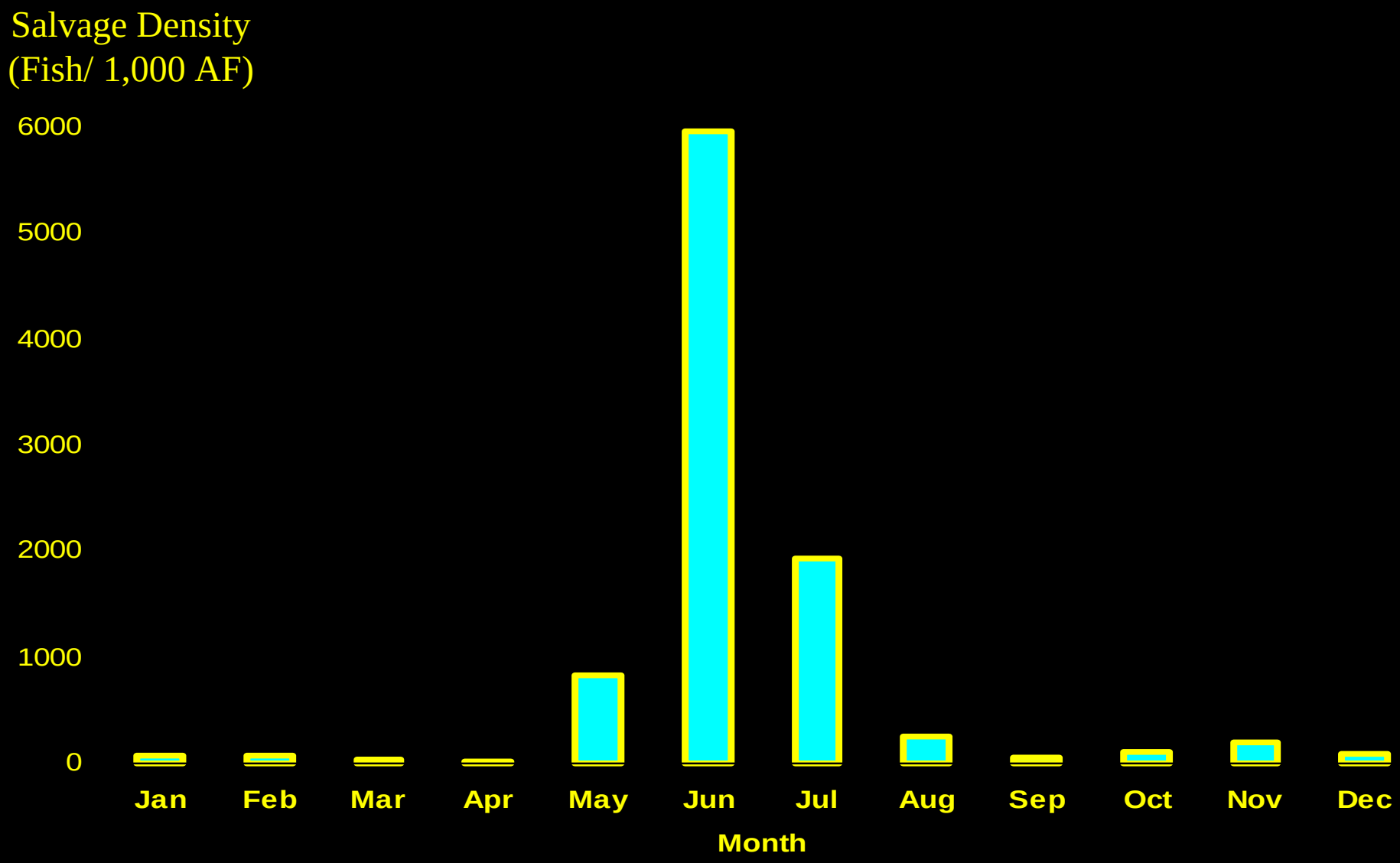


DIRECT LOSS EFFECTS SUMMARY

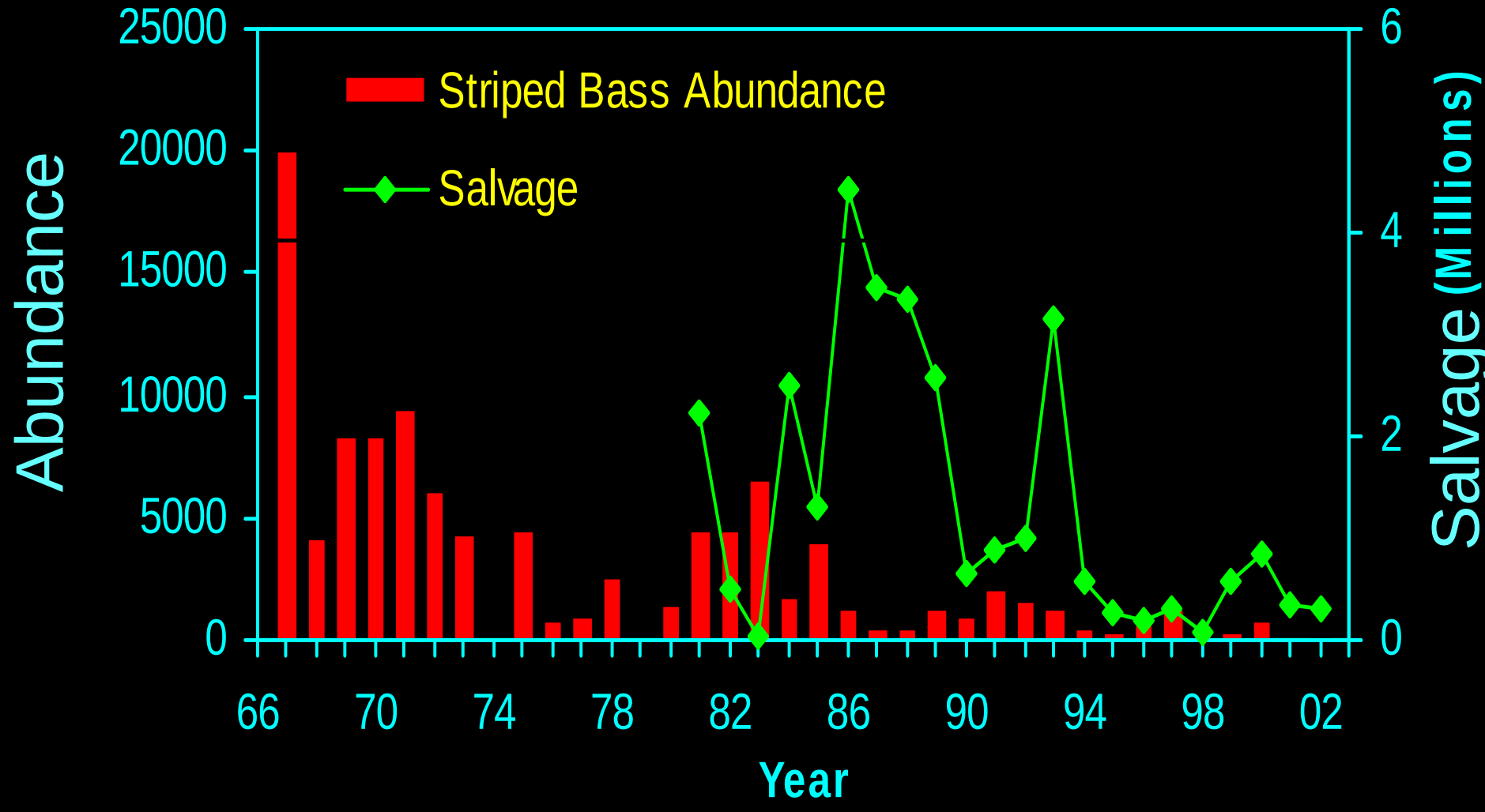
STRIPED BASS

- Exports and losses have been found important in the past analysis
- Losses are a substantial proportion of population
- Evaluation of losses complicated by affects of flow, variable ocean migration, changes in carrying capacity and reduced egg supply
- Recent analysis (Kimmerer et al. 2000 & 2001) did not examine entrainment losses

Monthly Striped Bass Salvage Density (SWP+CVP) 1993-2002



Striped Bass Abundance (FMWT) and Combined Mean May-Jul Salvage per AF by Year



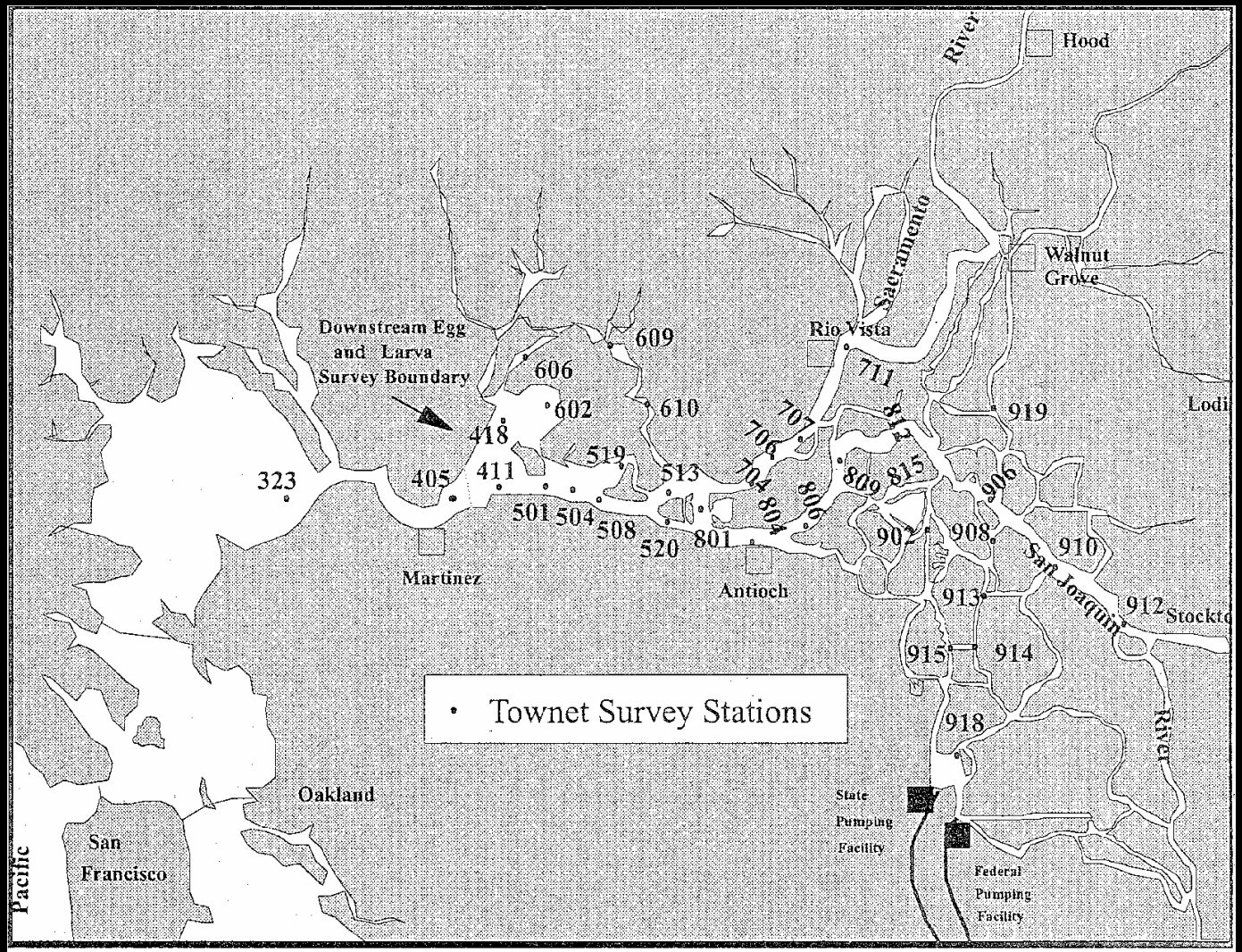
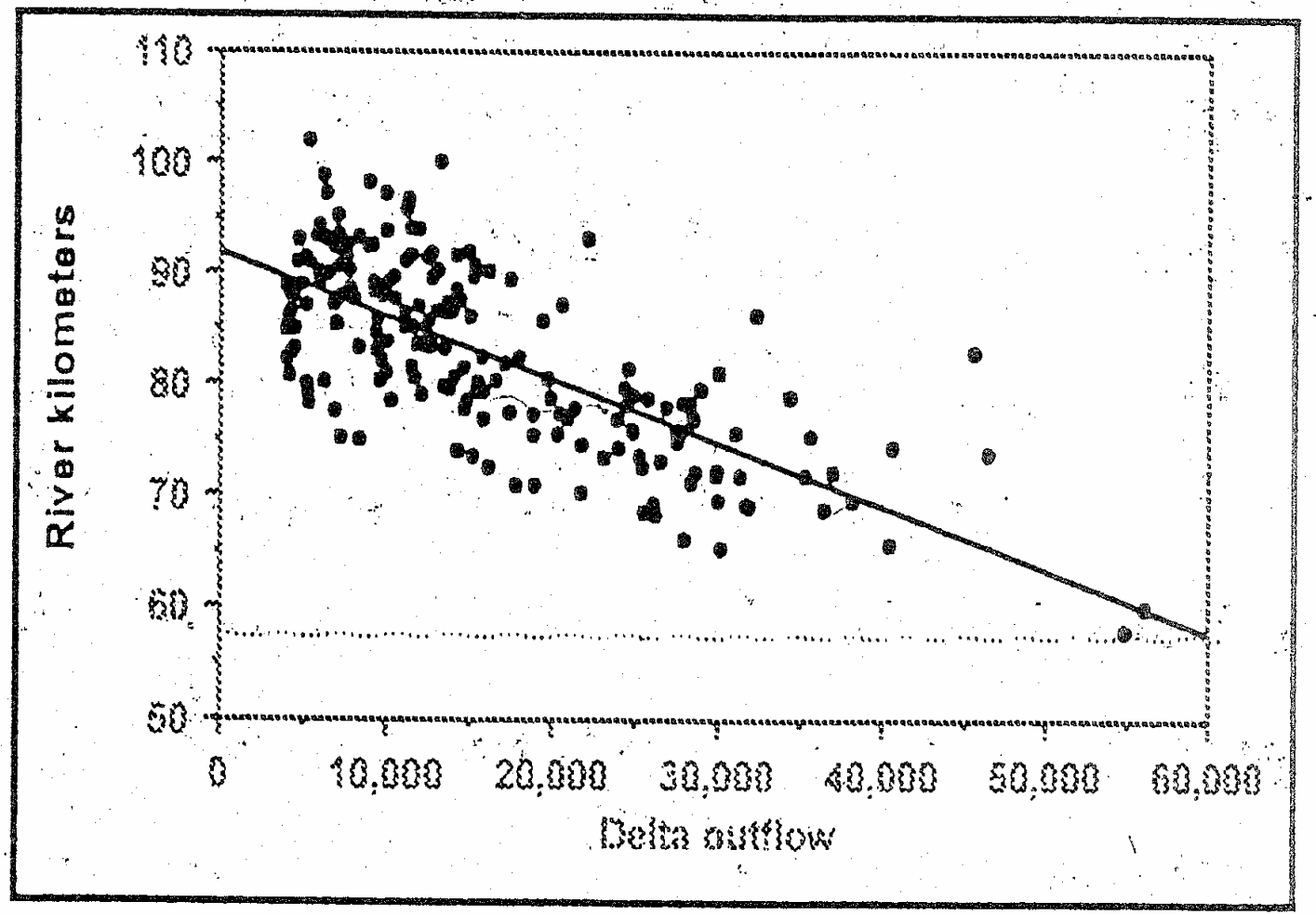
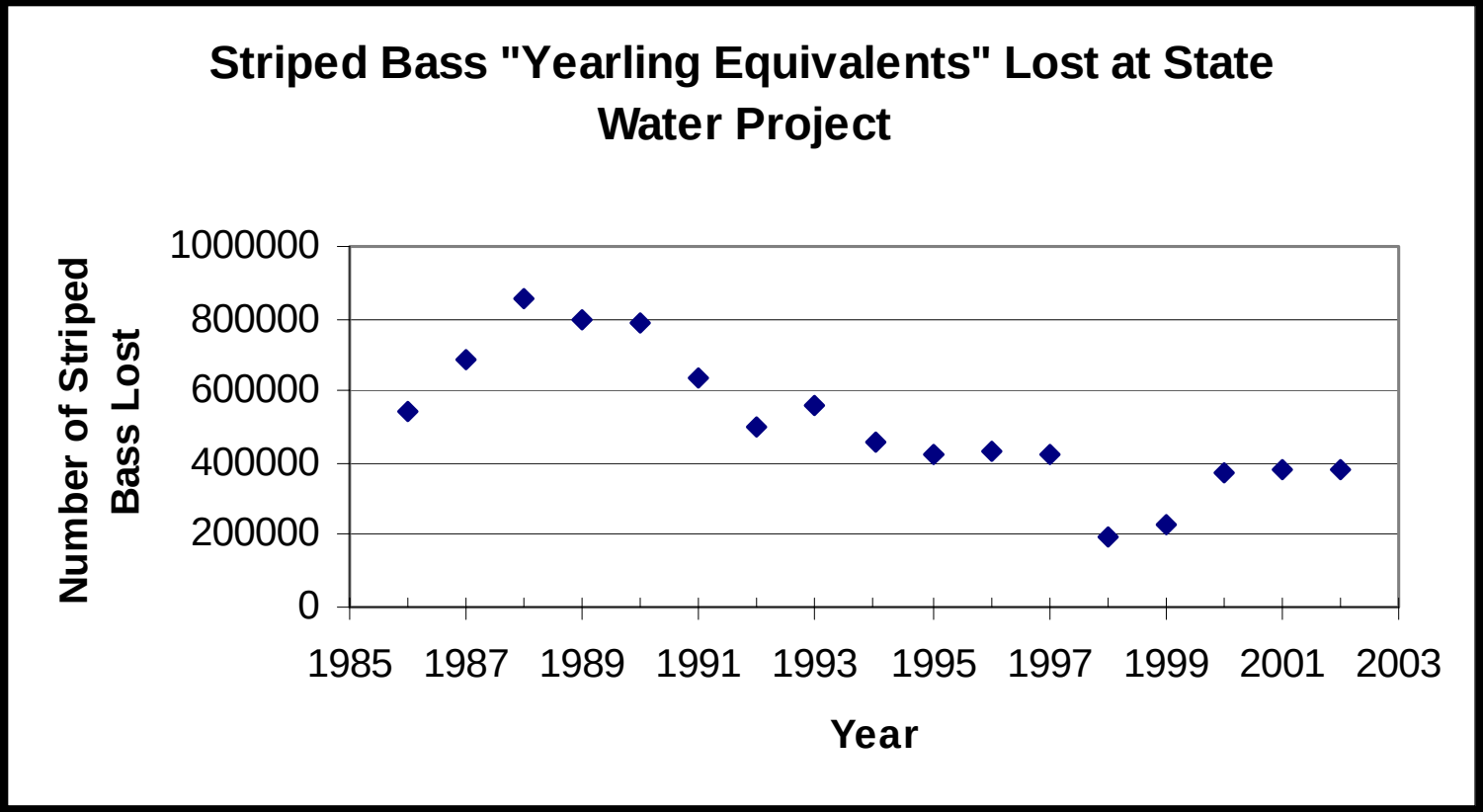


Figure 1
TOW-NET STATIONS AND LOWER BOUNDARY OF THE
1995 EGG AND LARVAL SURVEY STATIONS


River kilometers
110
100
90
80
70
60
50
0
10,000
20,000
30,000
40,000
50,000
60,000
Delta outflow


Striped Bass "Yearling Equivalents" Lost at State Water Project
Number of Striped Bass Lost
1000000
800000
600000
400000
200000
0
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
Year

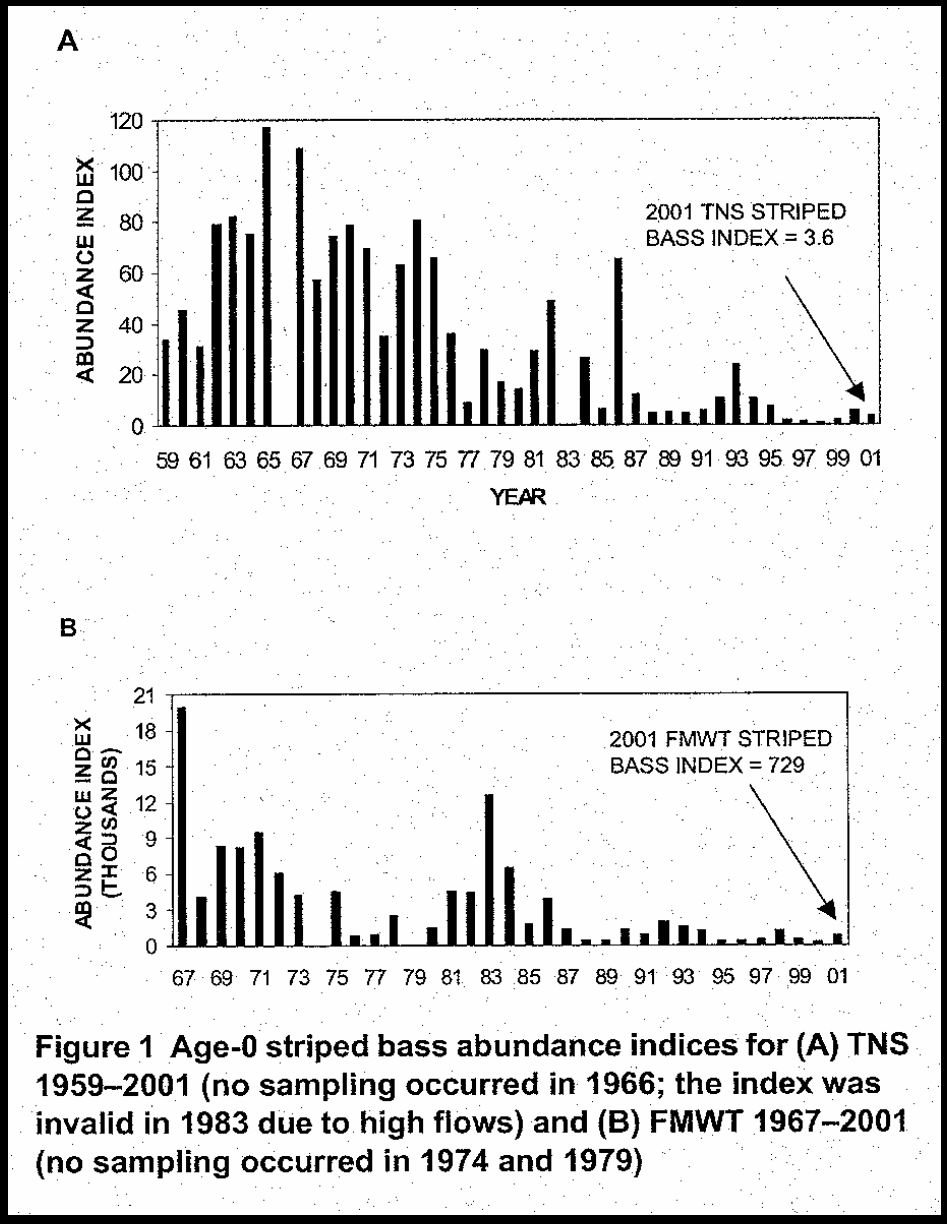


Figure 1 Age-0 striped bass abundance indices for (A) TNS 1959–2001 (no sampling occurred in 1966; the index was invalid in 1983 due to high flows) and (B) FMWT 1967–2001 (no sampling occurred in 1974 and 1979)

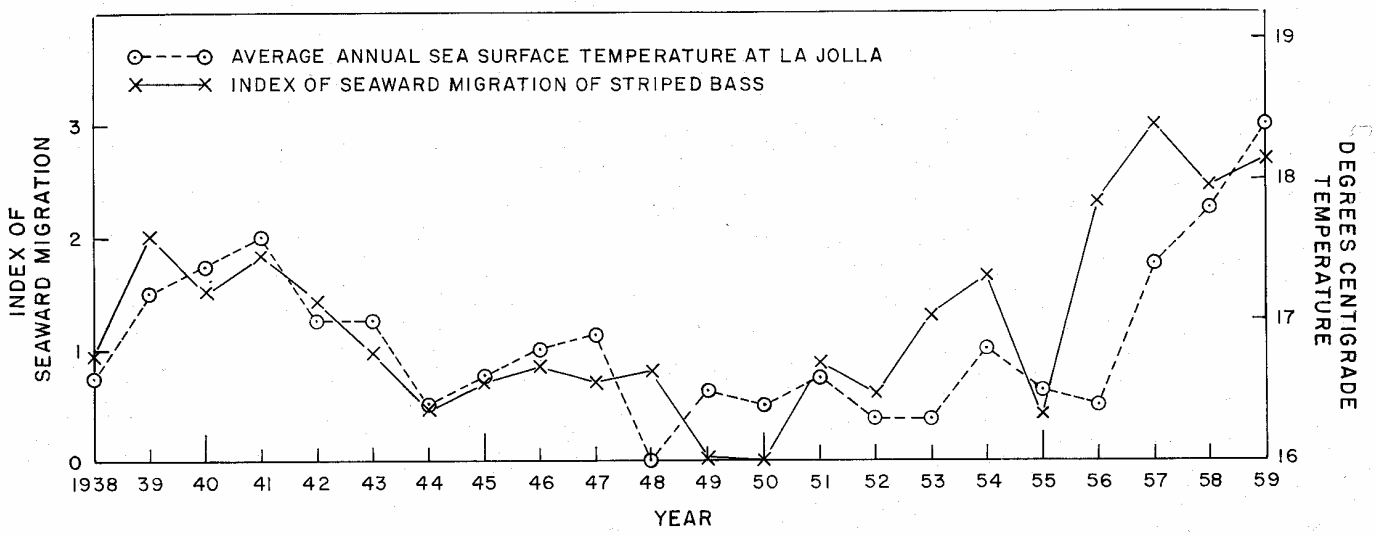


FIGURE 5. Average annual sea surface temperatures at La Jolla, and the index of seaward migration (Table 3) from 1938 through 1959.

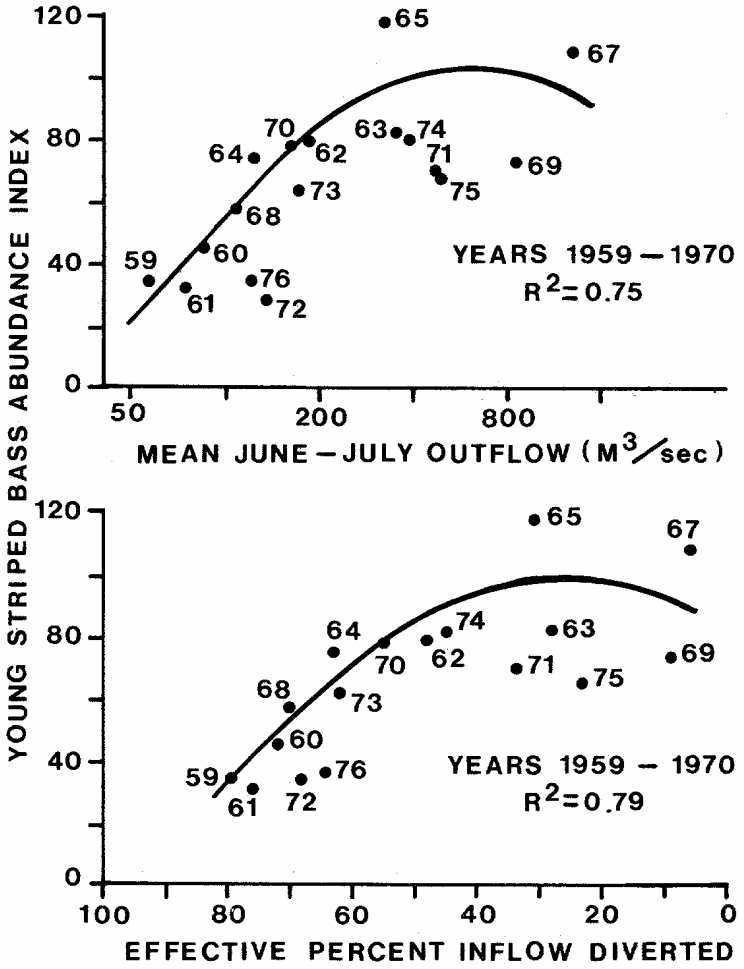


FIGURE 6.—*Relationship between total abundance of young striped bass in the Sacramento–San Joaquin Estuary and delta outflow and diversion. Curves are fits to 1959–1970 data.*

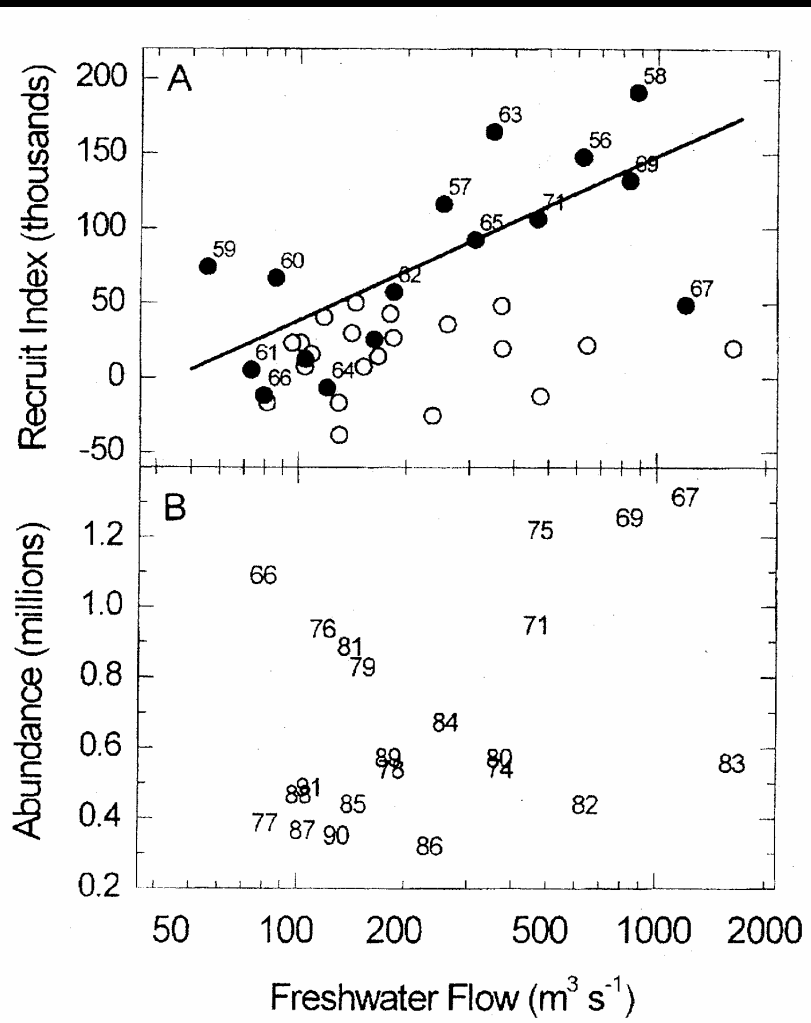


Fig. 4. Recruitment versus net delta outflow three years earlier. A) Recruitment index for 1956–1971 (solid circles) and 1972–1994 (open circles); numbers are years; solid line, prediction of robust regression model using only year-classes up to 1971. B) Petersen abundance estimate at age 3 years; numbers are years.

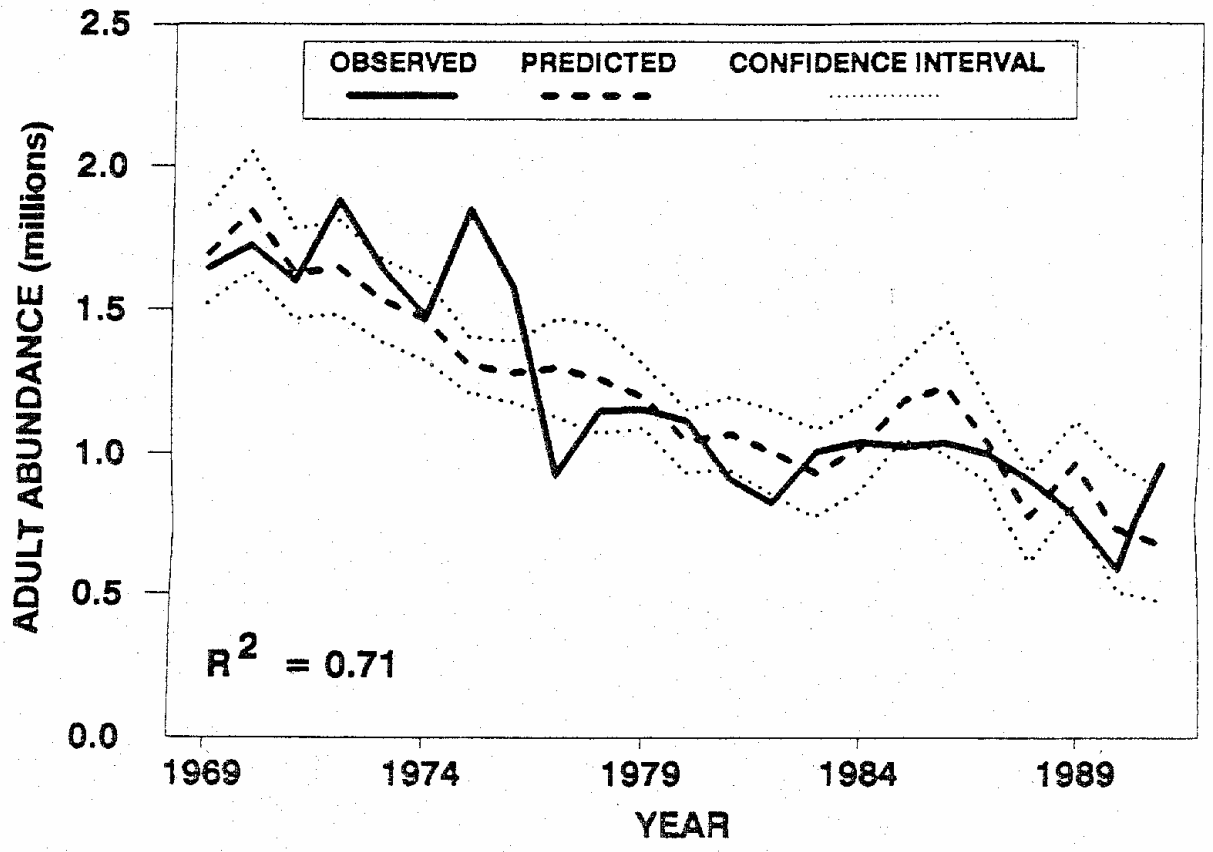
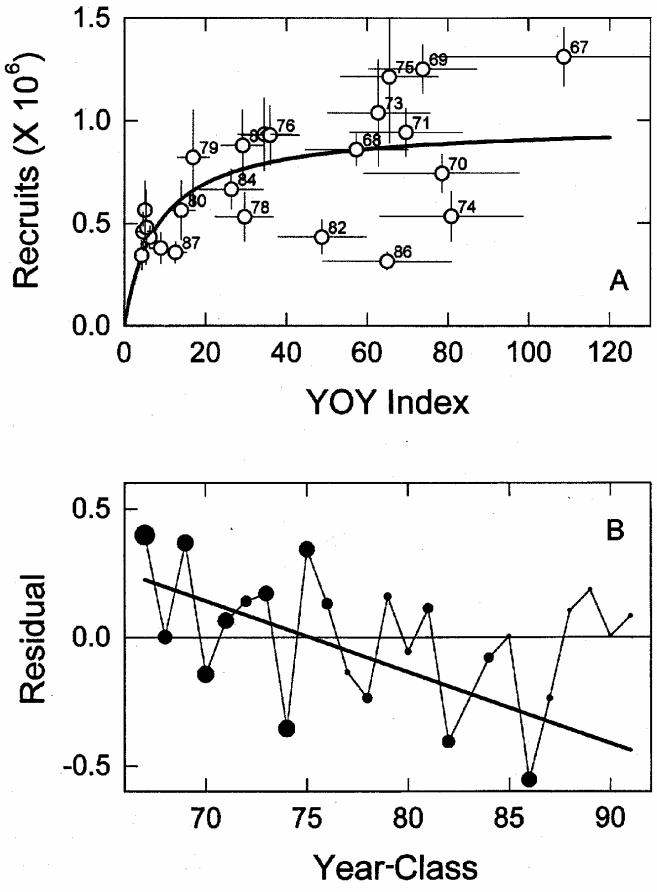


Figure 6. Observed and predicted adult striped bass abundance in the Sacramento-San Joaquin Estuary from 1969-1991. Predicted values are from the relationship between adult abundance and weighted mean young-of-the-year index and export loss rate 3-7 years earlier. The 95% confidence limits for the predicted values are shown.

Fig. 5. (A) Relationship between YOY and recruitment at age 3 fitted to a Beverton–Holt stock–recruit curve. Numbers are years, and horizontal and vertical lines are standard errors. (B) Time course of residual from Fig. 5A. The straight line is fitted by linear regression weighted by the YOY index (see text).

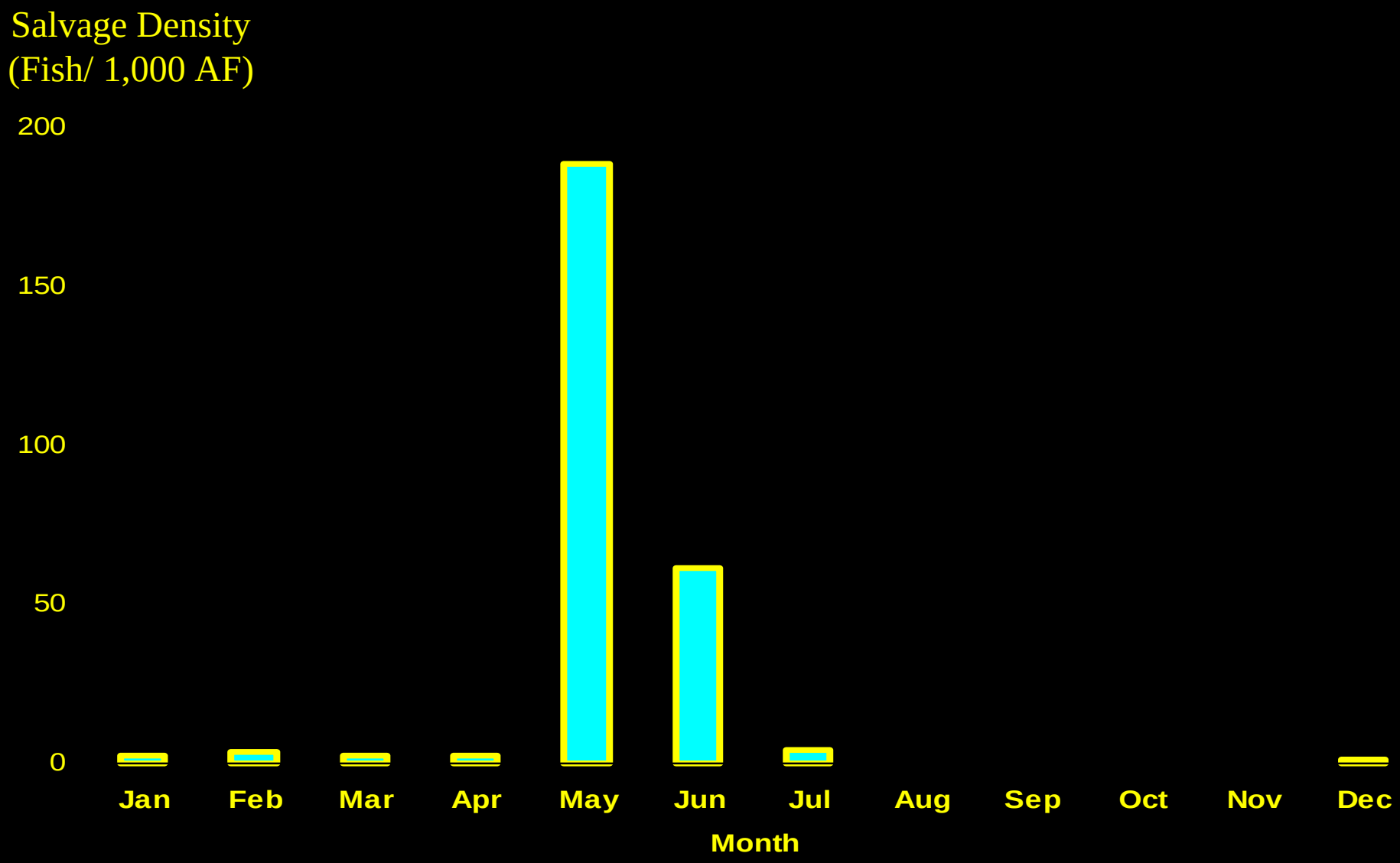


DIRECT LOSS EFFECTS SUMMARY

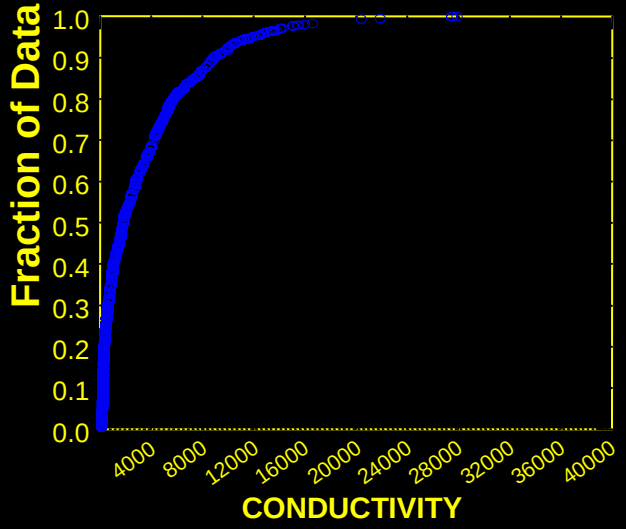
DELTA SMELT

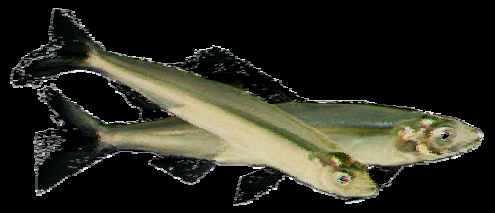
- Annual species
- Poor fit with S/R data
- Exposure high in dry years
- Losses are unknown and may be highest with fish below 20mm
- Relationship between X2 and abundance has flipped
- Salvage appears consistent with exposure
- Need multifactor analysis incorporating loss

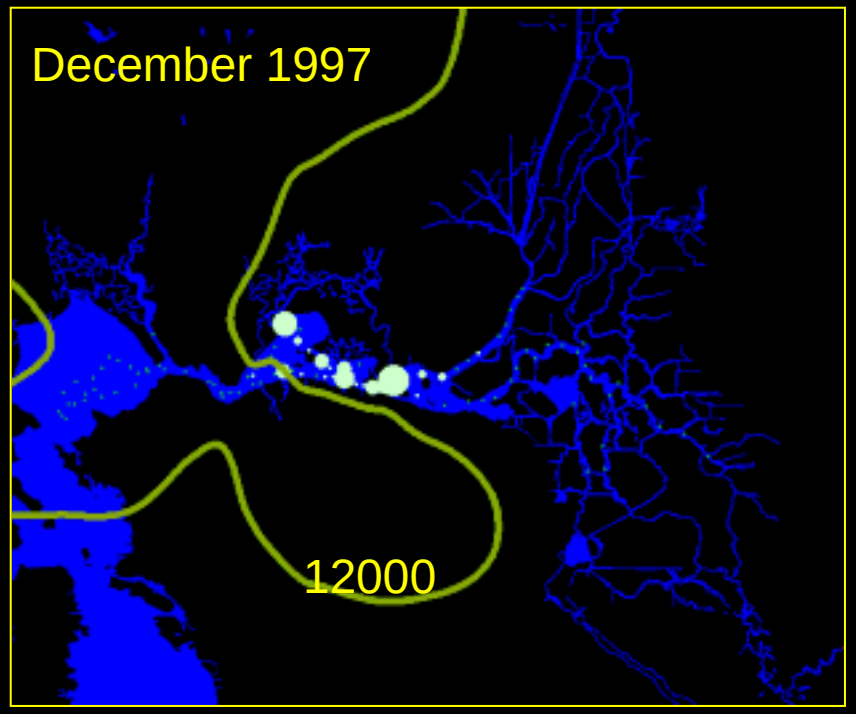
Monthly Delta Smelt Salvage Density (SWP+CVP) 1993-2002

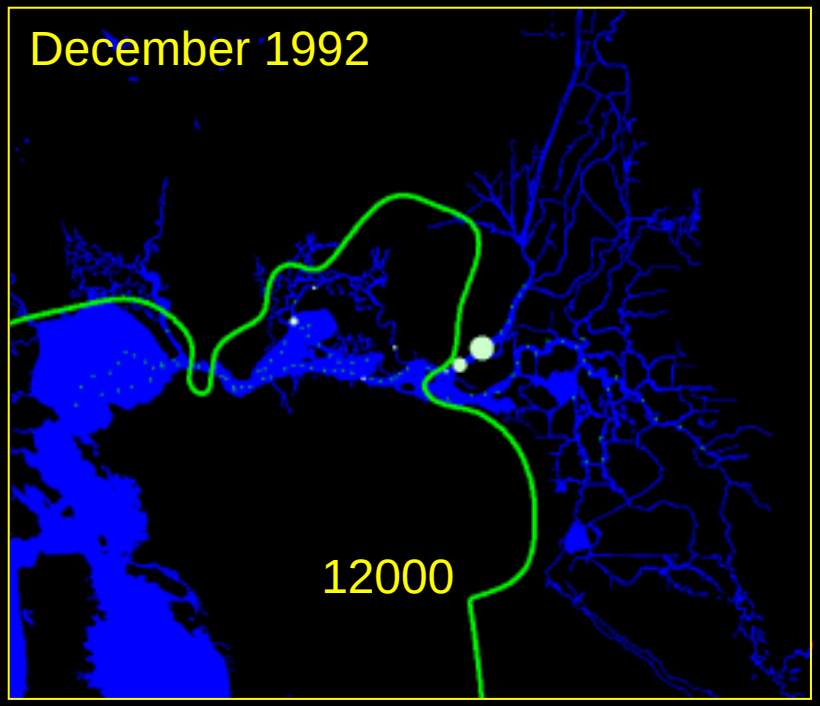


Delta Smelt Catch and EC data from Fall Midwater Trawl

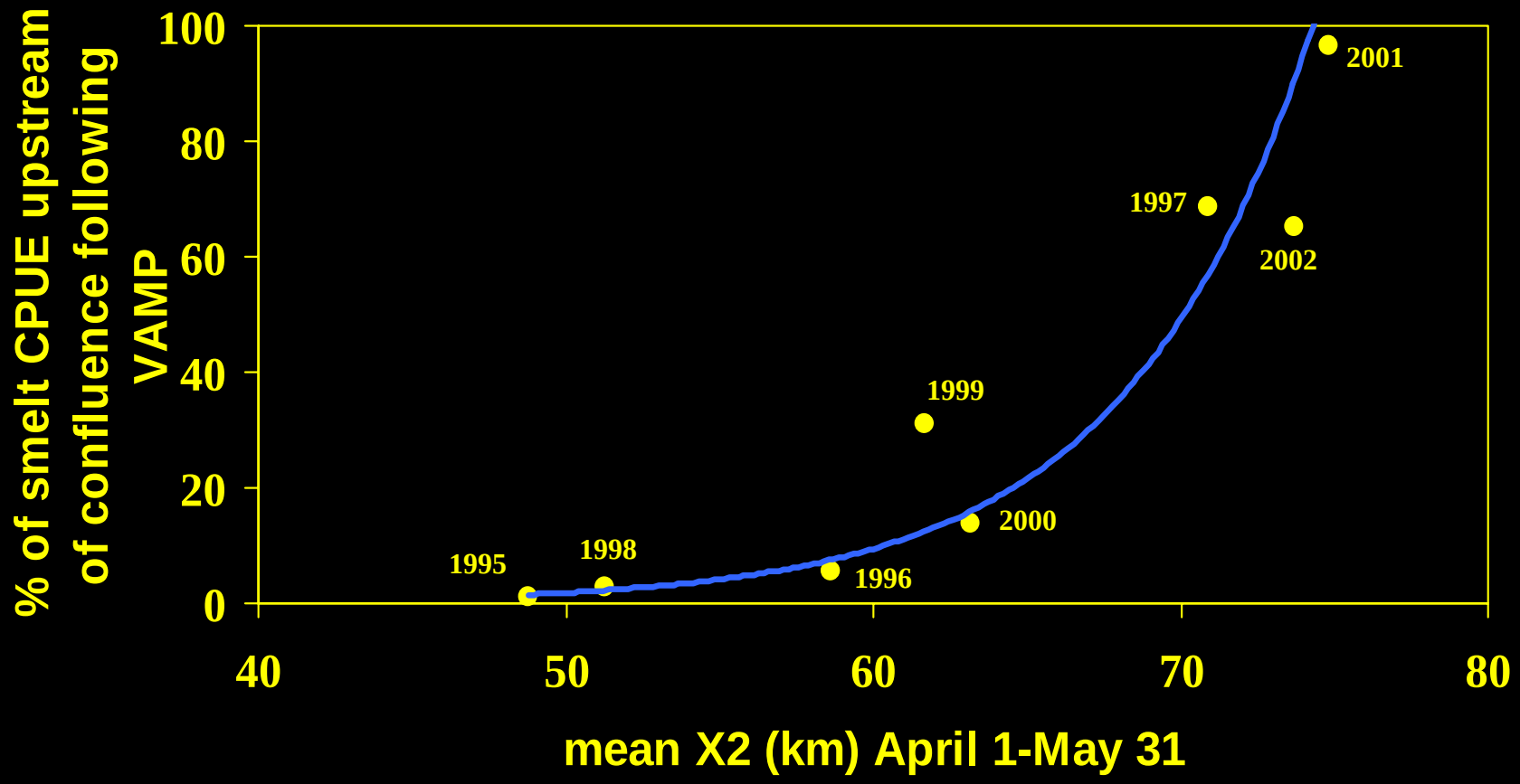




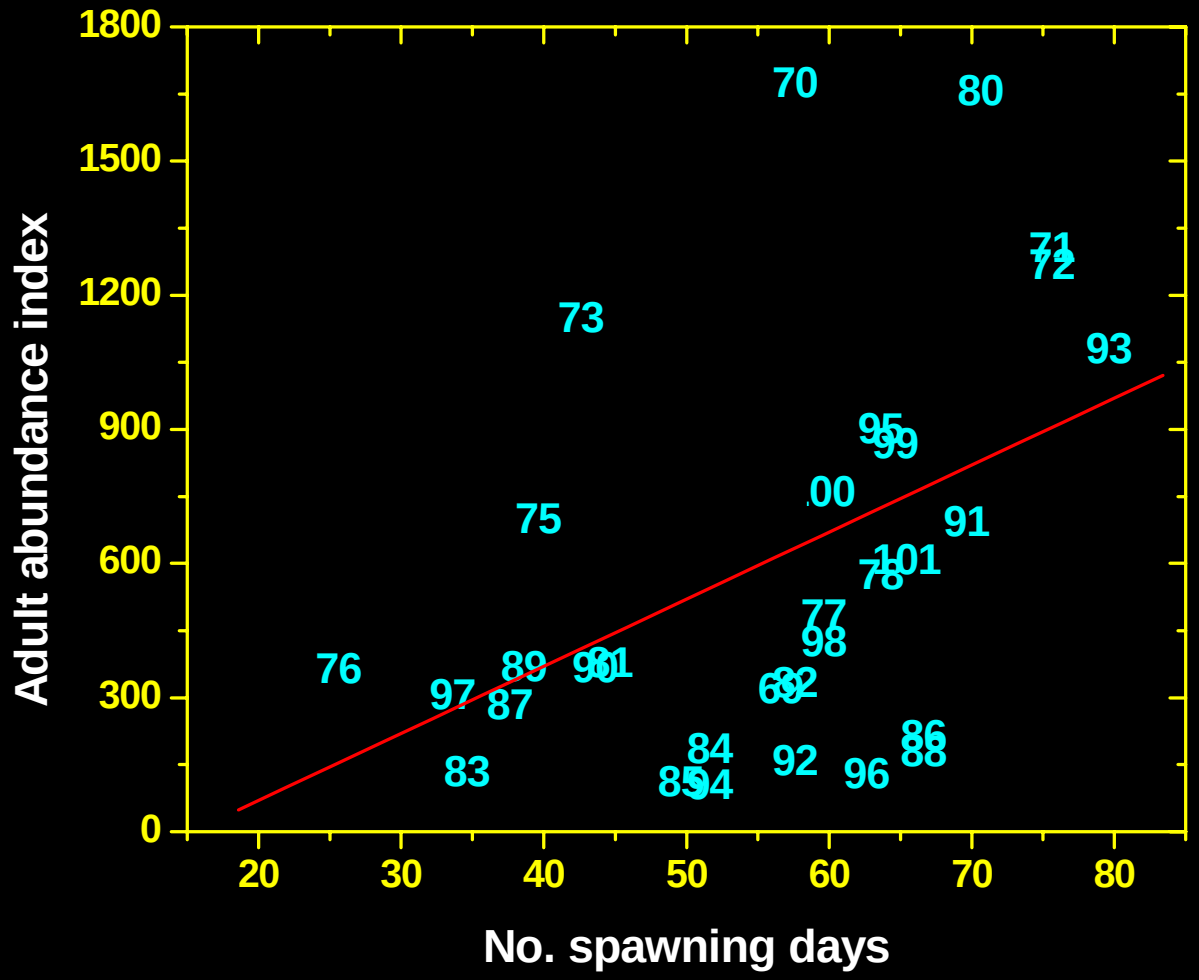




Post-larval macro-distribution

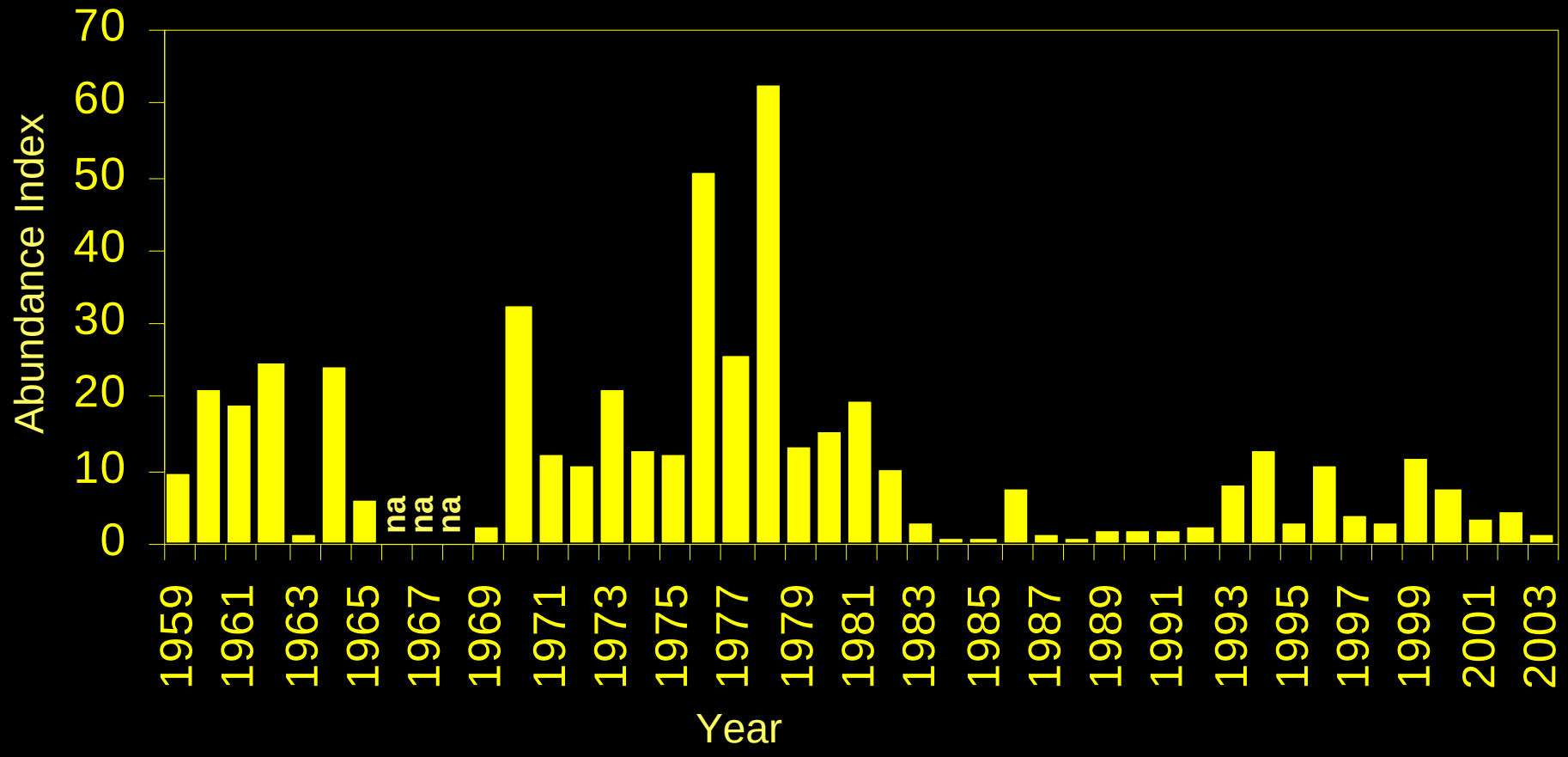


Nobriga, DWR

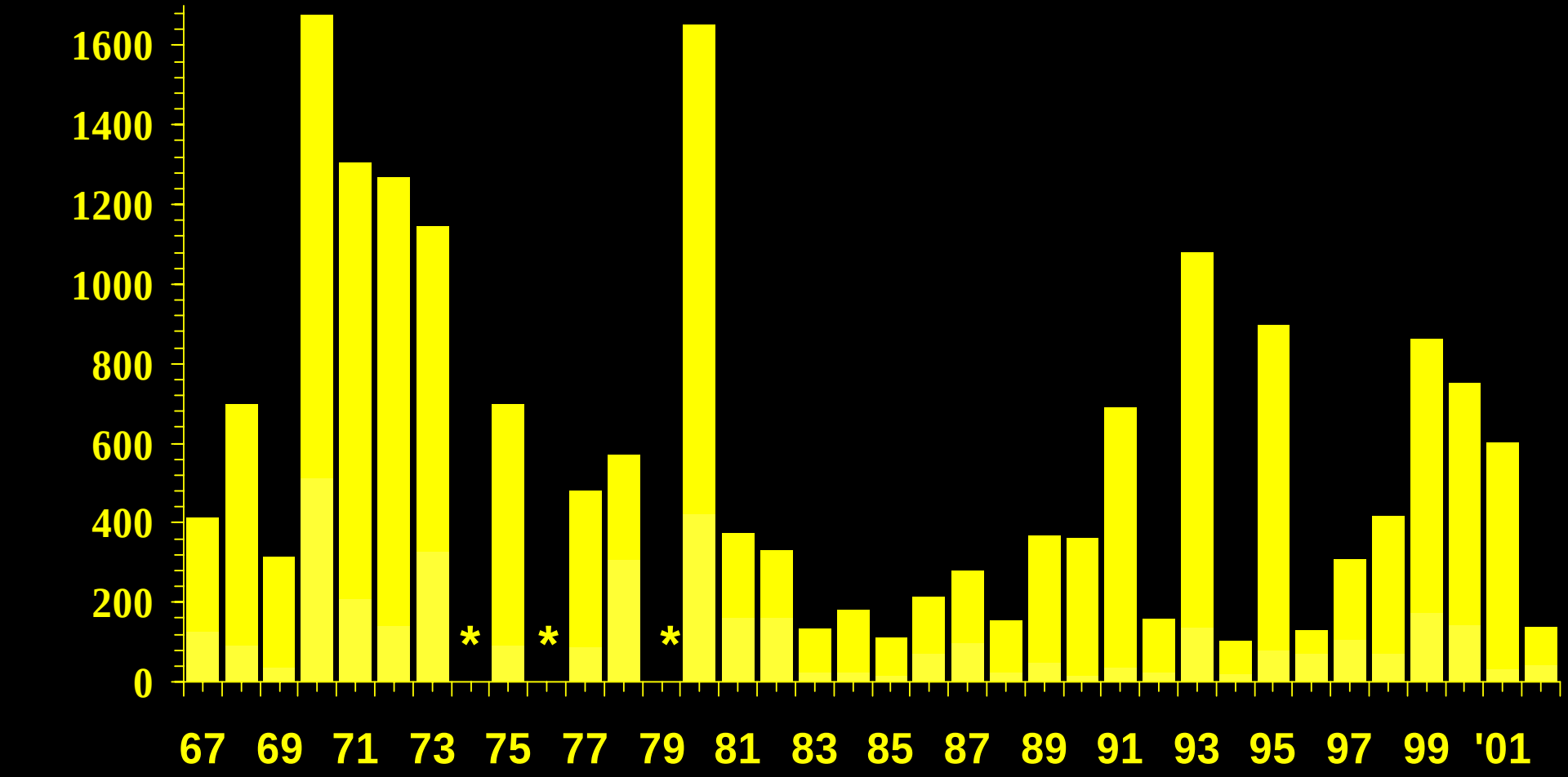

Adult abundance index
No. spawning days
1800
1500
1200
900
600
300
0
20
30
40
50
60
70
80
70
80
71
72
73
93
95
99
00
91
75
101
78
77
98
76
89
97
87
84
92
96
86
88
83
94

Bennett, UCD

Townet Survey

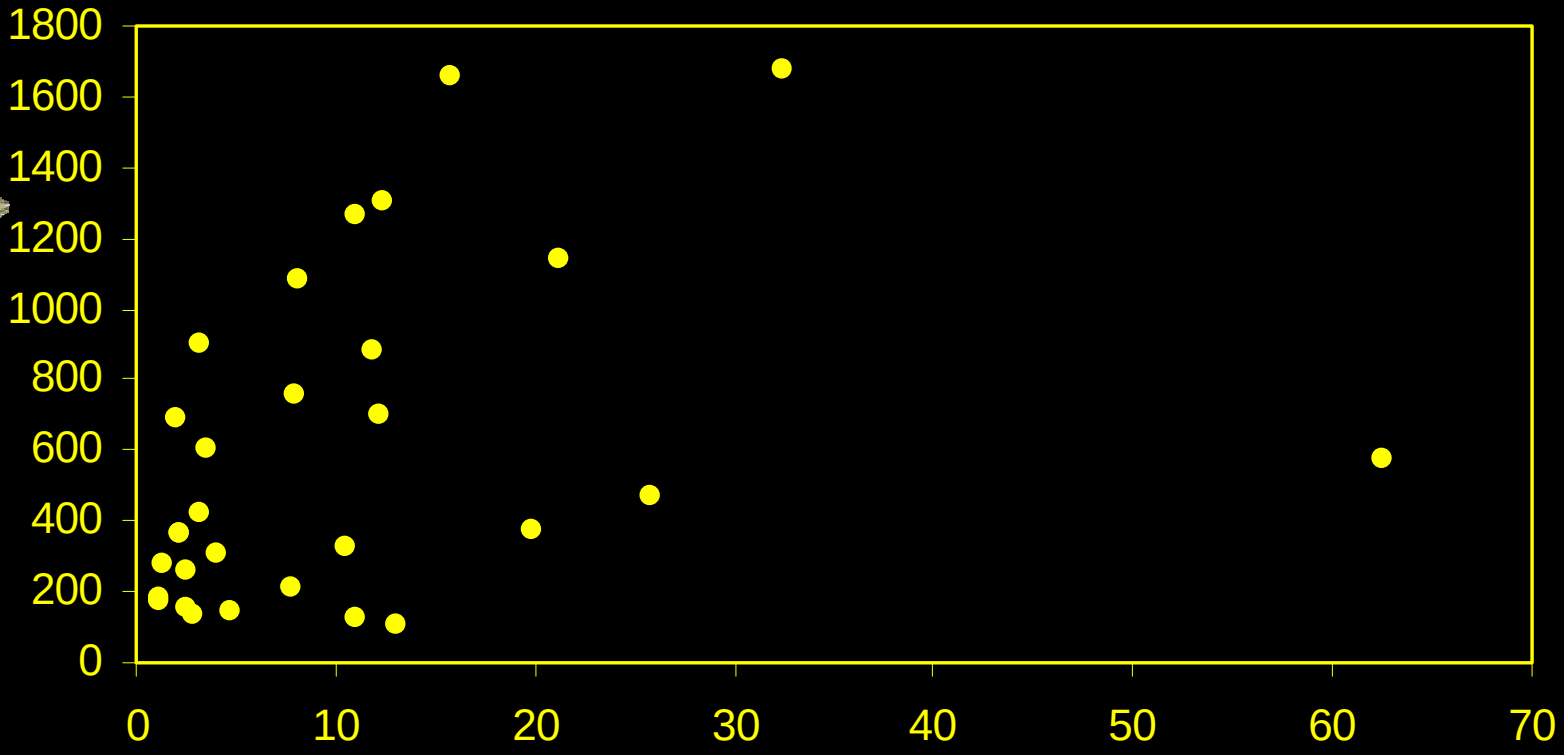


FALL MIDWATER TRAWL

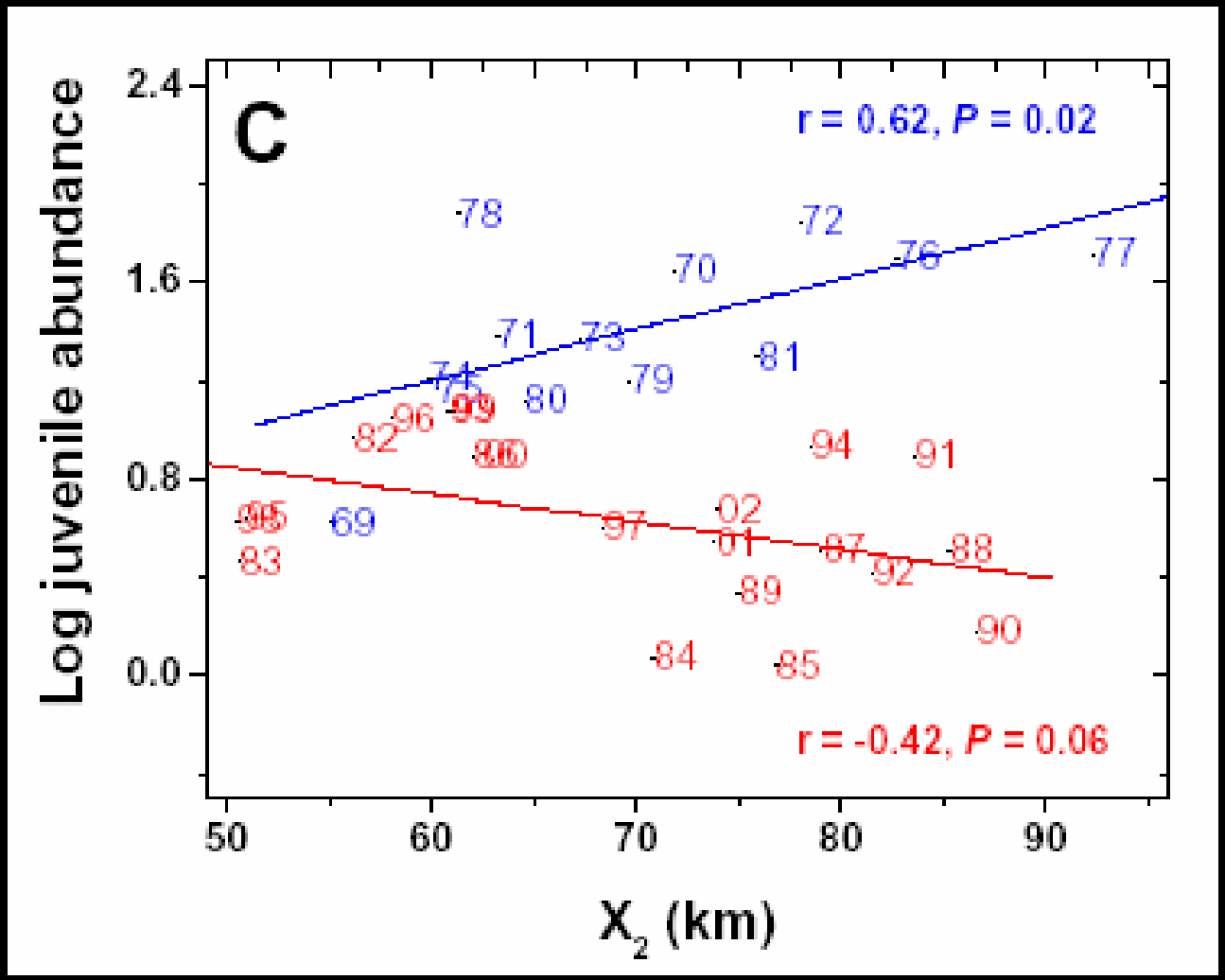


Stock-Recruitment Relationship

MWT



TNS

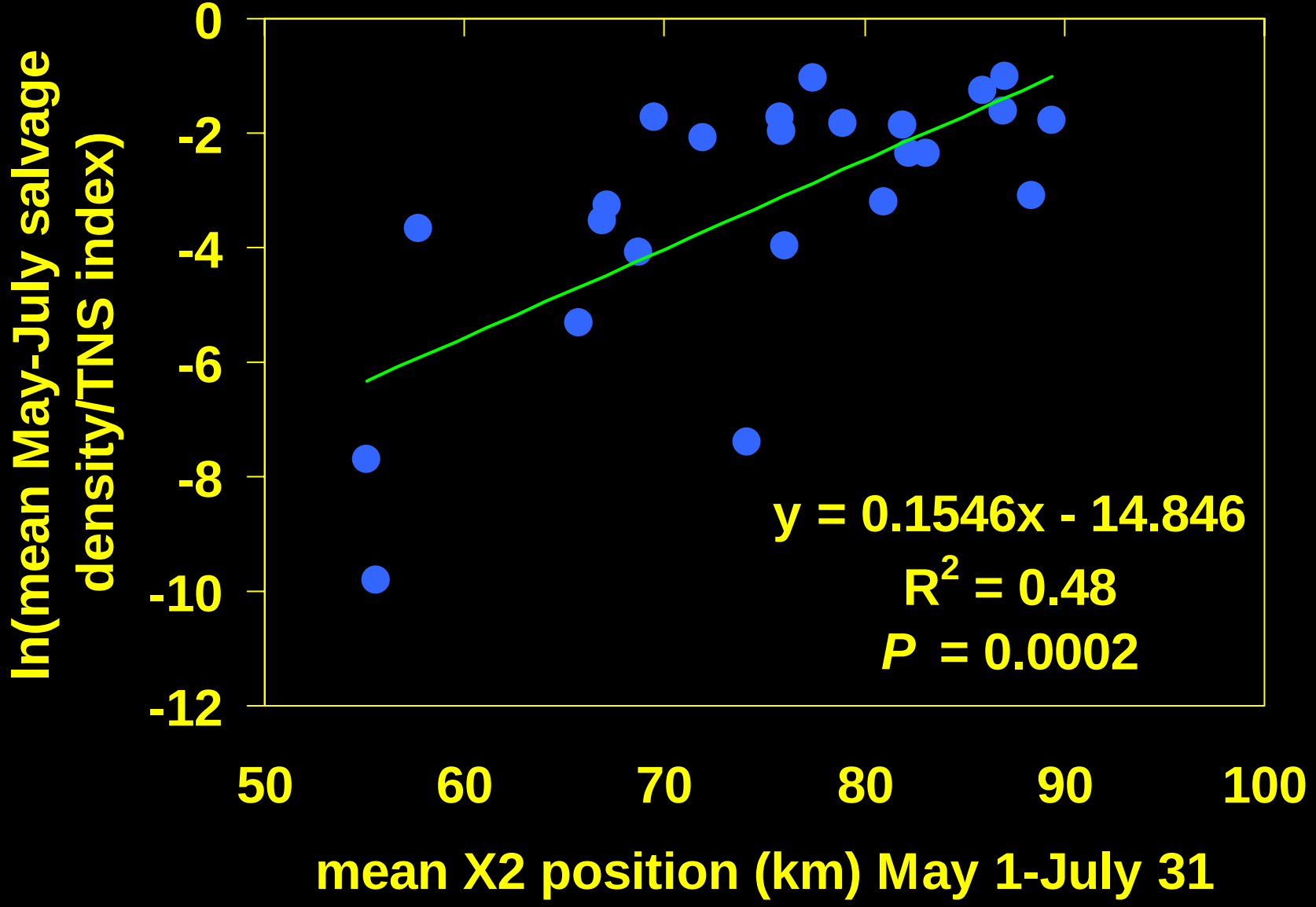

C
r = 0.62, P = 0.02
r = -0.42, P = 0.06
Log juvenile abundance
X2 (km)
2.4
1.6
0.8
0.0
50
60
70
80
90
78
72
70
76
77
71
73
81
74
79
80
96
82
94
91
69
97
02
01
87
88
83
92
89
90
84
85

TNS CATCH

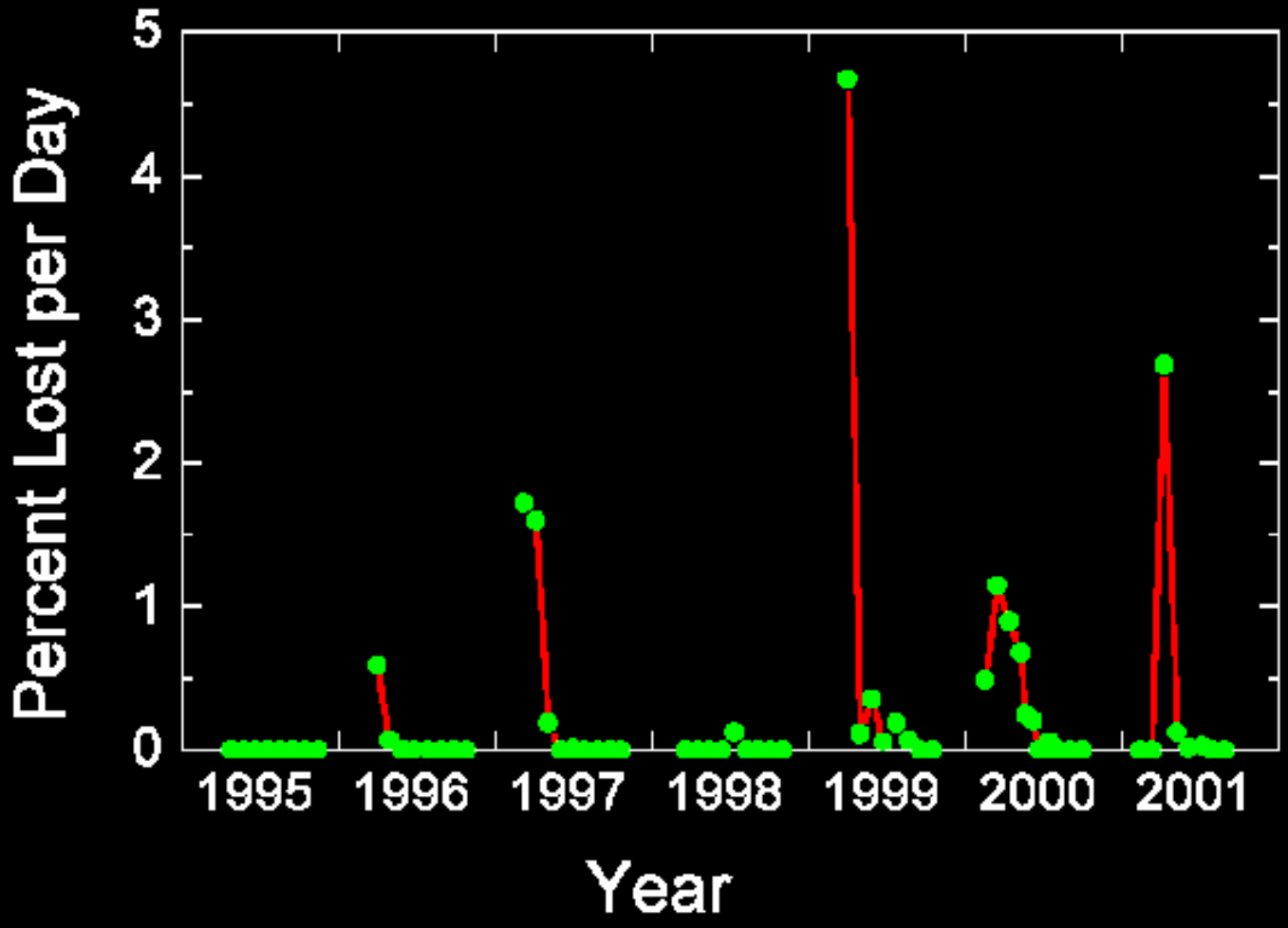
South Delta

	323	340	405	411	418	501	504	508	513	519	520	602	606	609	610	704	706	707	711	801	804	809	812	815	902	906	910	912	914	915	918	919
1959									18		1					224		105	26		1	27	7	5		1	4					
1960			10				2		37	11	4	5	4	7	4	599		46	35		4	28	11	46	3	42	26		5	3		
1961			2				2		9	4	3	33	47	139	61	235		147	180		21	28	80	16	22	25	31	1	42	59	18	11
1962						12	20	40	48	49	9	36	16	22	26	251	581	88	89	4		87	26	14		5	9	4	7	1	1	16
1963					1	1		5		2	2	8	1	9	4	2	3	1	1	3	9	5	1	19	1	23	14		7	1		4
1964			2				2	4	4		4	2			3	274	301	409	35	10	2	6	134	41	66	71	30	2	56	51	23	10
1965						3		5	11	2	3	3	2	34	21	27	8	9	2	8	29	7	6	57	14	116	18	1	30	14	12	4
1966	NO SURVEY																															
1967	NO DELTA SMELT ENUMERATED																															
1968																																
1969			5	6	1	18	3	5	4	5		57	3	14	5	2			2		1		1	1							2
1970						3	6	19	12	3	11	2			12	596	403	440	29	3	12	21	40	6	4	8	32	21	28	2	2	8
1971				48		82	27	57	44	118	16	118	11	86	86	3	1			21	11	8	15	16	14	30	18	2	17	5	7	12
1972						5	7	11	6	2	1	1	5	7	1	61	177	120		1	4	44	29	113	4	4	2	6	5		8	
1973				31		281	25	47	122	10	3	248		2	5					27	35	95					2		1	1		
1974			1	19		67	7	214	78	62	92	58	7	70	18	2		2		30	17	35	2	44	1	5		1	1		1	2
1975						5	4	36	242	107	100	36	23	198	123	9	3			50	11	9	27	12	2	4	14	2	2	2		2
1976				2		4	9	112	37	32	5	73	1	3	33	940	1076	99		28	39	89	20	16		1	9	6	4			1
1977							1	10	3	3	7	1				339	469	446	18	2	6	33	8	5	1	2	119	5			1	4
1978						1	2	95	92	32	43	1137	10	155	9	1061	266	1		3	4	12	1	1				1		1		1
1979				3		2	1	4	16	3	26	17		16		286	287	19		2	4	3				1	6	6			1	1
1980			2	2	1	28	79	45	139	13	42	24	29	75	2	186	25			50	6	38	8	2			2					3
1981			1	1		4	6	18	47	50	11	10		8	39	477	233	31		7	6	24	13	1	2					1		1
1982		38		25	2	39	72	31	24	102	216	139	22	56	13	1	3			10	8											
1983	5	22	4	28		3	1	2			1	63	3	21														1				
1984			2			3	3	6	11	9	5	13		3	3	7	3	2		1	1	1										
1985									4	1	1					18	14	2				1			1				2			
1986						2	2	8	26	2	8	7		4	2	215	65	2		1	1	3							7			
1987			1														12	30		1	8	15	1		2			1	2	1		
1988								1	3	1						21	9	10			2	5	3	1								
1989			1					1	6	2	3	3	3	8		14	95	4			3			3					1			
1990								1				5			3	52	26			1	5	5			1							1
1991													2	1		56	16	5				2	3	2		1	1					
1992								1	14		1					20	30	48			3	13								1		
1993			2	19		18	14	17	42	22	6	38		1		152	18	2			9	5										
1994			7			1		87	77	14	47	13		1	1	137	122	117	1	62	33	8		4			1			1		
1995		8	8	4	8	32	7	4	4	12	2	66		2		2				1												
1996		4	7	12	3	9	14		20	21	1	15	2	2		16	15	2		1												
1997			7				1	44	27	10	3	13				47	64	6		4		2										
1998	4	25	36	3	27	12	11	4		4	1	30	8	9	2	1						1										
1999	2	1	38	9	10	27	6	65	81	50	7	170	6	3		75	42	15		9	2	2	1	1								
2000			2	2	1	2		34	45	5	11	20	4	6	5	140	87	35		12	2	3					1	1				
2001		2		1				3	2	7	1	1			2	77	49	11		2	7	5	3	1								
2002						1		17	9		1	5				46	156	33	1	3		7										

YOY salvage



Nobriga, DWR



Kimmerer, RTC

THE DELTA SMELT NIGHTMARE SCENARIO

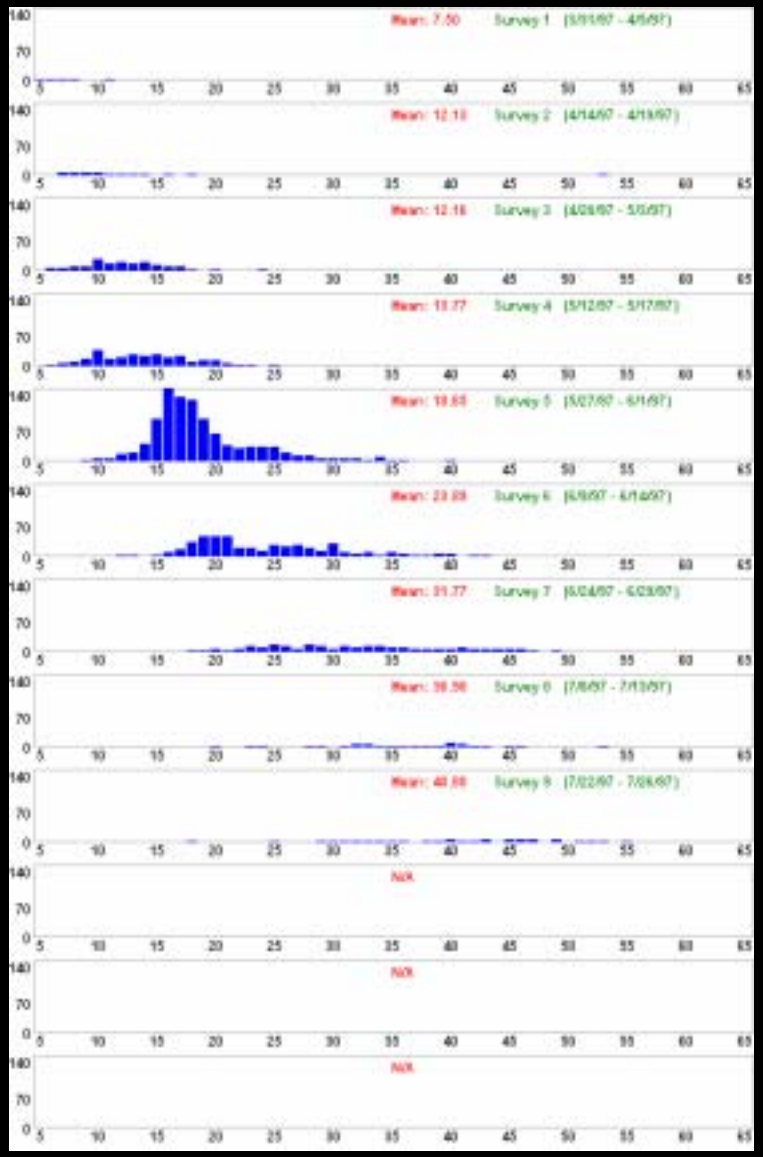
- Climate warming, plus
- Extended drought, plus
- Increased exports

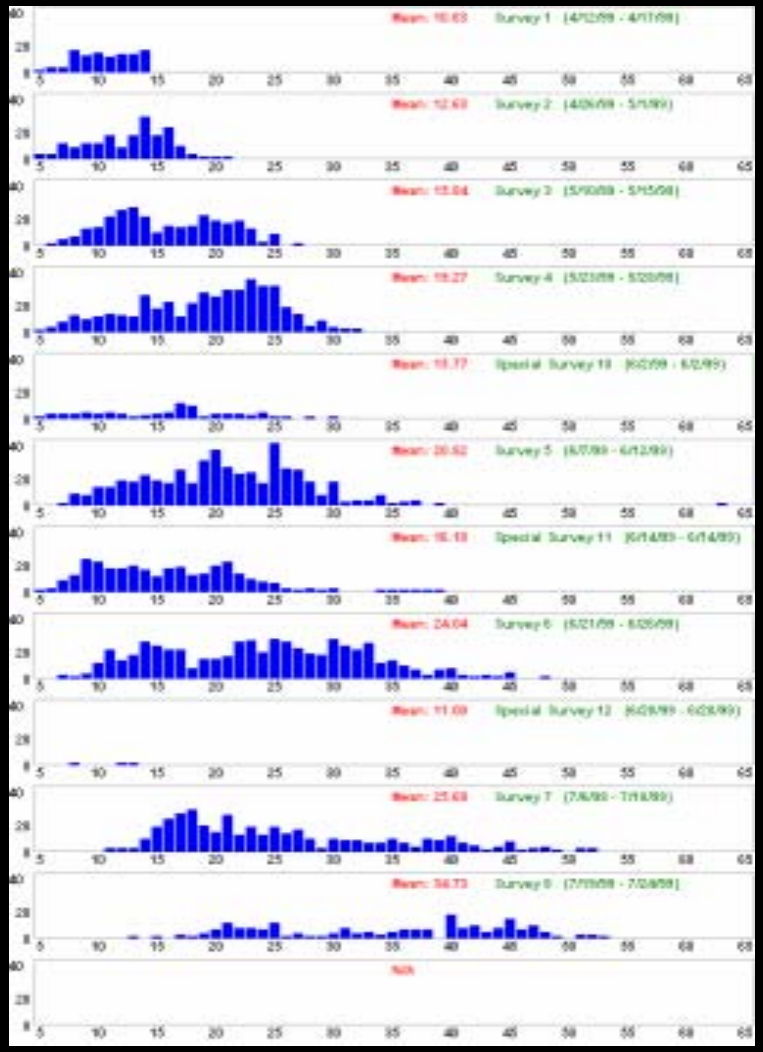
CAUTIONS REGARDING DENSITY DEPENDENCE /COMPENSATION

- Difficult to know the true form of the S/R relationship (Koslow 1992)
- Beverton-Holt curves assume DD underlies the plotted S/R data
- B-H requires that the S/R function passes through the origin
- A population in decline should not exhibit strong DD
- Unknown DD mechanism
- Assuming DD in the management of declining or depressed populations is risky
- DD should be given more weight in the post-recovery phase of Management

Improving measures

- Extend Kimmer et al. (2000, 2001)
- Investigate the effect of losses on longfin in dry years
- BJ: Develop fractional loss estimates for various lifestages
- Re-establish larval fish monitoring program
- Modeling
- Management for direct losses may increase indirect losses

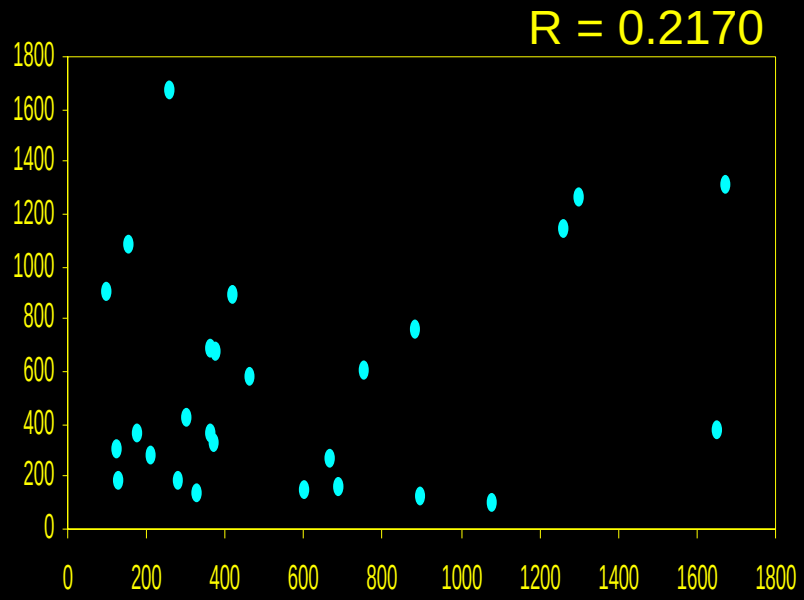

Mean: 7.50 Survey 1 (5/31/97 - 4/5/97)
Mean: 12.10 Survey 2 (4/14/97 - 4/19/97)
Mean: 12.16 Survey 3 (4/26/97 - 5/5/97)
Mean: 13.77 Survey 4 (5/12/97 - 5/17/97)
Mean: 19.65 Survey 5 (5/27/97 - 6/1/97)
Mean: 23.69 Survey 6 (6/9/97 - 6/14/97)
Mean: 31.77 Survey 7 (6/24/97 - 6/29/97)
Mean: 38.56 Survey 8 (7/8/97 - 7/13/97)
Mean: 48.88 Survey 9 (7/22/97 - 7/26/97)
N/A
N/A
N/A

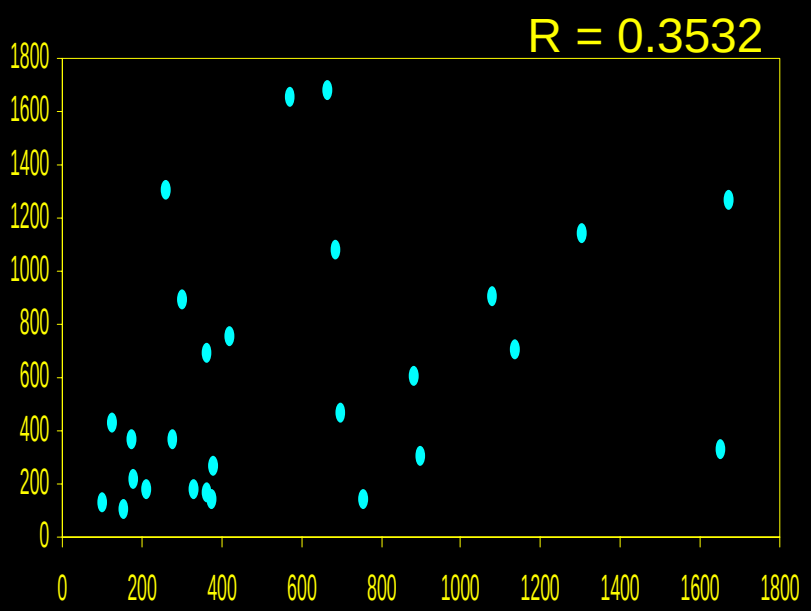

Mean: 10.63 Survey 1 (4/12/99 - 4/17/99)
Mean: 12.63 Survey 2 (4/26/99 - 5/1/99)
Mean: 15.04 Survey 3 (5/10/99 - 5/15/99)
Mean: 19.27 Survey 4 (5/23/99 - 5/28/99)
Mean: 15.77 Special Survey 10 (6/2/99 - 6/2/99)
Mean: 20.52 Survey 5 (6/7/99 - 6/12/99)
Mean: 16.13 Special Survey 11 (6/14/99 - 6/14/99)
Mean: 24.04 Survey 6 (6/21/99 - 6/26/99)
Mean: 11.09 Special Survey 12 (6/28/99 - 6/28/99)
Mean: 25.63 Survey 7 (7/6/99 - 7/11/99)
Mean: 34.73 Survey 8 (7/19/99 - 7/24/99)
N/A

1-Year Lag

2-Year Lag

MWT





TNS