Delta Flows and Delta Smelt

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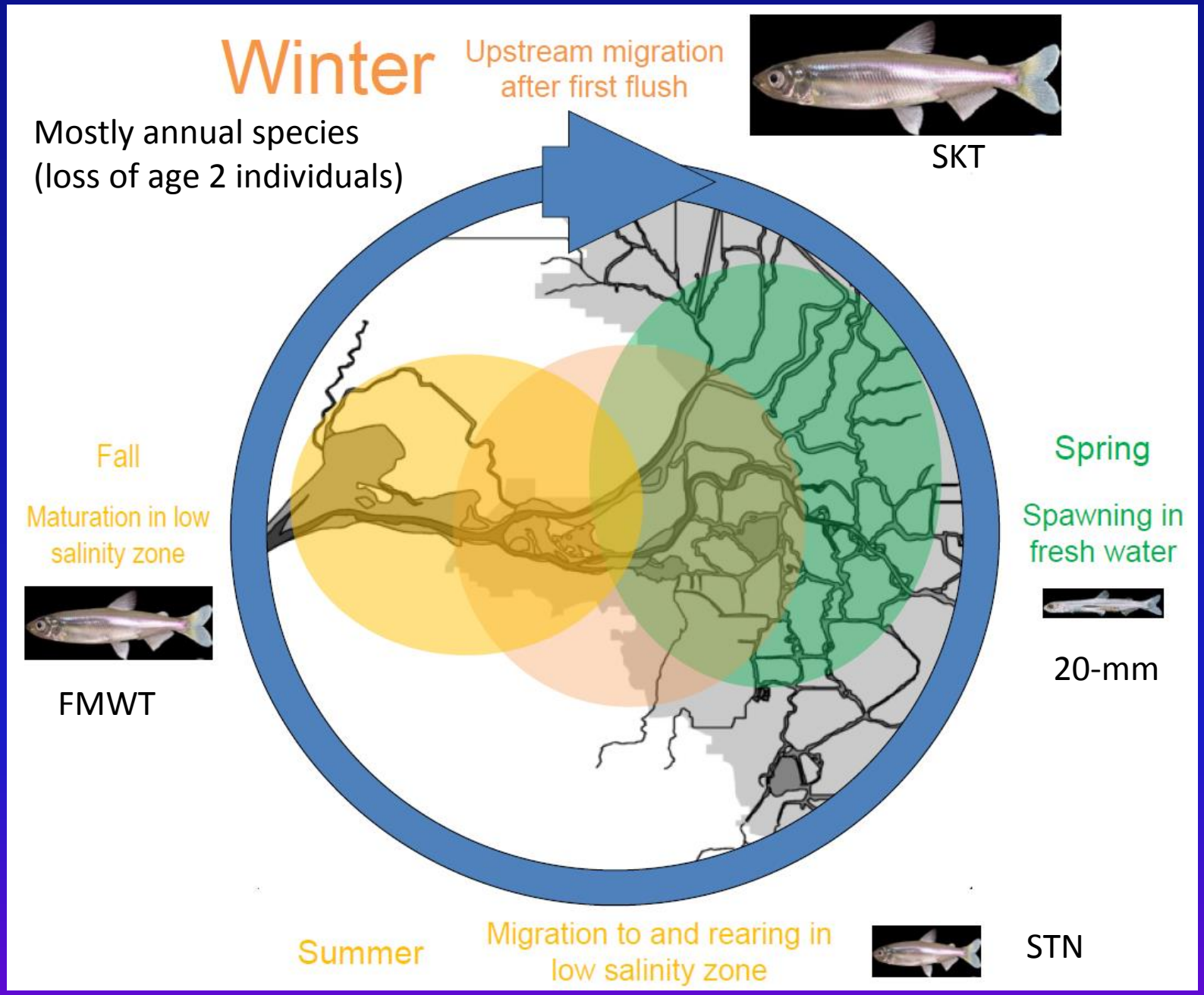
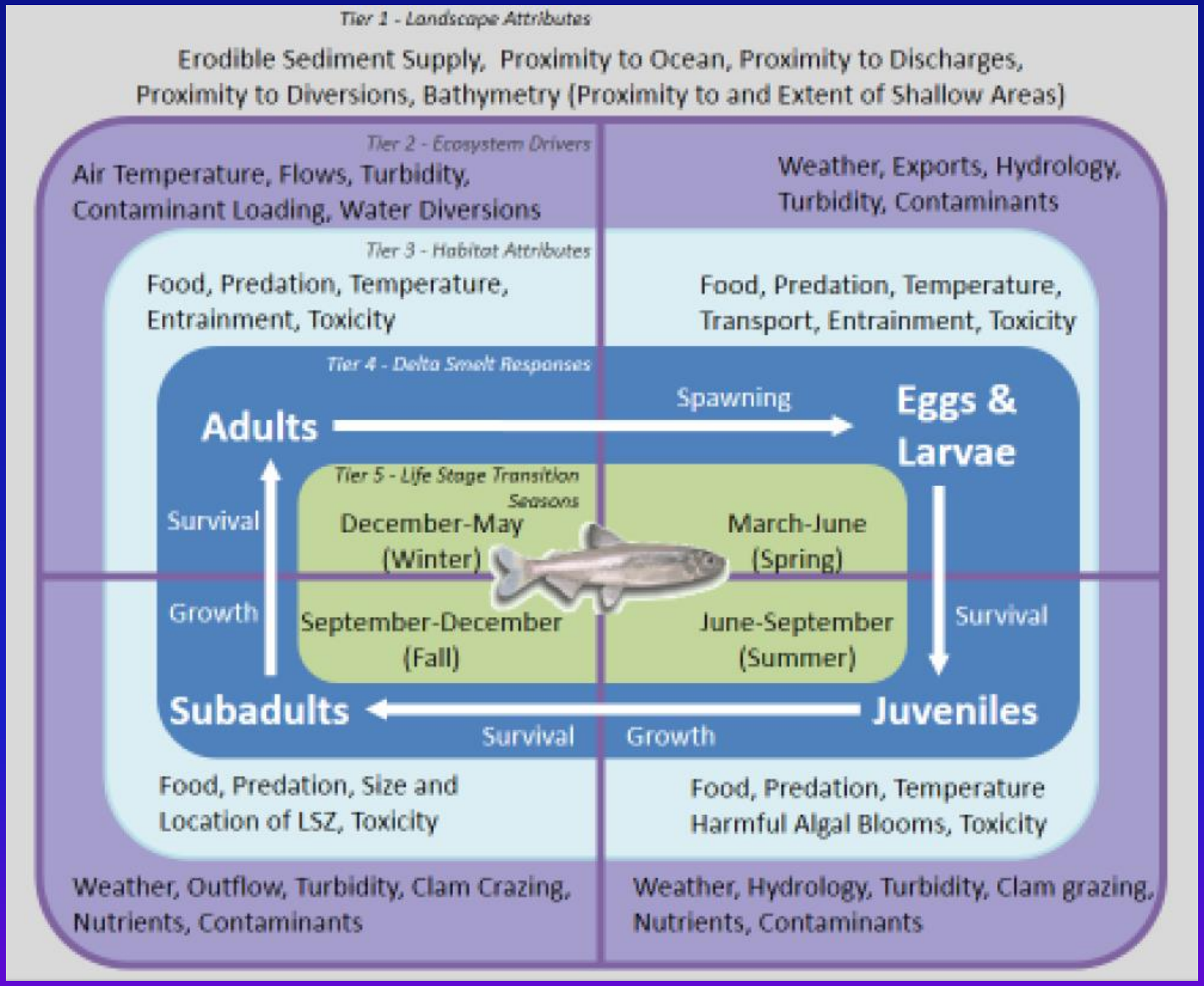


Adapted from MAST/IEP



Source: MAST/IEPT

Objectives

Evaluate relations between Delta flows and:

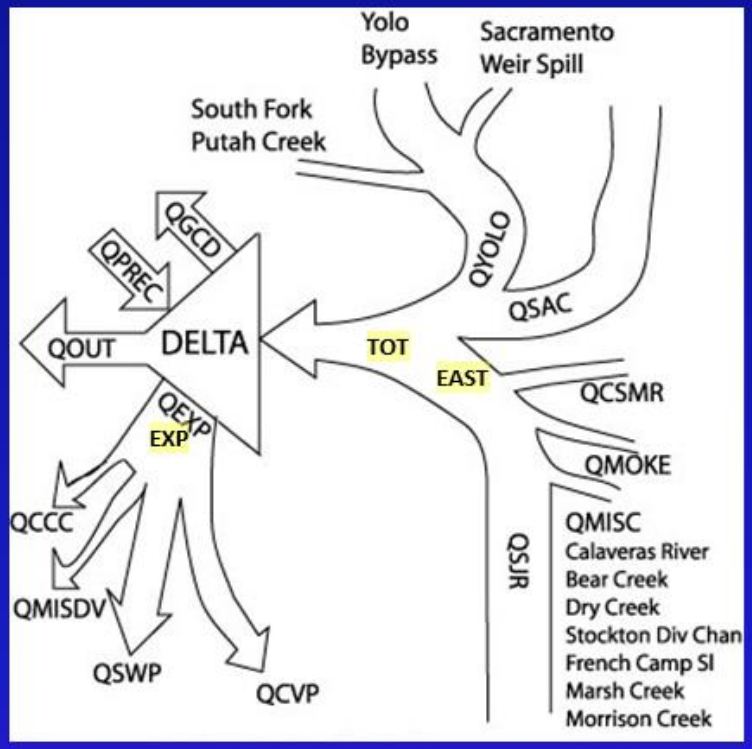
1- Delta Smelt abundance indices

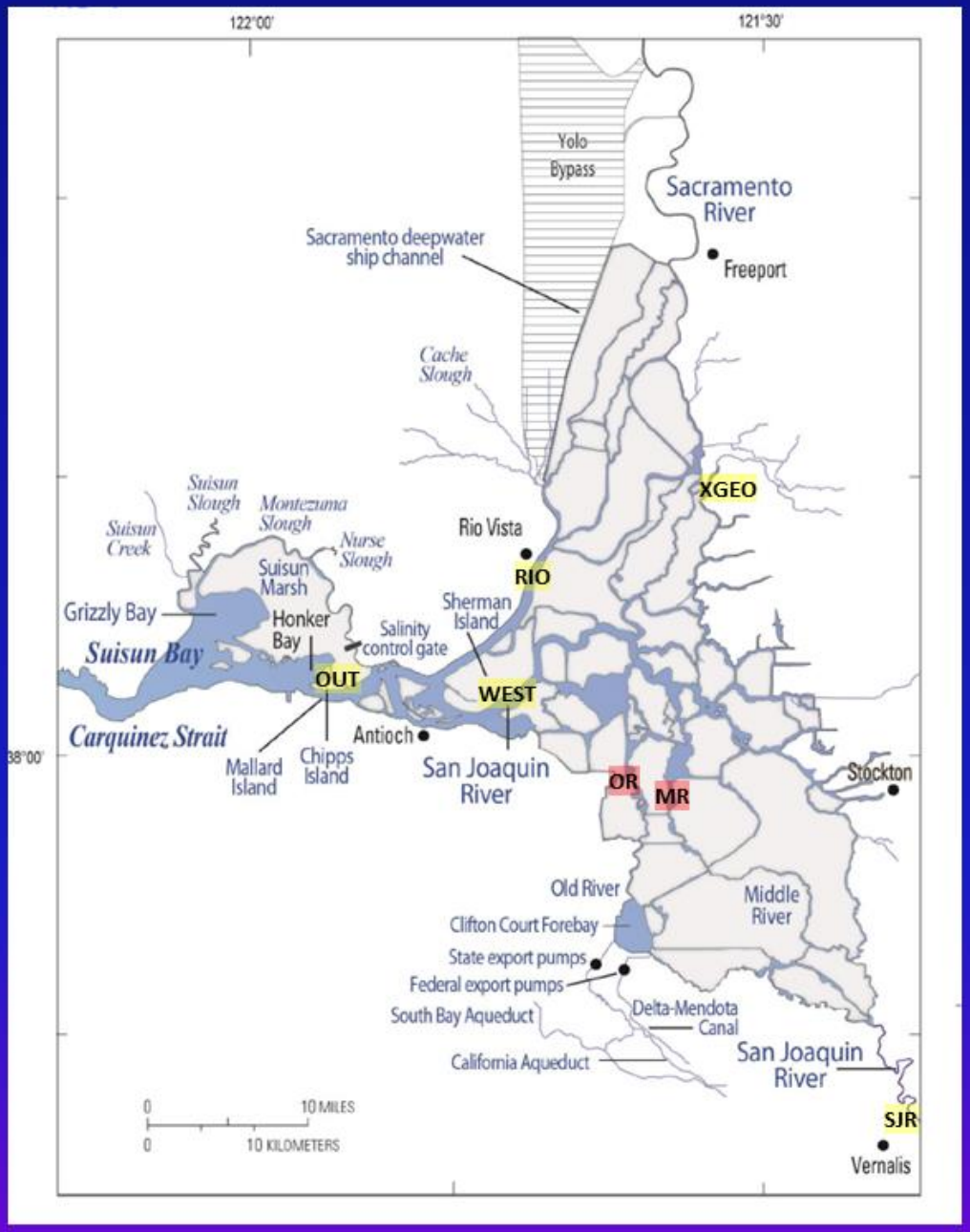
2- Delta Smelt proportional recruitment indices (PRI):

PRI = ratio of abundance indices for generation $_{t+1}$ / generation $_{t}$

3- Delta Smelt salvage

Estimates of Delta Flows





Dayflow

http://www.water.ca.gov/dayflow

OR + MR (OMR , USGS)

Dayflow derived flow indicators:

EXPIN: Export/Inflow Ratio. Combined State and Federal Exports / QTOT
EXPIN = (QCVP + QSWP - BBID) / QTOT.

QDIVER: Percent of Delta water diverted for internal use and exports.
QDIVER = [(QTOT - QOUT) / QTOT)] x 100

QEFFECT: Effective inflow to the western and central Delta
(QTOT - QSJ4SD), where QSJ4SD = amount of San Joaquin River water used in, or diverted from, the southern Delta

QEFFDIV: Effective percent diverted from the western and central Delta
[(QEEFECT - QOUT) /QEFFECT)] x 100

Fish Monitoring

Field Monitoring considered (DFW):

- 20 mm survey (larvae to early juveniles)
- Summer Tow Net survey (juveniles)
- Fall Mid Water Trawl survey (sub-adults)
- Spring Kodiak Trawl survey (adults)

Salvage Monitoring :

- Skinner Fish Salvage Facility (SWP)
- Tracy Fish Salvage Facility (CVP)

Data Analyses:

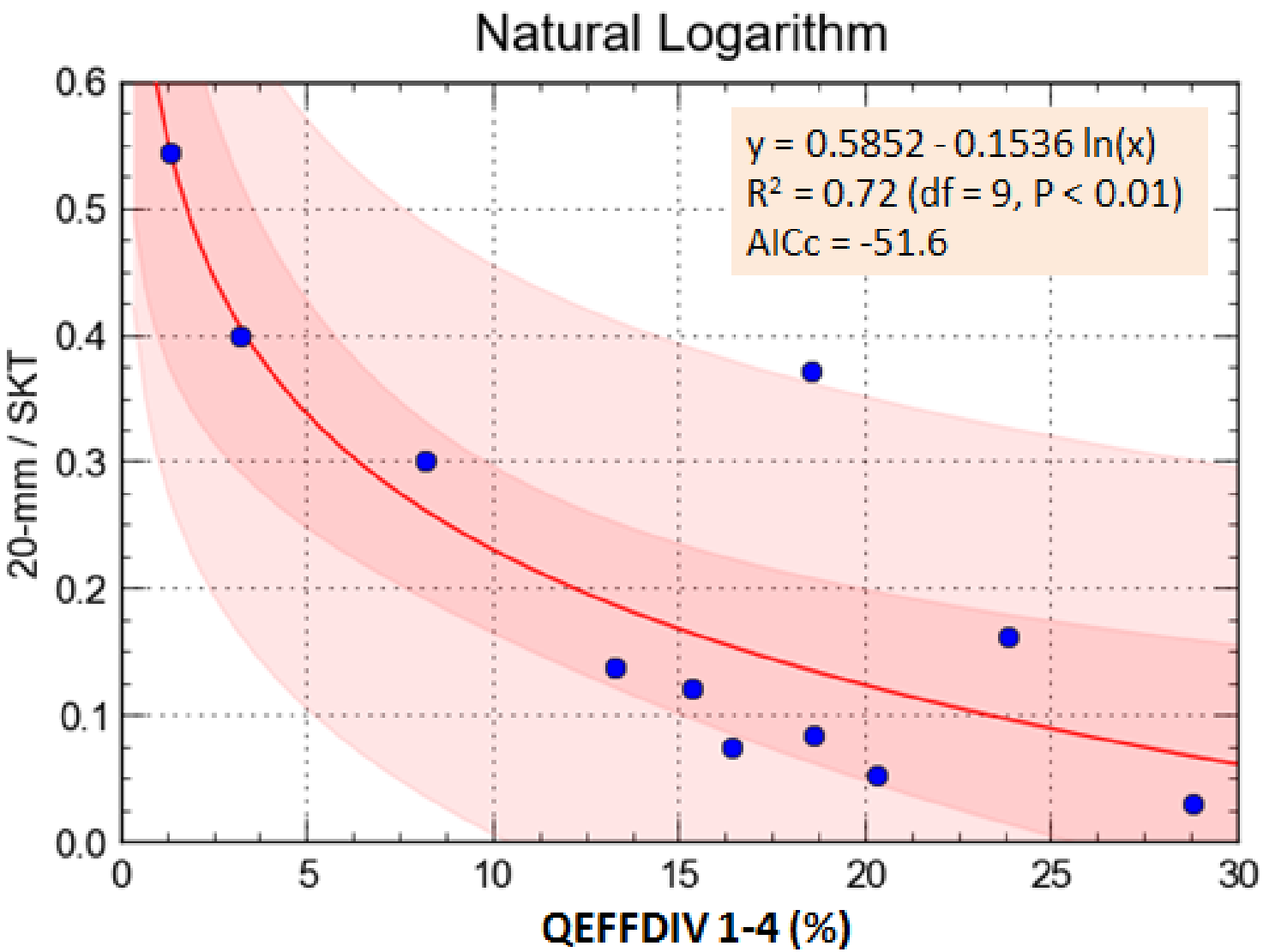
- Exploratory Spearman rank correlation analyses to evaluate potential associations between abundance indices (or proportional recruitment) and mean Dayflow variables (3, 4 and 5 months)
- Evaluate regression models between Delta Smelt proportional recruitment and Dayflow variables
- Evaluate regression models between salvage and selected Dayflow variables (QWEST, QRIO, QEXP, EXPIN, QEFFECT, QDIVER, QEFFDIV) and OMR

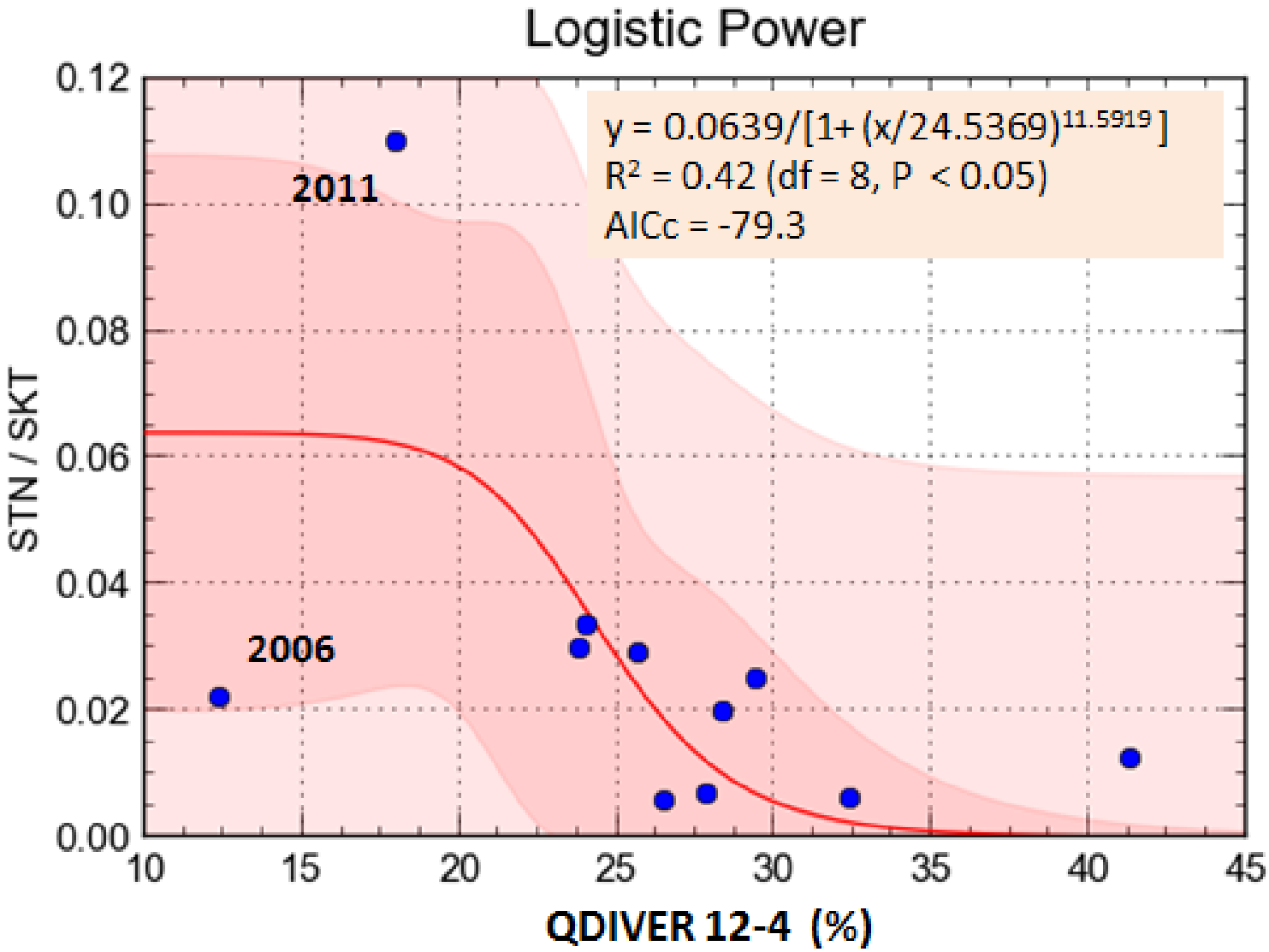
Life stages for which corresponding abundance indices were significantly associated to Dayflow estimates (based on Spearman rank correlations)*

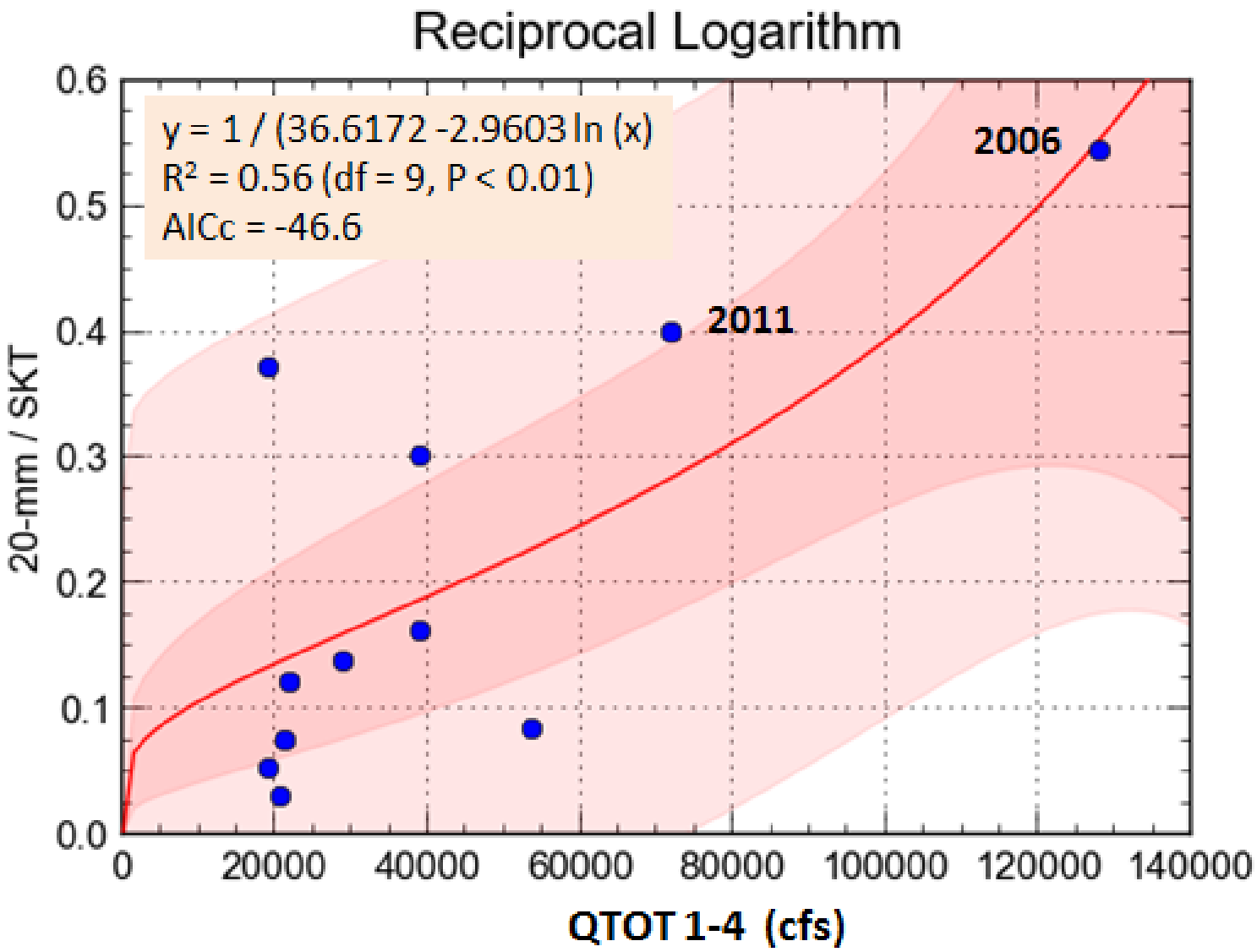
Months	QDIV	QEFDIV	EXPIN	QEXP	QWEST	QEFFECT	QOUT	QTOT	QRIO	QSJR	QEAST	QXGEO
9-11	-J, -S	-J, -S	-J, -S	-S	J, S	L	L, J	L	L	L	L	
9-12	-J, -S	-J, -S	-J, -S	-S	J, S	L	L	L	L	L	L	
9-1	-J, -S	-L,-S	-J, -S	-S	J, S					L		
10-12	-J, -L, -S	-L,-S	-J, -S	-J, -S	J, S	L, A	L	L, A	L	L	L	
10-1	-L, -J -S, -A	-J, -S	-J, -S	-J, -S	J, S							S
10-2	-J, -S	-J, -S	-J, -S	-J, -S	J, S		L	L		L	L	S
11-1	-J, -S, -A	-S, -A	-J, -S, -A	-J, -S	J, S							S
11-2	-J, -S, -A	-J, -S	-J, -S	-J, -S	J, S							L, S
11-3	-J, -S	-J, -S	-J, -S	-S, A	J, S	L						S
12-2	-J, -S,-A		-J, -S	-J, -S	J, S							L, S
12-3	-J, -S	-J, -S	-J, -S	-J, -S	J, S							L, S
12-4	-J, -S		-J, -S	-S		L			L			S
1-3	-J, -S	-J, -S	-J, -S	-S	J, S			S				S
1-4	-J		-J	-S								S
1-5	-J			-S								S
2-4			-J	-S								S
2-5				-S								S
2-6				L								S

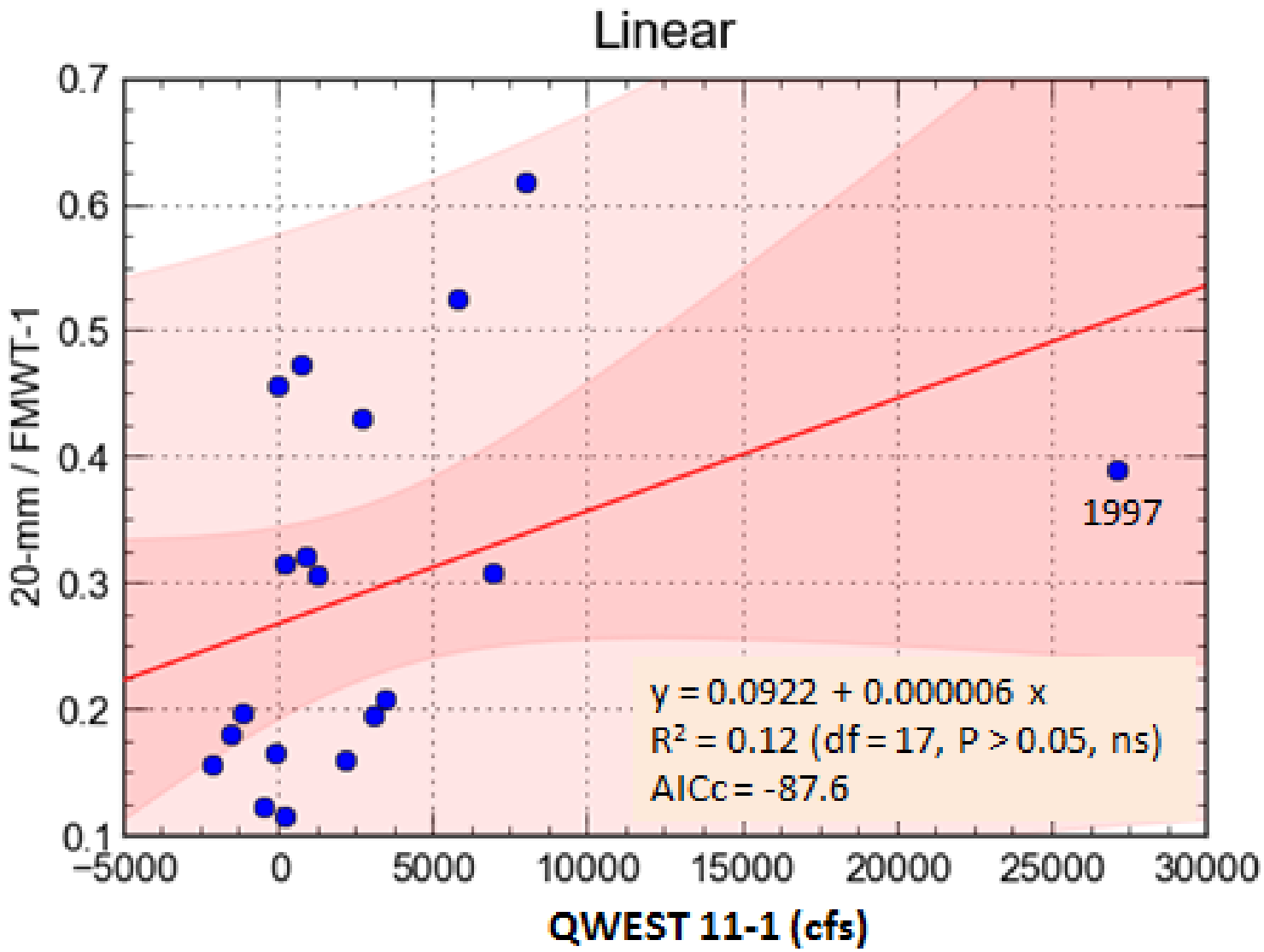
L = larvae-juveniles (20-mm)
J = juveniles (STN)
S = subadults (FMWT)
A = adults (SKT)

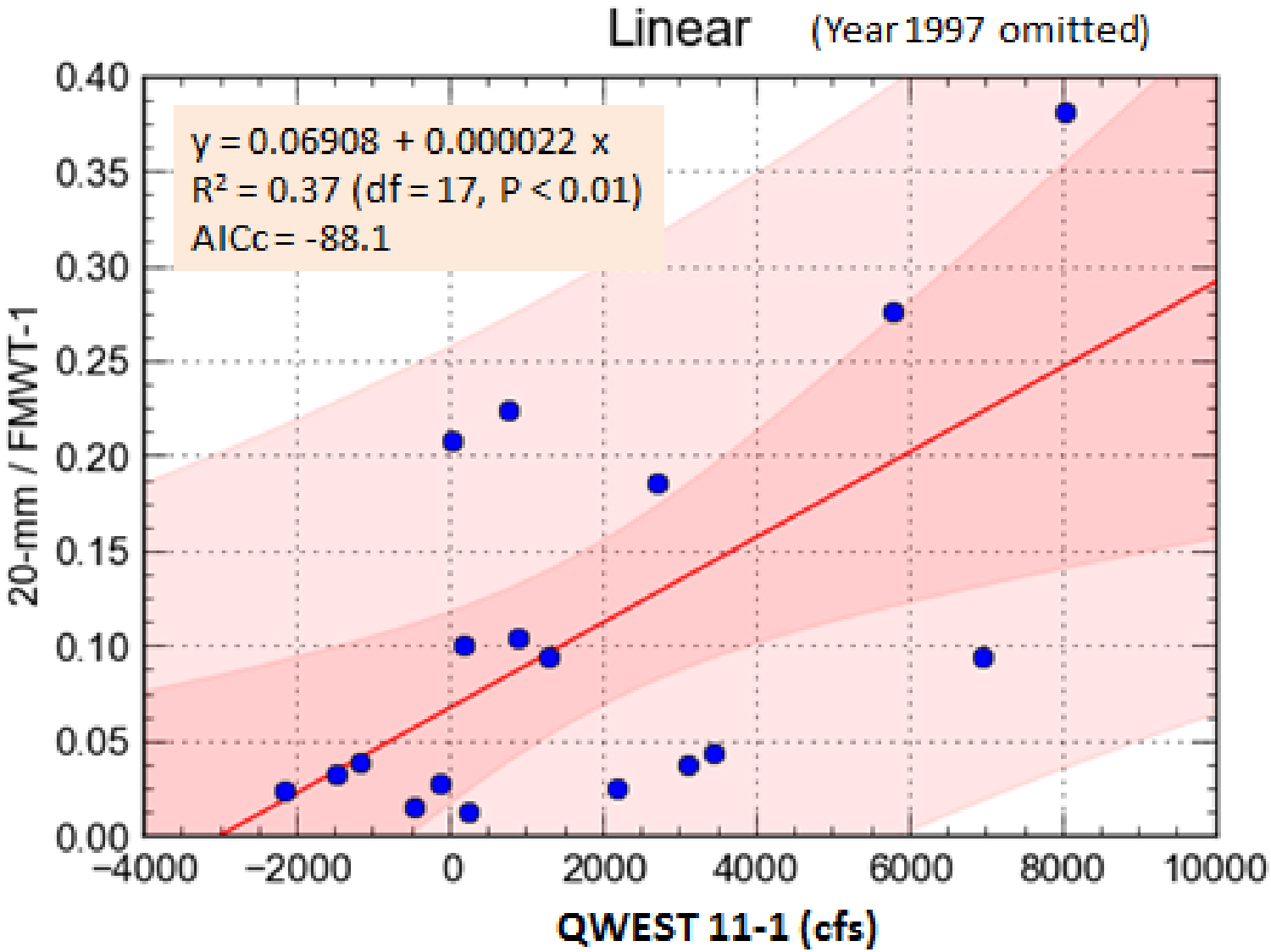
*Months lagged to previous year for FMWT and SKT.

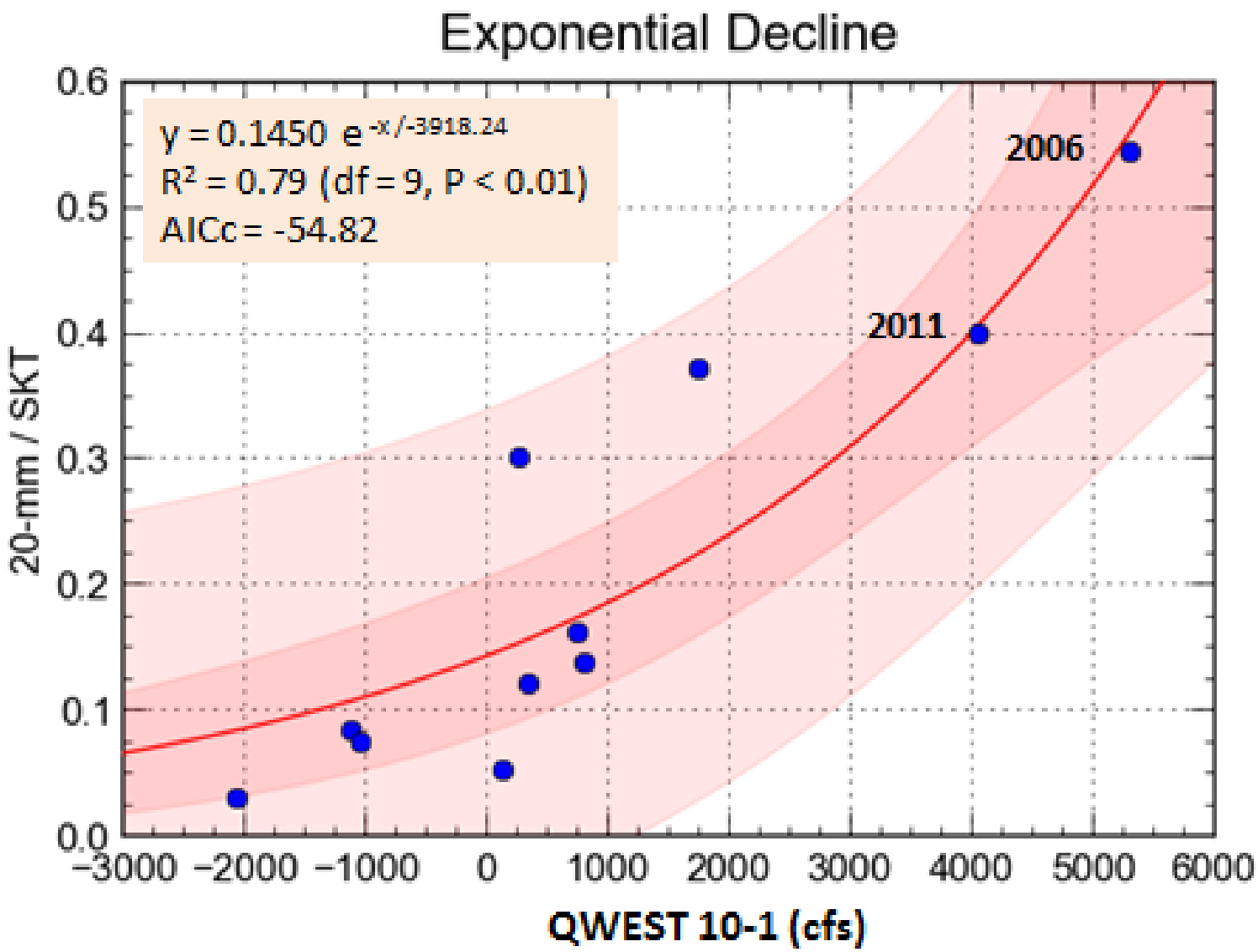

Natural Logarithm
y = 0.5852 - 0.1536 ln(x)
R² = 0.72 (df = 9, P < 0.01)
AICc = -51.6
20-mm / SKT
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
5
10
15
20
25
30
QEFFDIV 1-4 (%)

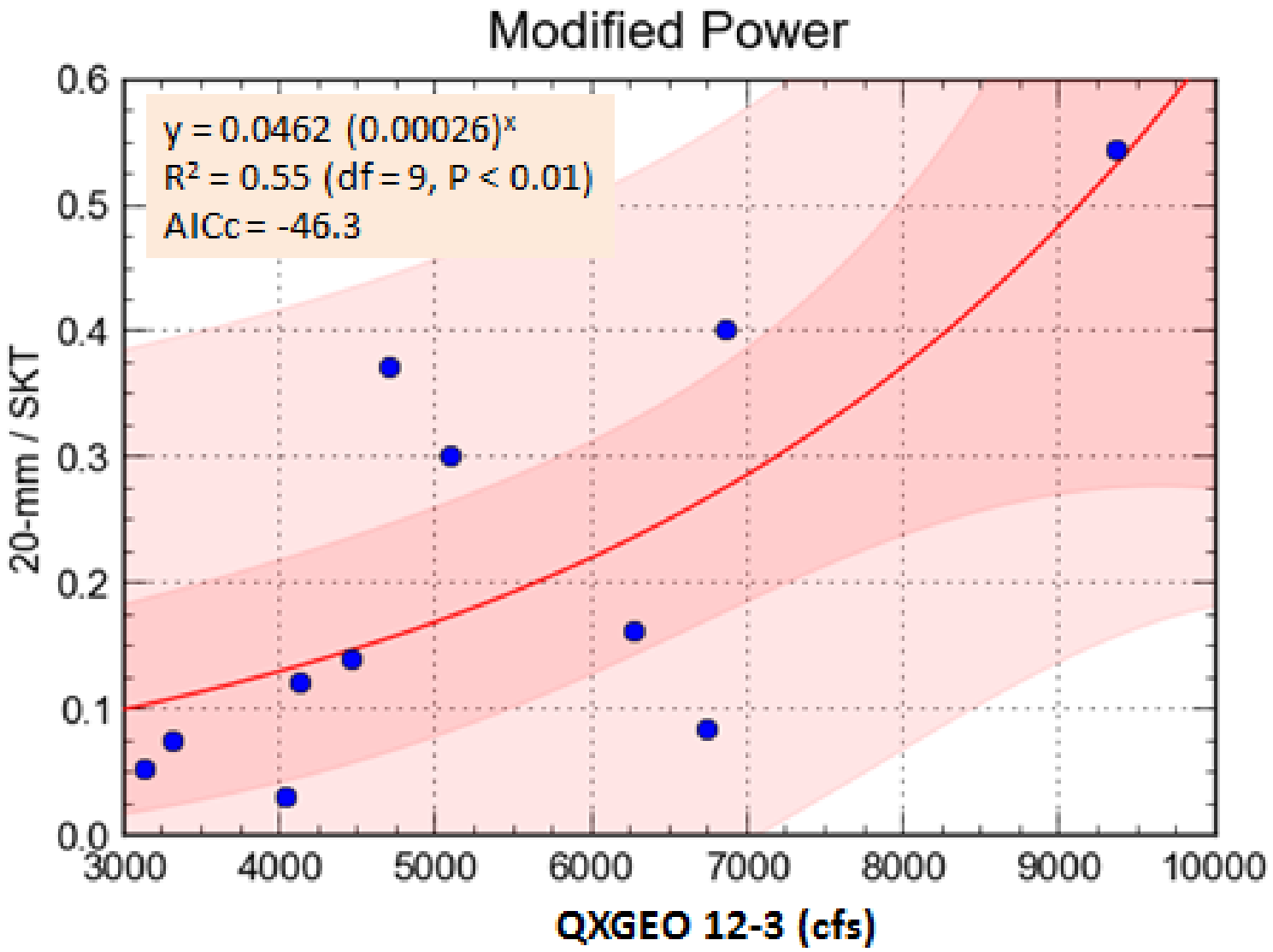

Logistic Power
y = 0.0639/[1+ (x/24.5369)^11.5919]
R² = 0.42 (df = 8, P < 0.05)
AICc = -79.3
2011
2006
STN / SKT
QDIVER 12-4 (%)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
10
15
20
25
30
35
40
45


Reciprocal Logarithm
y = 1 / (36.6172 -2.9603 ln (x)
R² = 0.56 (df = 9, P < 0.01)
AICc = -46.6
2006
2011
20-mm / SKT
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
20000
40000
60000
80000
100000
120000
140000
QTOT 1-4 (cfs)

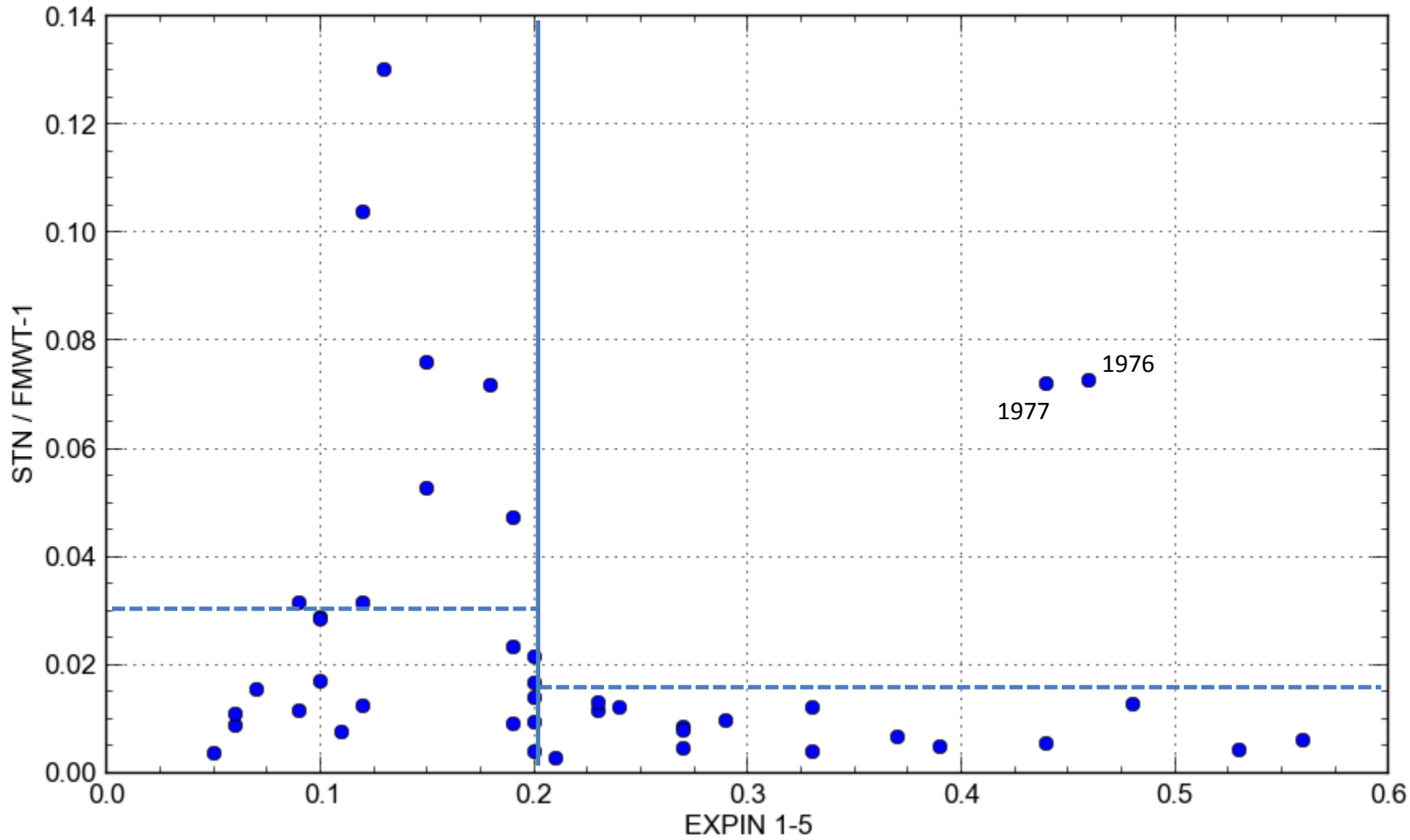

Linear
0.7
0.6
0.5
0.4
0.3
0.2
0.1
20-mm / FMWT-1
−5000
0
5000
10000
15000
20000
25000
30000
QWEST 11-1 (cfs)
1997
y = 0.0922 + 0.000006 x
R² = 0.12 (df = 17, P > 0.05, ns)
AICc = -87.6

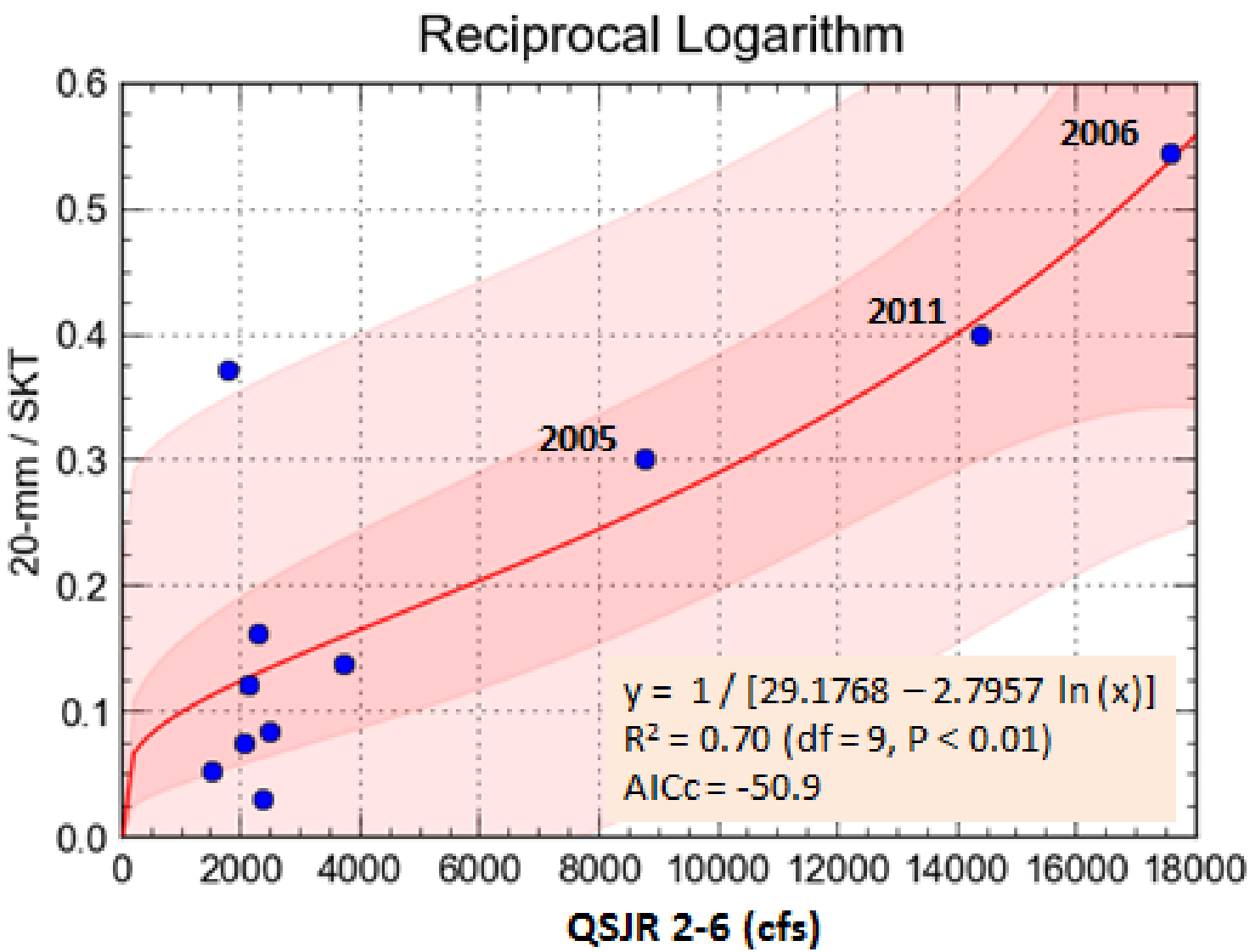

Linear
(Year 1997 omitted)
y = 0.06908 + 0.000022 x
R² = 0.37 (df = 17, P < 0.01)
AICc = -88.1
20-mm / FMWT-1
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−4000
−2000
0
2000
4000
6000
8000
10000
QWEST 11-1 (cfs)

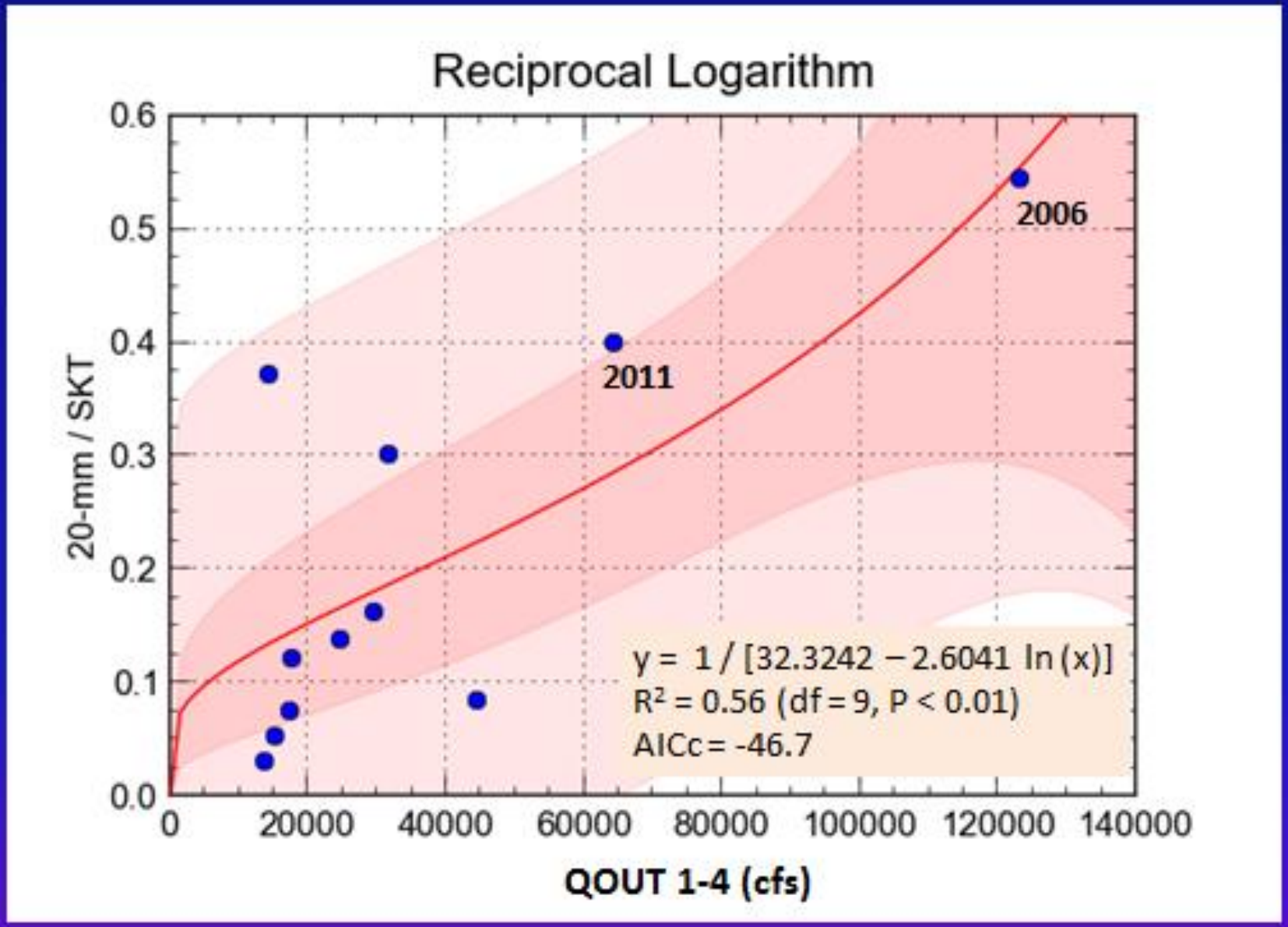

Exponential Decline
y = 0.1450 e^(-x/-3918.24)
R² = 0.79 (df = 9, P < 0.01)
AICc = -54.82
2006
2011
20-mm / SKT
0.0
0.1
0.2
0.3
0.4
0.5
0.6
−3000
−2000
−1000
0
1000
2000
3000
4000
5000
6000
QWEST 10-1 (cfs)


Modified Power
y = 0.0462 (0.00026)^x
R² = 0.55 (df = 9, P < 0.01)
AICc = -46.3
20-mm / SKT
0.0
0.1
0.2
0.3
0.4
0.5
0.6
3000
4000
5000
6000
7000
8000
9000
10000
QXGEO 12-3 (cfs)

Average proportional recruitment to the juvenile stage was 100% higher for years with average January-May EXPIN ≤ 0.2 (PRI = 0.314) vs years with EXPIN > 0.2 (PRI = 0.015, including years 1976 and 1977)



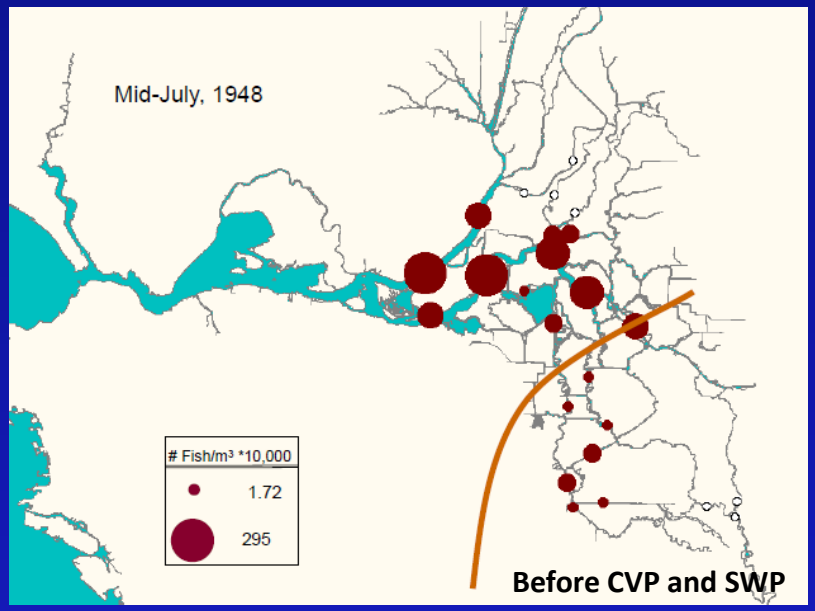

Reciprocal Logarithm
20-mm / SKT
QSJR 2-6 (cfs)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
2006
2011
2005
y = 1 / [29.1768 − 2.7957 ln (x)]
R² = 0.70 (df = 9, P < 0.01)
AICc = -50.9

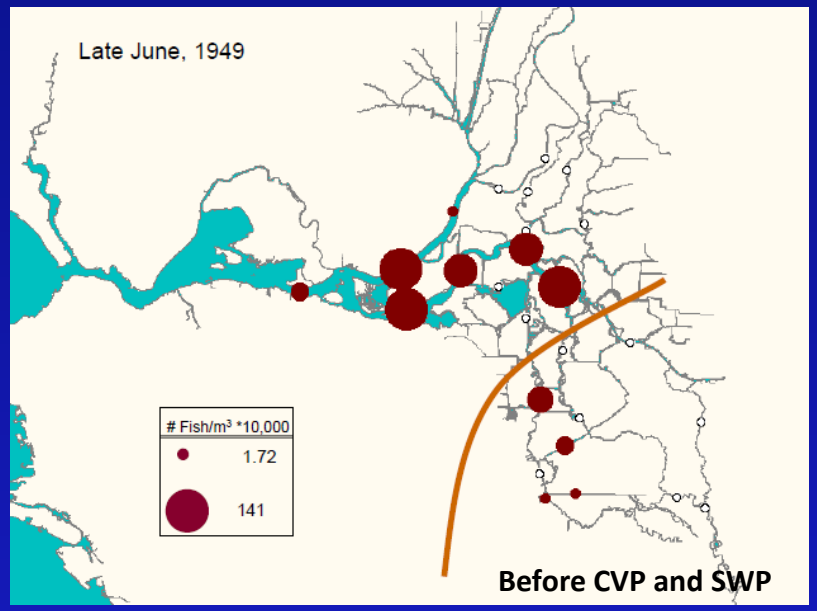

Reciprocal Logarithm
0.6
0.5
0.4
0.3
0.2
0.1
0.0
20-mm / SKT
0
20000
40000
60000
80000
100000
120000
140000
QOUT 1-4 (cfs)
2006
2011
y = 1 / [32.3242 − 2.6041 ln (x)]
R² = 0.56 (df = 9, P < 0.01)
AICc = -46.7

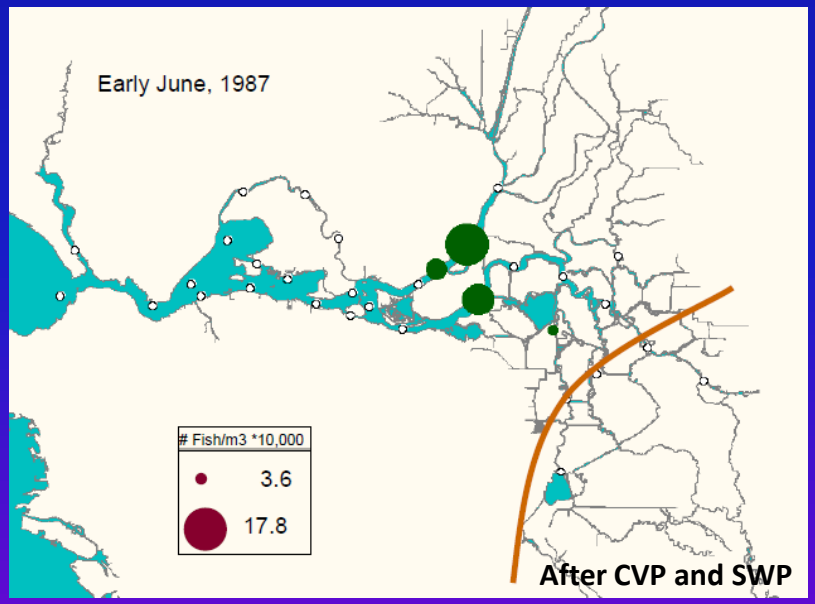
Delta Smelt Entrainment

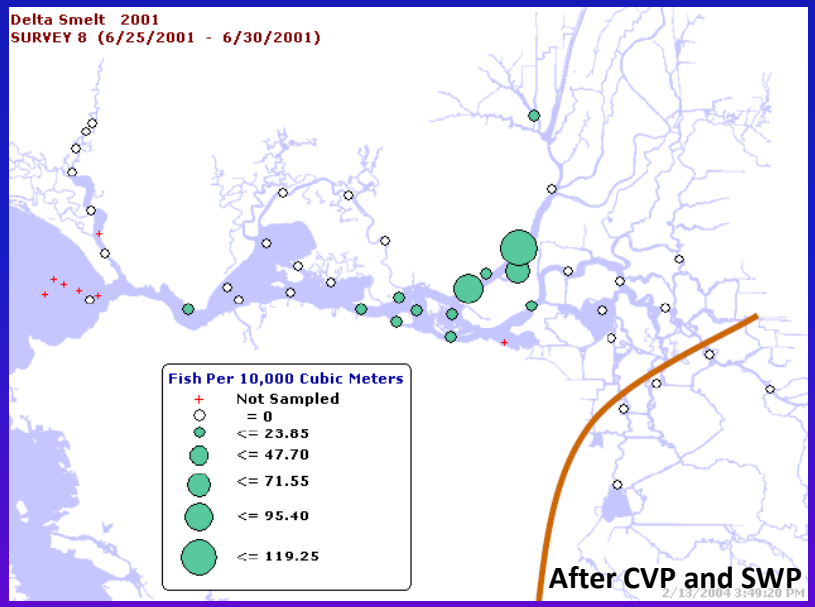
- No entrainment monitoring (salvage greatly underestimates entrainment losses)
- Salvage does not seem a consistent index of entrainment (Castillo *et al*. 2012)
- Modeled entrainment levels and attendant population level effects (e.g., Kimmerer 2008) have not taken into account the influence of entrainment on effective population size (Fisch *et al.* 2011) and selective removal of individuals (Bennett 2011).

Juvenile Delta Smelt distribution before and after south Delta water export operations were initiated



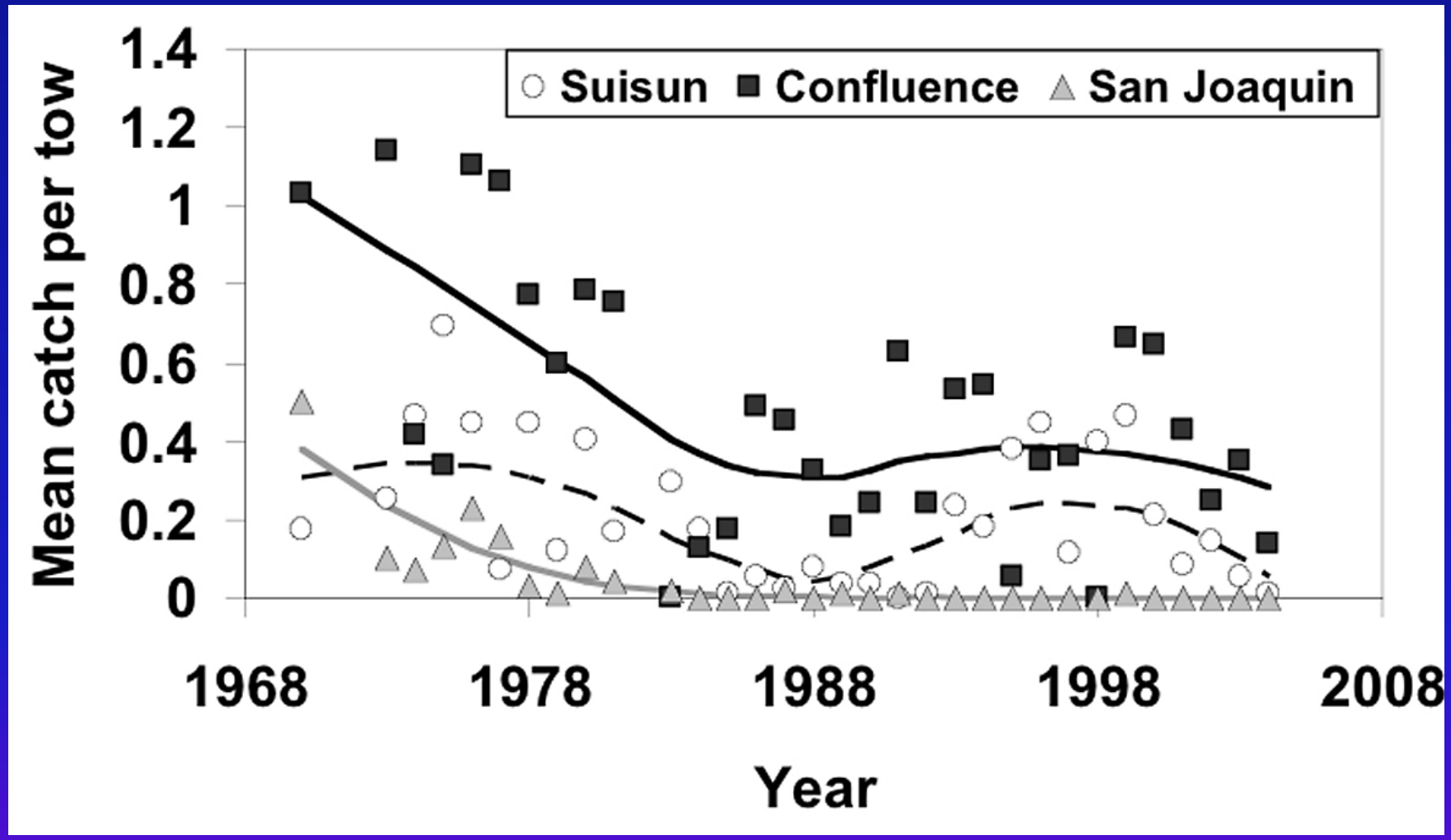






Red line denotes south Delta boundary (Mayfield *et al.* 2005, years 1948-49 after Erkkila 1950)

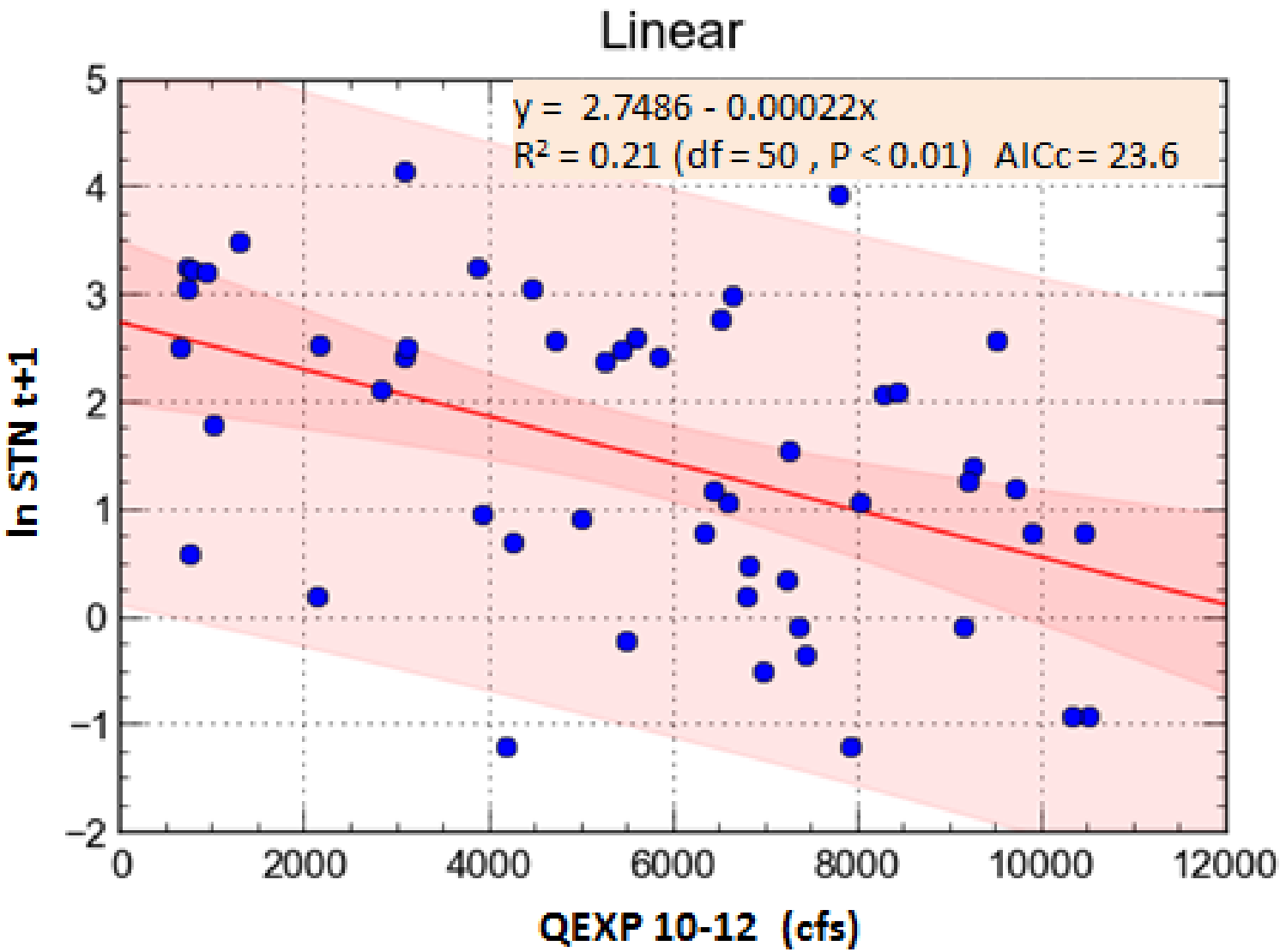
Delta Smelt juvenile have virtually disappeared in the San Joaquin region (Summer Tow Net Survey, mid 1960s to 2000s)

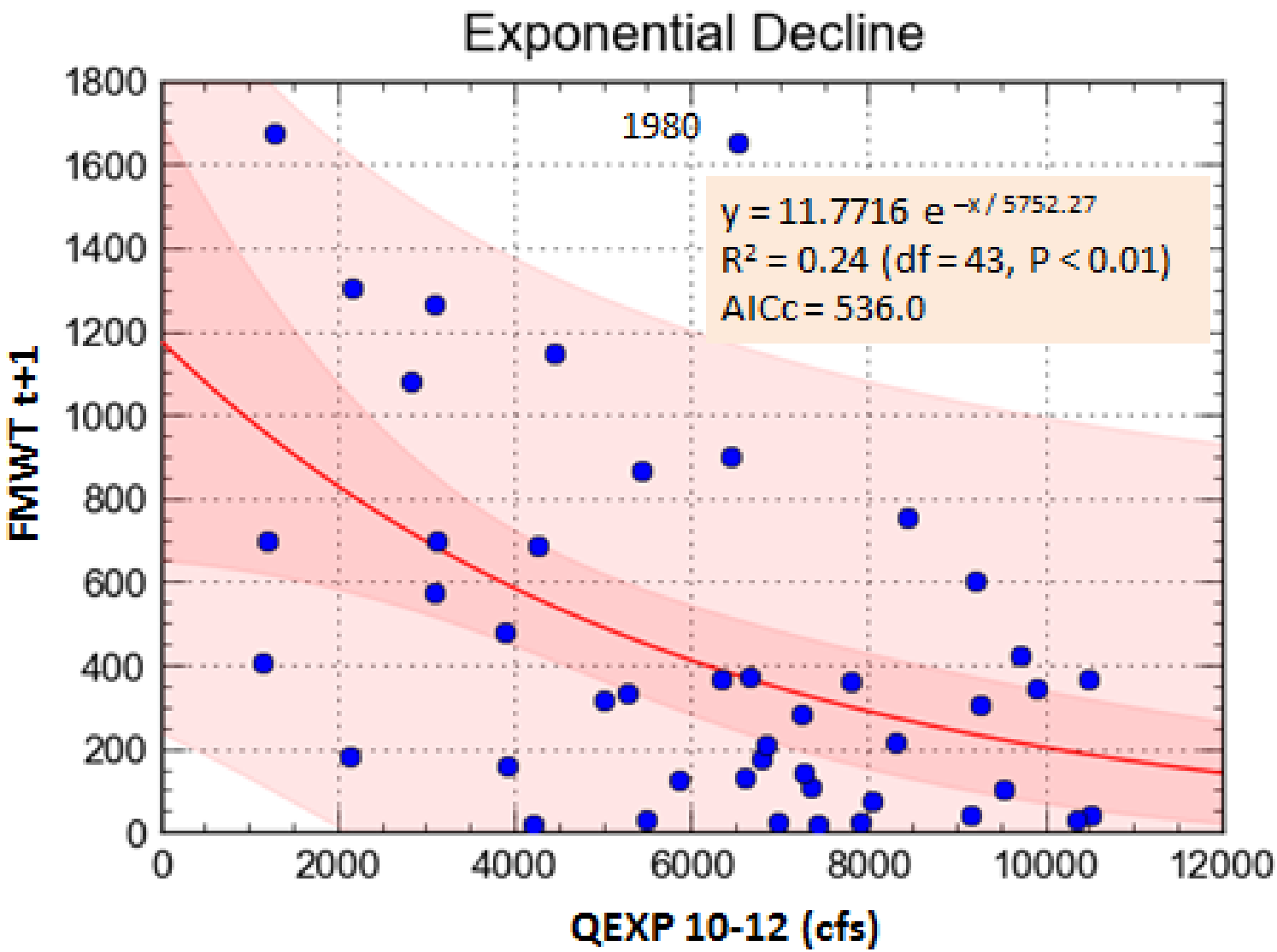


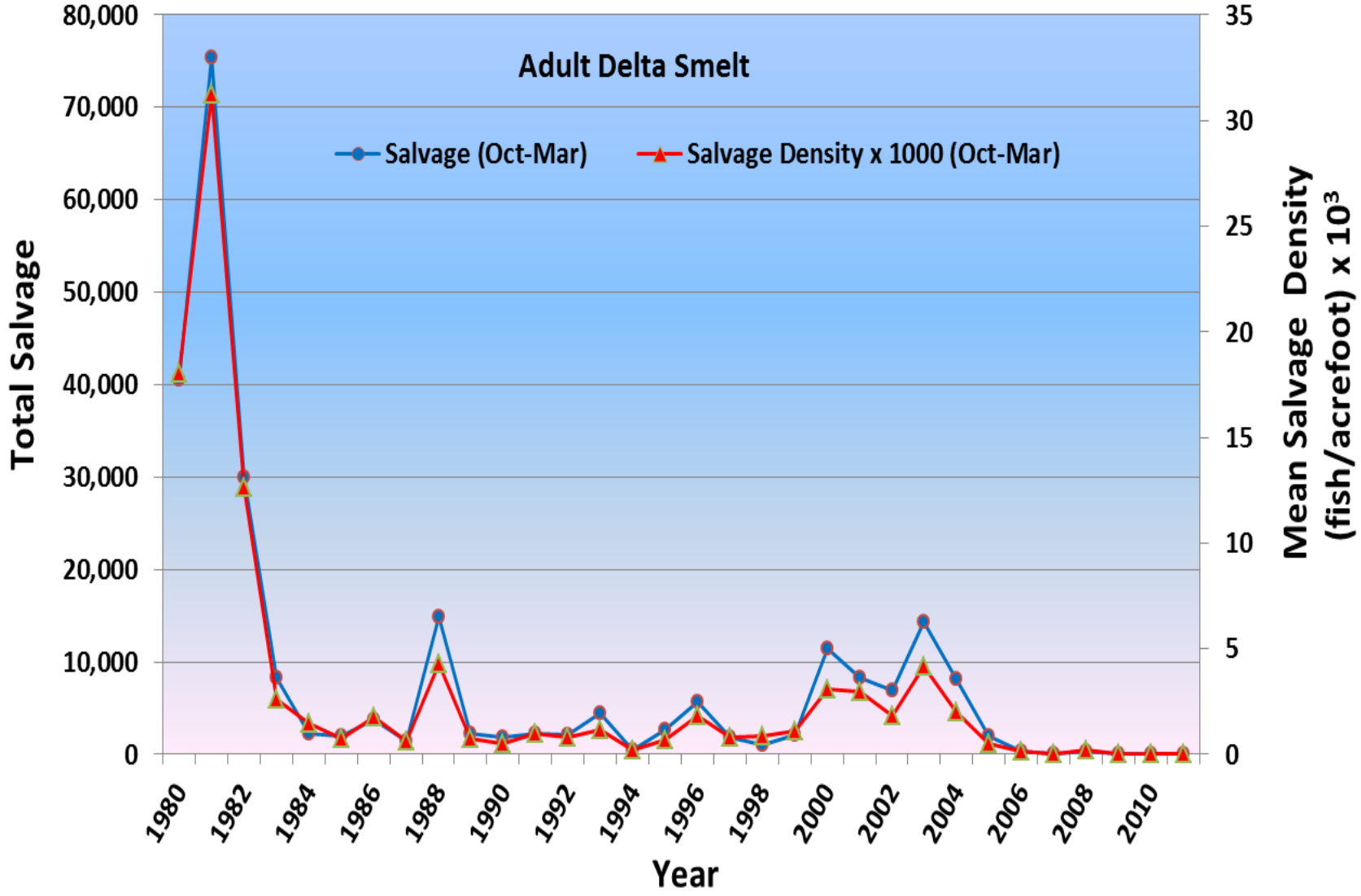
Nobriga et al. 2008

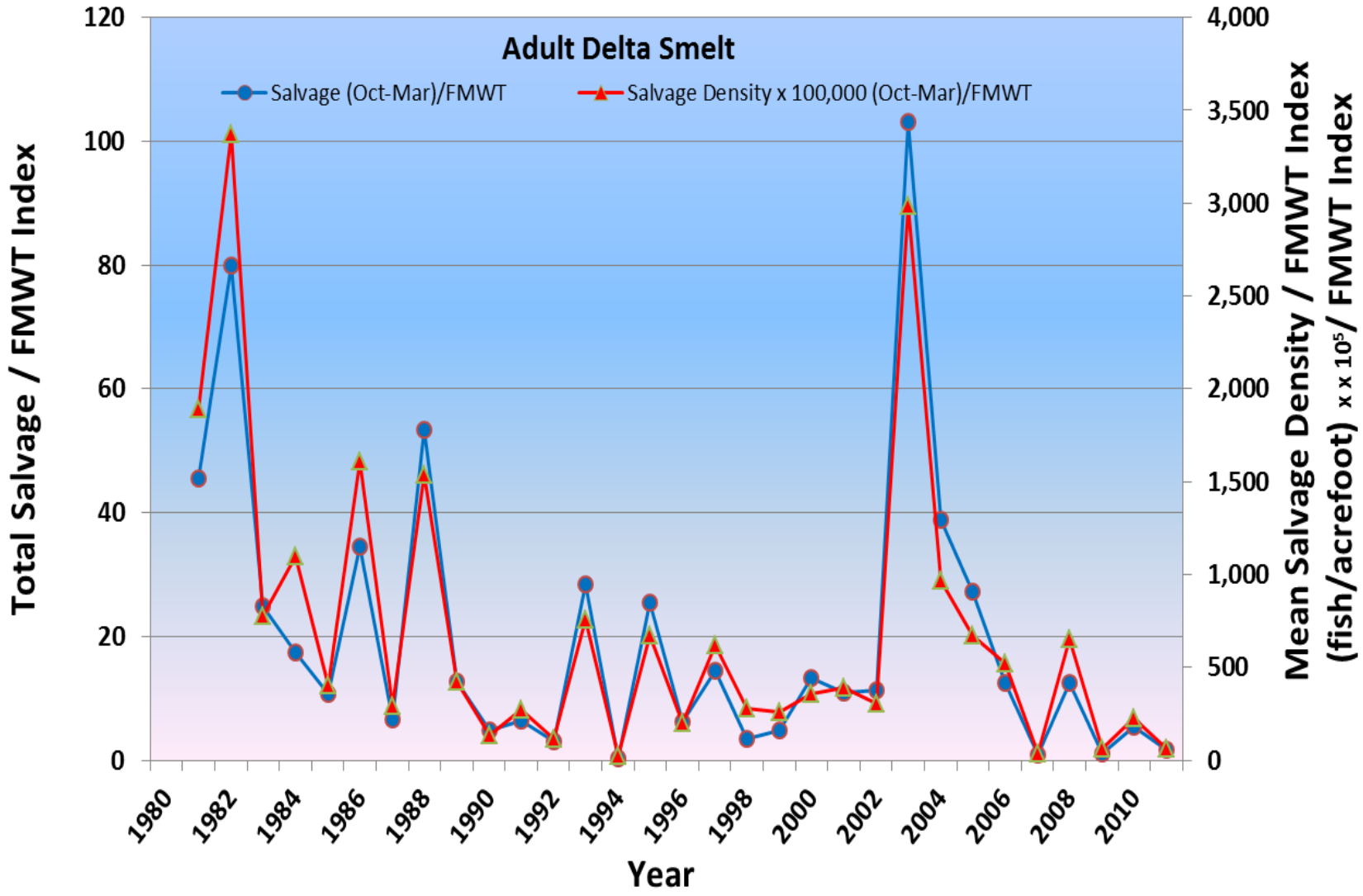
Monthly Delta Smelt Salvage 1980-2011:
Virtually no detection in summer and fall since the early 1990s

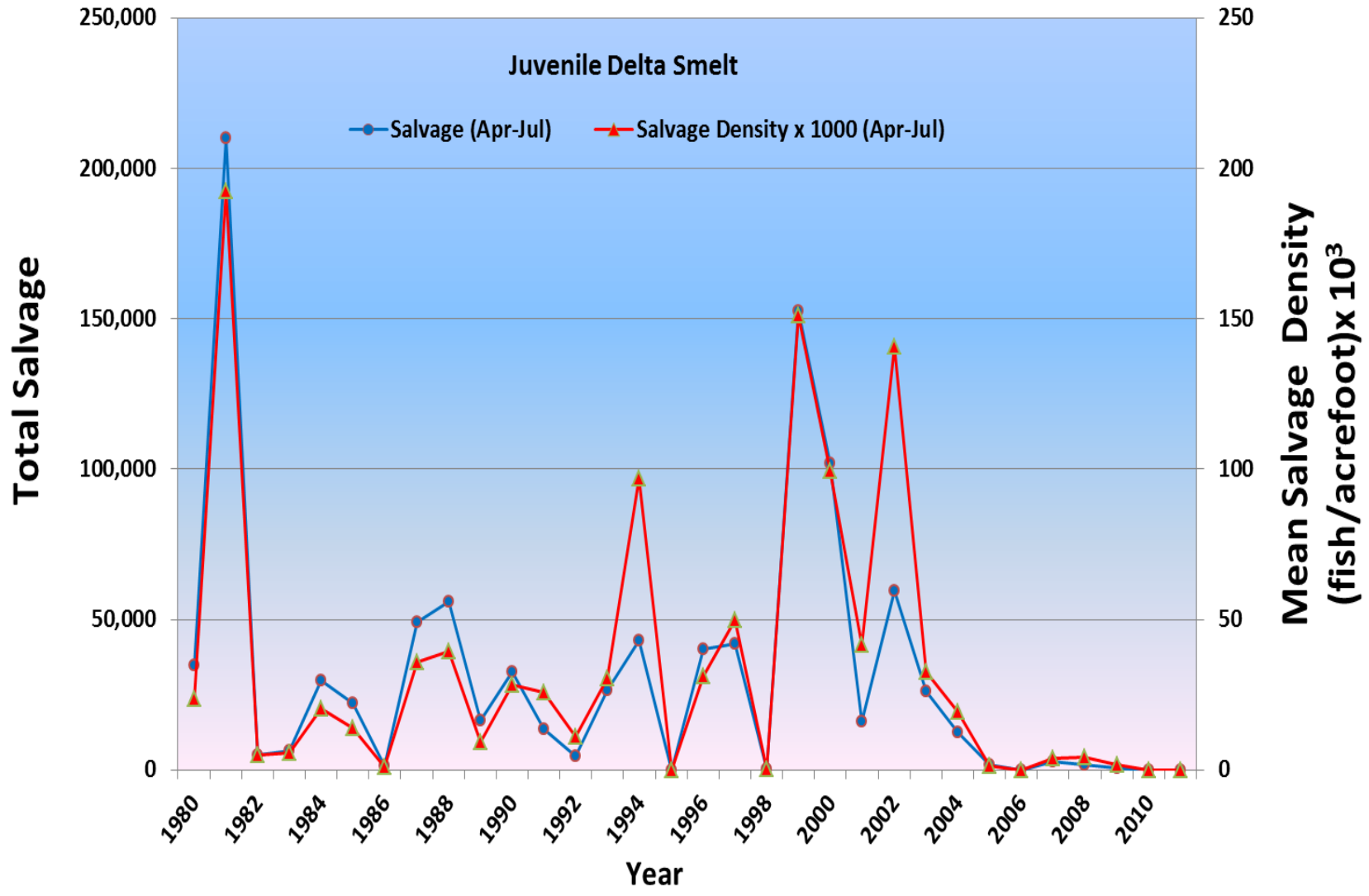
Year	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
1980	4607	4176	7906	4234	1237	13128	16201	7726	1740	12499	3527	8415
1981	20379	21061	9545	5565	97174	50822	56352	49081	2899	1554	5256	662
1982	6186	10200	6052	351	674	2544	1251	1910	917	784	891	804
1983	4358	1218	257	71	124	4620	1722	0	371	0	0	593
1984	0	35	1681	179	18300	8290	3033	897	24	152	120	321
1985	191	635	550	1435	7194	9794	3934	2177	1057	87	0	442
1986	1342	1271	661	522	180	171	400	1353	0	180	43	257
1987	48	144	719	19044	13380	14824	1958	2697	415	57	43	7688
1988	6329	661	170	0	8549	43667	3627	0	0	193	4	610
1989	1012	107	277	3945	4042	2997	5371	1309	429	111	474	0
1990	226	623	356	5647	5963	6357	14747	58	0	0	0	149
1991	598	369	1190	1424	635	6238	5337	1164	486	381	0	0
1992	119	757	846	85	1980	2367	24	0	0	0	0	0
1993	3086	1190	149	0	16789	8845	1047	24	0	0	0	88
1994	16	174	169	945	31877	8805	1518	0	0	0	0	54
1995	2057	481	16	24	0	0	0	0	0	0	0	0
1996	4189	1290	155	111	30399	9441	148	0	0	0	12	18
1997	0	80	1730	1159	32828	7876	228	0	0	0	0	281
1998	130	24	592	48	4	66	124	0	0	0	0	16
1999	28	1466	564	410	58929	73368	19858	48	0	0	24	126
2000	802	7819	2746	1746	49653	49124	1513	6	26	27	310	192
2001	181	3870	3748	520	13134	2325	6	0	0	0	0	1129
2002	5231	280	225	396	47361	11908	24	0	0	0	0	2800
2003	9549	1491	483	492	16177	9580	12	0	0	0	0	126
2004	4594	1161	2267	276	5755	6392	18	0	0	0	0	0
2005	1647	371	0	0	529	1193	0	0	0	0	0	0
2006	36	72	216	12	0	0	0	0	0	0	0	0
2007	0	36	0	24	428	1509	711	0	0	0	0	0
2008	46	221	83	6	911	757	14	0	0	0	0	0
2009	0	8	16	0	423	314	0	0	0	0	0	4
2010	0	44	44	0	23	6	0	0	0	0	0	0
2011	8	4	36	3	0	0	0	0	0	0	0	0

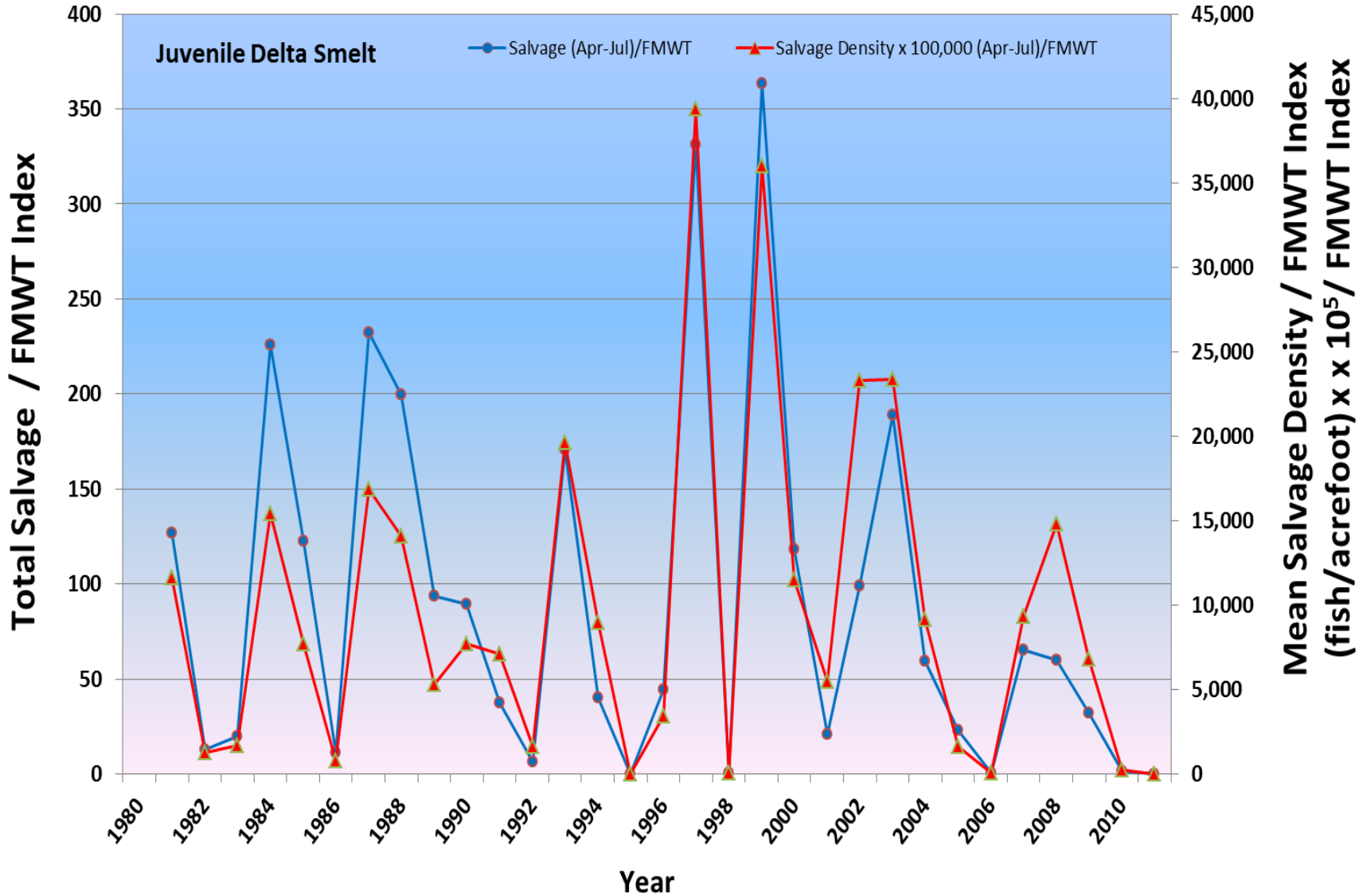

Linear
y = 2.7486 - 0.00022x
R² = 0.21 (df = 50 , P < 0.01) AICc = 23.6
ln STN t+1
QEXP 10-12 (cfs)
5
4
3
2
1
0
−1
−2
0
2000
4000
6000
8000
10000
12000


Exponential Decline
1980
y = 11.7716 e^(−x / 5752.27)
R² = 0.24 (df = 43, P < 0.01)
AICc = 536.0
FMWT t+1
QEXP 10-12 (cfs)
0
200
400
600
800
1000
1200
1400
1600
1800
0
2000
4000
6000
8000
10000
12000


Adult Delta Smelt
Salvage (Oct-Mar)
Salvage Density x 1000 (Oct-Mar)
Total Salvage
Mean Salvage Density (fish/acrefoot) x 10³
Year
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
35
30
25
20
15
10
5
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

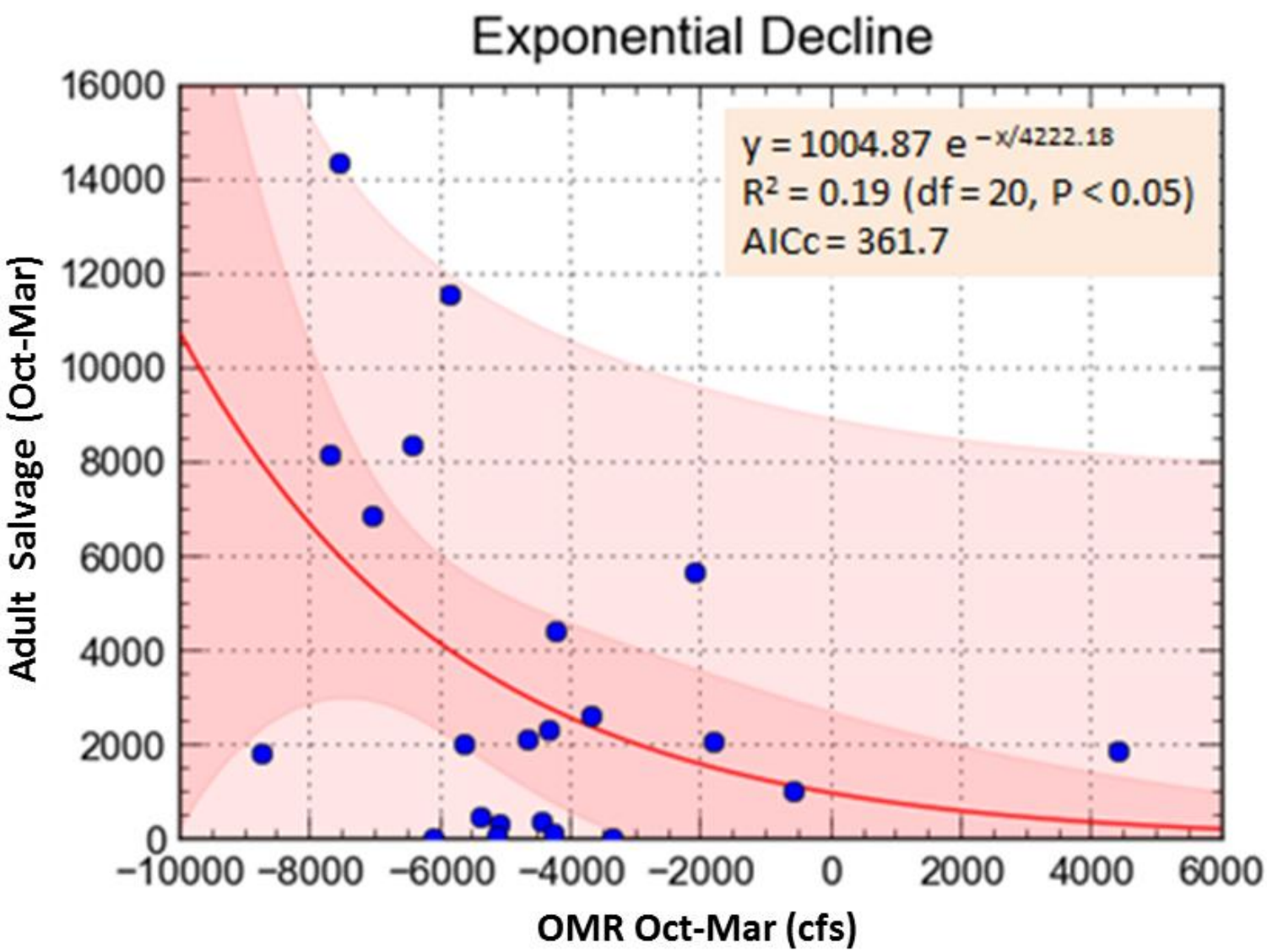

Adult Delta Smelt
Salvage (Oct-Mar)/FMWT
Salvage Density x 100,000 (Oct-Mar)/FMWT
Total Salvage / FMWT Index
Mean Salvage Density / FMWT Index
(fish/acrefoot) x x 10^5/ FMWT Index
Year
0
20
40
60
80
100
120
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010


Juvenile Delta Smelt
Salvage (Apr-Jul)
Salvage Density x 1000 (Apr-Jul)
Total Salvage
Mean Salvage Density (fish/acrefoot)x 10³
Year
250,000
200,000
150,000
100,000
50,000
0
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010


Juvenile Delta Smelt
Salvage (Apr-Jul)/FMWT
Salvage Density x 100,000 (Apr-Jul)/FMWT
Total Salvage / FMWT Index
Mean Salvage Density / FMWT Index
(fish/acrefoot) x x 10^5/ FMWT Index
Year
0
50
100
150
200
250
300
350
400
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010

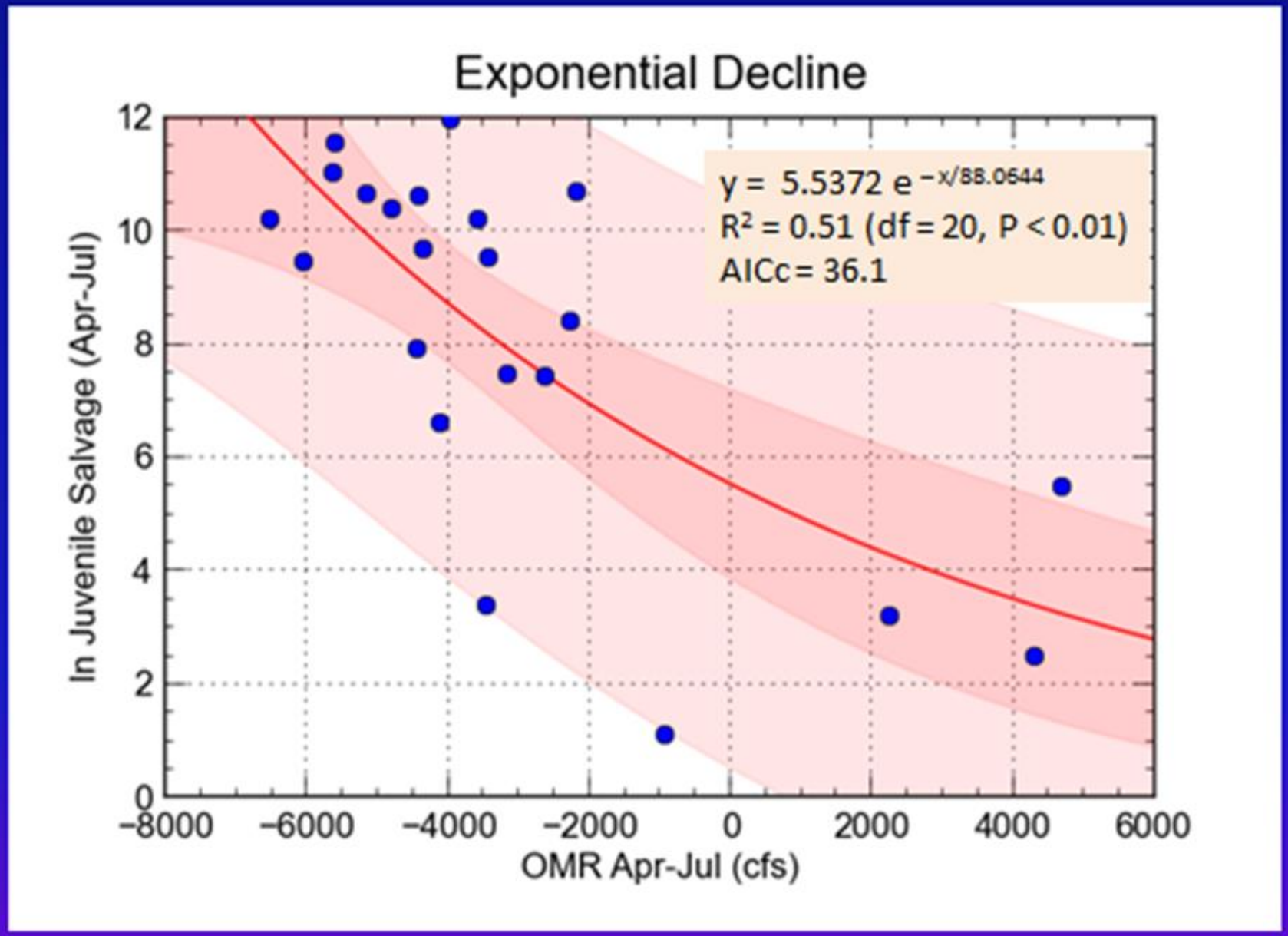
OMR was the only flow variable significantly correlated to adult salvage (1990-2011)

No significant relations for period 1980-2011 (high salvage over a wider range of OMR flows)



OMR was the only flow variable significantly correlated to juvenile salvage (1990-2011)

No significant relations for period 1980-2011 (high salvage over a wider range of OMR flows)



Conclusions

- Delta Smelt abundance indices and proportional recruitment indices seem positively influenced by Delta flow estimates: QWEST, QTOT, QRIO, QSJR, QEAST, QXGEO, QOUT, QEFFECT

- Delta Smelt abundance indices and proportional recruitment indices seem negatively influenced by Delta diversion estimates: EXPIN, QDIVER, QEFFDIV, QEXP

- Salvage-OMR relations were only apparent following the virtual disappearance of Delta Smelt, both in the South Delta since the early 1980s and in salvage from summer to fall since the early 1990s

- Accounting for the influence of Delta flows and diversions on Delta Smelt habitat and entrainment is central to the sustainability of this endemic listed species

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