Data Analyses in Relation to Water Flow for Species in the Sacramento-San Joaquin Delta

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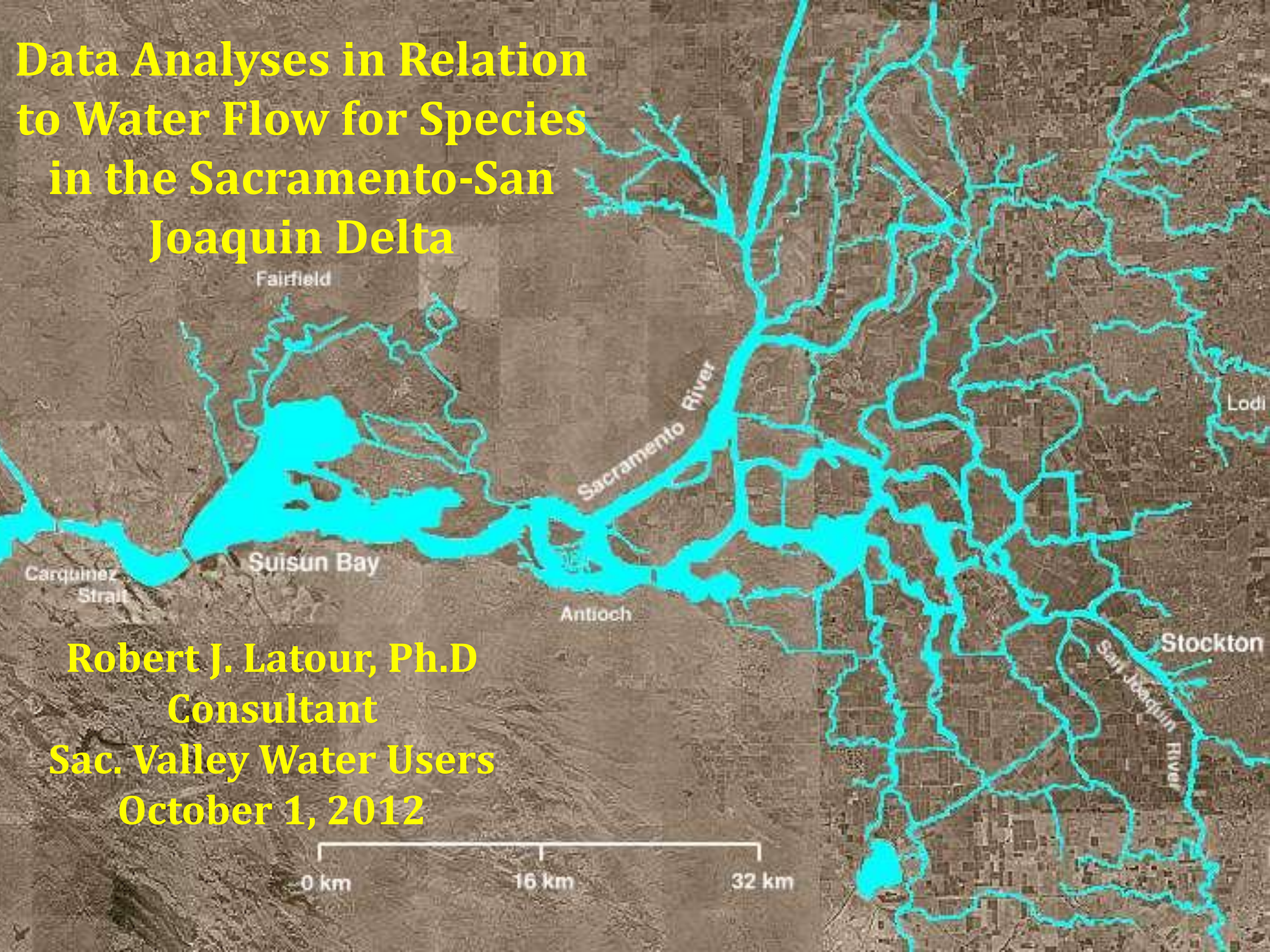


Professional Background

- Ph.D., Biomathematics, North Carolina State University
- Associate Professor, Department of Fisheries Science, Virginia Institute of Marine Science (VIMS)
- VIMS' mission: research, education, advisory service
  - School of Marine Science, College of William & Mary
  - Virginia state agency – Dep't of Fisheries Science
    - Implement fish monitoring
    - Provide scientific support to regulatory agencies
- VIMS uses surveys as platforms for state and regional fish research

Research, Education   Products for management

  - ChesMMAP – mainstem Chesapeake Bay
  - NEAMAP – coastal Atlantic, NC to New England

Chesapeake Bay

Methods to Improve Understanding of Fish Populations

- ***Apply standard catch-per-trawl-tow analysis to DFG raw fall mid-water trawl (FMWT) data***
  - Existing FMWT abundance index is based on (average fish caught) x (water volume), so index values are difficult to interpret

Delta smelt

- No documented understanding of how the number of fish caught per individual trawl tow relates to different environmental variables
- None of the variables considered, including spring flows, explain much of the overall variation in trawl data for pelagic fishes
- *Year* is a 'better' predictor of pelagic abundance than spring flow – *Year is* a composite of environmental conditions in a given year
- *Different fish species have varying relationships with different flow variables*
  - Wide range of trawl catches at different levels of flow
  - Delta smelt abundance has an inverse relationship with the "best" fitting spring flow variable
- *Turbidity has a stronger relationship with pelagic fish abundance than flow does*
  - Turbidity coefficient is twice as large as 'best' fitting flow variable for longfin

Methods to Improve Understanding of Fish Populations (cont)

Longfin smelt

- ***Further catch-per-tow analyses could:***
  - *Identify broad temporal/spatial shifts in habitat use over 1967-2010 FMWT period*
  - *Analyze turbidity-abundance relationship with more robust turbidity data*: literature indicates significant reductions in Delta turbidity occurred concurrent with pelagic fish population declines

- ***Reallocate existing resources to maximize information gathered by FMWT***
  - *FWMT catches very few of target species per trawl:* 1967-2010 average = 0.17 delta smelt per tow
  - Similar trawls in Chesapeake Bay catch 10-20 of target species per tow
  - It may be possible to reduce number of tows without increasing error of indices and reallocate resources to pilot trawl projects:
    - *Sample more locations and more depths to identify changes in habitat use*
    - *Investigate diel movements*
    - *Investigate trawl net performance*

Scope of Analysis

- Address workshop notice's questions about uncertainty in 2010 Delta flow criteria report analysis and new information

- Articles suggest a positive relationship between flow and abundance:
  - Jassby et al. 1995; Kimmerer 2002: X2 ↑ leads to a ↓ in species relative abundance
  - Sommer et al. 2007: ↑ flow leads to ↑ species relative abundance

Threadfin shad

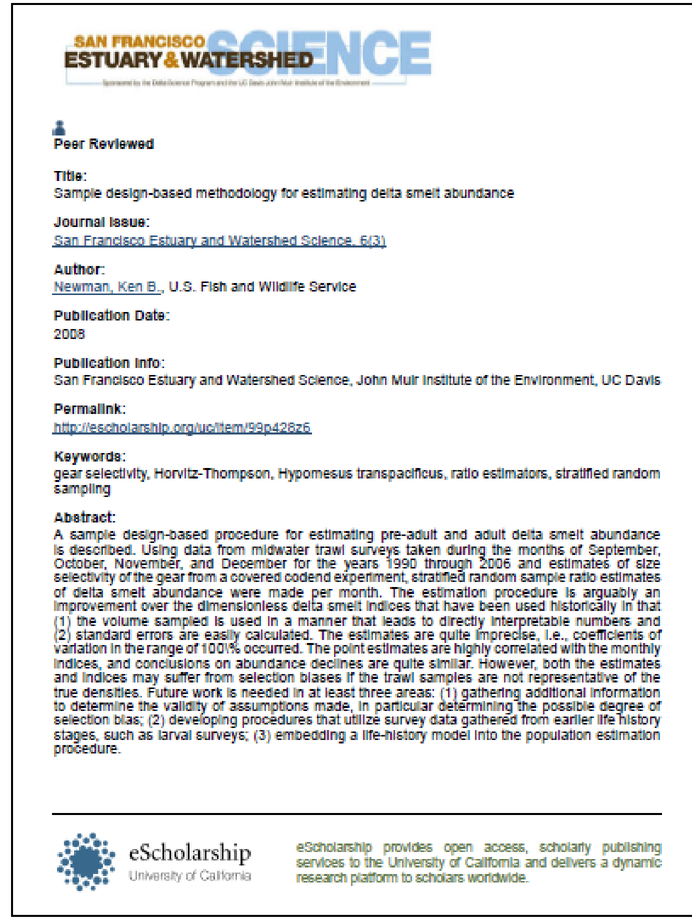
- Prior analyses based on abundance indices or coarse metrics of catch-per-trawl based on DFG FMWT survey data

- Issues analyzed:
  - Uncertainties in FMWT survey methodology and DFG abundance indices
  - Analysis of FWMT survey data to provide standardized abundance estimates and error margins (estimates of precision)
  - Application of standard statistical methods to analyze relationships between raw of catch-per-trawl data and spring flow variables

- Develop recommendations for further analysis with existing resources

Initial Impressions & Analytical Direction

- ***Uncertainty in FMWT abundance indices***
  - FMWT abundance index difficult to interpret because it is based on (fish caught) x (water volume) – What does change from 11864 to 7408 (fish caught) x (water volume) mean?
  - Index has no estimate of error range
- ***Apply statistical models to raw data to address FMWT issues***
  - Reliance on USFWS work, paper by USFWS biologist (Newman 2008) similarly identified constraints with FMWT
  - Newman (2008) suggested statistical models with additional covariates for better understanding of FMWT data


SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Peer Reviewed

Title:
Sample design-based methodology for estimating delta smelt abundance

Journal Issue:
San Francisco Estuary and Watershed Science, 6(3)

Author:
Newman, Ken B., U.S. Fish and Wildlife Service

Publication Date:
2008

Publication Info:
San Francisco Estuary and Watershed Science, John Muir Institute of the Environment, UC Davis

Permalink:
http://escholarship.org/uc/item/99p428z6

Keywords:
gear selectivity, Horvitz-Thompson, Hypomesus transpacificus, ratio estimators, stratified random sampling

Abstract:
A sample design-based procedure for estimating pre-adult and adult delta smelt abundance is described. Using data from midwater trawl surveys taken during the months of September, October, November, and December for the years 1990 through 2006 and estimates of size selectivity of the gear from a covered codend experiment, stratified random sample ratio estimates of delta smelt abundance were made per month. The estimation procedure is arguably an improvement over the dimensionless delta smelt indices that have been used historically in that (1) the volume sampled is used in a manner that leads to directly interpretable numbers and (2) standard errors are easily calculated. The estimates are quite imprecise, i.e., coefficients of variation in the range of 100\% occurred. The point estimates are highly correlated with the monthly indices, and conclusions on abundance declines are quite similar. However, both the estimates and indices may suffer from selection biases if the trawl samples are not representative of the true densities. Future work is needed in at least three areas: (1) gathering additional information to determine the validity of assumptions made, in particular determining the possible degree of selection bias; (2) developing procedures that utilize survey data gathered from earlier life history stages, such as larval surveys; (3) embedding a life-history model into the population estimation procedure.

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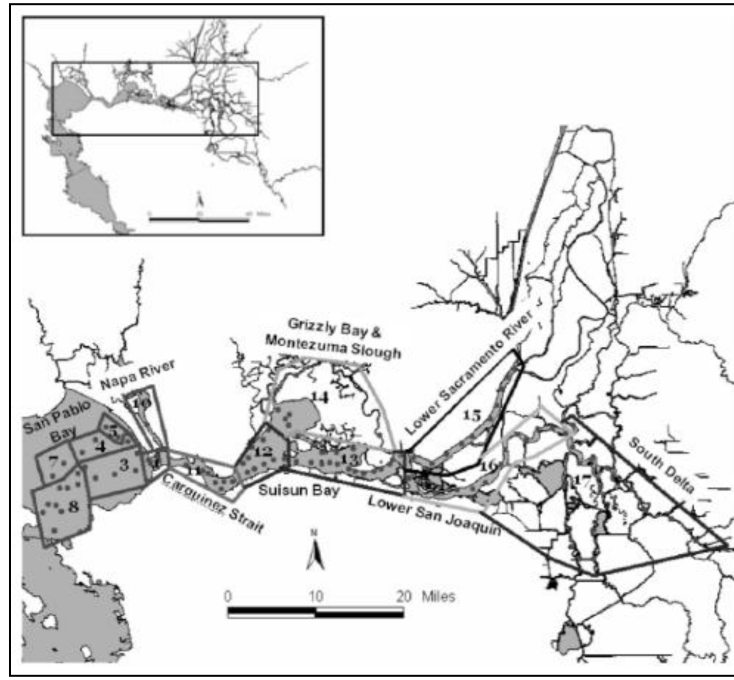
Initial Impressions

- ***Uncertainties in FMWT data***
  - ***Low catch rates of target species.*** **1967-2010 averages:**
    - Delta smelt: 0.17 fish-per-tow
    - Splittail: 0.02 fish-per-tow
    - Starry flounder: 0.04 fish-per-tow
    - *Compare:* VIMS Juvenile Finfish Trawl Survey – since 1950s, 20 and 10 fish-per-tow of targeted species
  - ***FMWT does not account for habitat changes***
    - fixed sampling stations that would not identify changes in habitat use
  - ***Submissions to SWRCB show changes in habitat use***
    - Independent science panel, p. 8



Newman 2008

Independent Science Panel:

"[L]ongfin smelt distribution has shifted to downstream bays and into deeper waters"

"While the center of distribution of delta smelt is still in the low-salinity zone, the species has shown evidence of increasing use of Cache Slough Complex in the north Delta."

"Threadfin shad center of distribution used to be in the south Delta . . ., but the species has recently been concentrated in the Sacramento Deep Water Ship Channel"

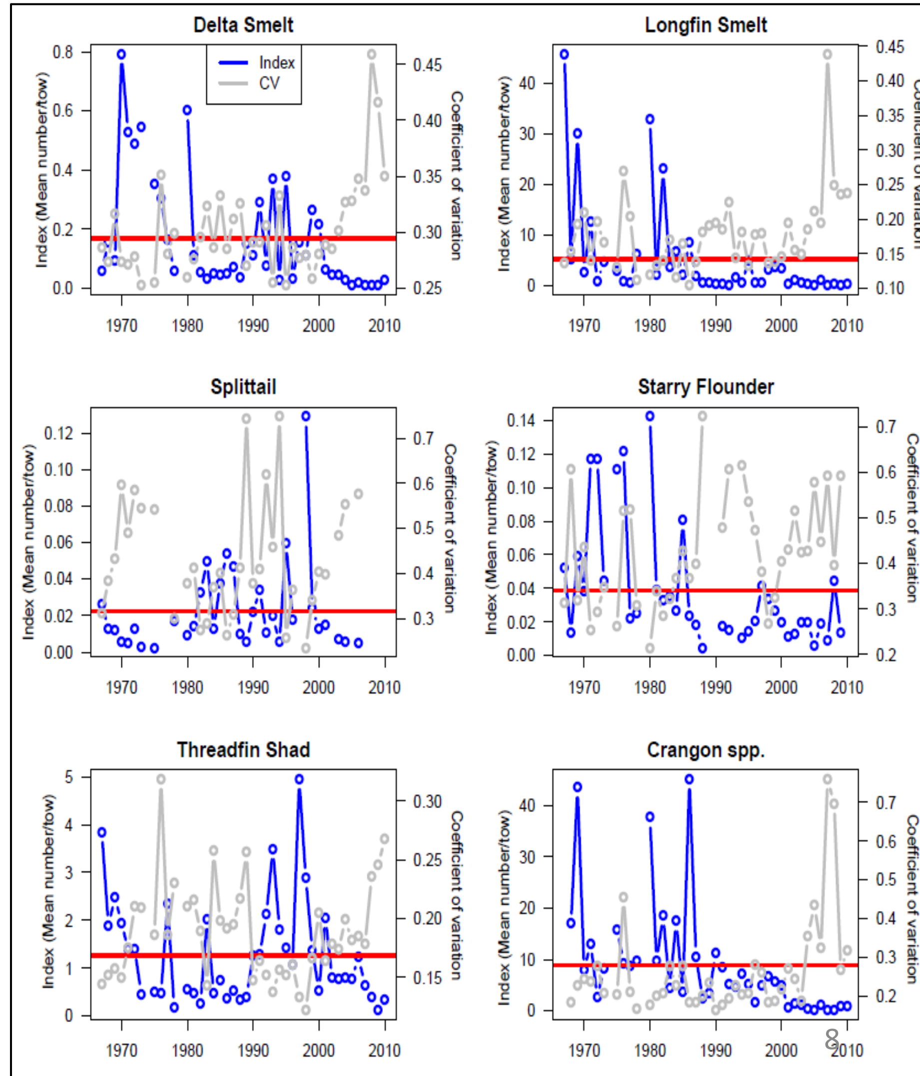
Statistical Analysis – Initial Steps

- Applied generalized linear model (GLM) to FMWT data
  - GLMs commonly are used to derive abundance indices (mean catch-per-tow) and to examine significance of covariates like flow and turbidity

- Due to low encounter-per-tow, I analyzed raw FMWT data in two categories:
  - *Likelihood of catching at least one fish of a species* (presence/absence – binomial)
  - *No. of fish caught on successful tows* (relative abundance – lognormal)

- The following covariates all were statistically significant
  - *Year*: discernible trends in catch-per-tow over years
  - *Month*: differing catch-per-tow results in different months
  - *Area*: differing catch-per-tow results due to location of tow within Delta
  - *Secchi*: ↑ catch-per-tow with ↑ turbidity

- Coefficients of variation (CV) are acceptable to support analyses



Statistical Analysis – 'Best' Fitting Flow Covariates

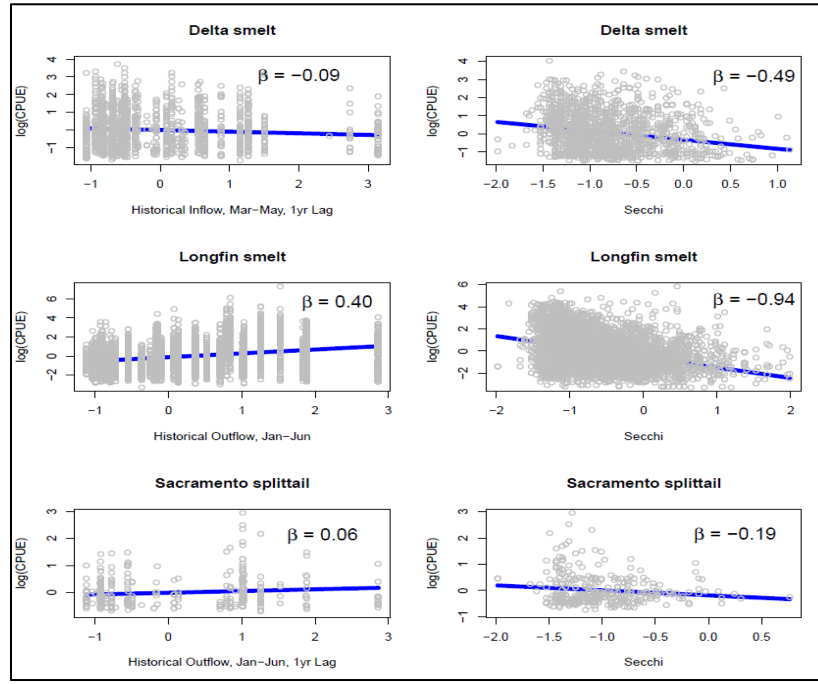
- Substituted 16 different 'spring' flow variables for *Year* in statistical analysis
- Different 'spring' flow covariates were the 'best' fit for different species and for presence/ absence and abundance

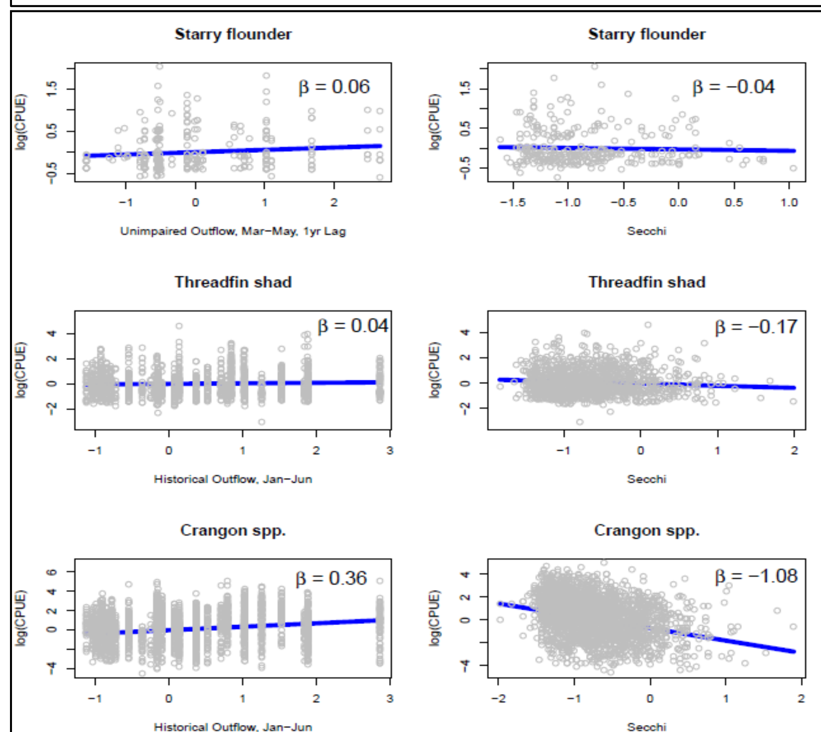
Species	Presence/Absence (Binomial ΔAIC=0)	Abundance (Lognormal ΔAIC=0)
Delta smelt	Unimpaired Inflow, Jan-Jun	Historical Inflow, Mar-May, 1yr Lag
Longfin smelt	Unimpaired Inflow, Jan-Jun	Historical Outflow, Jan-Jun
Sacramento splittail	Unimpaired Inflow, Jan-Jun	Historical Outflow, Jan-Jun, 1yr Lag
Starry flounder	Historical Outflow, Jan-Jun	Unimpaired Outflow, Mar-May
Threadfin shad	Historical Outflow, Jan-Jun	Historical Outflow, Jan-Jun
Crangon spp.	Unimpaired Outflow, Mar-May	Historical Outflow, Jan-Jun

- *Unimpaired flow* covariates were most common 'best' fitting covariate
  - *Unimpaired flow* is calculated, not actual, flow
  - 'Best' fit does not guarantee any particular level of biological response

Statistical Analysis – Flows

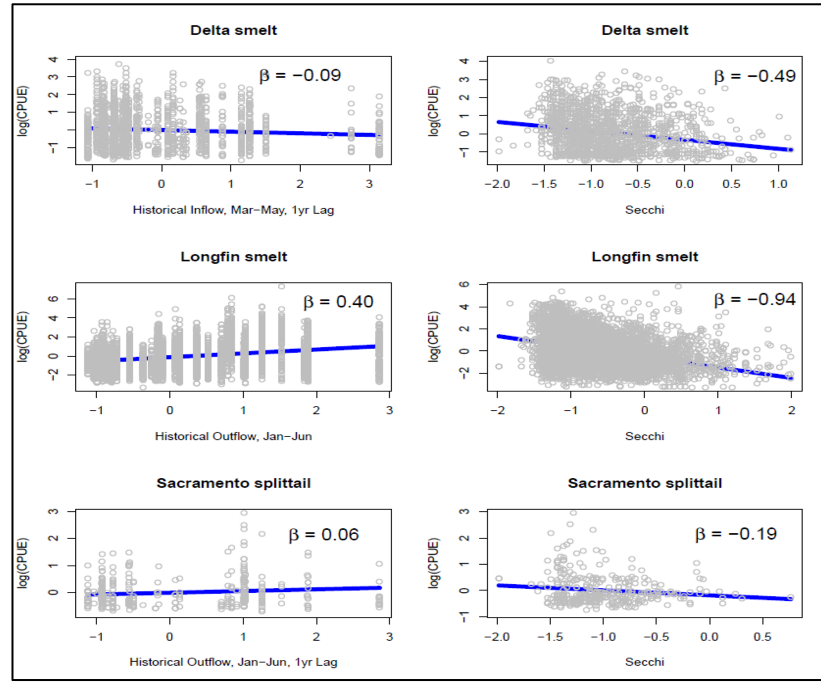
- ***CPUE analysis shows widely variable flow-abundance relationships, with turbidity relating more strongly to relative abundance***
  - Flow relationships based only the small portion of tows that actually caught the target species
  - 'Best' fitting spring flow variables show widely varying relationships with trawl catches
  - 'Best' fitting flow variable was different for different species

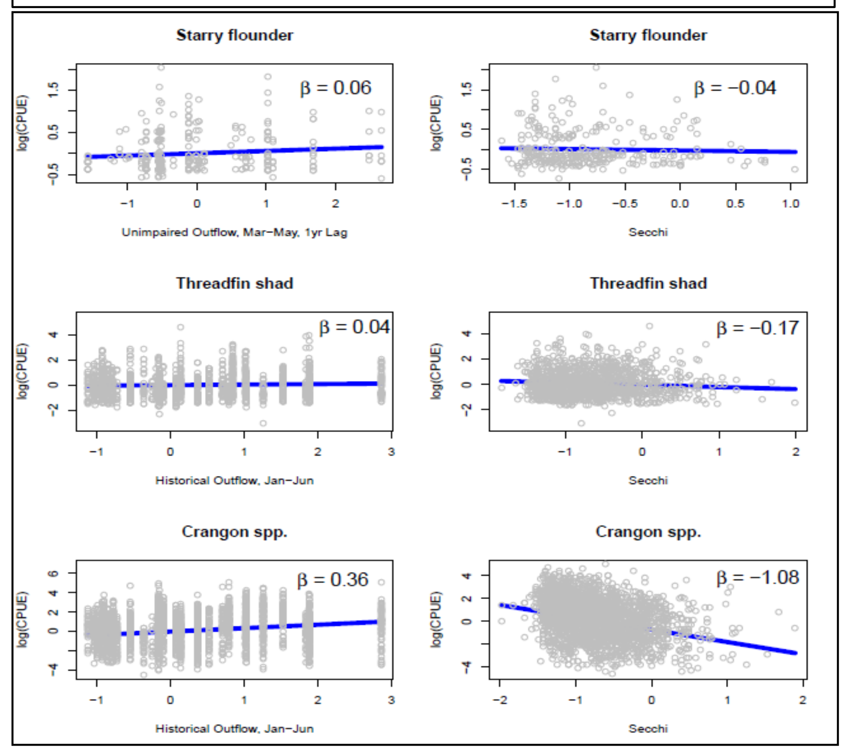




Statistical Analysis – Flows (cont)

- ***No flow variable explains much of the variation in pelagic fish catch data***
  - Statistically significant relationships exist, i.e., coefficients are different than 0. Statistical significance does not always equal biological significance
  - The high degree of variability at each flow level means that flow levels, by themselves, do not have much biological significance
  - Specifically, flow variables' very small coefficients indicate that spring flow does not strongly relate to fish catch

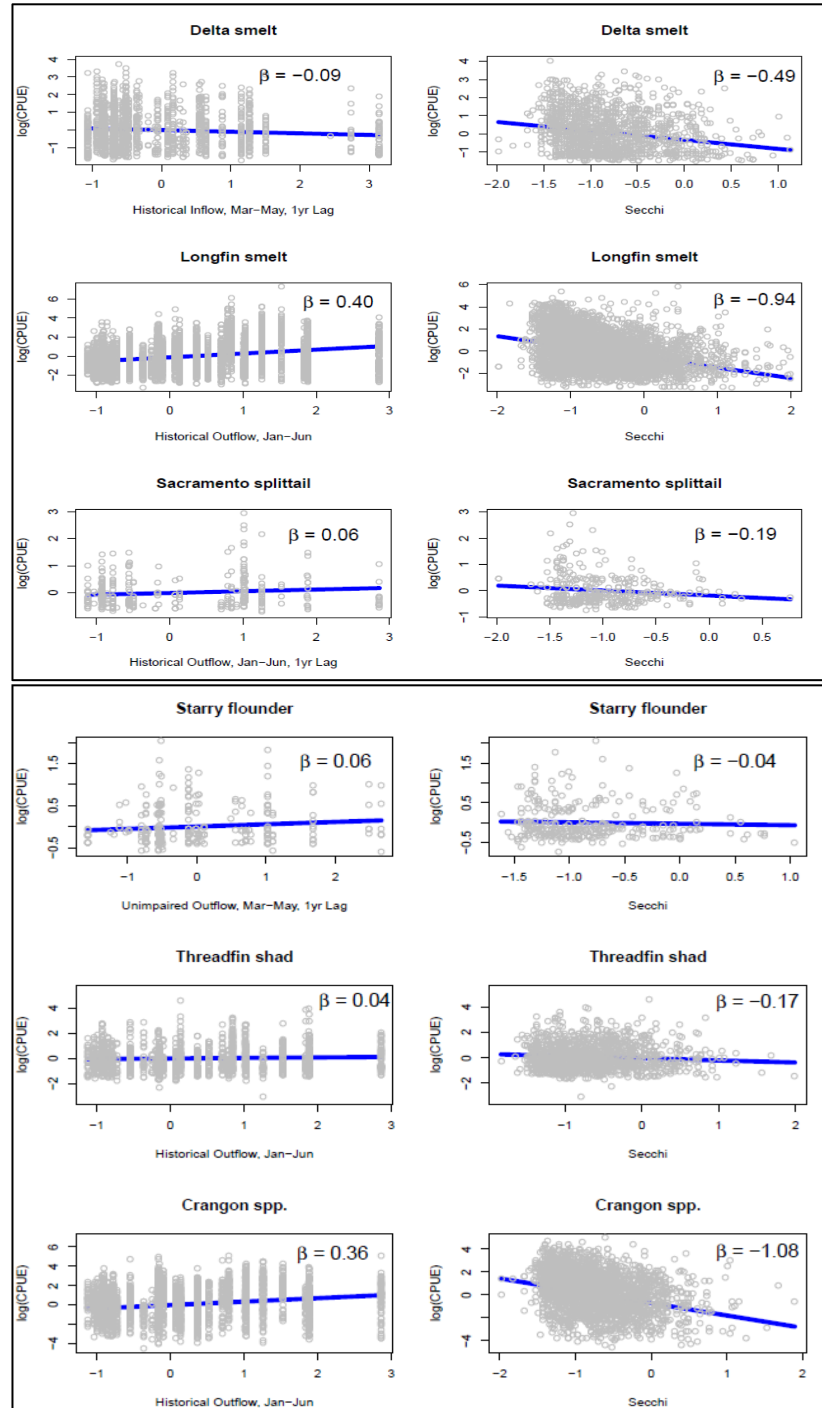




Statistical Analysis – Flows (cont)

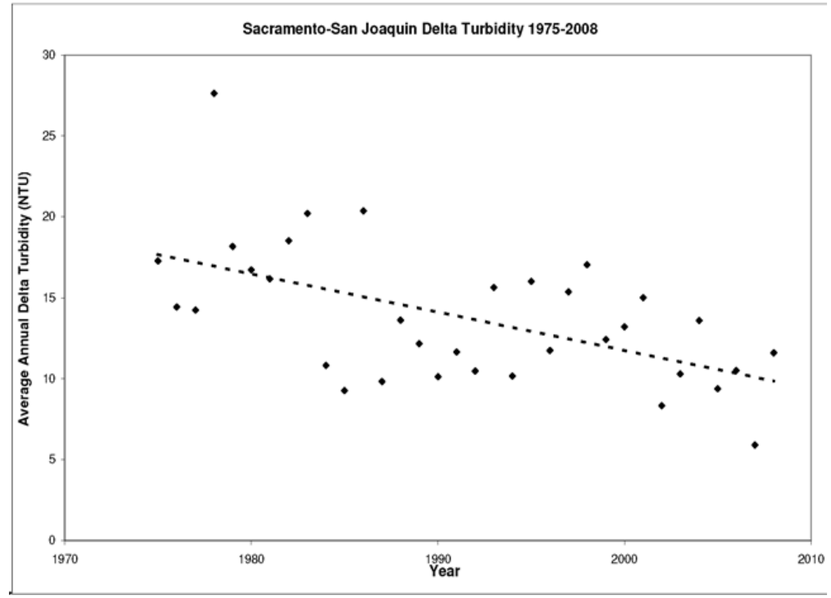
- ***Different species have different relationships with 'best' fit spring flow variable***
  - Delta smelt's abundance has an inverse relationship with 'best' fit flow variable
  - Longfin smelt's abundance relationship with turbidity is double its relationship with the 'best' fit flow variable

- ***Turbidity consistently has a stronger relationship (i.e., higher β) with abundance than flow does***
  - Lower Secchi depth means higher turbidity
  - Turbidity has a positive relationship with abundance



Statistical Analysis – Turbidity

- ***Turbidity has stronger relationship with abundance than flow does***
  - Turbidity-abundance relationship is at least twice as strong as flow-abundance relationship
- ***Delta turbidity has declined significantly as pelagic fish populations have declined***
  - 40% turbidity decline 1975-2008
  - Step-decline in Delta turbidity in late 1990s
- ***Turbidity may affect pelagic fish abundance and surveys in many ways – higher turbidity means:***
  - Decreased predation
  - Higher primary productivity
  - Decreased gear avoidance



Cloern et al. 2011

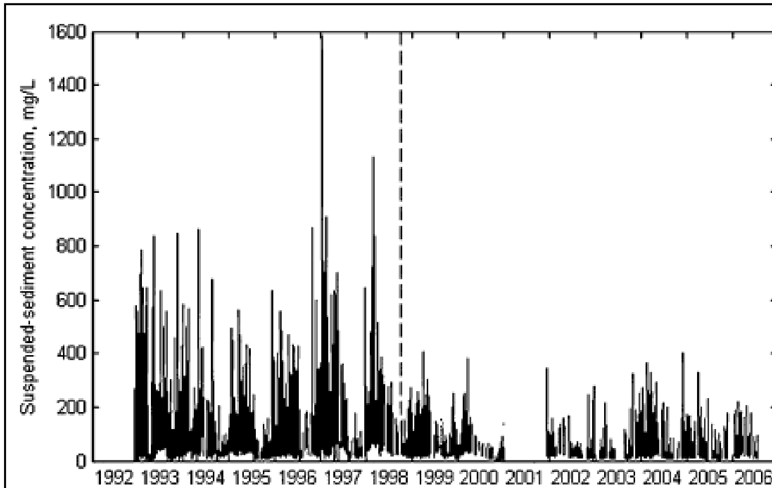


Fig. 4 Suspended-sediment concentration, mid-depth, Point San Pablo. The *vertical dashed line* indicates when the step decrease occurred

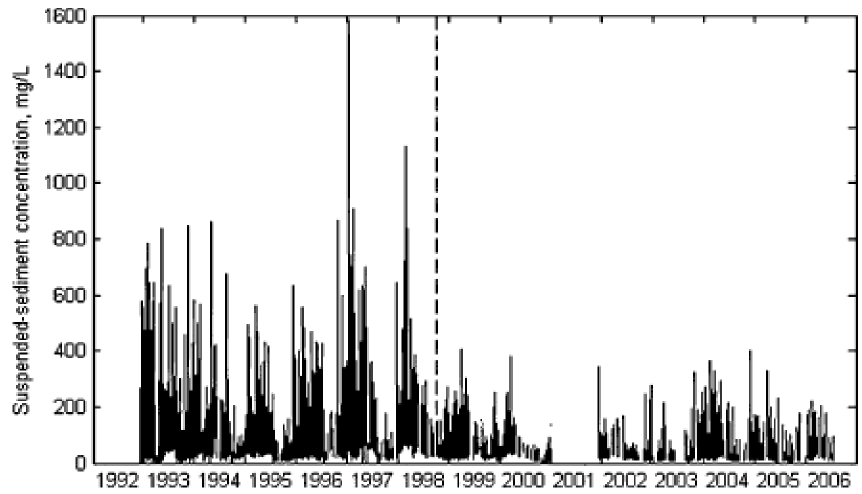
Schoellhamer 2011

Recommendations – Existing Data

- ***SWRCB could further analyze existing data to identify trends and most important habitat and implementation measures***

- ***Turbidity – SWRCB should investigate with more robust turbidity data***
  - *Secchi* is a coarse measure of turbidity
  - More robust data is available – Schoellhamer (2011) uses total suspended solids data

- ***Habitat use – trends in FMWT catch data***
  - Analyzing trends in *Region* factor in FMWT data could identify changing habitat use and subregions for specific attention
  - Changes in distribution noted by science panel



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Schoellhamer 2011

Independent Science Panel (*p 8*):

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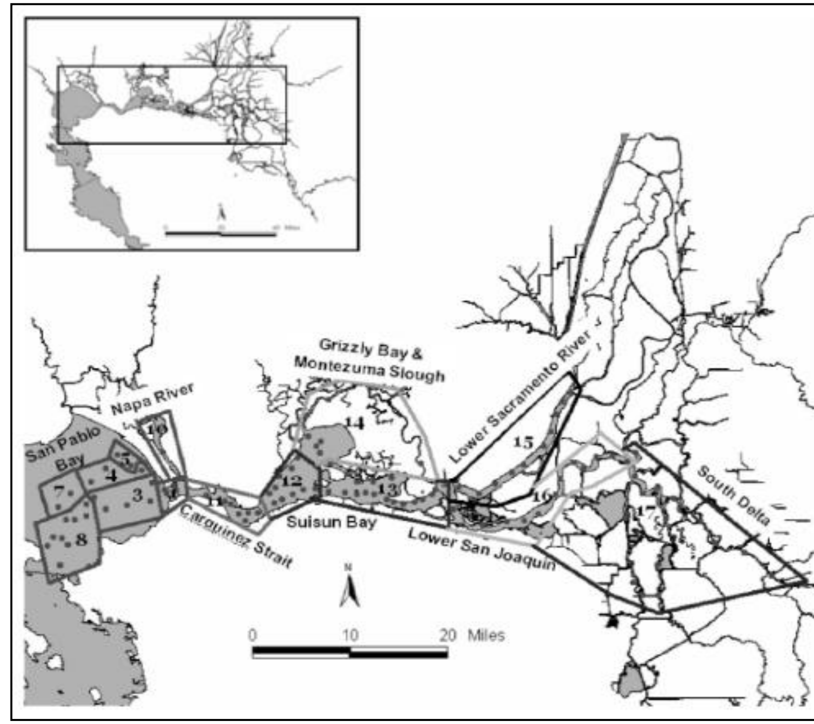
Recommendations – Existing Resources

- ***DFG may be able to reduce FMWT tows without increasing sampling error and reallocate resources to pilot and additional studies***
- ***Pilot studies***
  - Additional locations/depths/habitats to assess any changes in habitat use
  - Trawl net performance in variable conditions (flume tank tests)
- ***Changes to FWMT trawls***
  - Expand trawl hours to assess diel movements and differential tow success
  - For example, add plankton sampling



Centre for Sustainable Aquatic Resources, Memorial University, Newfoundland

Conclusions

- ***Uncertainties in FMWT Abundance Index***

    - FMWT does not capture changes in habitat use – independent science panel shows changes in habitat use by several species

    - FMWT abundance index difficult to understand. What does change from 11864 to 7408 (fish caught) x (water sampled) mean?

    - No estimate of error range in abundance index

    - FMWT catches very few of target species per tow

- ***Statistical CPUE analysis based on FMWT raw data indicates widely variable flow-abundance relationships and that turbidity has better relationship with abundance than flow does***

    - No flow variable explains much of the variation in pelagic fish abundance

    - 'Best' fit flow variable is different for different species

    - Small and variable relationships between catch and flow covariates – A small, but inverse, relationship exists between delta smelt and 'best' fit spring flow variable

    - Turbidity consistently has a stronger relationship to abundance than flow does