

EFFECTS OF WATER PROJECT OPERATIONS ON JUVENILE SALMON SURVIVAL IN THE DELTA: LITERATURE AND DATA REVIEW

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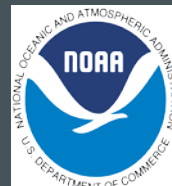
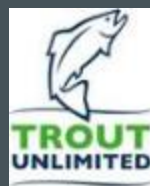
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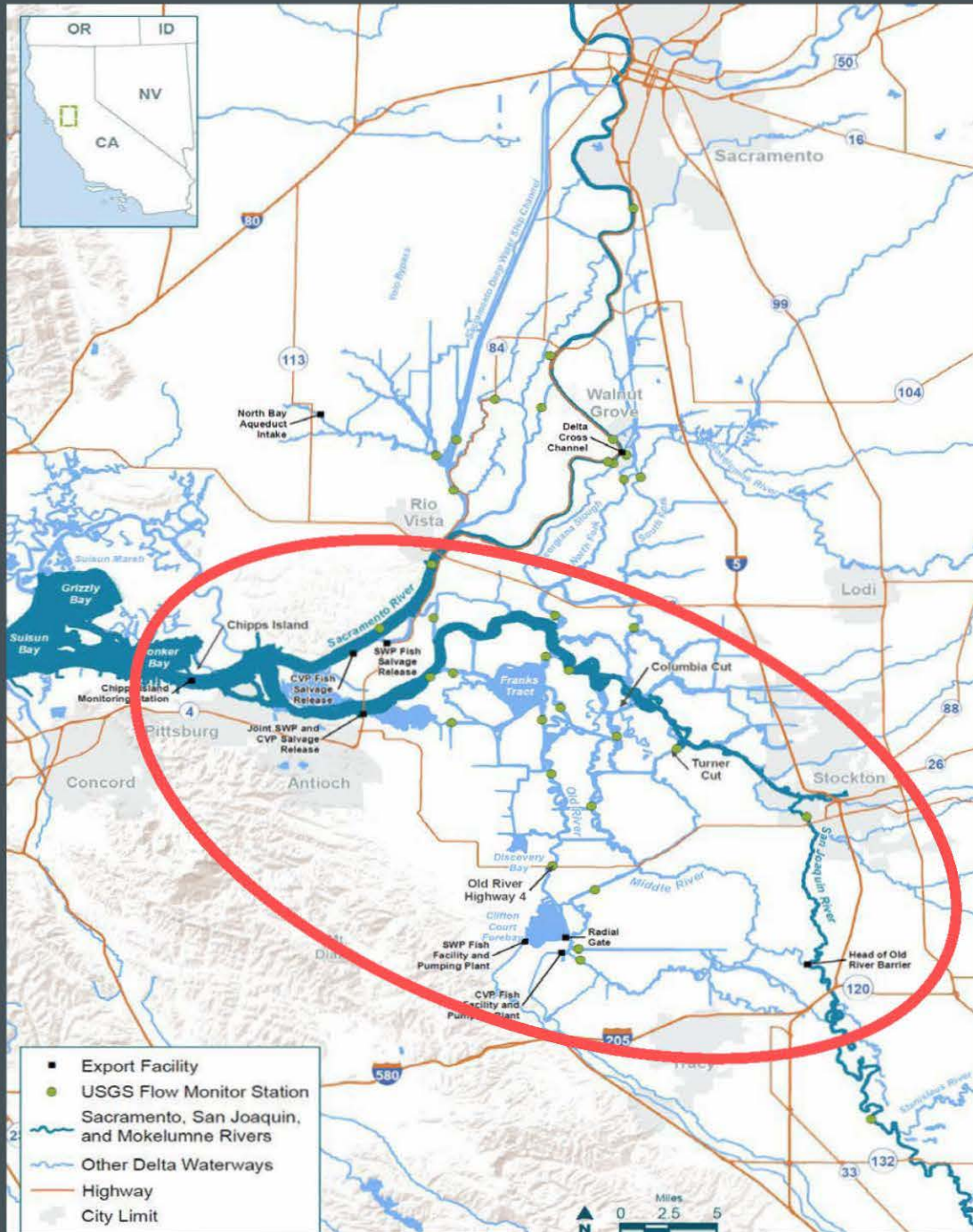
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SCOPE AND METHODS OF OUR REVIEW

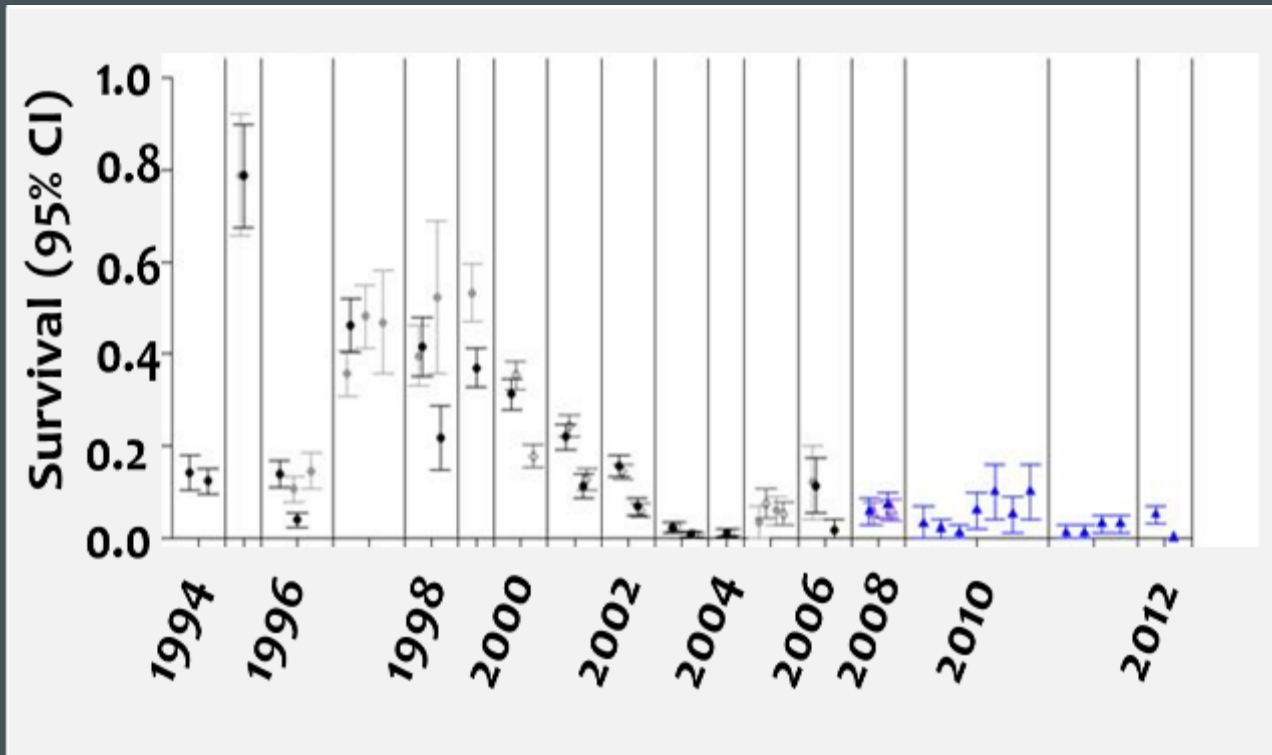
- Effects of
 - Delta inflow (San Joaquin River or Sacramento River)
 - Export rates
 - San Joaquin River Inflow : Exports (I:E)
 - Exports : Delta inflow (E:I)
- On
 - Hydrodynamic Conditions in Delta (flow and water velocity)
 - Route Selection
 - Travel Time
 - Survival in and through the Delta
- Using
 - Literature Review
 - Visual inspection of graphical results (aka, scatterplots)



SURVIVAL DATA

THROUGH-DELTA SURVIVAL

- Through-Delta survival has been consistently low for San Joaquin River Chinook salmon



San Joaquin River Fall-Run Chinook Salmon

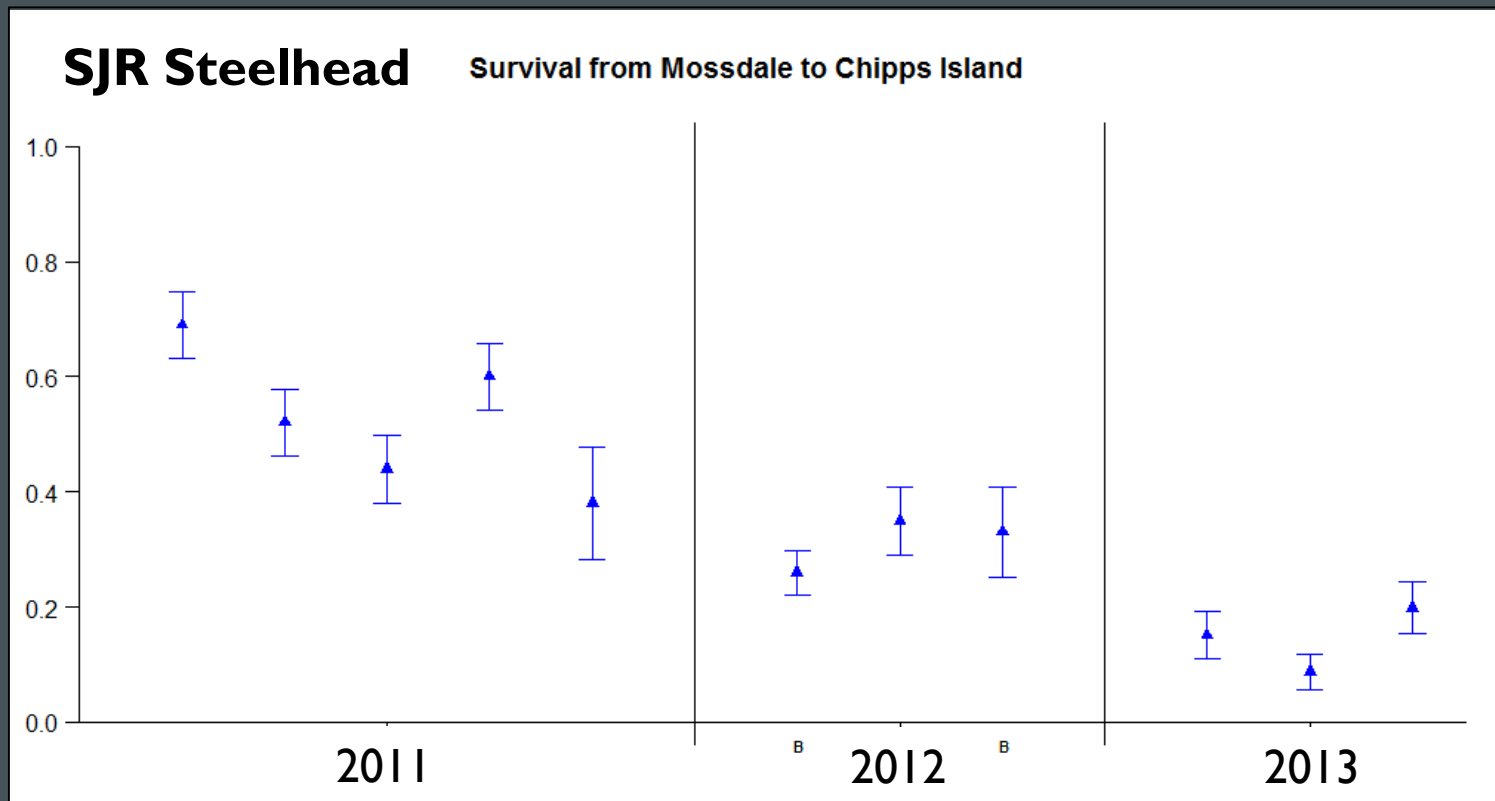
THROUGH-DELTA SURVIVAL

Sacramento River Chinook Salmon

Run	Year	Estimate
Winter	2013, 2014	0.32, 0.35
Spring	2013, 2014	0.30, 0
Fall/Spring	2013	0.17
Fall	2013	0
Late-Fall	Dec 2006, Jan 2007	0.351, 0.543
	Dec 2007, Jan 2008	0.174, 0.195
	Dec 2008, Jan/Feb 2009	0.368, 0.339, 0.64
	Dec 2009, Jan/Feb 2010	0.464, 0.374, 0.52

THROUGH-DELTA SURVIVAL: STEELHEAD

River Basin	Year	Estimate
Sacramento	2009, 2010	0.57, 0.47
San Joaquin	2011, 2012 (2013, 2014)	0.54, 0.32 (0.15, 0.25)



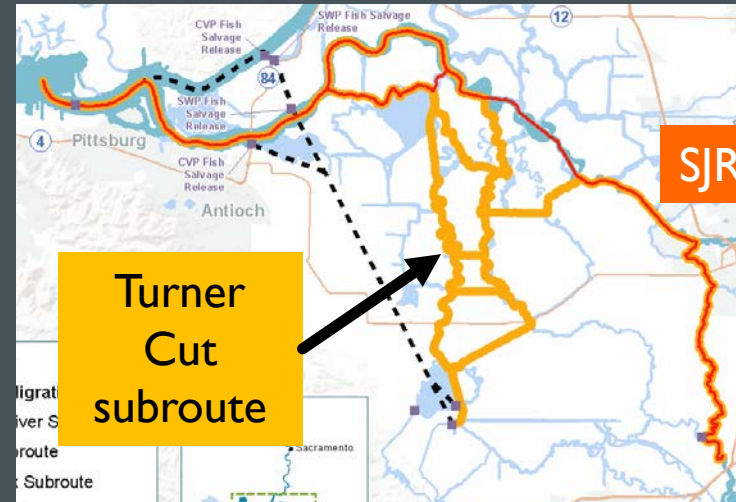
ROUTE-SPECIFIC SURVIVAL

San Joaquin River Fall-Run Chinook

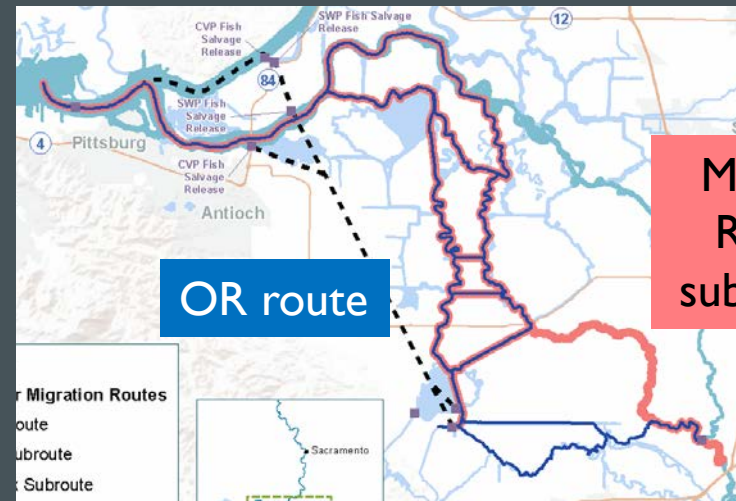
CWT 1985 – 1990:
Survival through Delta is higher for San Joaquin River route than Old River route

AT 2010 – 2012:

- No difference between SJR route and OR route
- Survival is lower through Turner Cut subroute



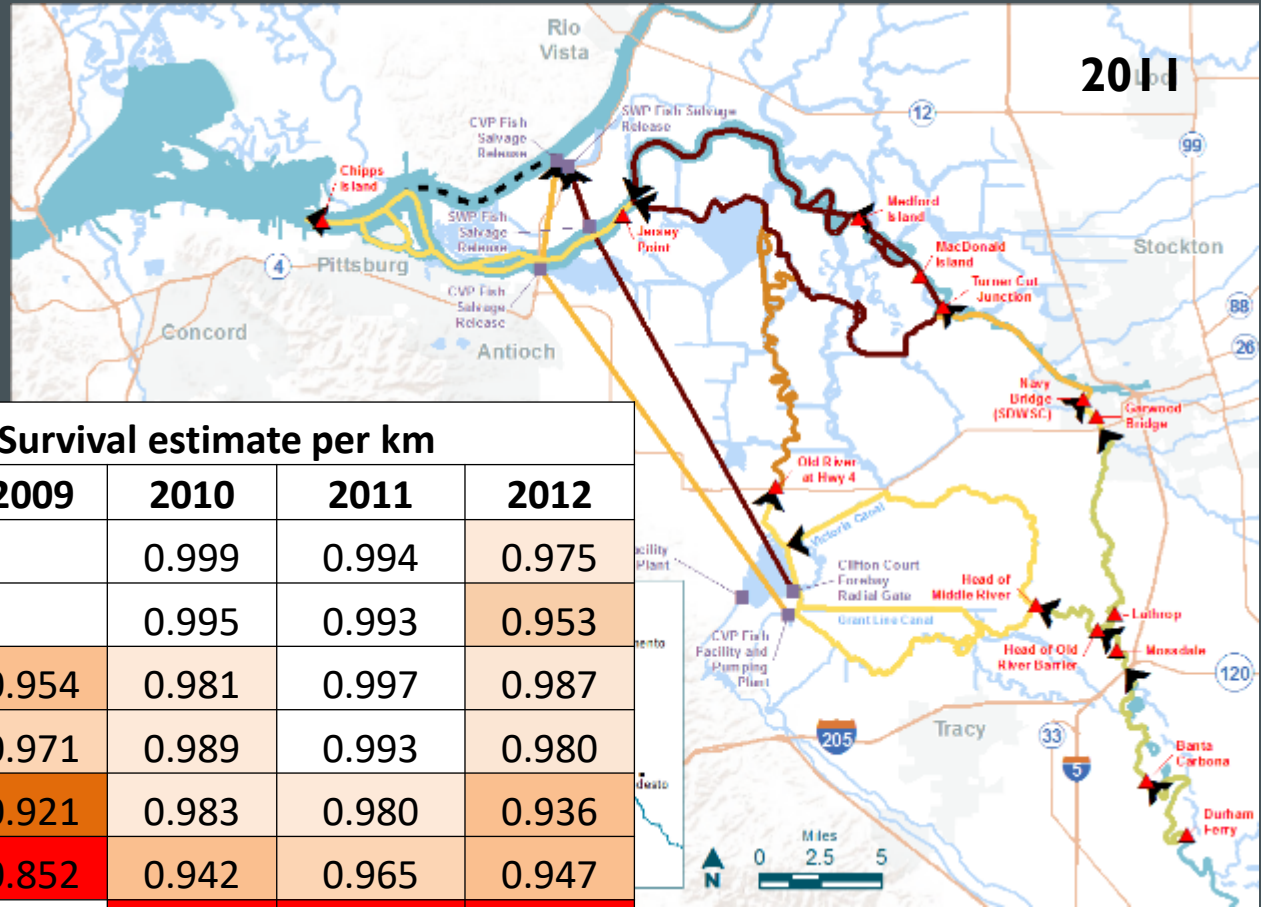
SJR route



Middle River subroute

SPATIAL HETEROGENEITY IN SURVIVAL

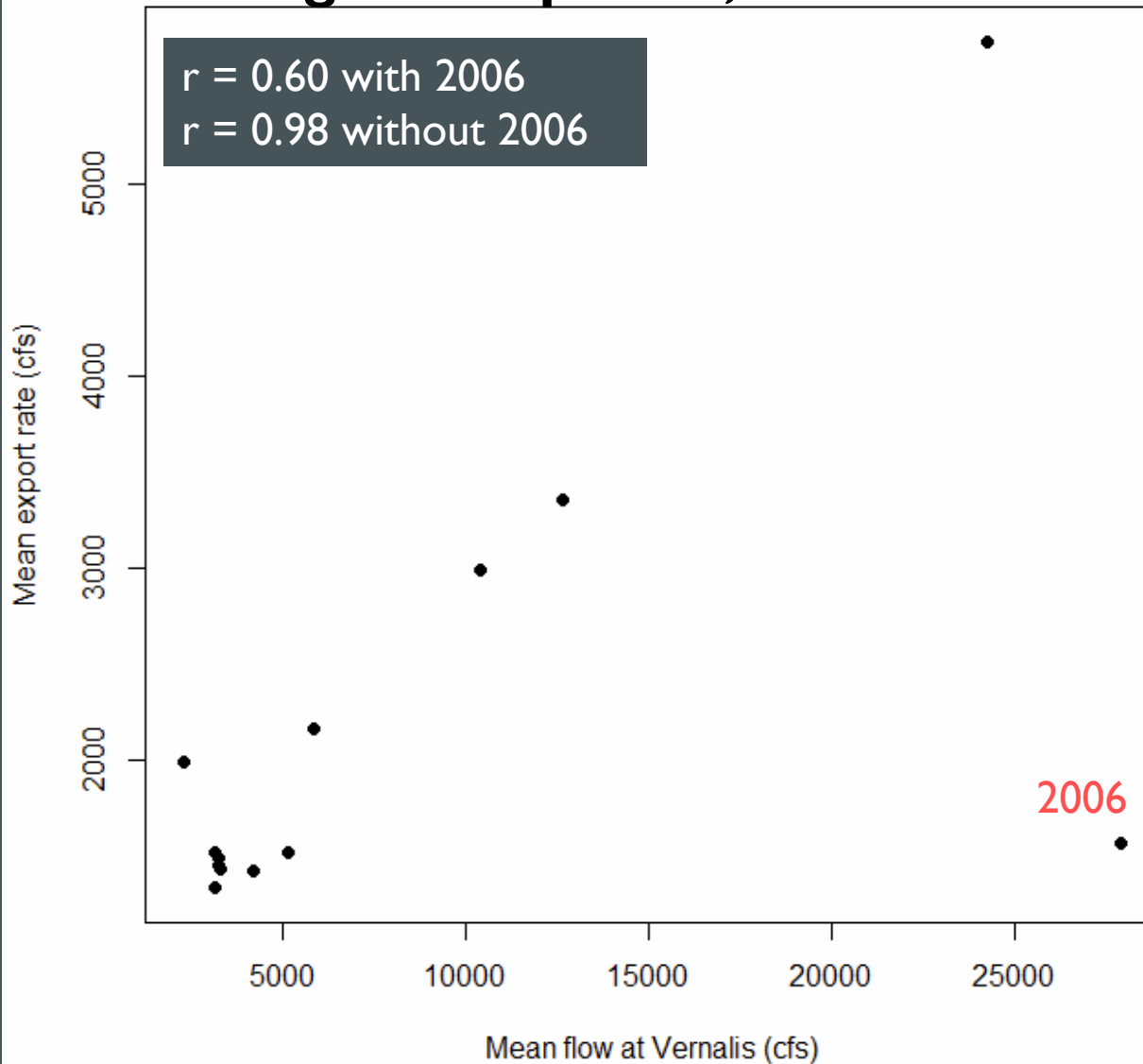
SJR Fall-Run Chinook



Reach	Survival estimate per km				
	2008	2009	2010	2011	2012
DF to Banta Carbona			0.999	0.994	0.975
BCA to Mossdale			0.995	0.993	0.953
Mossdale to OR	0.967	0.954	0.981	0.997	0.987
Lathrop to Garwood	0.986	0.971	0.989	0.993	0.980
Garwood to SDWSC	0.955	0.921	0.983	0.980	0.936
SDWSC to Turner Cut	0.958	0.852	0.942	0.965	0.947
MacDonald to Medford			0.863	0.833	0.852
Turner Cut to Jersey Pt (Interior Route)	0			0	0
Medford to Jersey Pt				0.881	0.964
Jersey Pt to Chipps Is	0.981			0.983	0.971

SURVIVAL VS INFLOW, EXPORTS, I:E, E:I

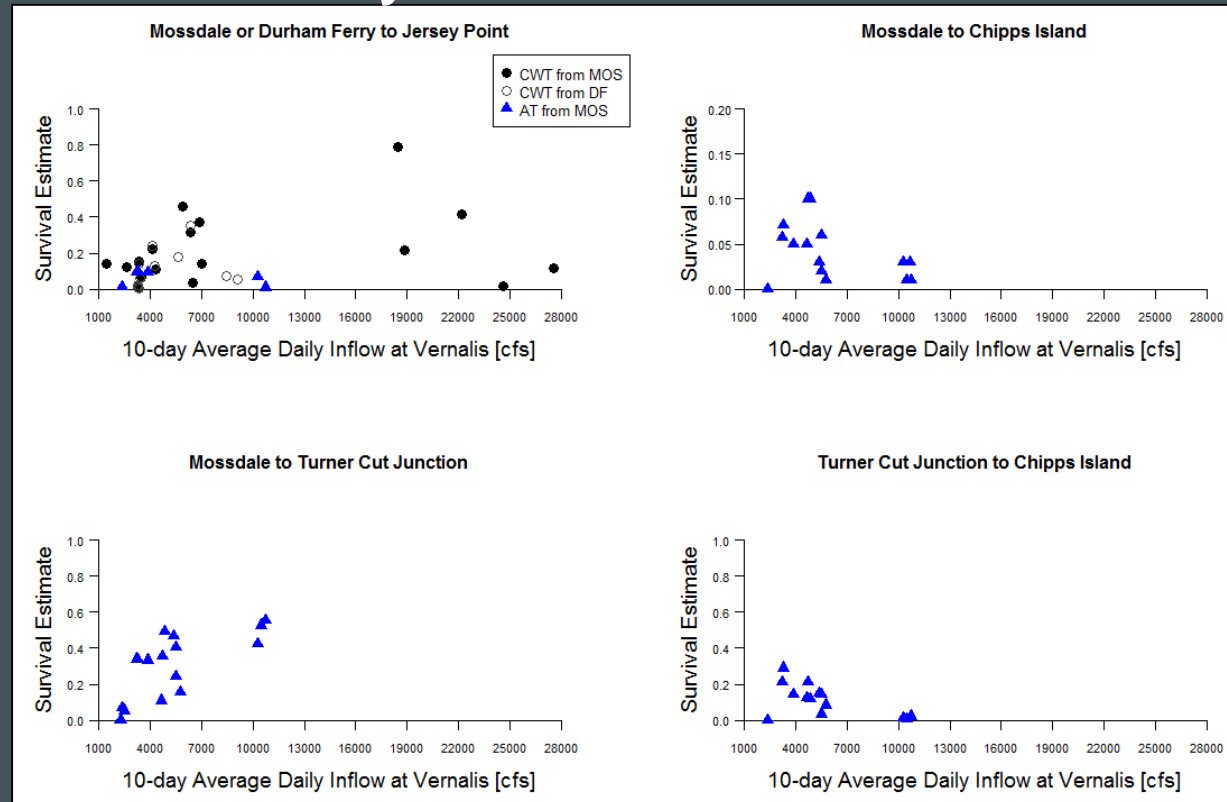
Observed mean SJR inflow and exports during VAMP period, 2000 – 2011



DELTA SURVIVAL VS INFLOW: SAN JOAQUIN

- Positive association between Vernalis flow and survival
- Delta/ocean recoveries of CWTs (Newman 2008)
 - Not seen with only ocean recoveries (Zeug and Cavallo 2013)
 - Not seen for high flows
- Visual inspection
 - Regional differences
- Similar pattern for I:E

SJR Fall-Run Chinook



DELTA SURVIVAL VS INFLOW: SACRAMENTO

- Positive association between Sacramento River flow and survival to Chipps Island
- Perry 2010 (Late-fall; AT; FL=156 mm)
- Newman 2003 (Fall; CWT; FL = 81 mm)
- Regional variation in relationship
 - Michel et al. 2015 (Late-fall; AT)
 - High flow year vs low flow years:
 - High flow:
 - Higher survival in riverine reaches
 - Not in tidal/estuarine reaches

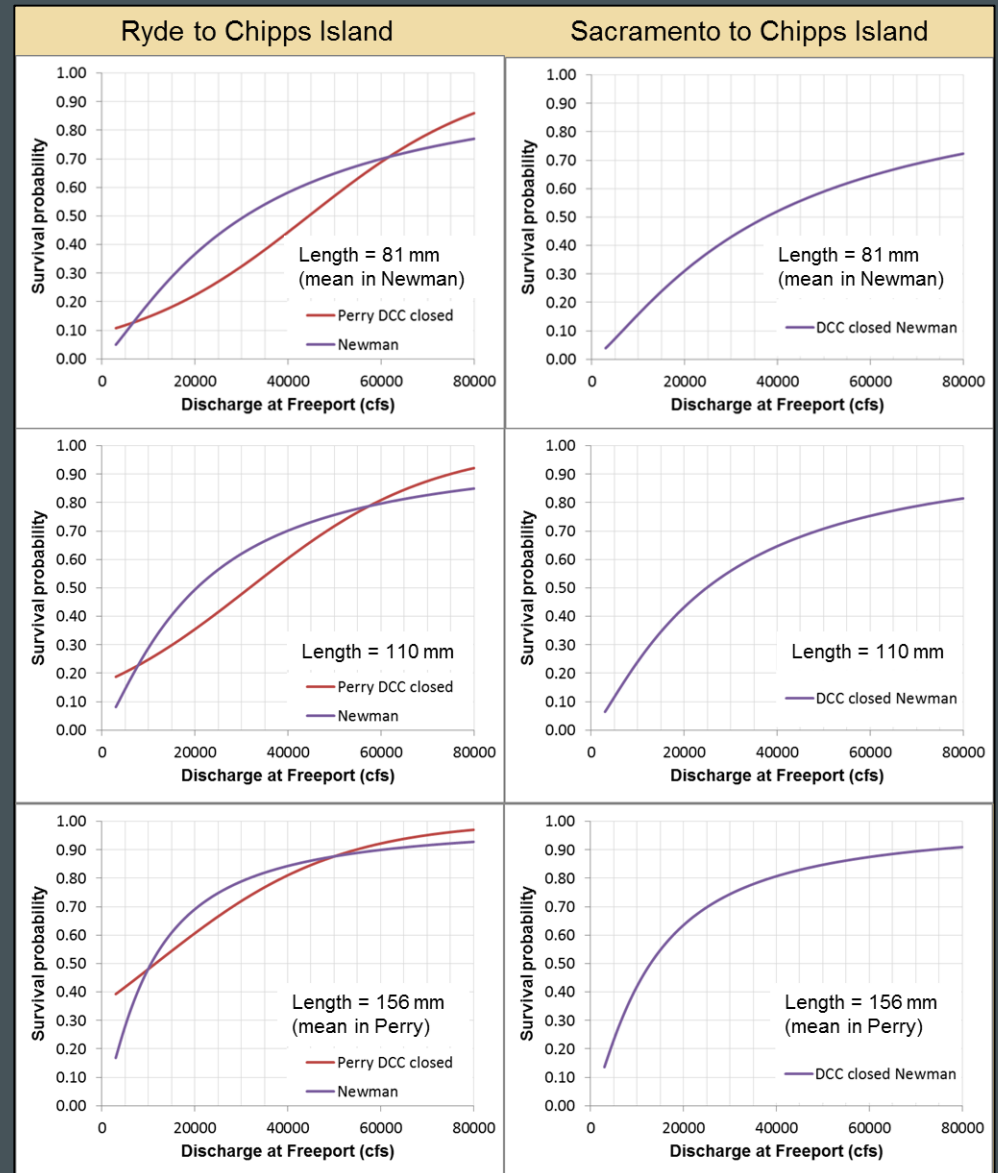
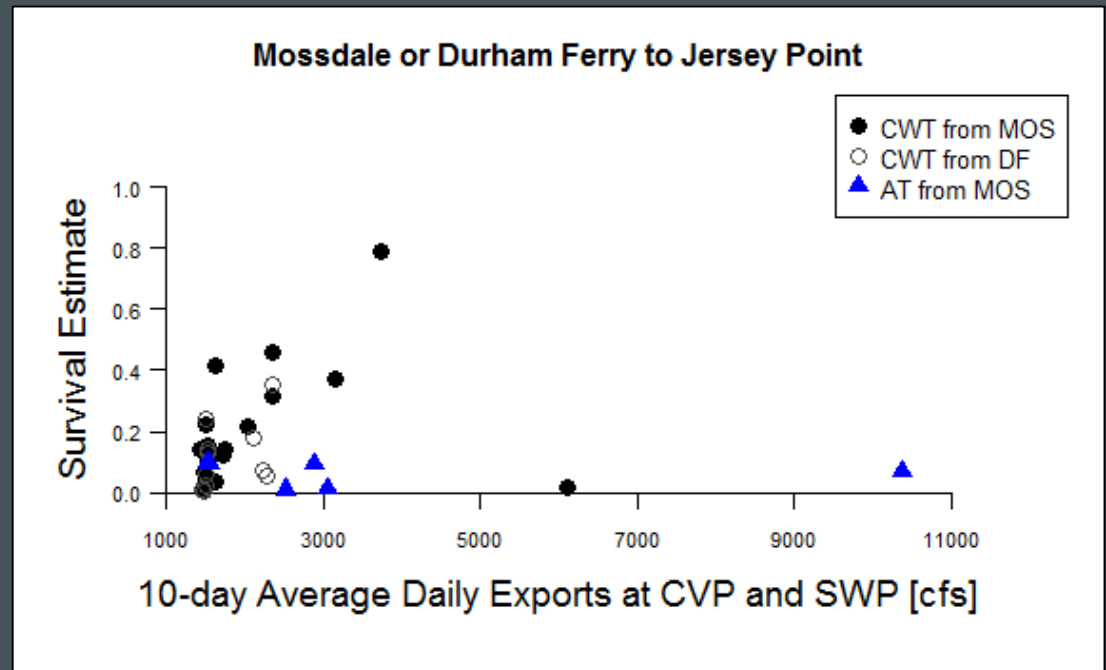


Figure courtesy of Russell Perry, USGS

DELTA SURVIVAL VS EXPORTS: SAN JOAQUIN

SJR Fall-Run Chinook

- Positive association?
 - Fall-run Chinook
 - CWT (Newman 2008; SJRGA 2008)
 - Scatterplots
 - Meaningful?
 - Correlation between inflow and exports?
 - Not observed using ocean recovery rates (Zeug and Cavallo 2013; CWT)
- Low survival for high export rates; few observations



DELTA SURVIVAL VS EXPORTS: SACRAMENTO

- Negative association with Delta survival
 - Fall-run; Delta/ocean recoveries (Newman 2003; CWT)
 - Not observed for late-fall-run (Perry 2010; AT)
- Negative association with relative survival of Interior Delta route to mainstem Sacramento River route
 - Newman and Brandes 2010 (Late-fall; CWT)
 - But non-exports model had comparable weight

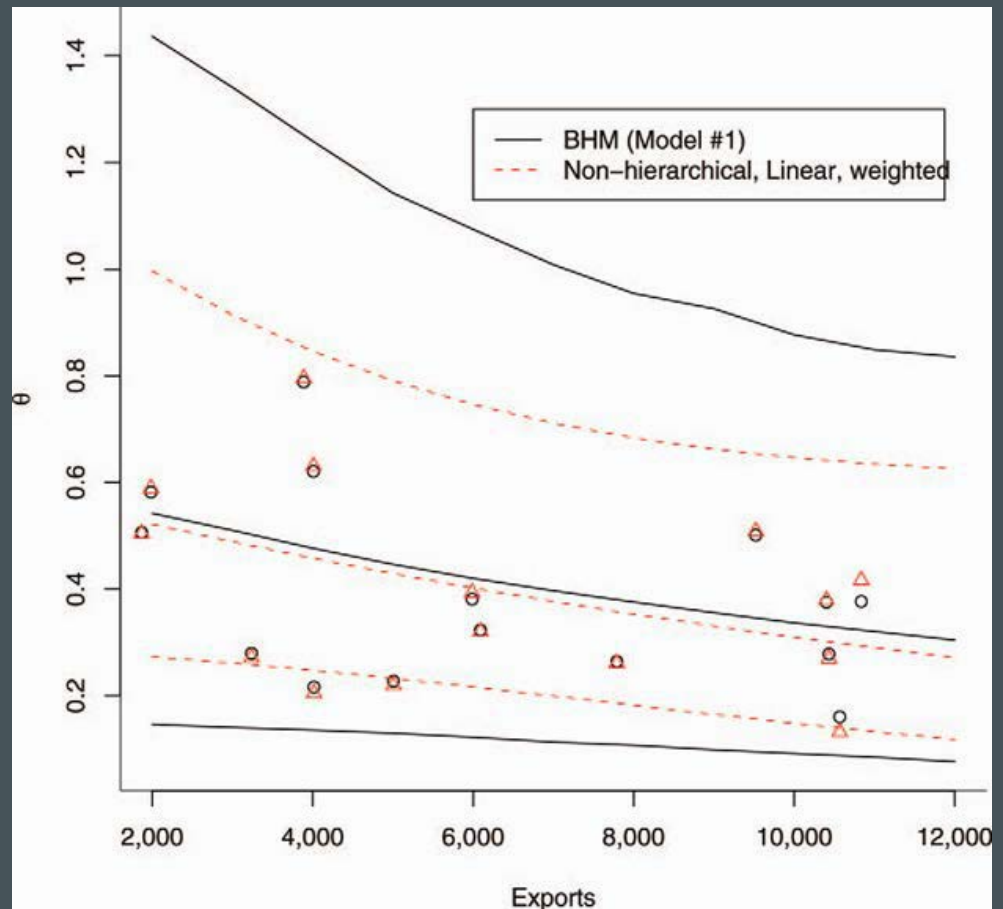


Figure from Newman and Brandes 2010
Relative survival of GS : SAC route

RELATIVE DELTA SURVIVAL VS DELTA E:I

- Sacramento River Chinook
- Negative association between E:I and Delta survival for fall-run
 - Cunningham et al. 2015 (stage-structured life cycle model)
 - Newman and Rice 2002 (small effect, not statistically significant)
- CWT recovery rates: Lack of support for E:I models vs E+I models
 - Newman and Brandes 2010 – late-fall run (Delta + ocean recoveries)
 - Zeug and Cavallo 2014 – fall, late-fall, winter runs (salvage at facilities)

SUMMARY

- Salmon survival in the South Delta is low
 - Especially for San Joaquin River Chinook
 - Spatial variability in survival
 - Route differences in survival? Not consistently
- Relationships between survival and
 - Delta inflow: spatially heterogeneous; inconsistent pattern
 - I:E: similar to Delta inflow
 - Exports: uncertain, not well-supported by data
 - E:I: not well-supported by data

UNCERTAINTIES AND GAPS

- Insufficient data on survival in Delta for steelhead, Sacramento River Chinook (all runs)
- Tagging studies represent only part of life history, populations: smolt-sized hatchery fish
- Limited understanding of indirect effects of water project operations on mortality in Delta
- Formal analysis of relationships between inflow, exports, I:E and survival is incomplete for existing data

CONSTRAINTS ON UNDERSTANDING

- All observations are in the presence of management operations (I:E, E:I, OMR restrictions)
 - → difficult to assess their effectiveness
- There has been low variability and limited replication in conditions during tagging studies
 - Most observations of smolt survival have been at low levels of inflow and exports
- Low overall survival makes it difficult to detect changes in survival
- What is the survival target?
 - Lack biological objectives for Delta survival that we all agree on
 - → difficult to design studies to test effectiveness of management actions

ACKNOWLEDGEMENTS

■ Data and Findings

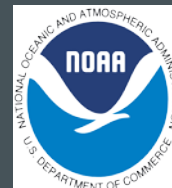
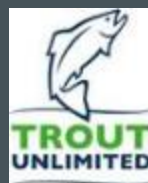
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- Gabriel Singer (UC Davis)
- Ken Newman (USFWS)

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- Chuck Hanson (Hanson Environmental, Inc.)
- Patricia Brandes (USFWS)
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- Shelia Greene (Westlands Water)
- Rene Henery (UNR, Trout Unlimited)
- Joshua Israel (USBR)
- Daniel Kratville (DFW)
- Joe Miller (Anchor QEA)
- Mike Schiewe (Anchor QEA)
- Meiling Roddam (SWRCB)



EXTRAS

LITERATURE

	San Joaquin		Sacramento	
Through-Delta Survival	Brandes and McLain 2001 Newman 2008 SJRGA 2006 – 2013	Holbrook et al, 2009 Buchanan et al. 2013, 2015 Buchanan 2013, 2014 (STH)	Perry 2010 Perry et al. 2010, 2012, 2013	Ammann Singer
Route-Specific Survival	Brandes and McLain 2001 SJRGA 2011 – 2013 Holbrook et al. 2009	Delaney et al. 2012 Buchanan et al. 2013, 2015 Buchanan 2013, 2014 (STH)	Newman and Brandes 2010 Perry 2010 Perry et al. 2010	
Reach-Specific Survival	SJRGA 2010 – 2013 Holbrook et al. 2009	Buchanan et al. 2013, 2015 Buchanan 2013, 2014 (STH)	Perry 2010	
Survival vs. Inflow	Kjelson and Brandes 1989 SJRGA 2007	Newman 2008 Zeug and Cavallo 2013, 2014 Buchanan	Newman and Rice 2002 Newman 2003 Kimmerer 2008 Perry 2010	Perry Michel et al. 2015 Zeug and Cavallo 2013, 2014
Survival vs. Exports	SJRGA 2007 Newman 2008	Zeug and Cavallo 2013, 2014 Buchanan	Newman and Rice 2002 Newman 2003 Newman and Brandes 2010	Perry 2010 Zeug and Cavallo 2013, 2014 Cunningham et al. 2015
Survival vs. I:E or E:I	SJRGA 2007 Zeug and Cavallo 2014	Buchanan	Newman and Rice 2002 Newman and Brandes 2010	Zeug and Cavallo 2014 Cunningham et al. 2015

Journal article
Technical report

Dissertation
Book Chapter

Personal Communication

ADDITIONAL DATA PRESENTATIONS FOR SJR CHINOOK

■ Data

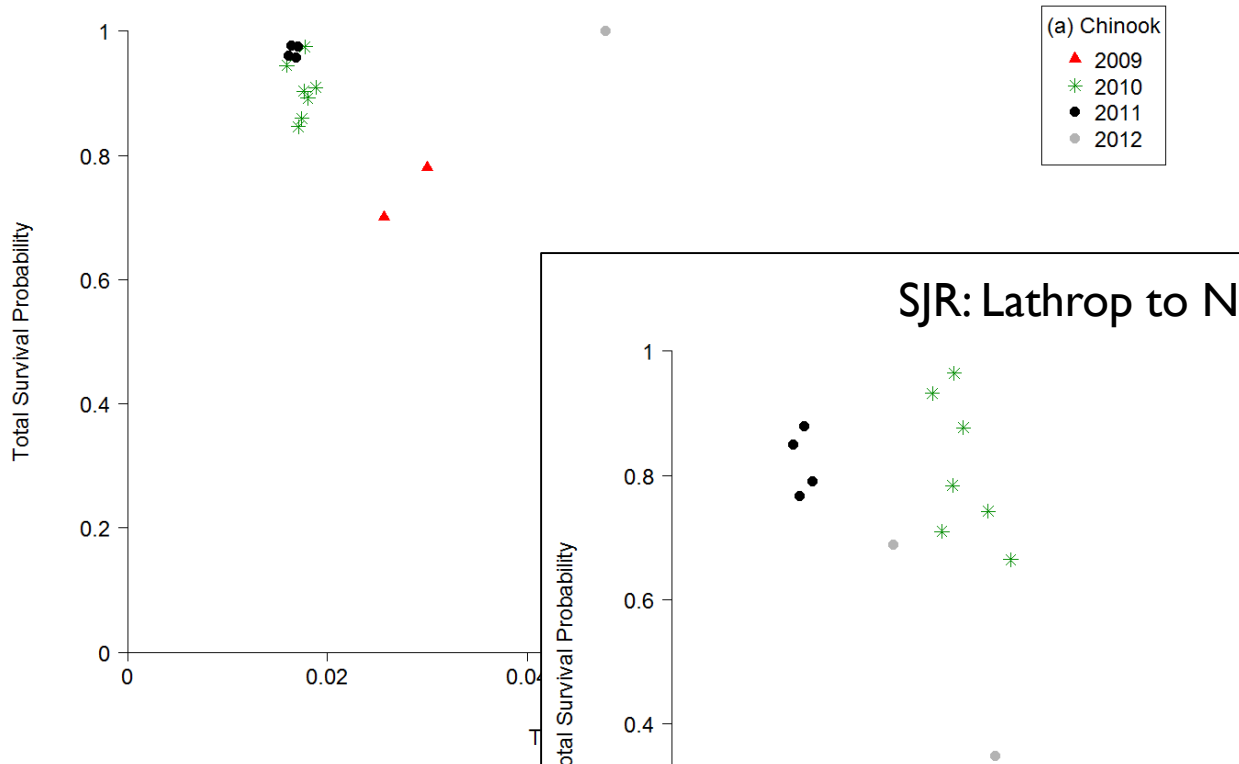
- Coded-wire tag studies: 1994 – 2006 (Brandes and McLain 2001; Newman 2008; VAMP)
- Acoustic-telemetry studies: 2008 – 2012 (VAMP, South Delta Chinook tagging studies)
- Exports, Delta Inflow at Vernalis, I:E
 - Dayflow database
 - 10-day average from start of release

■ Analyses

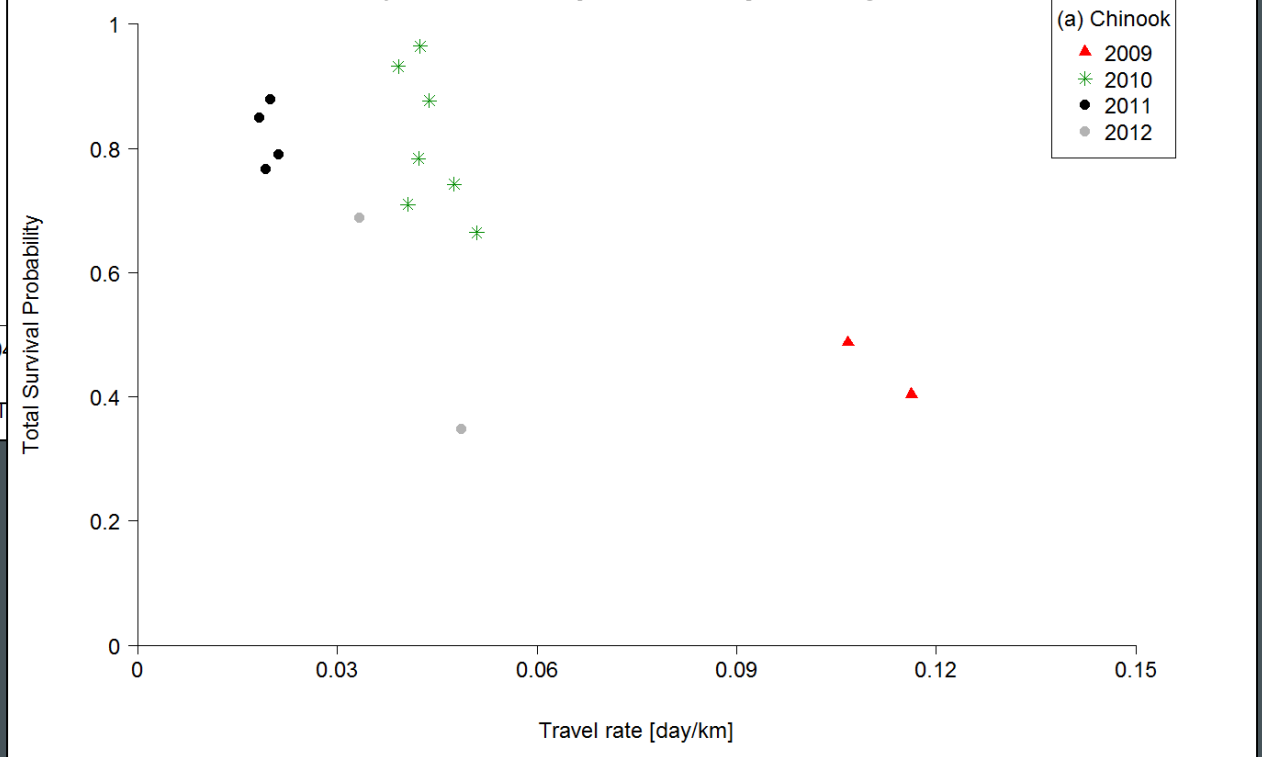
- Visual inspection of graphical results (aka, scatterplots)
- = informal, preliminary results

SURVIVAL VS TRAVEL RATE

OR: Head of Old River to head of Middle River



SJR: Lathrop to Navy Bridge



DELTA SURVIVAL VS SAN JOAQUIN I:E

SJR Fall-Run Chinook

- Positive association for $I:E \leq 3$
- More complex pattern for $I:E > 3$
 - Real complexity?
 - Natural variability and few observations?
 - Difficult to interpret effects of ratio
- Regional differences
 - Similar to inflow pattern

