Impacts of Interior Delta Flows on NMFS Listed Salmonids

Jeffrey Stuart, M.S.
Li-Ming (Lee) He, Ph.D.

NOAA Fisheries West Coast Region
California Central Valley Area Office

Bay-Delta Science Conference
October 29, 2014

NMFS ESA Listed Species That May be Affected in the Delta

- Sacramento River Winter-run Chinook Salmon Evolutionarily Significant Unit – Endangered
- Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit – Threatened
- California Central Valley Steelhead Distinct Population Segment – Threatened
- Southern Distinct Population Segment of North American Green Sturgeon - Threatened

NMFS RPA Actions for Protecting Juvenile Fish Outmigrating Through Delta

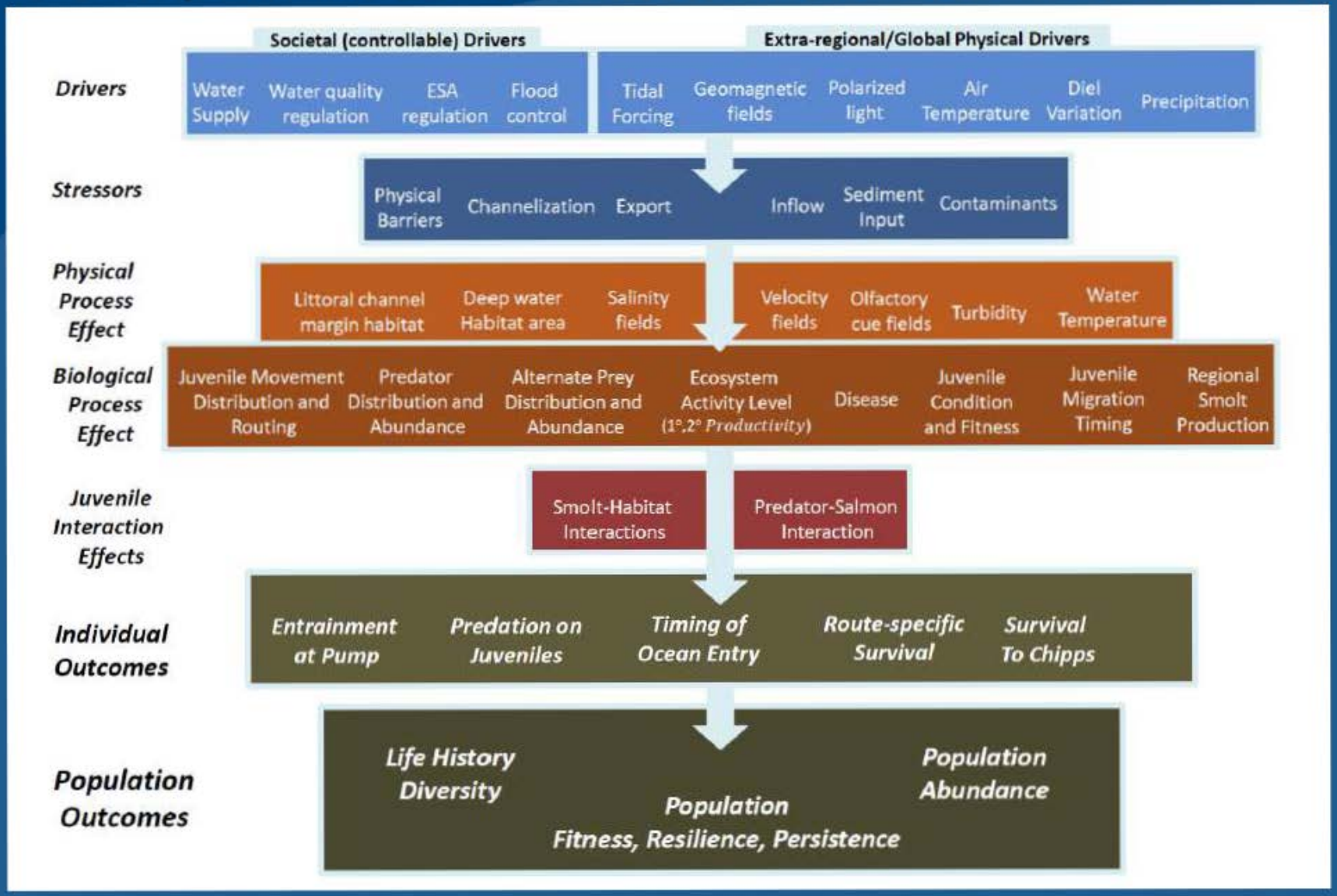
Element	Trigger	Action
DCC Gates	Number of out-migrating fish captured @ Knights Landing, Sherwood Harbor, and in Sacramento Beach Seines	Close Gates

Element	Trigger	Action
OMR Flow	Fish Loss Density at Projects	Make OMR flow less negative
Water Export	Fish Loss Density at Projects or SJR flow	Reduce exports

Scientific Support for the RPA Actions

- Large Quantities of Juvenile Fish Entrained with Water Exported by the CVP and SWP and Collected in salvage
- Juvenile Fish Entrainment Correlated to Water Export or OMR flow
- Lower Juvenile Fish Survival in Entrainment Routes Leading to the Projects

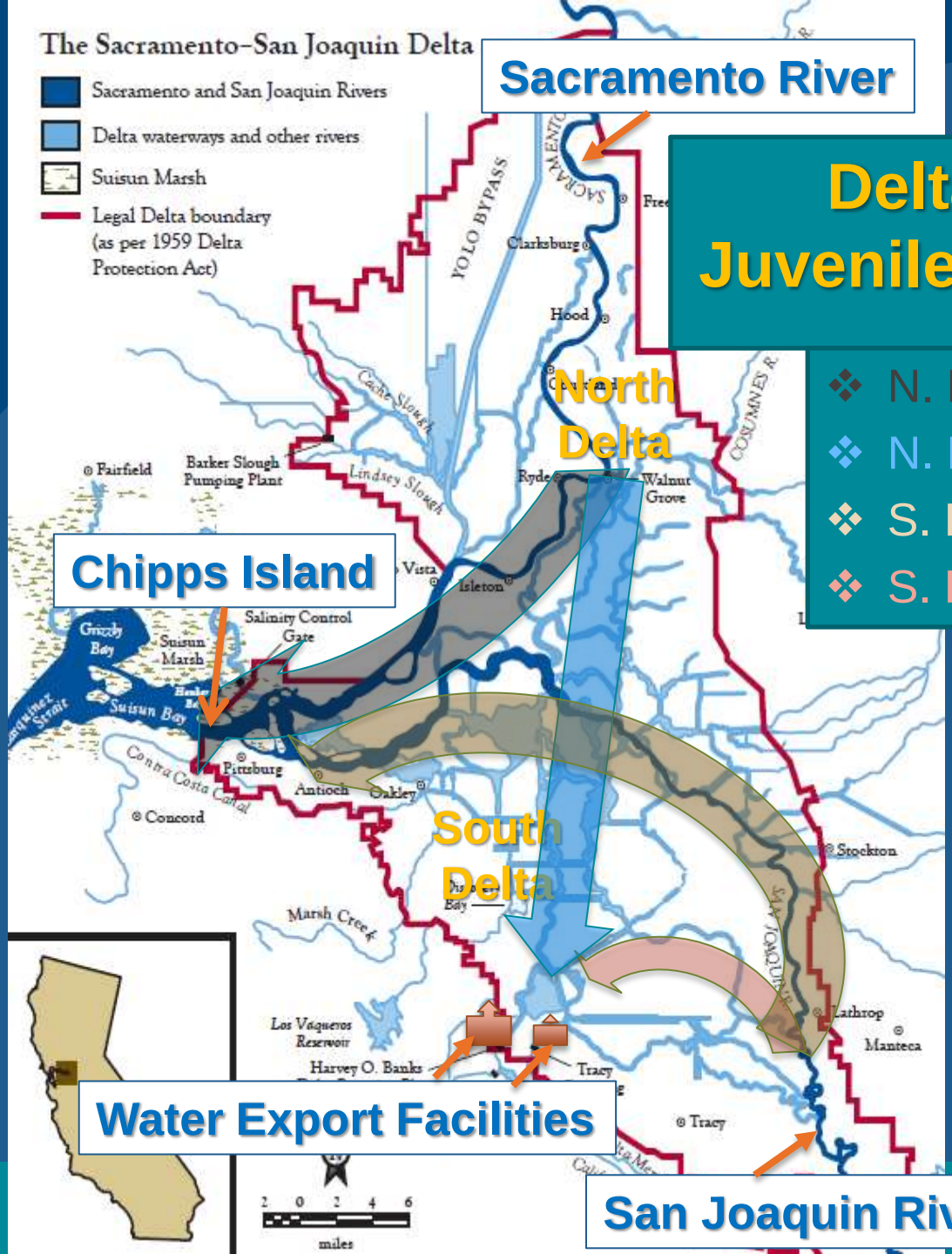
Conceptual Model for Delta Salmonid Juvenile Survival



(South Delta Salmonid Research Collaboration 2014)

Delta Water Flow and Juvenile Salmonid Movement

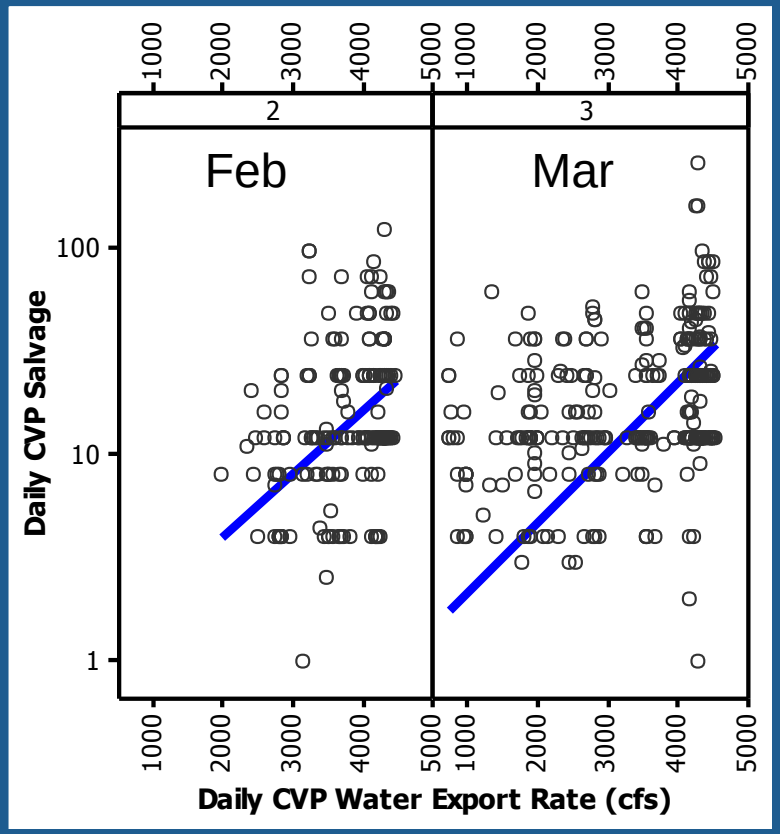
- N. Delta - Chipps Island (CI)
- N. Delta – S. Delta – WEF – CI
- S. Delta - CI
- S. Delta – WEF - CI



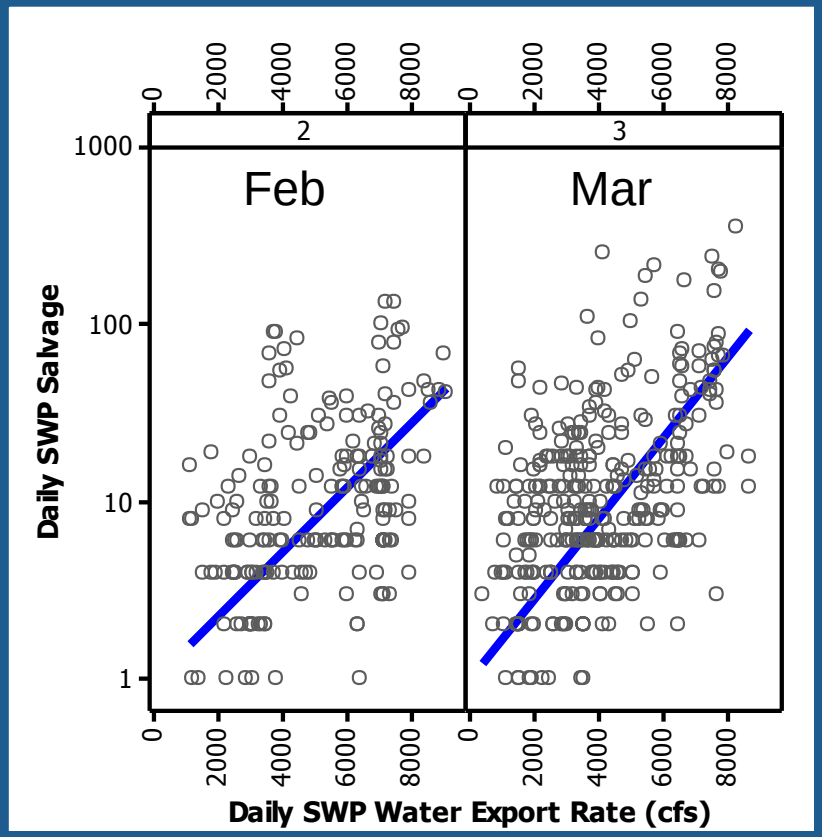
Wild Juvenile Winter-run Chinook Salmon

Daily Salvage Increases with Increasing Water Export

CVP



SWP

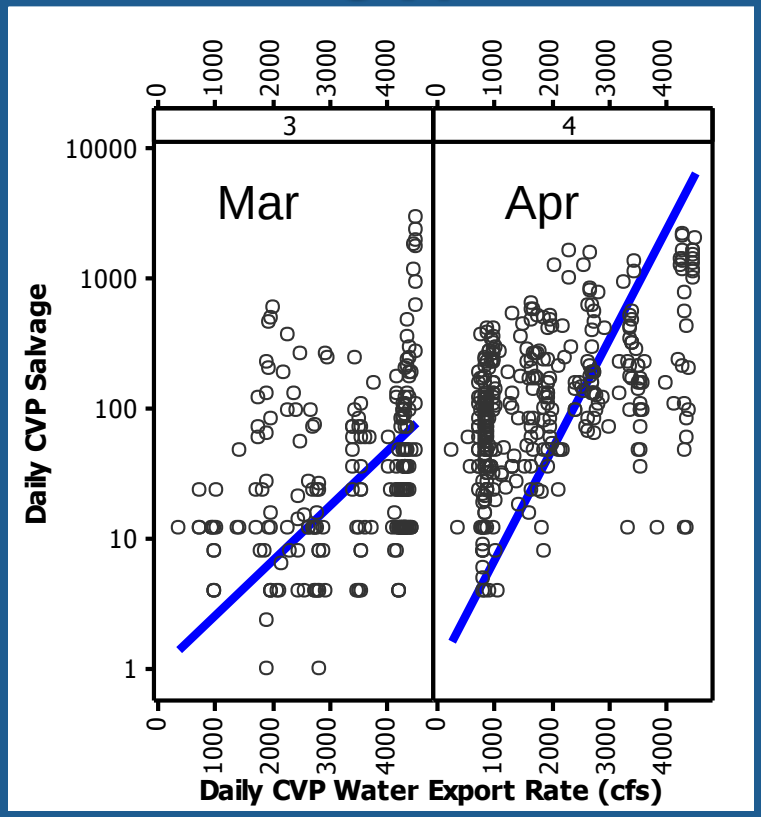


(1993-2011 Data)

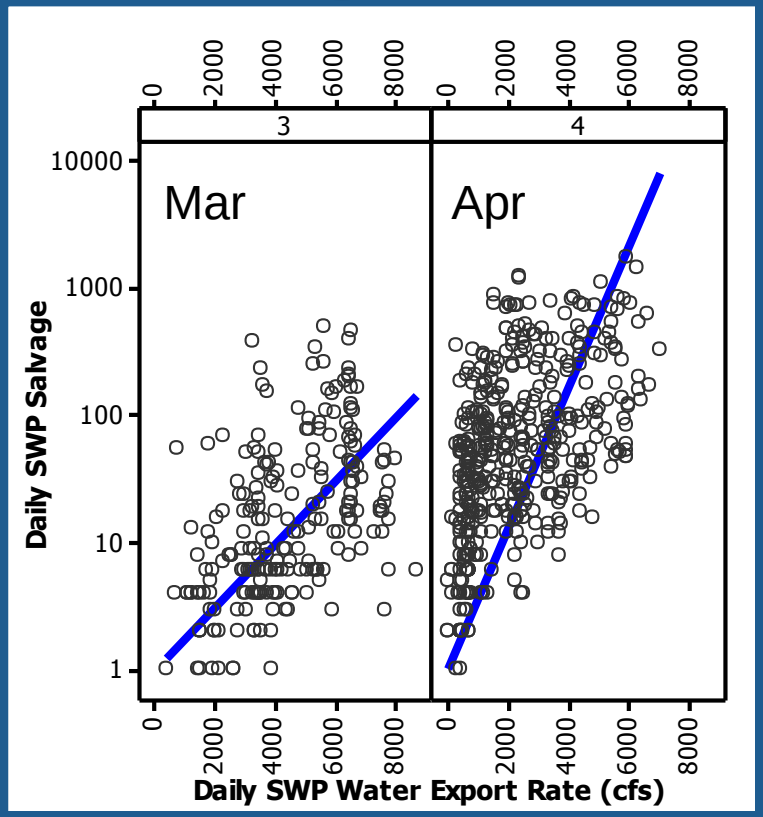
Wild Juvenile Spring-run Chinook Salmon

Daily Salvage Increases with Increasing Water Export

CVP



SWP

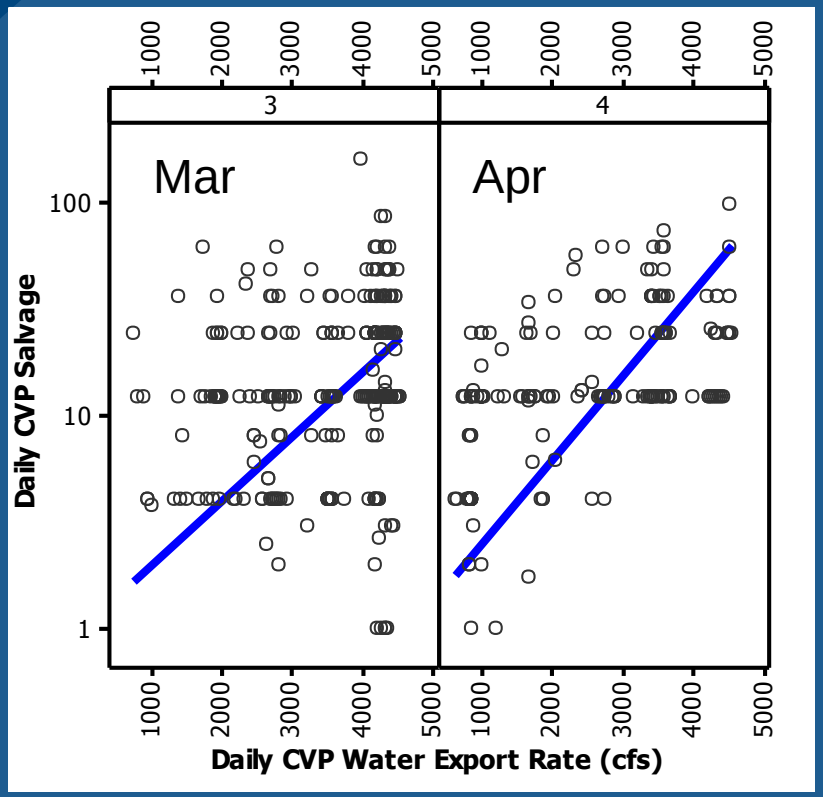


(1993-2011 Data)

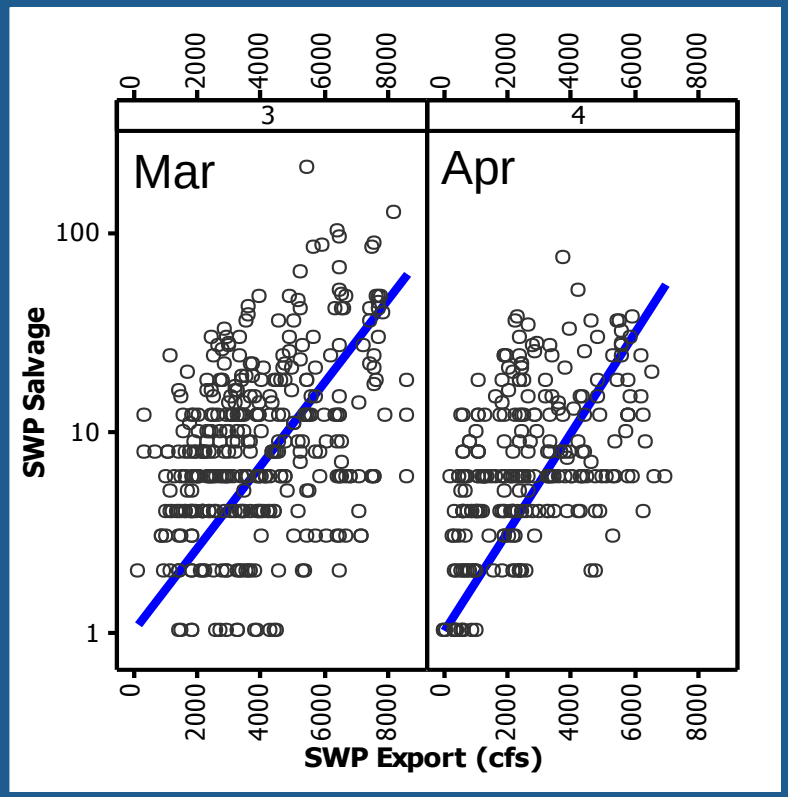
Wild Juvenile Steelhead

Daily Salvage Increases with Increasing Water Export

CVP



SWP

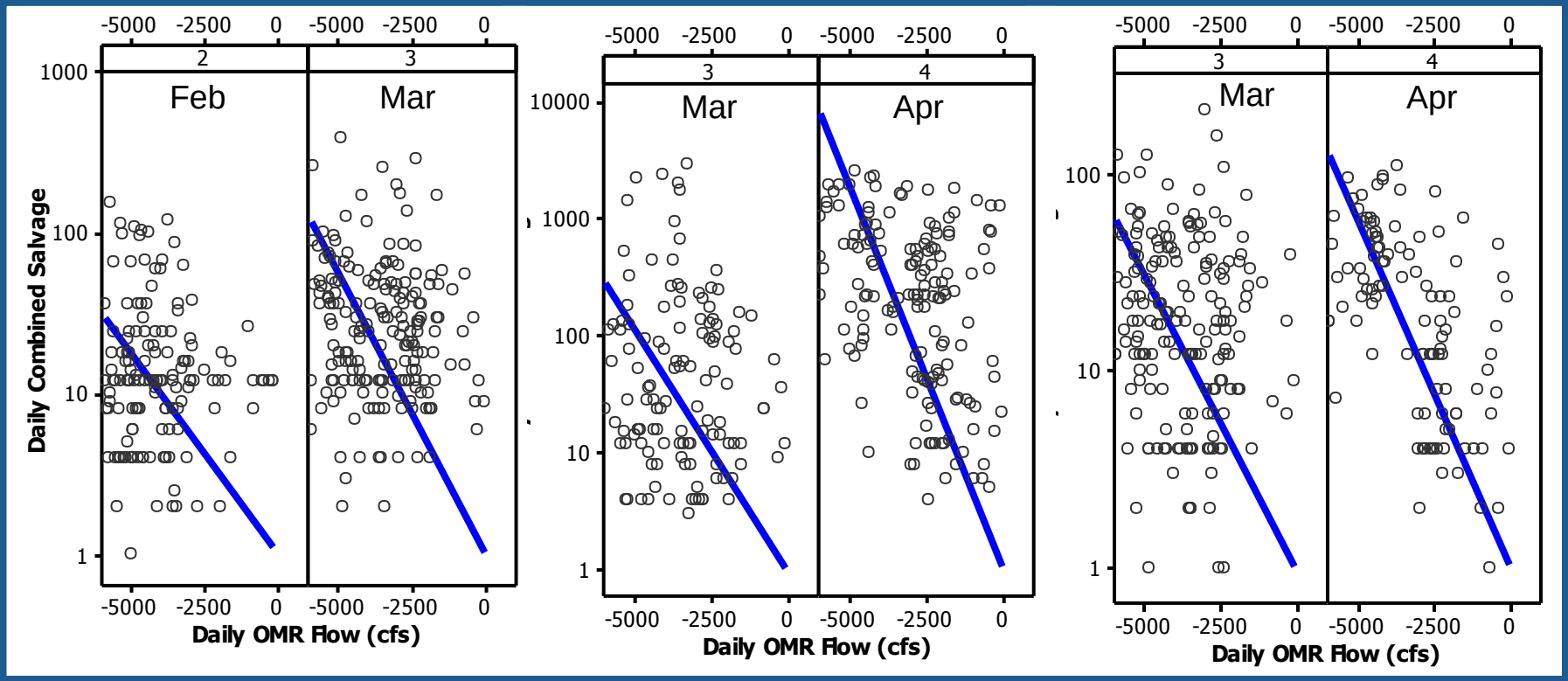


(1993-2011 Data)

Wild Juvenile Chinook and Steelhead

Daily Salvage Decreases as OMR Flows become Less Negative

Winter-run **Spring-run** **Steelhead**



(1993-2011 Data)

Factors Affecting Juvenile Fish Salvage or Loss in the Delta

- **WATER EXPORTS** – CVP and SWP, individually or combined
- **FISH ABUNDANCE** – daily influx and daily abundance
- **FLOW** – inflow, outflow, OMR
- **TIDE HEIGHT -** (mean, minimum, and maximum heights) indexed to Golden Gate tidal record.
- **PREDATION** (no daily estimates for this factor therefore not discussed further in this presentation)

- Data for water exports, flow, and tidal heights factors gathered from CDEC, USGS, and NOAA gauges

Juvenile Fish Flux and Abundance

Calculated Fish Flux from Data Gathered by the USFWS Delta Juvenile Fish Monitoring Program (DJFMP) from 1993 to 2012.

3 Sites Used:

- Chipps Island Trawl (western Delta)
- Sherwood Harbor Trawl (Sacramento River)
- Mossdale Trawl (San Joaquin River)

Analysis of Data

- We assume that factors affecting salvage will have similar influences on loss
- Two methods used to assess how factors influence salvage and loss
  - Pearson's Correlation Coefficient (r) between individual pairs of factors
  - Multiple linear regression with stepwise regression procedure for each factor

Pearson's Correlation Coefficient Summary – WR Chinook salmon

- Salvage or Loss at the SFPF or TFCF individually or combined is positively and significantly correlated with water exports (SWP, CVP, or combined), Sacramento River flow, and fish influx or abundance.

- Salvage or Loss at the SFPF individually or combined with the TFCF is negatively and significantly correlated with OMR flow and the San Joaquin River I:E ratio.

- Mean tidal height and Maximum tidal height are positively and significantly correlated with the SFPF salvage and loss

Stepwise Multiple Linear Regression for Salvage

Number of models that selected each factor as an "important" variable for wild salmonids

Variables	Number of Models			
	Winter-run	Spring-run	Steelhead	Total
Water Export (CVP, SWP, or Combined)	12	9	11	32
Delta Juvenile Fish Abundance	11	12	6	29
Tide Height (±)	4	8	3	15
Inflow (Sac River, SJ River (-), or Combined)	2	5	4	11
Delta Outflow	1	5	1	7
SJ River Inflow to Water Export Ratio (-)	2	4	0	6
OMR Flow (-)	1	2	2	5

(1993-2011 Data)

Conclusions

- Juvenile salmonids listed under the ESA are entrained by the water export facilities each year, sometimes in substantial numbers,
- Juvenile salmonid salvage increases significantly with increasing water export and increasing juvenile salmonid abundance in the Delta,
- To a lesser extent, based on statistical analysis, increases in the San Joaquin River flow and I:E ratio as well as more positive OMR flows can reduce salmonid salvage,
- Management measures to reduce juvenile salmonid entrainment into the Delta interior and S. Delta (*e.g*., DCC gates closure, more positive OMR flows or reductions of water exports) will increase their overall Delta survival.

Acknowledgements

- USFWS Delta Juvenile Monitoring Program Staff
- CDFW Mossdale Monitoring Staff
- Bureau of Reclamation Tracy Fish Collection Facility Staff
- Department of Water Resources Skinner Fish Protection Facility Staff

Questions?

Additional Slides on Juvenile Fish Survival

OMR Flow Strongly Correlated to Water Export

Head of Old River Barrier: No

$$Q_{OMR} = -555 - 0.897\ Q_{EXP} + 0.552\ Q_{SJR}$$

$$N = 5815 \quad r^2 = 0.971$$

Head of Old River Barrier: Yes

$$Q_{OMR} = -1109 - 0.669\ Q_{EXP} + 0.092\ Q_{SJR}$$

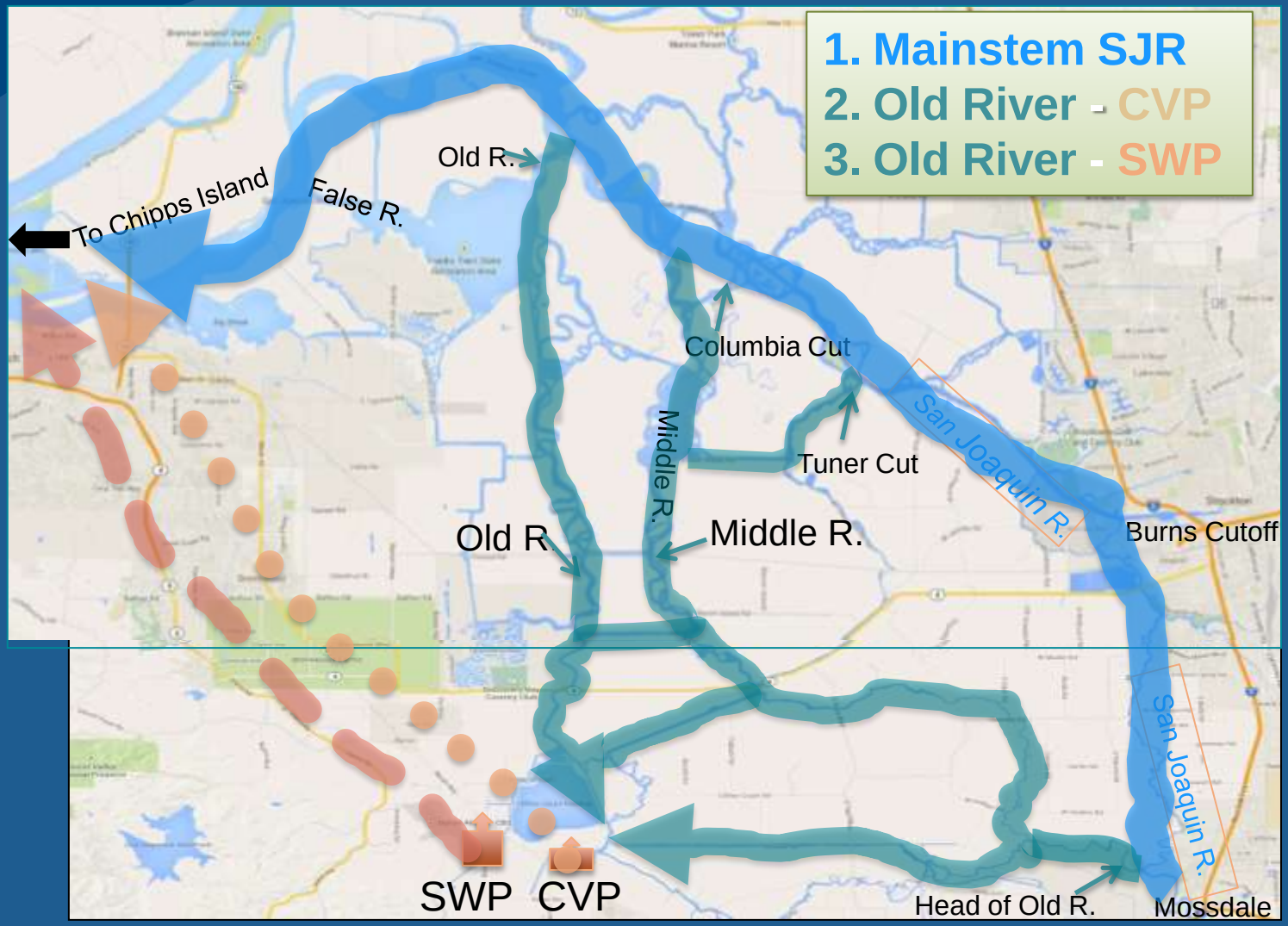
$$N = 230 \quad r^2 = 0.766$$

(1987-2012 Data)

Sac River Juvenile Fish Migration Routes

1. Mainstem Sac River
2. Delta Cross Channel
3. Georgiana Slough
4. DCC/GS – OMR – Export Facilities

SJ River Juvenile Fish Migration Routes



Juvenile Chinook Survival to Chipps Island

Area	Route	Survival	
		CWT	AT
North Delta	Mainstem Sac River	0.51①	0.40 ③
	Delta Cross Channel	N/A	0.16 ③
	Georgiana Slough	0.14①	0.22 ③
South Delta	Mainstem SJ River	0.39②	0.01-0.04④
	Old River - CVP	0.21②	0.03 ④
	Old River - SWP		0.005 ④
N. Delta & S. Delta	DCC/GS - OMR - CVP	N/A	0.04 ⑤
	DCC/GS - OMR - SWP	N/A	0.01 ⑤

1. USFWS 2001, 2003, 2005, 2007
2. Brandes and McLain 2001
3. Perry 2010
4. Buchanan 2012, Buchanan *et al*. 2013
5. Estimated

Juvenile Chinook Survival

N. Delta to Chipps Island Coded-wire Tag Studies

Year	Sac R	Georg Sl
1997	0.670	0.030
1998	0.685	0.236
1999	0.507	0.308
2000	0.197	0.067
2002	0.722	0.225
2003	0.397	0.017
2004	0.293	0.081
2005	0.586	0.187
Ave	0.507	0.144

(USFWS 2001, 2003, 2005, 2007)

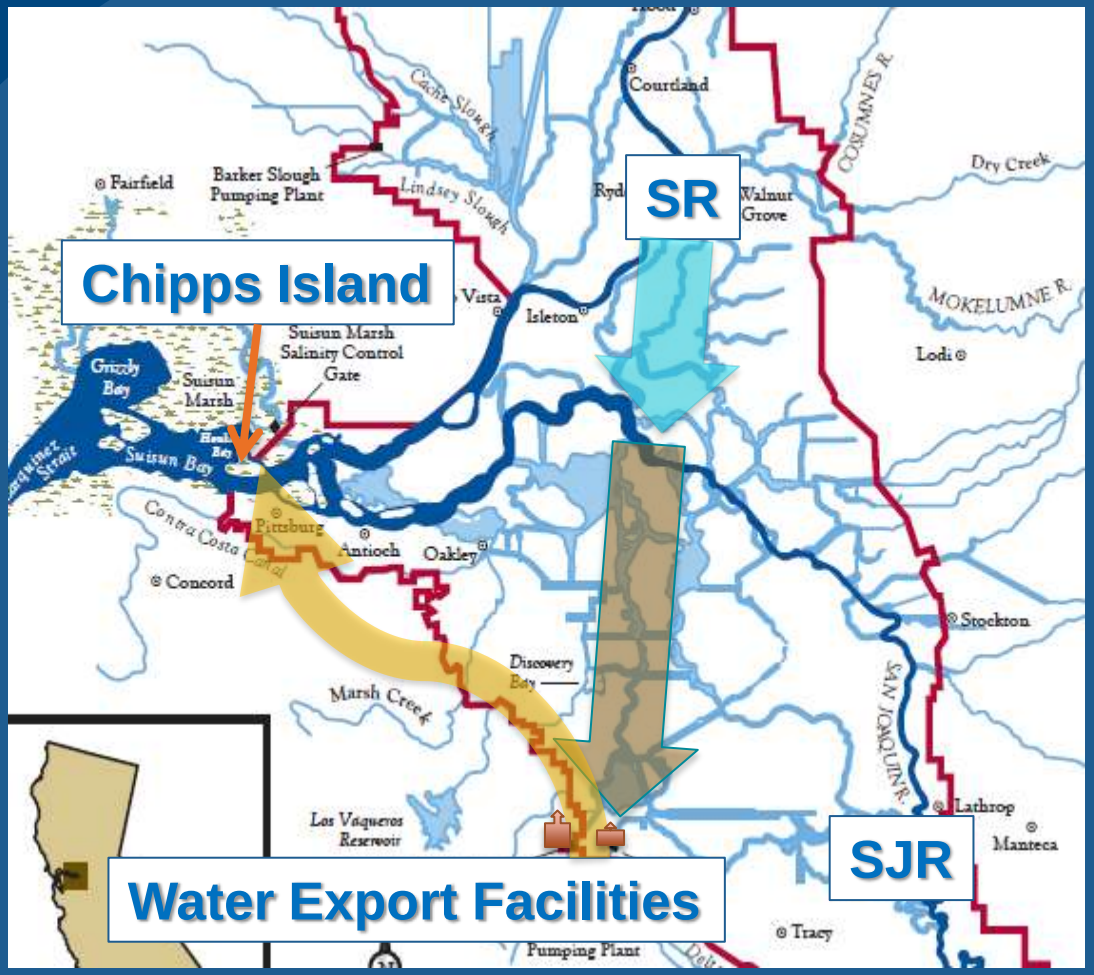
Juvenile Chinook Survival
N. Delta to Chipps Island Acoustic Tag Studies

S_{SR} = 0.40
S_{DCC} = 0.16
S_{GS} = 0.22

(Based on 6 acoustic tagged Chinook salmon studies in 2006-2009. Perry 2010)

Juvenile Chinook Survival

N. Delta – S. Delta – Export Facilities – Chipps island



Route	CVP	SWP
N. Delta ①	0.40	
S. Delta ②	0.40	
Facility ③	0.22	0.07
Entire Route	0.04	0.01

1. Perry 2010
2. Assumed to be equal to N. Delta
3. He 2014 (Unpublished)

Juvenile Chinook Survival in S. Delta

Coded-Wire Tag Studies

1. Mainstem SJR – Chipps Island: 0.39
2. SJR – Old River – Chipps Island: 0.21

Year	Released in SJR at Dos Reis	Released in Old River
1985	0.59	0.62
1986	0.34	0.20
1987	0.83	0.16
1989	0.15	0.07
1990	0.04	0.02
Ave	0.39	0.21

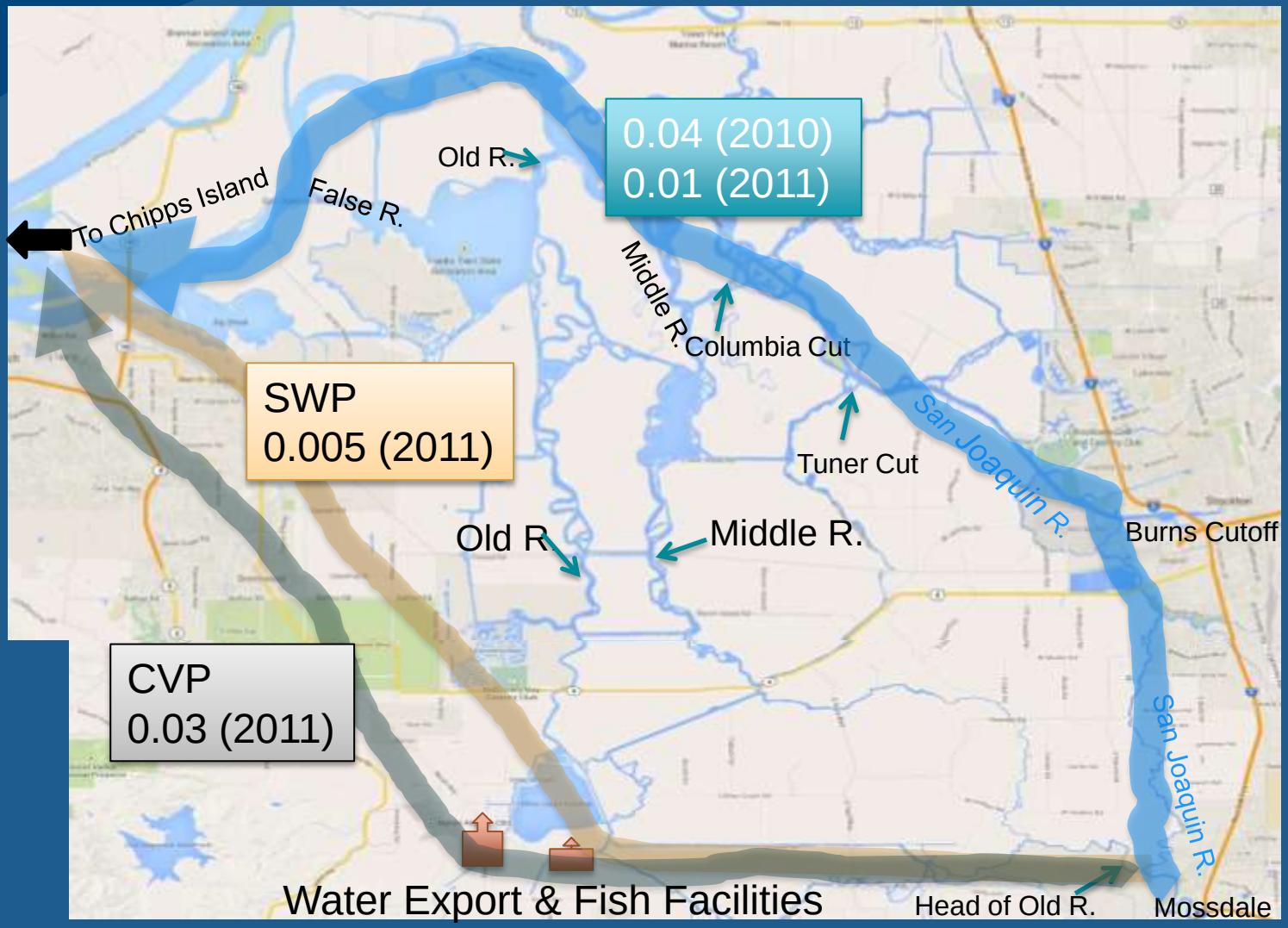
(Brandes and McLain 2001)

Juvenile Chinook Survival in SJR

2011 Acoustic Tag Studies (Buchanan 2012)

Juvenile Chinook Survival in South Delta

2010 & 2011 Acoustic Tag Studies
(Buchanan 2012, Buchanan *et al*. 2013)



MLR Model Results Summary

Wild Winter-run Chinook salmon – SFPF (no HORB installed)

Dataset		ALL	DEC	JAN	FEB	MAR	APR	# Models
Number of Samples		469	46	101	117	163	41	4
R^2		0.234	NV	0.527	0.501	0.259	NV	
Adjusted R^2		0.231		0.513	0.493	0.245		
p		0.000		0.000	0.000	0.000		
Water Export	SWP	0.387		0.644	0.510	0.432		4
	CVP	Not Applicable						
	Combined							
OMR			NV				NV	0
Inflow	SR							0
	SJR							
	Combined							
Delta Outflow								0
I/E Ratio								0
Tide Height	Minimum					-0.220		2
	Mean			0.265				
	Maximum							
Daily Abundance		0.300			0.451	0.288		4
Ln(Daily Abundance)				0.338				

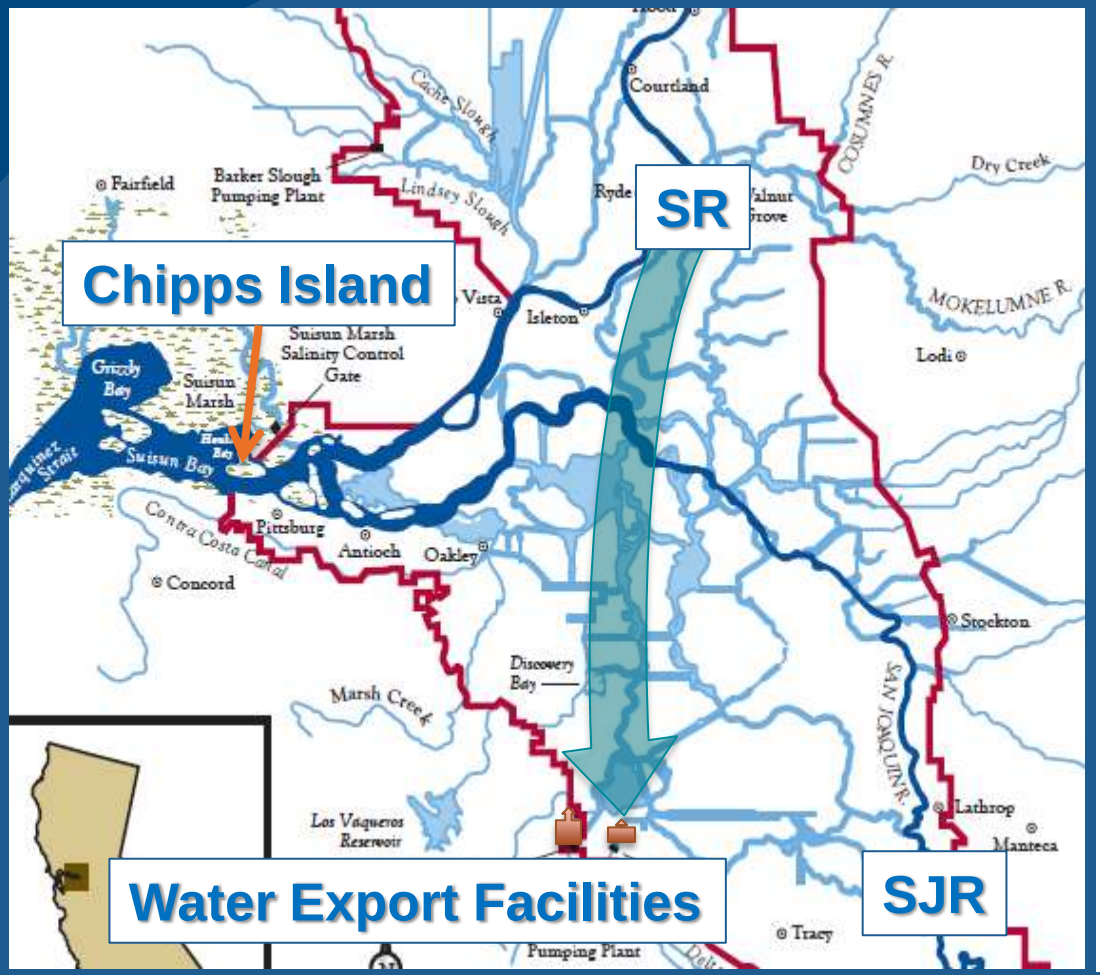
NV = No variables were entered into the equation.
Blanks indicate that a variable was not selected by a model.

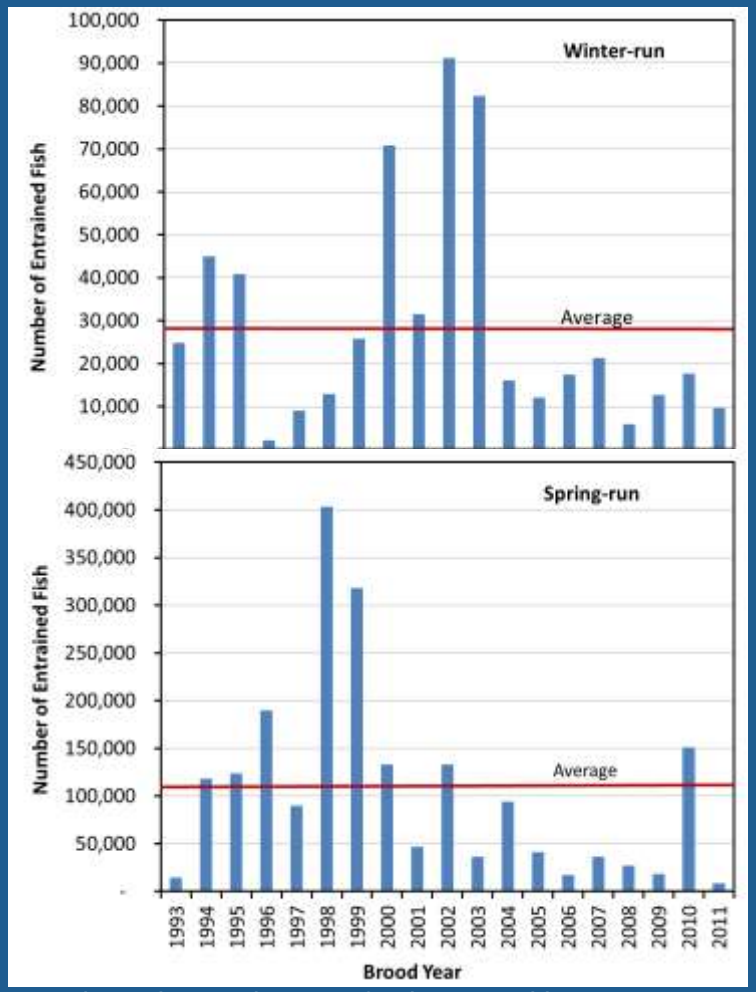
MLR Model Results Summary
Wild Winter-run Chinook salmon – TFCF
(no HORB installed)

Dataset		All	DEC	JAN	FEB	MAR	APR	# Models
Number of Samples		416	41	65	130	138	41	6
R^2		0.145	0.155	0.408	0.383	0.041	0.360	
Adjusted R^2		0.139	0.134	0.378	0.379	0.033	0.343	
p		0.000	0.011	0.000	0.000	0.018	0.000	
Water Export	SWP	Not Applicable						4
	CVP	0.192		0.534		0.201	0.600	
	Combined	Not Applicable						
OMR								0
Inflow	SR							1
	SJR			-0.350				
	Combined							
Delta Outflow				0.362				1
I/E Ratio								0
Tide Height	Minimum							1
	Mean	-0.102						
	Maximum							
Daily Abundance		0.305	0.394					3
Ln(Daily Abundance)					0.619			
Blanks indicate that a variable was not selected by a model.								

Juvenile Chinook Entrainment to Water Export Facilities

(Wild and Hatchery)

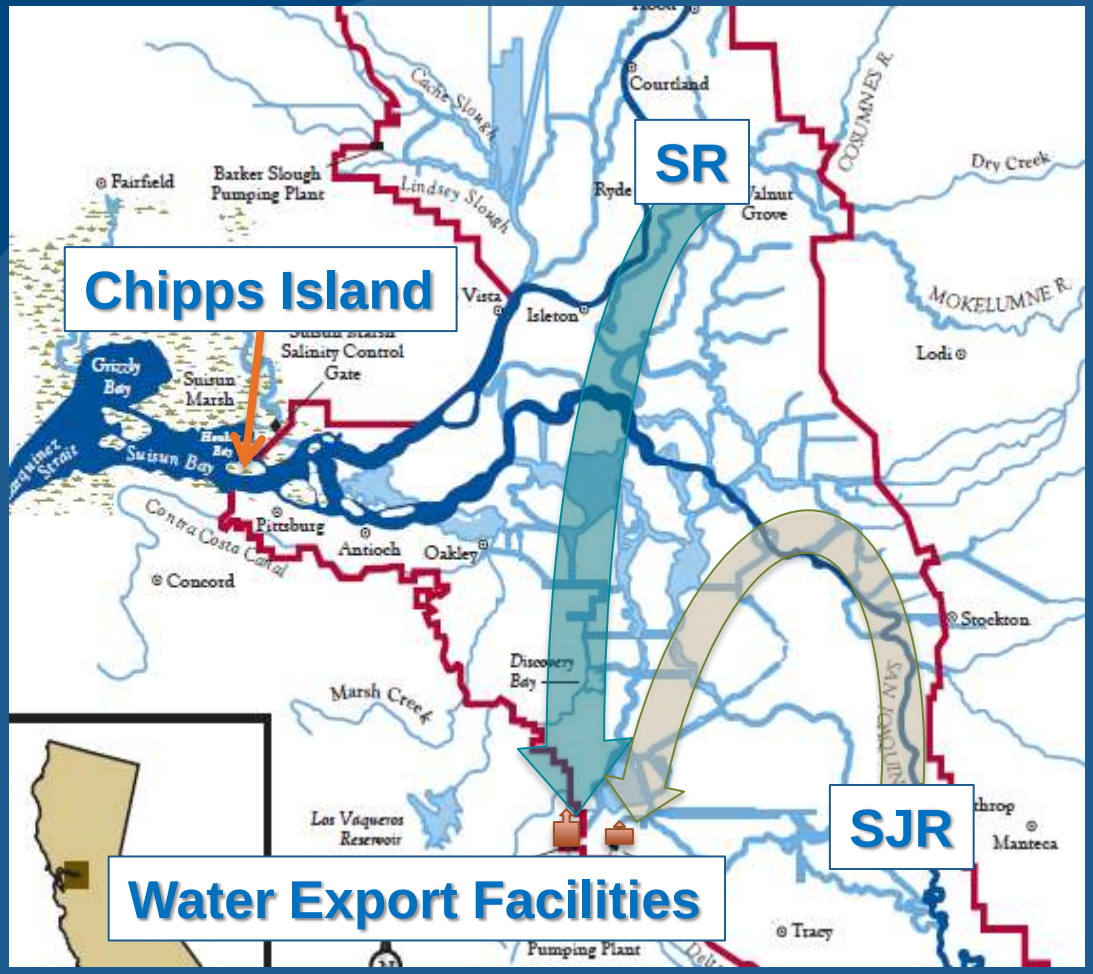


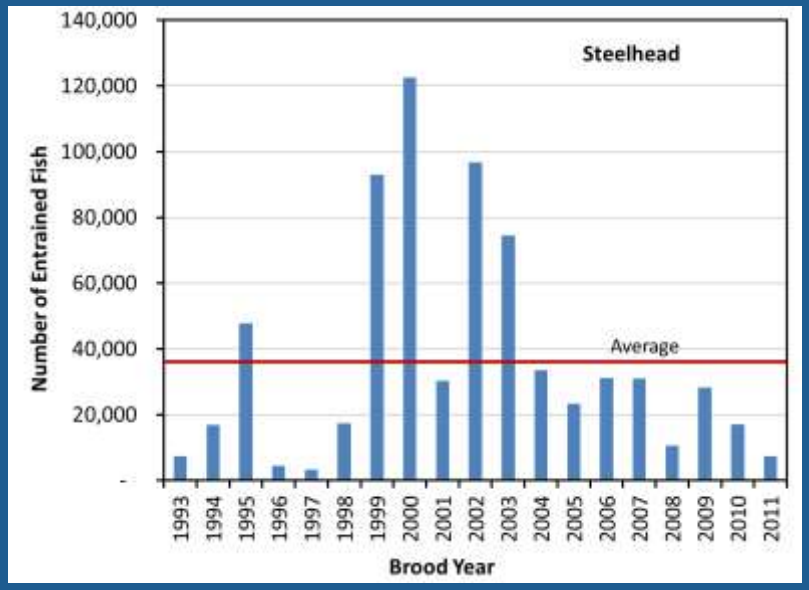


(Entrainment is sum of salvage and loss. Runs are assigned based on the length-at-date method.)

Juvenile Steelhead Entrainment to Water Export Facilities

(Wild and Hatchery)





~90% from SR

~10% from SJR

Based on Flux data

(Entrainment is sum of salvage and loss.)

Pearson's Correlation Coefficient Table wild winter-run Chinook salmon

Variables	Statistic	LN(SWP Salvage)	LN(CVP Salvage)	LN(Combined Salvage)	LN(SWP Loss)	LN(CVP Loss)	LN(Combined Loss)
SWP Export	Pearson r	.407**	.084*	.200**	.393**	.016	.382**
	Sig. (2-tailed)	.000	.023	.000	.000	.668	.000
	N	857	732	1186	836	727	1168
CVP Export	Pearson r	.073*	.247**	.153**	.057	.114**	.062*
	Sig. (2-tailed)	.031	.000	.000	.095	.002	.032
	N	870	744	1204	849	739	1186
Combined Export	Pearson r	.338**	.152**	.214**	.321**	.052	.324**
	Sig. (2-tailed)	.000	.000	.000	.000	.163	.000
	N	857	732	1186	836	727	1168
OMR Flow	Pearson r	-.215**	-.019	-.171**	-.202**	.038	-.189**
	Sig. (2-tailed)	.000	.668	.000	.000	.400	.000
	N	561	500	790	543	495	775
I:E Ratio	Pearson r	-.140**	-.023	-.150**	-.125**	.019	-.121**
	Sig. (2-tailed)	.000	.537	.000	.000	.610	.000
	N	855	729	1183	834	724	1165
SJR Flow	Pearson r	-.049	.001	-.086**	-.042	.003	-.031
	Sig. (2-tailed)	.152	.969	.003	.220	.931	.291
	N	868	741	1201	847	736	1183
SR Flow	Pearson r	.204**	.133**	.111**	.211**	.116**	.184**
	Sig. (2-tailed)	.000	.000	.000	.000	.002	.000
	N	870	744	1204	849	739	1186

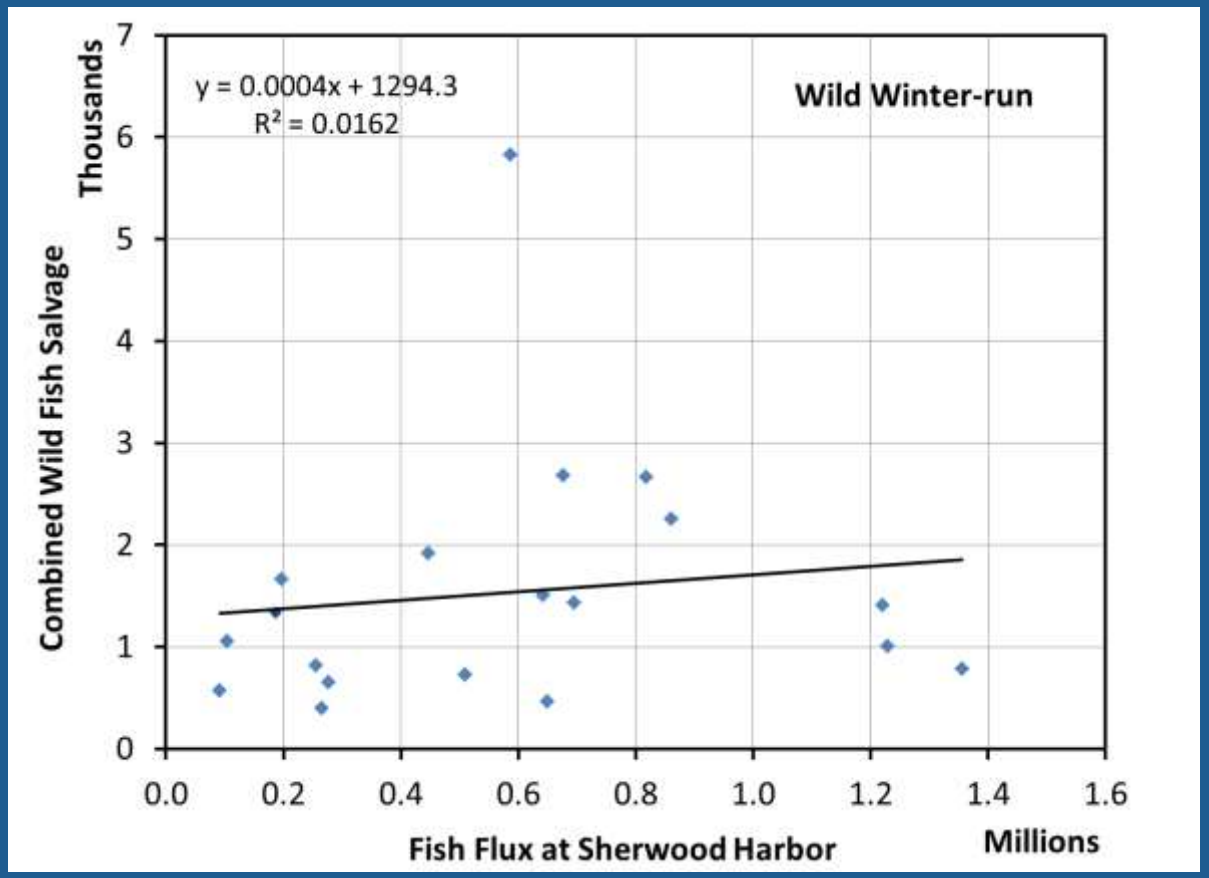
(1993-2011 Data)

Pearson's Correlation Coefficient Table wild winter-run Chinook salmon

Variables	Statistic	LN(SWP Salvage)	LN(CVP Salvage)	LN(Combined Salvage)	LN(SWP Loss)	LN(CVP Loss)	LN(Combined Loss)
Minimum Tide Height	Pearson r	.065	.016	.018	.053	.015	.066*
	Sig. (2-tailed)	.056	.667	.528	.124	.684	.024
	N	870	744	1204	849	739	1186
Mean Tide Height	Pearson r	.139**	.017	.015	.132**	-.011	.070*
	Sig. (2-tailed)	.000	.647	.597	.000	.762	.016
	N	870	744	1204	849	739	1186
Maximum Tide Height	Pearson r	.084*	.034	.023	.085*	-.003	.038
	Sig. (2-tailed)	.013	.361	.423	.013	.925	.193
	N	870	744	1204	849	739	1186
Fish Flux at Sherwood Harbor	Pearson r	.122**	.151**	.076**	.110**	.163**	.072*
	Sig. (2-tailed)	.000	.000	.008	.001	.000	.013
	N	870	744	1204	849	739	1186
Fish Influx	Pearson r	.126**	.154**	.080**	.114**	.167**	.075**
	Sig. (2-tailed)	.000	.000	.006	.001	.000	.010
	N	870	744	1204	849	739	1186
15d Total Influx	Pearson r	.202**	.263**	.166**	.196**	.260**	.149**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	870	744	1204	849	739	1186
Daily Abundance	Pearson r	.176**	.268**	.159**	.169**	.268**	.128**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	801	672	1101	782	667	1085
LN(DA)	Pearson r	.207**	.227**	.187**	.193**	.224**	.162**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000
	N	737	630	1017	721	625	1001

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

(1993 – 2011 Data)

Annual Fish Flux through Delta and Fish Salvage (CVP and SWP)