# San Francisco Bay Delta Ecosystem Changes & the Low Salinity Zone

SWRCB San Francisco Estuary low-salinity zone workshop

# California Department of Fish & Game

September 5, 2012

# KEY POINTS

**(P. Coulston (DFG), SWRCB Workshop I, 9/5/12)**

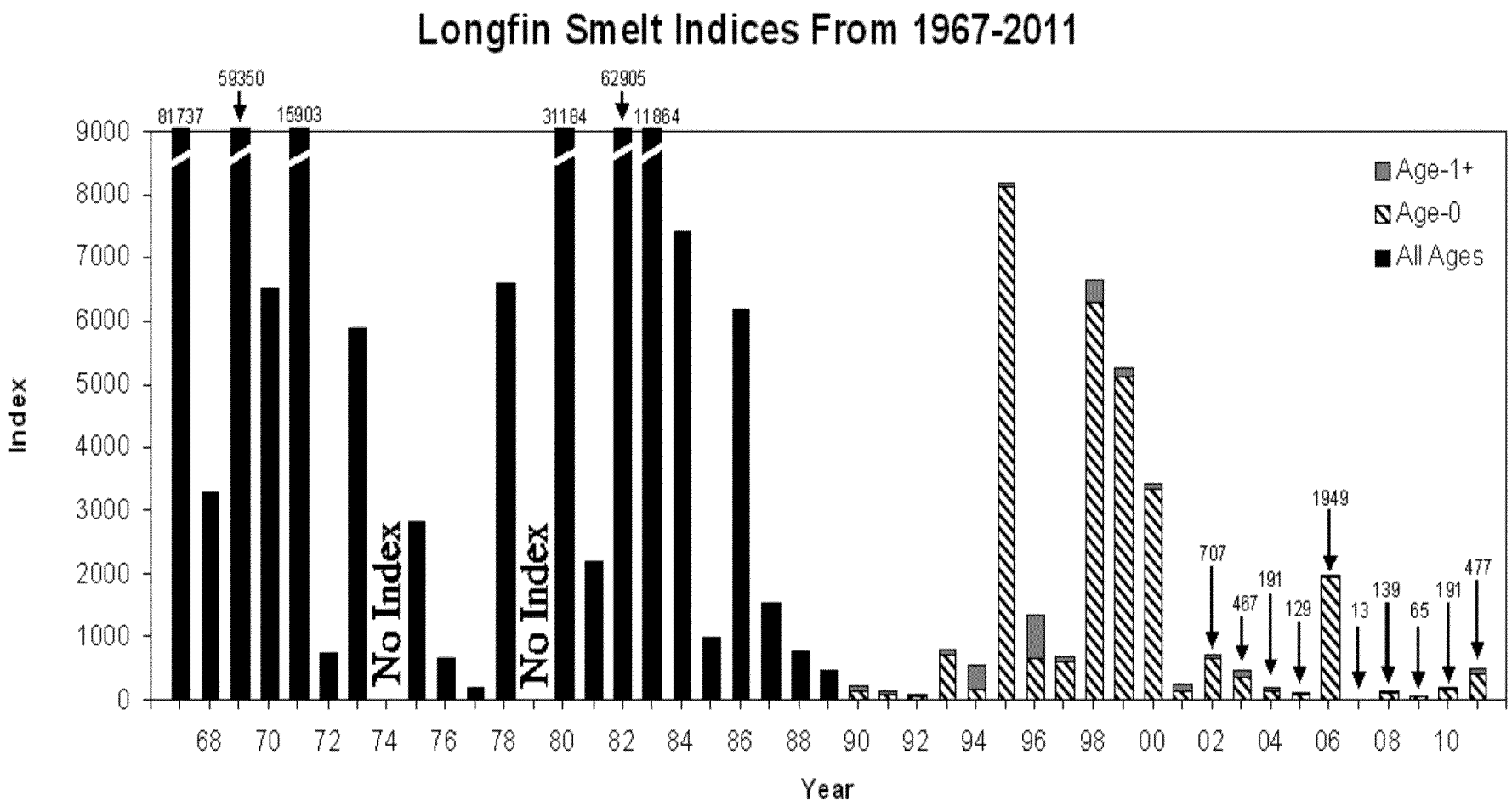
- Delta smelt (DS) and longfin smelt (LFS) are at risk
- Extensive new information available and emerging
- Delta outflow impairment levels threaten LFS viability
- Trends in fall LSZ habitat threaten DS viability
- LSZ and key species respond positively to Delta outflow
- Bay-Delta Plan insufficiently protective of smelt species
- 2011 exhibits the potential of improved Plan objectives
- Consider the “bay” species

## SMELT SPECIES ARE AT RISK:

# LISTING ACTIONS SINCE 2006

- January 2010: Delta smelt moved from threatened to endangered status under CESA
- April 2010: USFWS finds that delta smelt warrant endangered status under federal ESA
- April 2010: Longfin smelt listed as threatened under CESA
- April 2012: USFWS finds that the listing of the longfin smelt Bay-Delta DPS is warranted

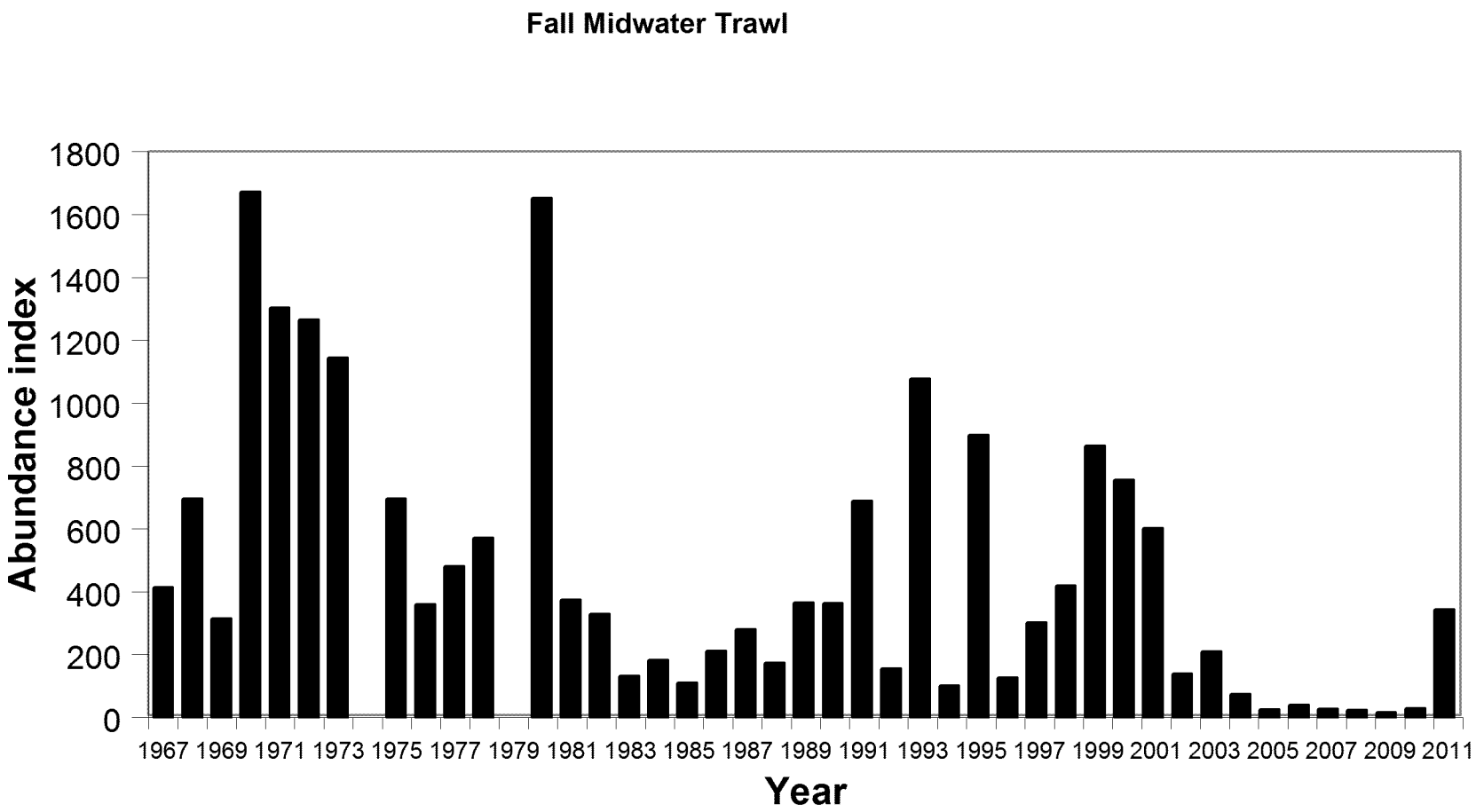
# SMELT SPECIES ARE AT RISK:
# Longfin Smelt Status



# Current (2006) BP objectives appear insufficiently protective of LFS population viability

- LFS production responds strongly and positively to winter-spring outflow, particularly spring flows
- Impairment of spring (March-May) outflow has been substantial ( (6 to 82%, avg.= 56%, 1982-2003)
- Current levels of outflow impairment likely, substantially limit annual LFS (and prey) production in many years
- Current BP objectives allow for very high levels of outflow impairment
- Annual LFS production levels are fluctuating (with flow) at very low levels
- LFS may seldom experience cohort-over-cohort population growth, arguably threatening viability
- Modest flow response in 2011

# SMELT SPECIES ARE AT RISK:
# Delta Smelt Status

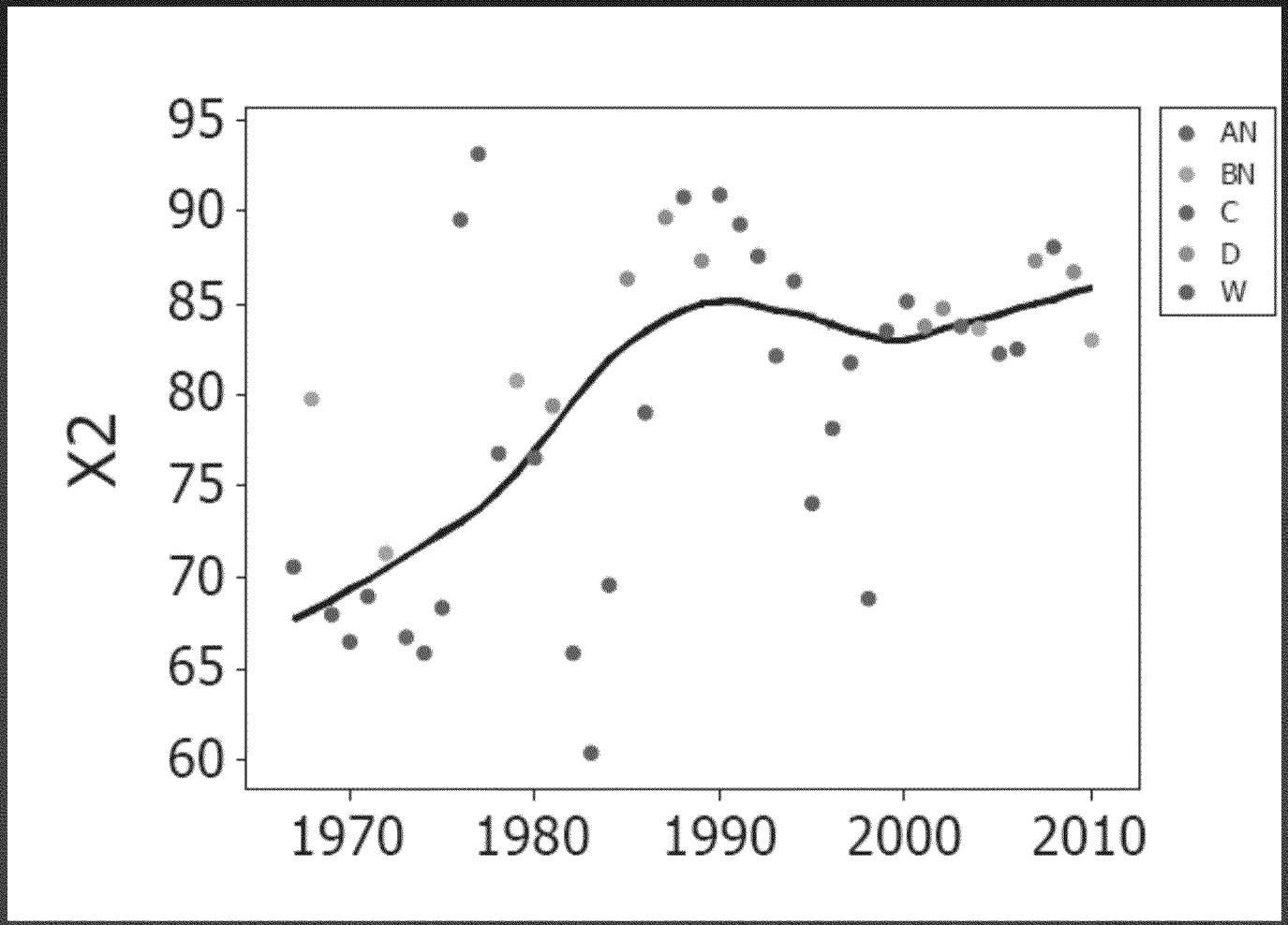


# Detrimental Fall Habitat Conditions appear to Threaten Delta Smelt Viability

- Delta smelt live primarily within the LSZ
- Fall indices recently ~10% of previous 30 years
- Increased frequency of record low indices
- Summer – Fall LSZ position influences cohort survival
- Striking detrimental trends are evident in fall X2 position, thus LSZ extent and condition.
- BP summer-fall outflow objectives do not guard against high summer-fall X2, irrespective of water year type
- Encouraging “bump” in fall 2011 index

# Recent History of Fall X2

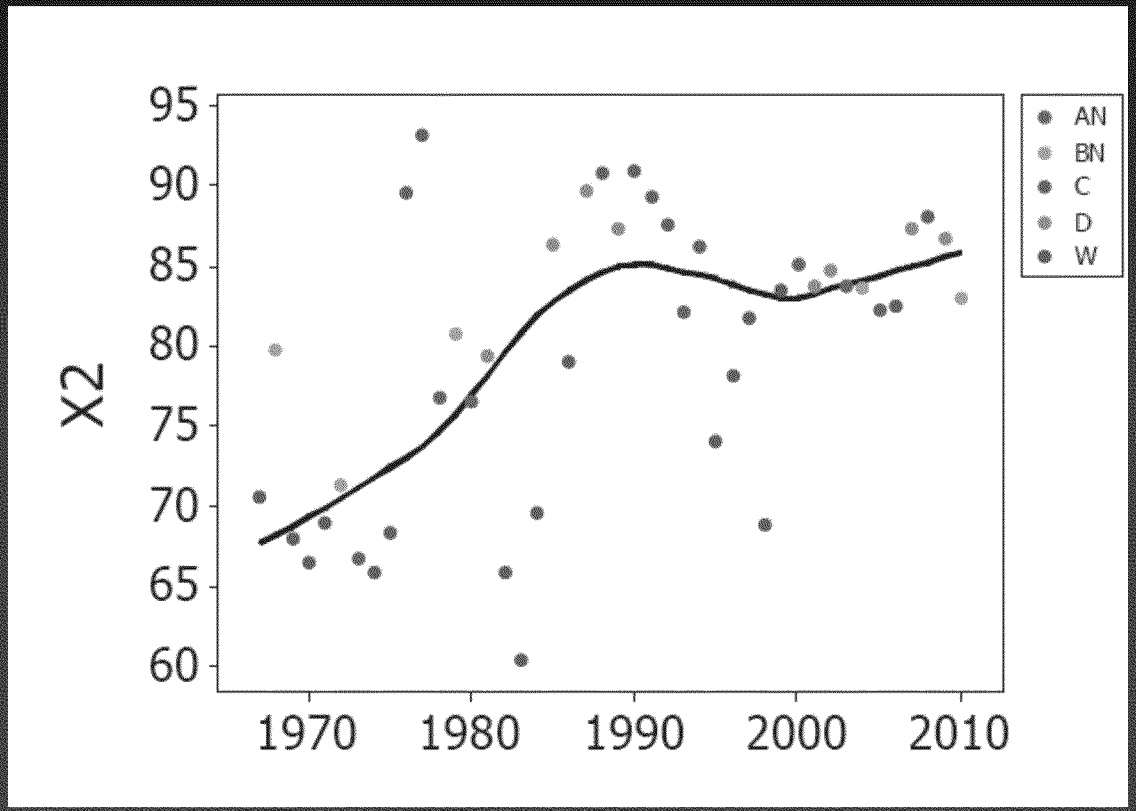
## (Avg. Sept.-Dec. X2)




Adapted from F. Feyrer 9/7/11 testimony during litigation of 2008 BO RPA_

# DS Recruitment in Relation to Fall X2

## (Avg. Sept.-Dec. X2)




Recruitment Progression (FMWT > 20mm > FMWT)

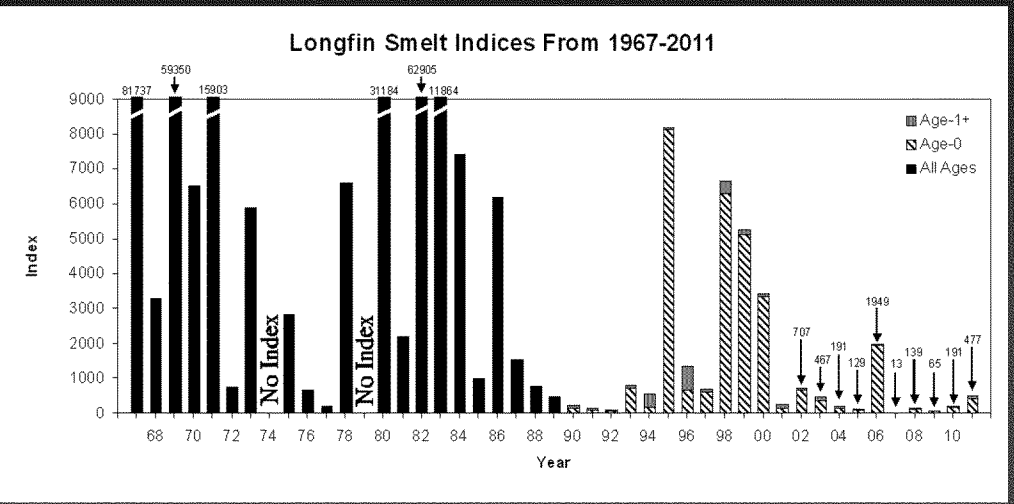
2009-2011: 17 > 3.8 > 29

29 > 8.0 > 343

2005-2006: 26 > 9.9 > 41

Adapted from F. Feyrer 9/7/11 testimony during litigation of 2008 BO RPA

# 2011 SMELT FLOW RESPONSE

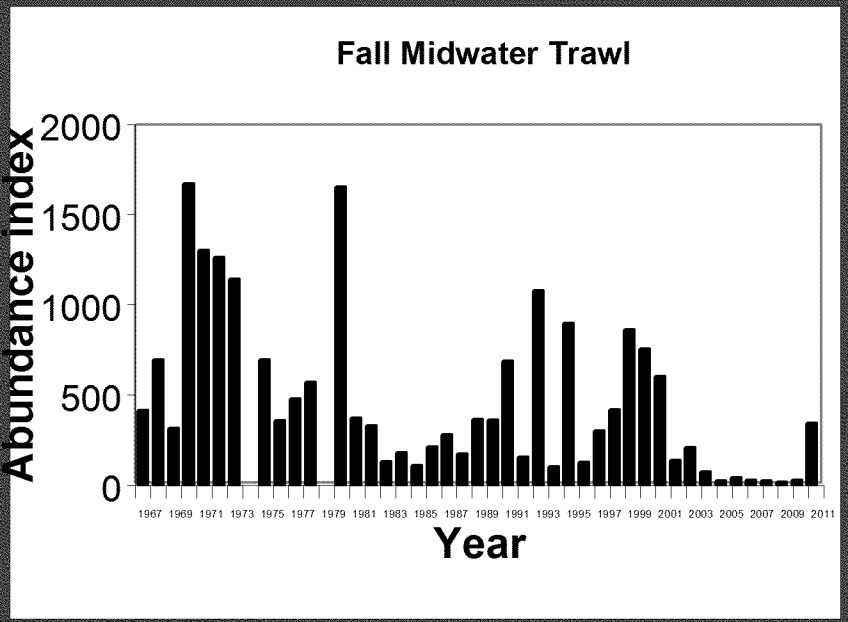



LFS Recruitment Ratios
(FMWT/FMWT-2yrs)

| 2006 | 2010 | 2011 |
|---|---|---|
| 10.2 | 1.3 | 7.3 |

D. Smelt Recruitment Ratios
(FMWT/20mm)

| 2006 | 2010 | 2011 |
|---|---|---|
| 4.1 | 7.6 | 42.9 |



# Some Sources of Useful, "Additional" Information

Available

- 2010-2012 ESA/CESA Listing Documents
- '11 and early '12 IEP indices and survey data
- Federal fall outflow A.M. Plan, and ISP review
- Various independent science reviews

Pending

- FLaSH Study Results
- BDCP Effects Analysis, Conservation Measures
- LFS analysis incorporating S/R considerations

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# ADAPTIVE MANAGEMENT CONSIDERATIONS

John Shelton, DFG Central Region

# What's Next

Adaptive Management

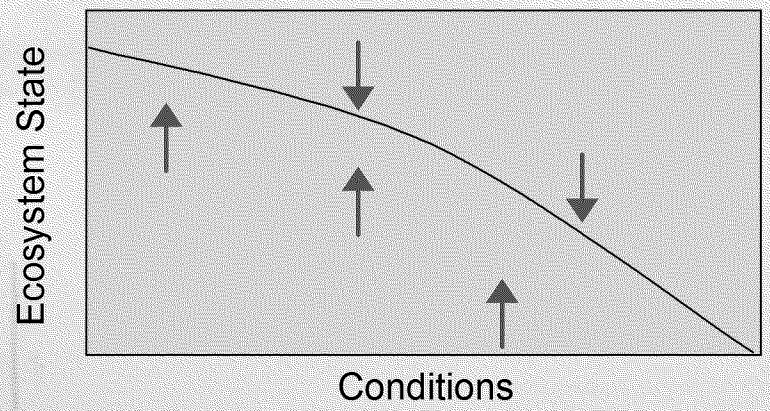
- Why (complex adaptive system)
- Adaptive Management model is well vetted
- Where we are (conceptually) in this process
- What we need out of WQCP

Climate Change

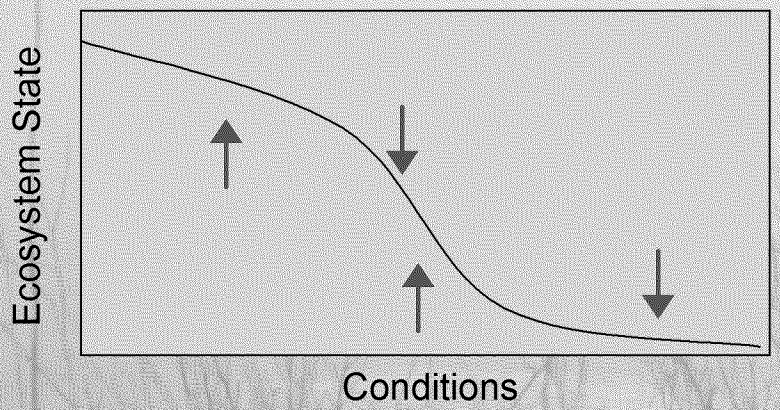
- Stages of response

John Shelton

# Complex Systems




Ecological Systems tend to be Non-linear



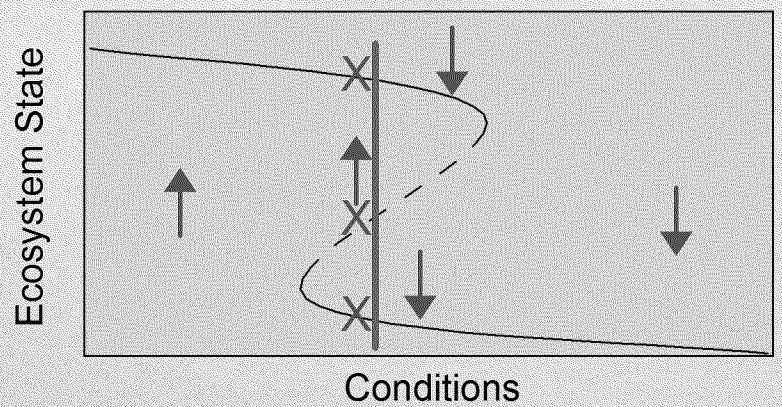

This Non-linearity can be pronounced

The arrows indicate the direction of change when the system is out of equilibrium.

Modified from: Scheffer, M., Brock, W. & Westley, F. 2000. Socioeconomic mechanisms preventing optimum use of ecosystem services: an interdisciplinary theoretical analysis. Ecosystems 3, 451-471

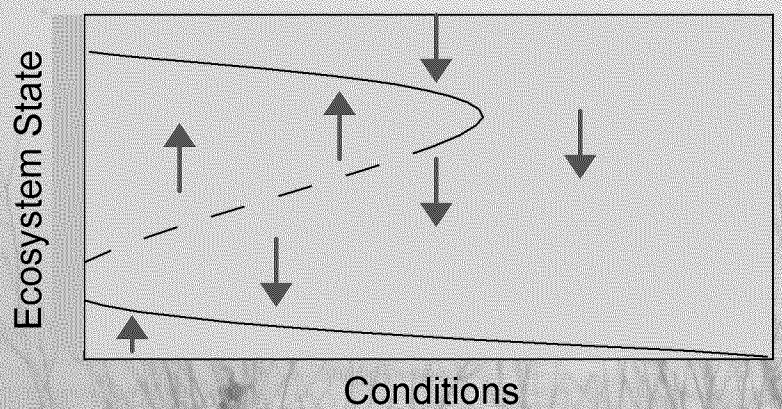
# Critical Transitions - Hysterisis

Ecosystem
Equilibrium States




Hysteresis occurs when there is a fold of the “equilibrium line” that results in:

- Different “paths” of change
- Tipping point characteristics




Further folding of the equilibrium line can lead to irreversible system dynamics

Modified from: Scheffer, M., Brock, W. & Westley, F. 2000. Socioeconomic mechanisms preventing optimum use of ecosystem services: an interdisciplinary theoretical analysis. Ecosystems 3, 451-471

# Complex Adaptive Systems

**Nonlinear Interactions**

- Multiple individual parts undergoing simultaneous nonlinear interactions
- Emergent behavior is more than the sum of the parts

**Aggregate Behavior**

- Impact of the system is its aggregate behavior
- Aggregate behavior feeds back to the parts and modifies their behavior

**Change**

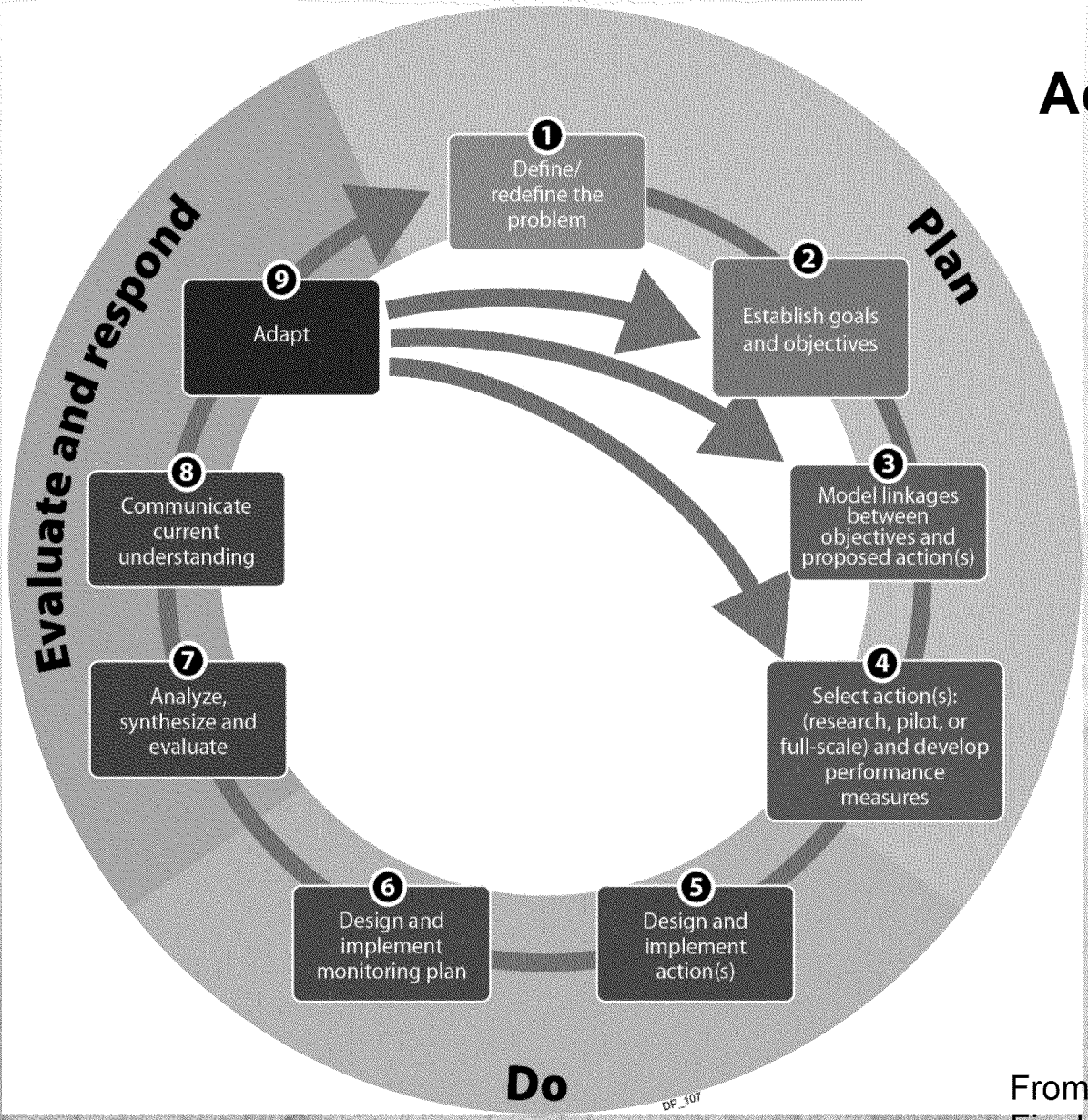
- Interaction of the parts evolves over time
- Parts may face perpetual novelty
- Typically operate far from optimum and far from equilibrium

**Anticipation**

- Individual parts anticipate the consequences of their responses
- Aggregate anticipation affects the system's behavior
- Is the least understood property of such systems

Modified from: Holland, J. H. 1975. *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control, and Artificial Intelligence*, USA: MIT Press

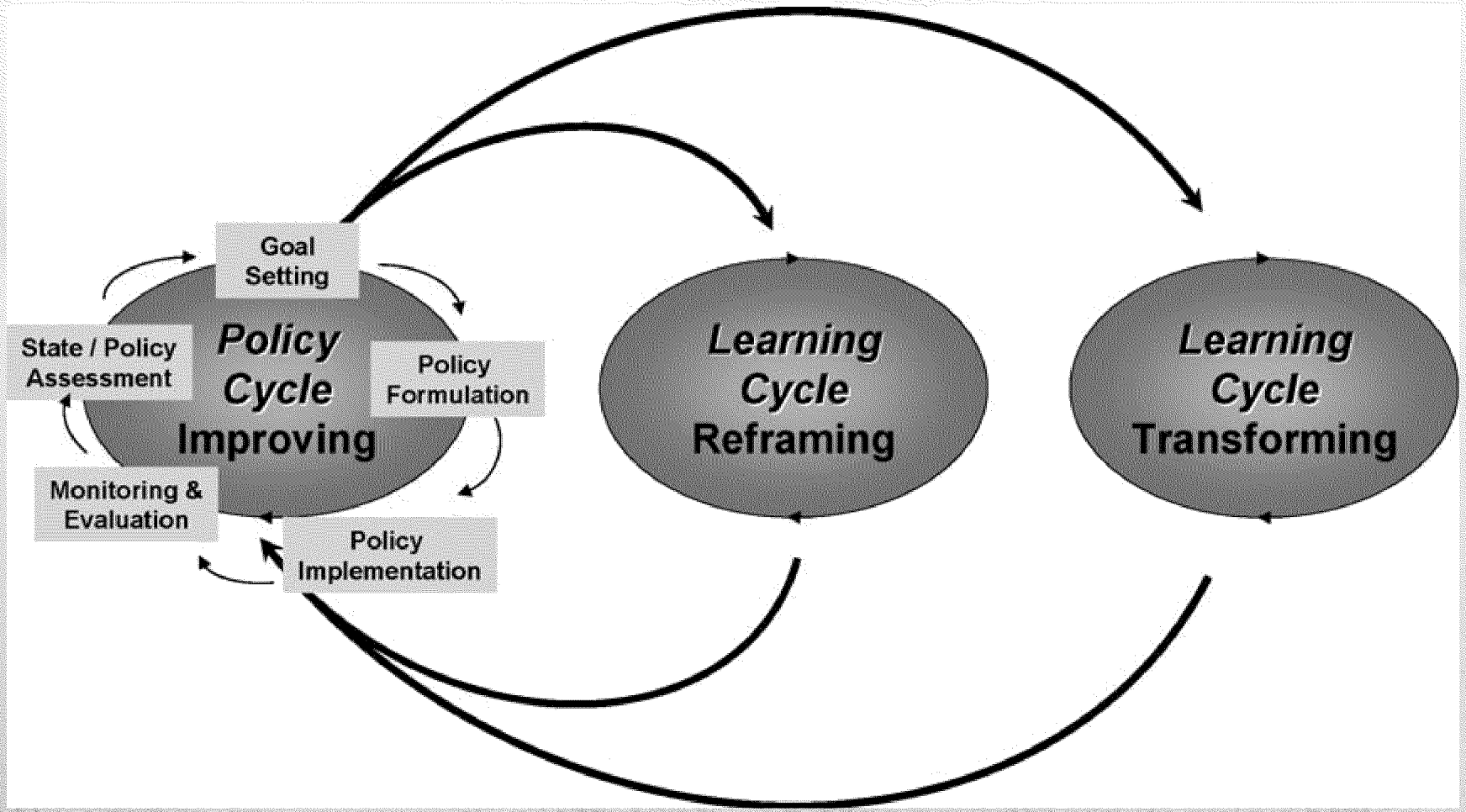
# Adaptive Management




The Delta Independent Science Board noted that the Delta Plan provides:

- ✓an excellent description of adaptive management
- ✓Represents an effective synthesis of the existing literature
- ✓Is presented in a manner that is instructive

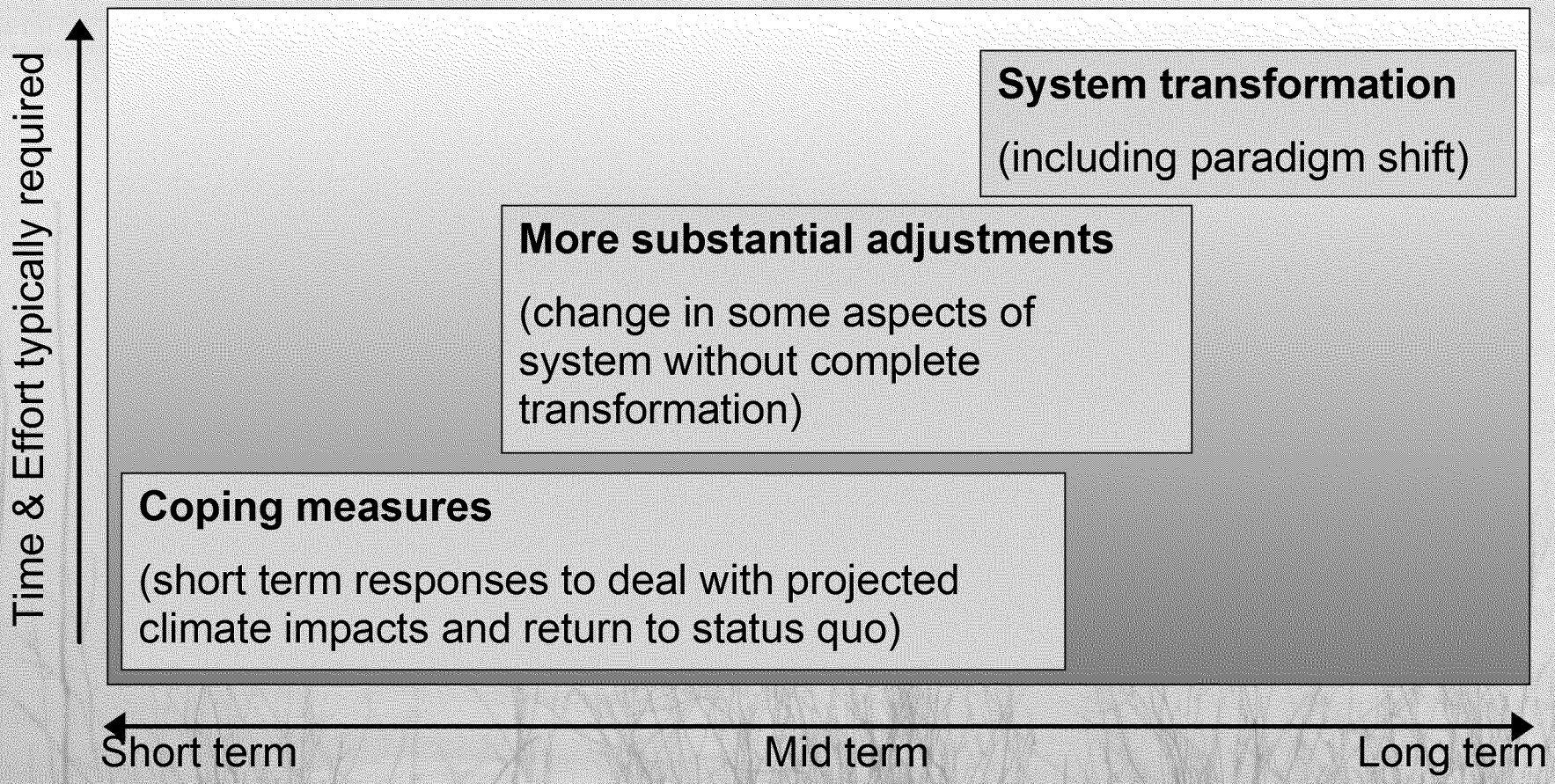
From: Delta Stewardship Council. 2012. Final Staff Draft of the Delta Plan. Available online: http://deltacouncil.ca.gov/delta-plan. Accessed 8/10/12.




Short term — Mid term — Long term

From: Pahl-Wostl C. 2009. A conceptual framework for analyzing adaptive capacity and multi-level learning processes in resource governance regimes. Glob Environ Change 19:354–365.

# Scope and Scale of Adaptation to Climate Change




Modified from: Moser SC, Ekstrom JA. 2010. A framework to diagnose barriers to climate change adaptation. Proc Natl Acad Sci USA 107:22026–22031.

# Summary

- Adaptive Management
  - Delta is a Complex Adaptive System
  - Requires Adaptive Management
  - Adaptive Management Model is well accepted
  - Delta Ecosystem Management
    - – "Transformed" by Delta Reform Act & Co-Equal Goals
    - - Current Processes need to "Re-Frame"
    - - Need clear objectives to have effective "Policy Cycle"
- – Climate Change
  - Response related to Time Horizon

# SWRCB San Francisco Estuary low-salinity zone workshop

U.S. Fish and Wildlife Service

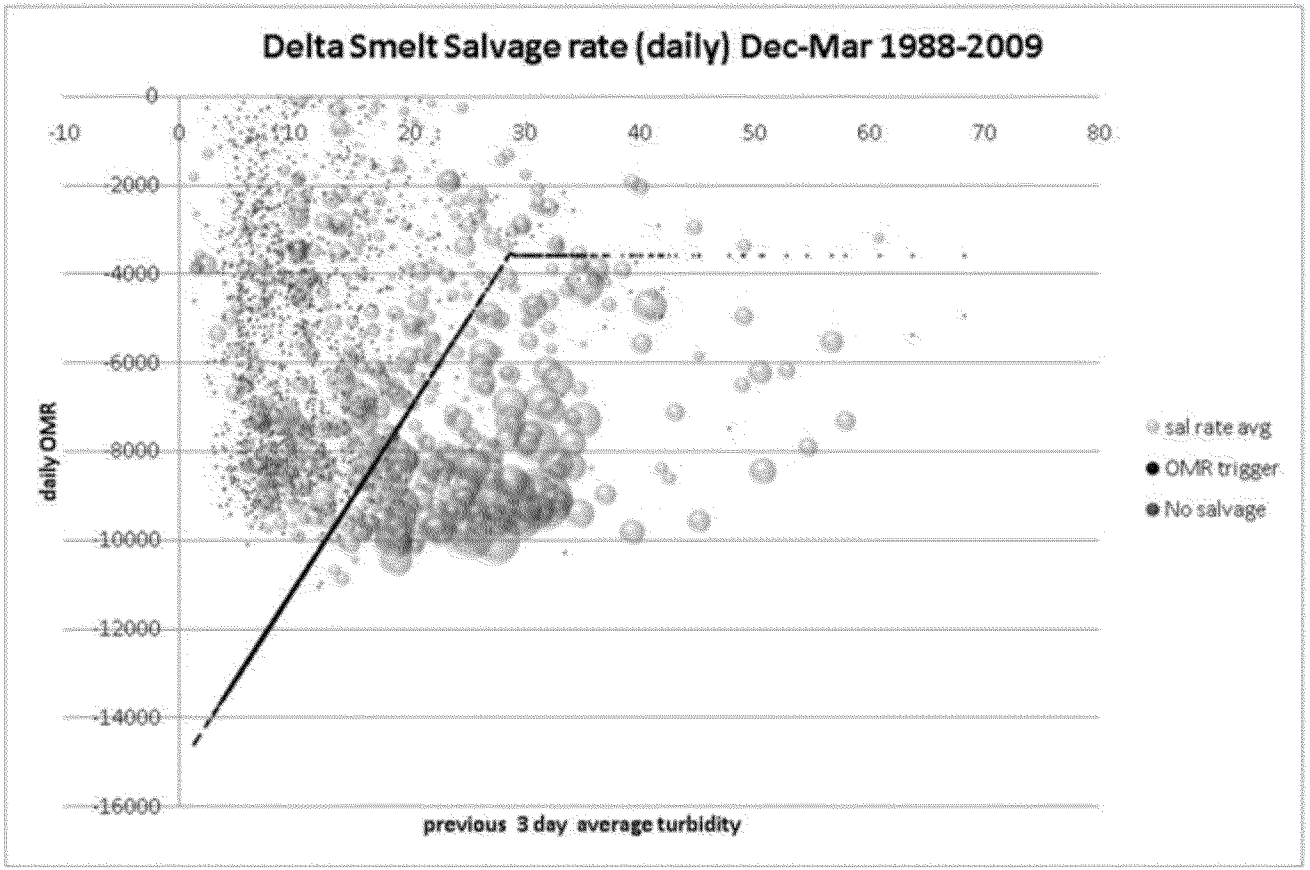
September 5, 2012

# Key points

1. Please see April 2012 key points
2. We suggest the Board model a range of flow objectives that could be incorporated into the WQCP
3. OMR flows contribute to the entrainment risk of adult delta smelt
4. OMR flows drive entrainment of larval delta smelt
5. Multiple factors have contributed to the long-term degredation of the LSZ. However, Delta outflow is still an extremely important aspect of habitat suitability for delta smelt

# NEW SCIENCE REGARDING ADULT DELTA SMELT ENTRAINMENT

# High adult delta smelt salvage usually happens when OMR flows are negative and turbidity is high

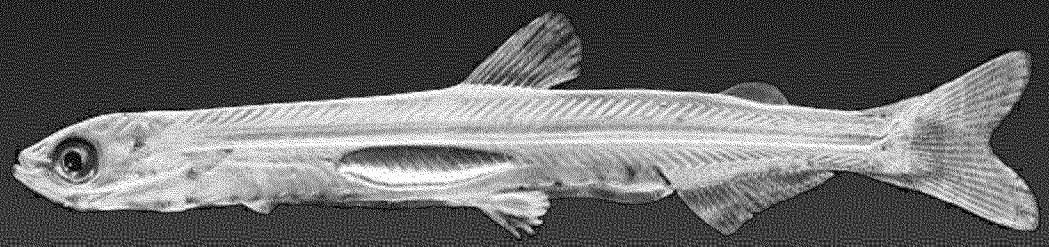



Source: Declaration of Dr. Richard Deriso

# Time scale affects OMR-salvage linkage: a direction for adaptive management

| Time step (days) | Starting OMR (cfs) | | Turbidity threshold (NTU) | | Alternative OMR |
|---|---|---|---|---|---|
| 1 | -3000 | Until | 13 | Then | -1900 |
| 7 | -5200 | Until | 23 | Then | -1900 |
| 14 | -3300 | Until | 25 | Then | -2500 |
| 24 | -4600 | Until | 29 | Then | -3600 |
| 28-31 | -4200 | Until | No threshold | Then | -4200 |

Source: USFWS unpublished data analysis



# NEW SCIENCE REGARDING LARVAL DELTA SMELT ENTRAINMENT

# Modeling and data agree on driver of larval delta smelt entrainment

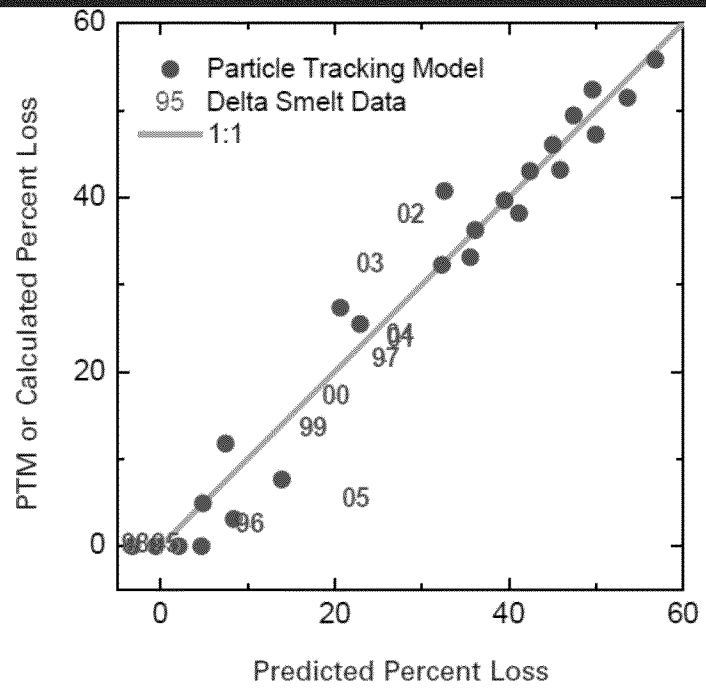
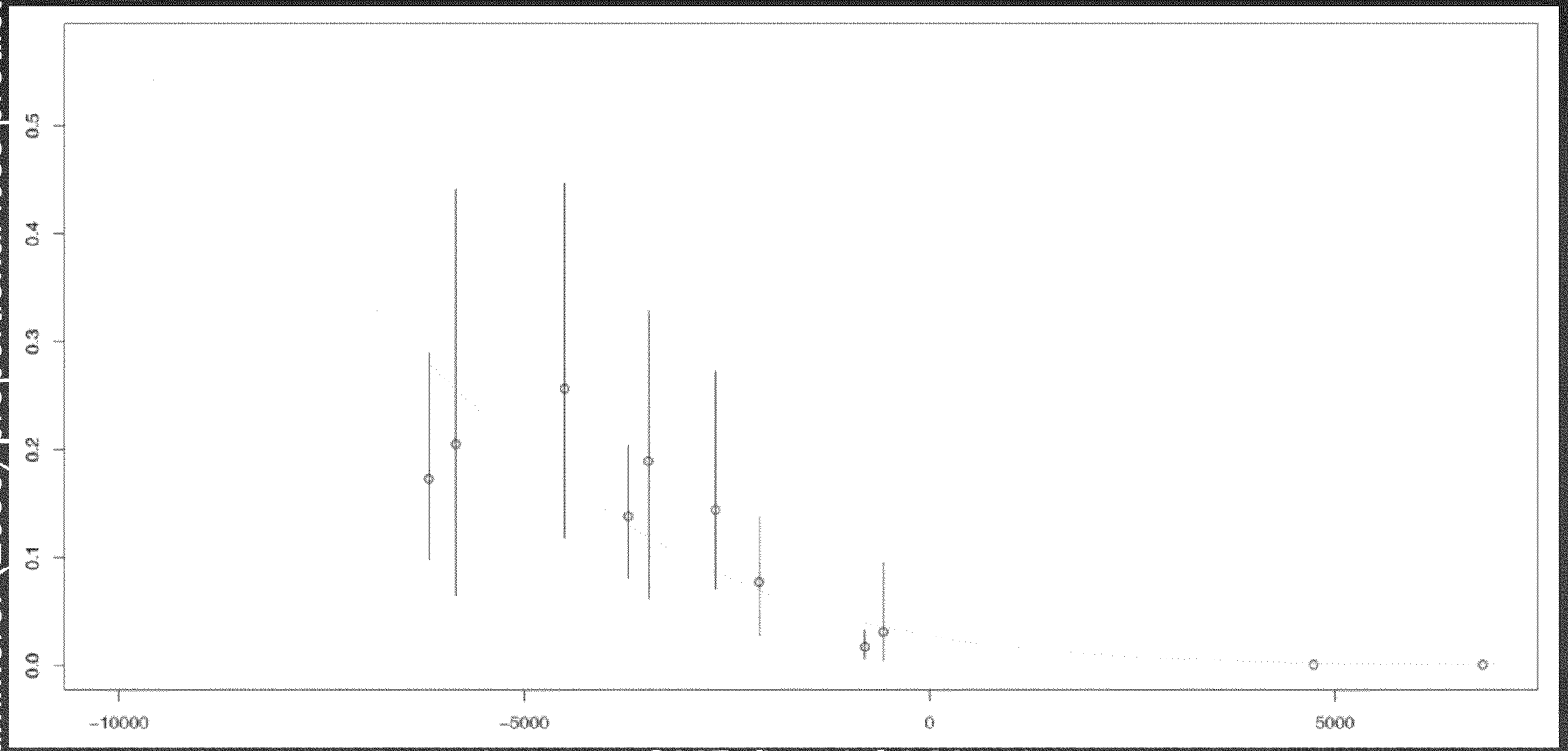



**Figure 16.** Larval/juvenile delta smelt. Predicted percent loss to the population by regression using log of Delta inflow and log of export flow as predictors (with interaction), and particle-tracking model results as the dependent variable (circles), with the line indicating a 1:1 relationship. The regression is:

Source: Kimmerer (2008) San Francisco Estuary and Watershed Science

# OMR flow drives larval delta smelt entrainment




Source: USFWS unpublished data analysis

# Entrainment can contribute to delta smelt decline

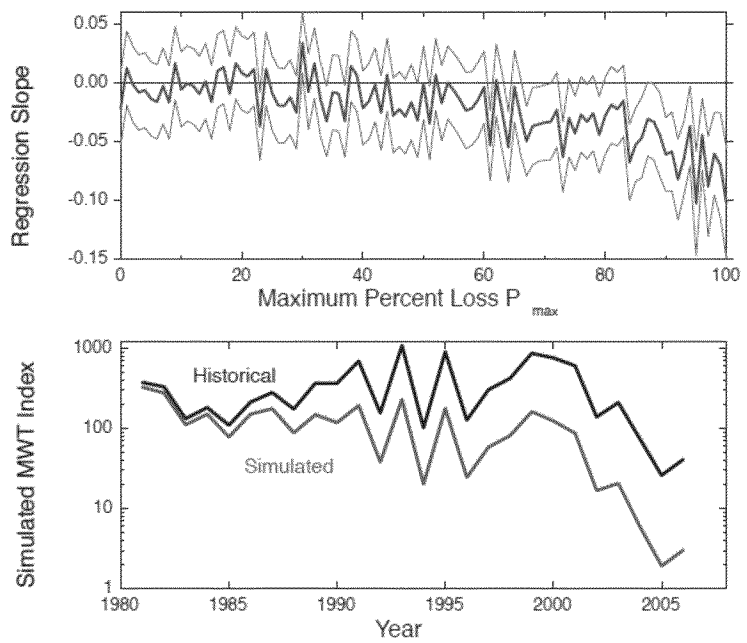
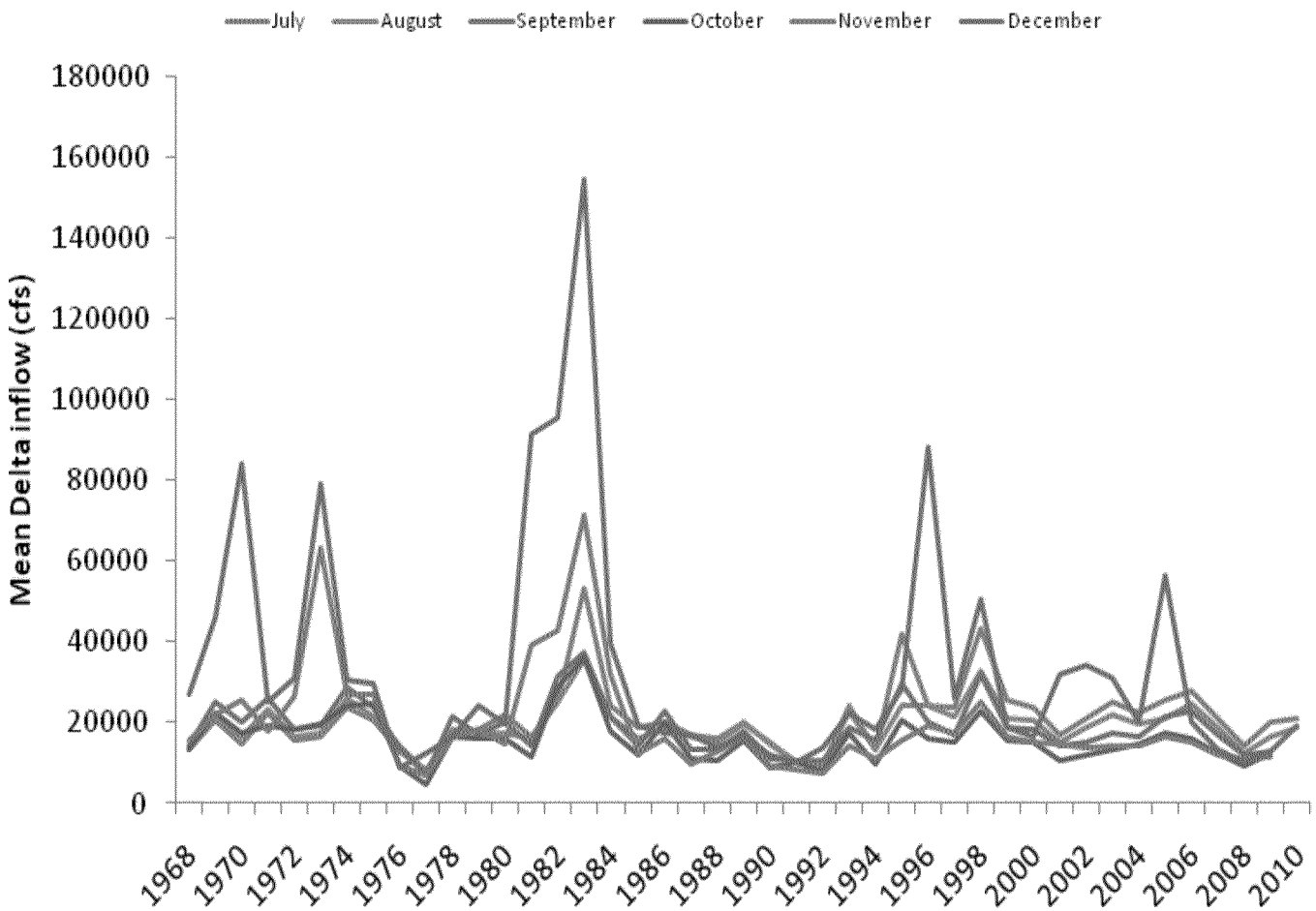



**Figure 3** Results of simulation of ability to detect export loss through regression analysis. Upper panel: individual simulation results giving the slope (thick blue line) and 95% confidence limits (thin red lines) for regressions of the stock-recruit index on southward OMR flow. Lower panel: trajectory of the fall midwater trawl index (upper line) and the same index with a 20% $P_{max}$ value imposed for the entire time series (mean $P_L$ ~10%). This is for illustration only (see text), and does not imply anything about the cause of the decline in delta smelt.

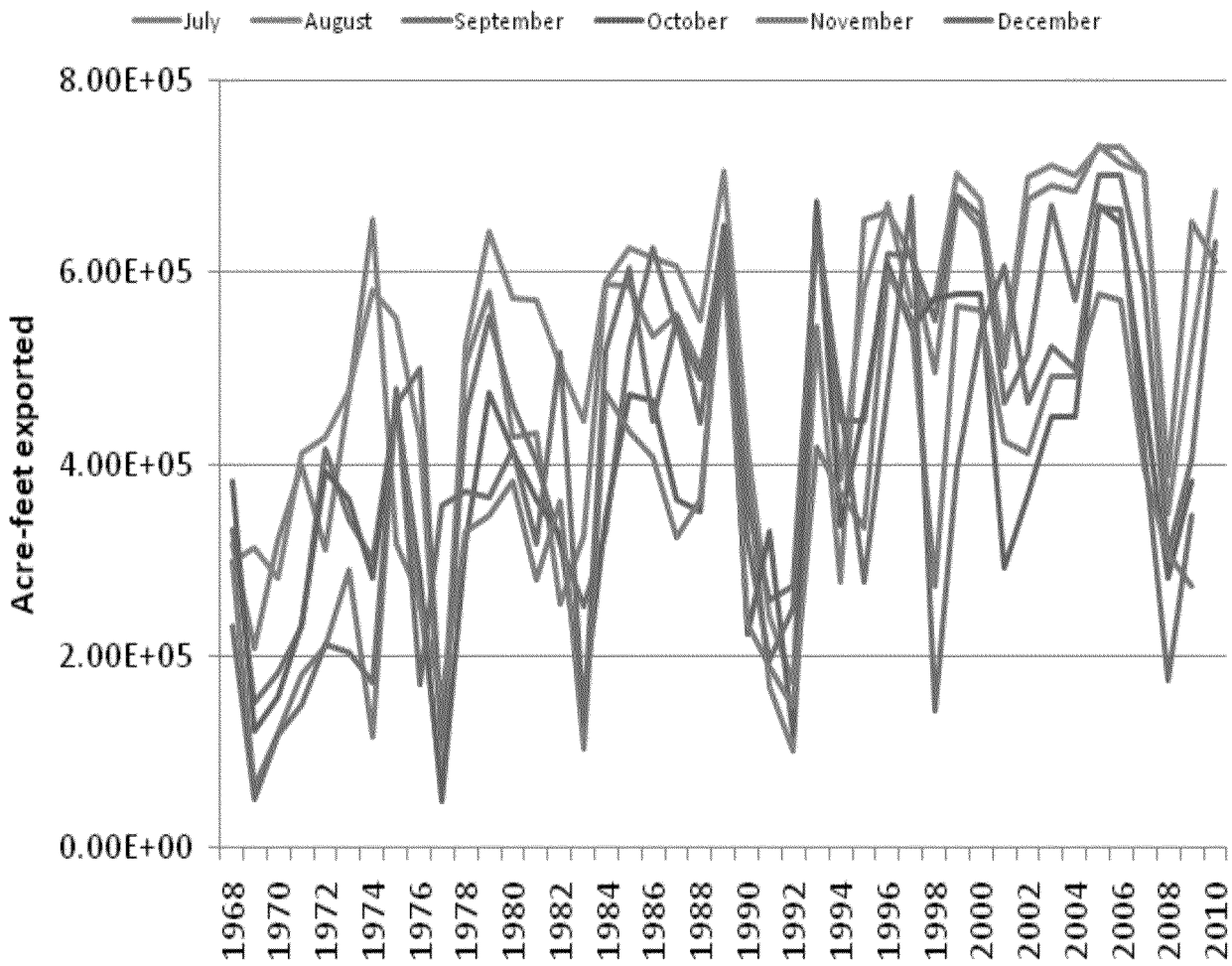
Source: Kimmerer (2011) San Francisco Estuary and Watershed Science

# NEW SCIENCE REGARDING DELTA SMELT REARING HABITAT

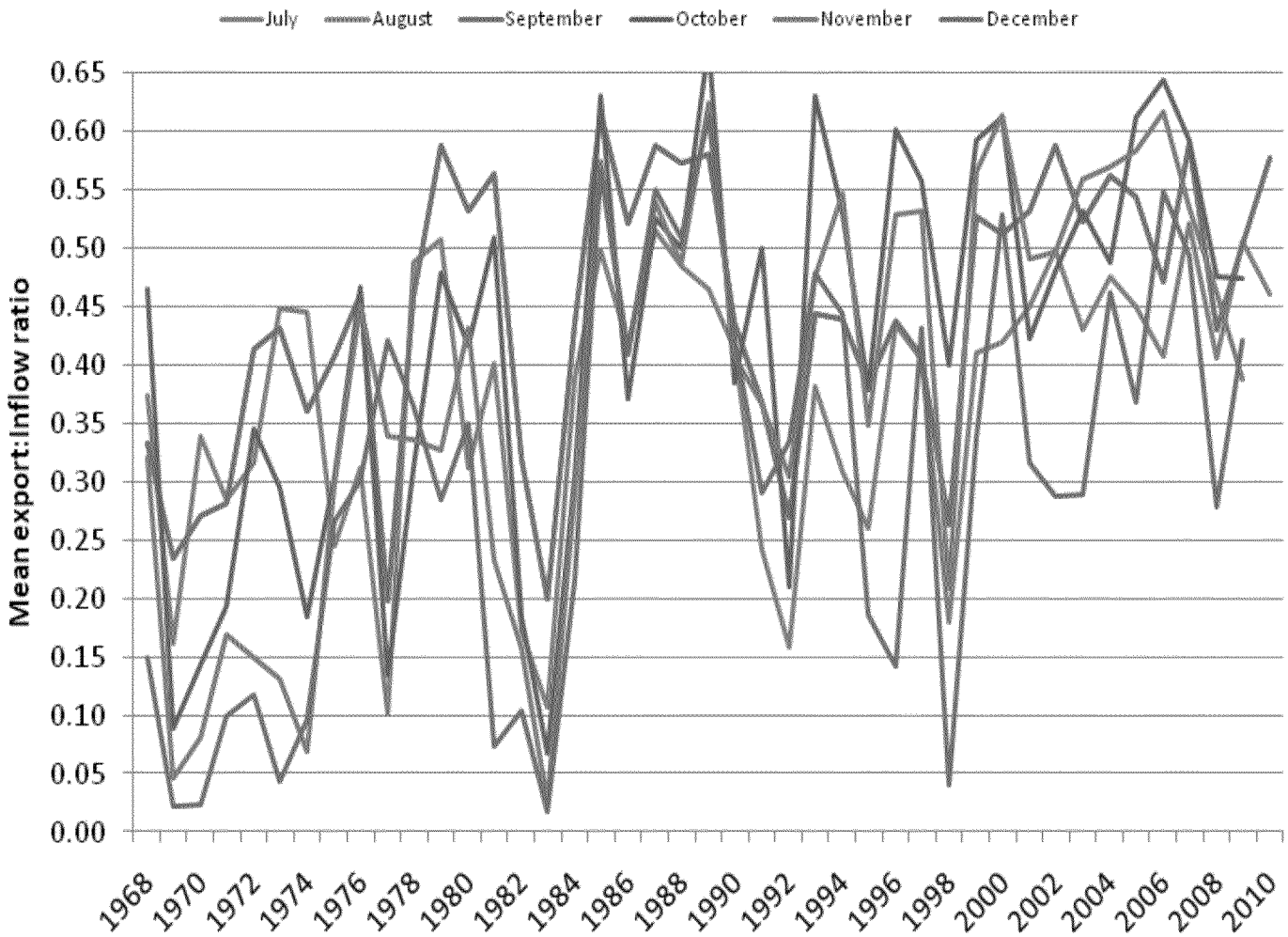
# Time series of summer-fall Delta inflow



# Time series of summer-fall exports



# Time series of summer-fall E:I ratios



# Feyrer et al. (2011)

- Fall habitat suitability has declined
- Fall habitat suitability is closely, but nonlinearly related to X2
- Fall habitat suitability correlated with abundance

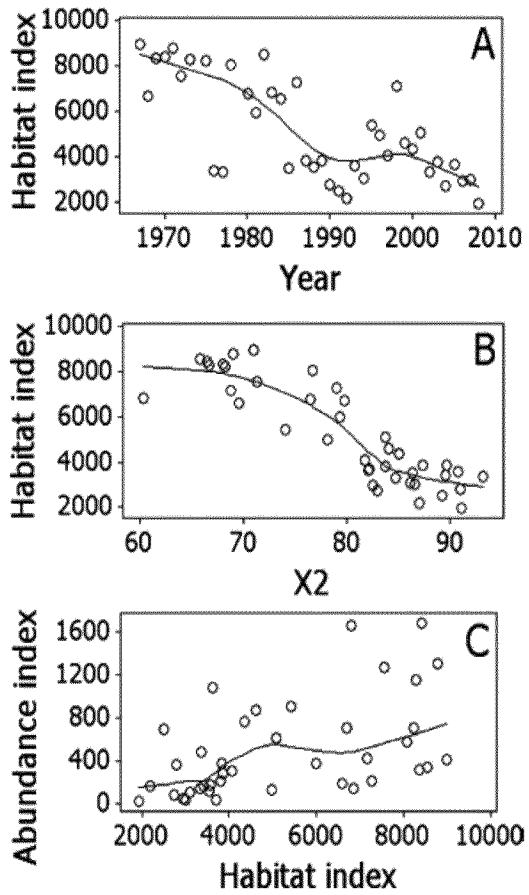



**Fig. 2** Plots of the habitat index time series (**a**), relationship between *X2* (km) and the habitat index (**b**), and relationship between the habitat index and delta smelt abundance measured as the fall midwater trawl index. Curves are LOESS smooths

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SWRCB San Francisco Estuary low-salinity zone workshop

# U.S. Environmental Protection Agency

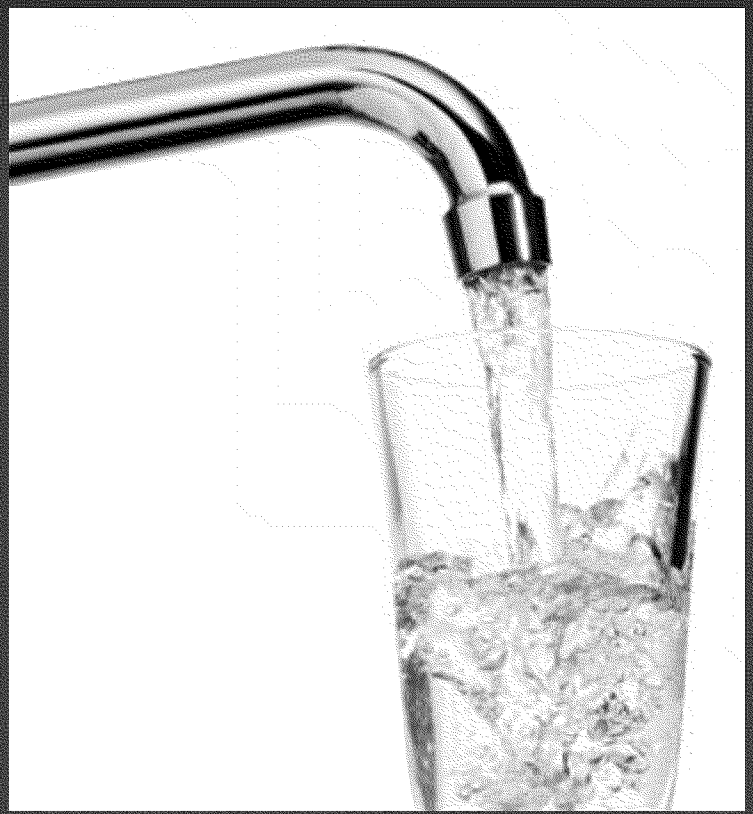
September 5, 2012

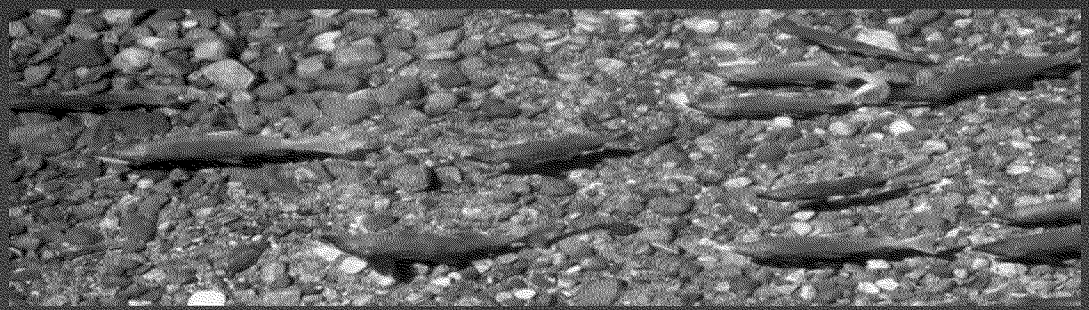
# Outline

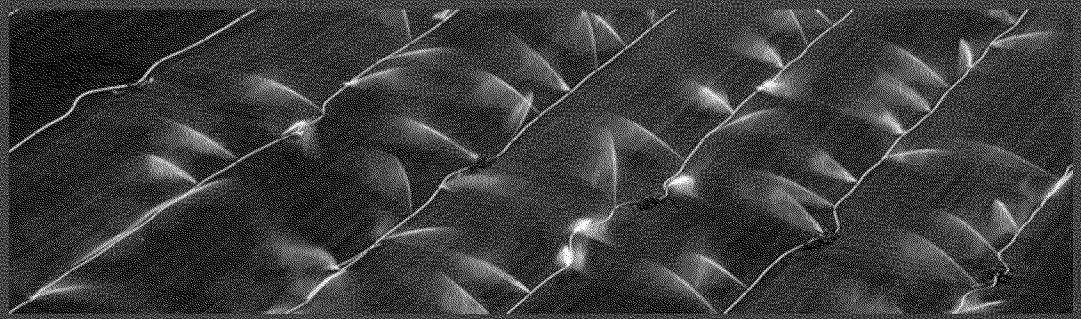
- Clean Water Act
- New information
- Bay-Delta Basin Plan

Clean Water Act

# Water Quality Standards





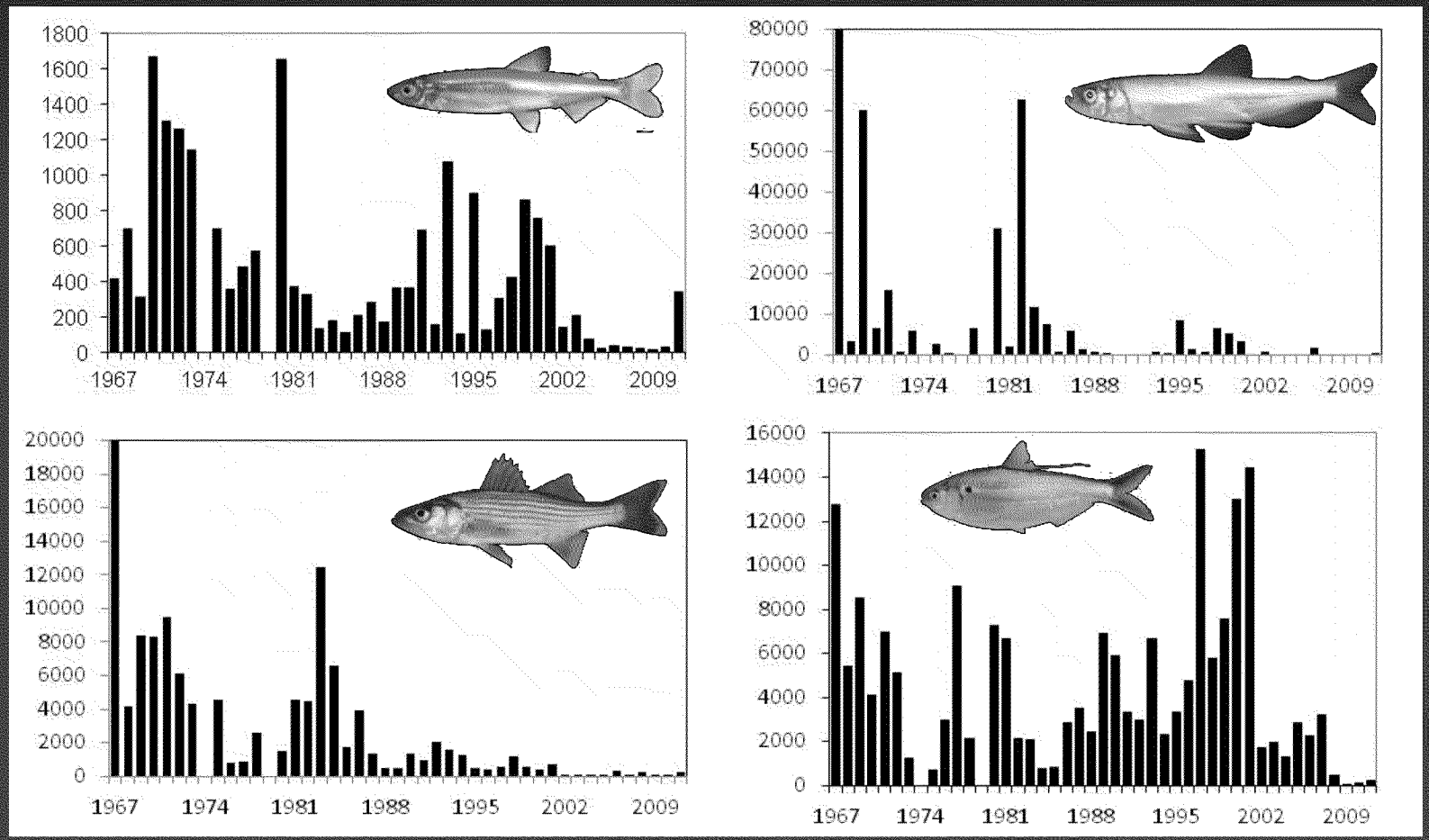


New Information

# EPA SF Bay Delta Action Plan

www.epa.gov/sfbaydelta/actionplan

## Aquatic life beneficial uses are not adequately protected



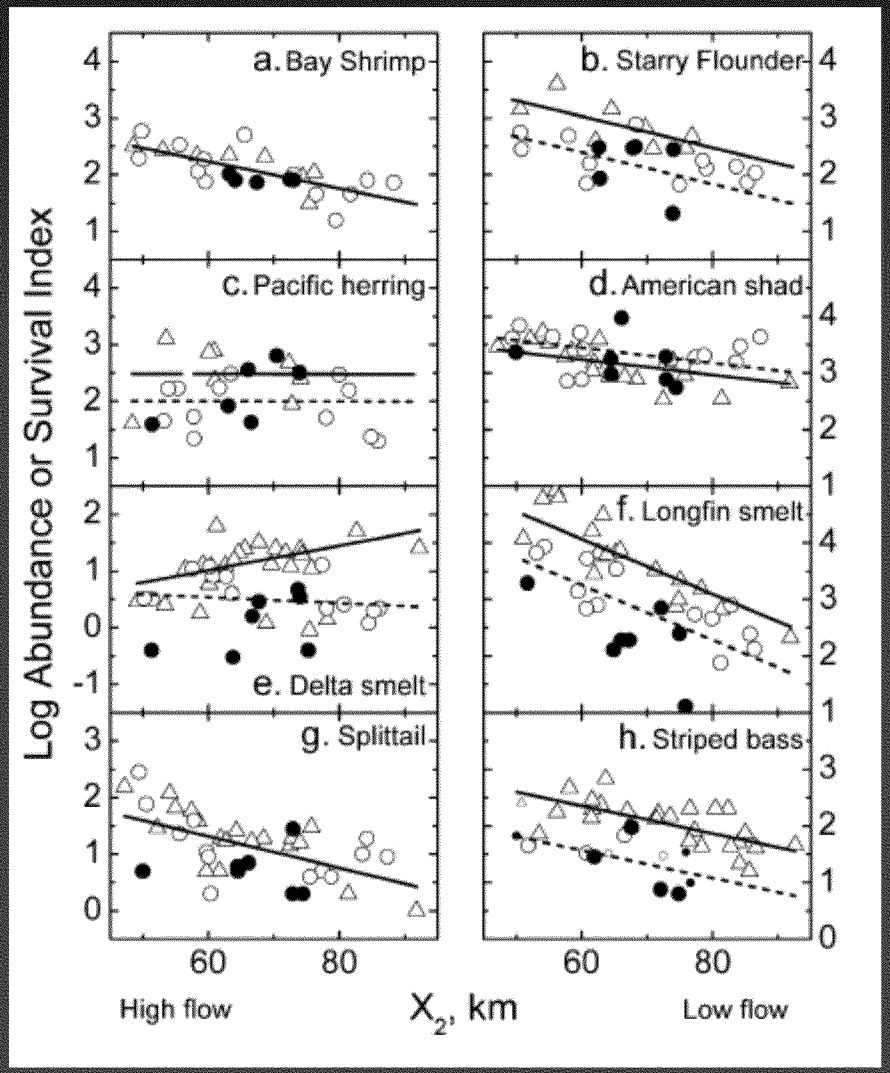

Source DFG 2008 Fall MW Trawl -- No sampling 1974 and 1979

# EPA SF Bay Delta Action Plan

- First Priority: Update flow standards
- Other actions: address RMP, TMDL, Se objectives, pesticide PP, MeHg, & BDCP.
- Flow standards are essential for success of other efforts

New Information

# Evaluation & Support for X2



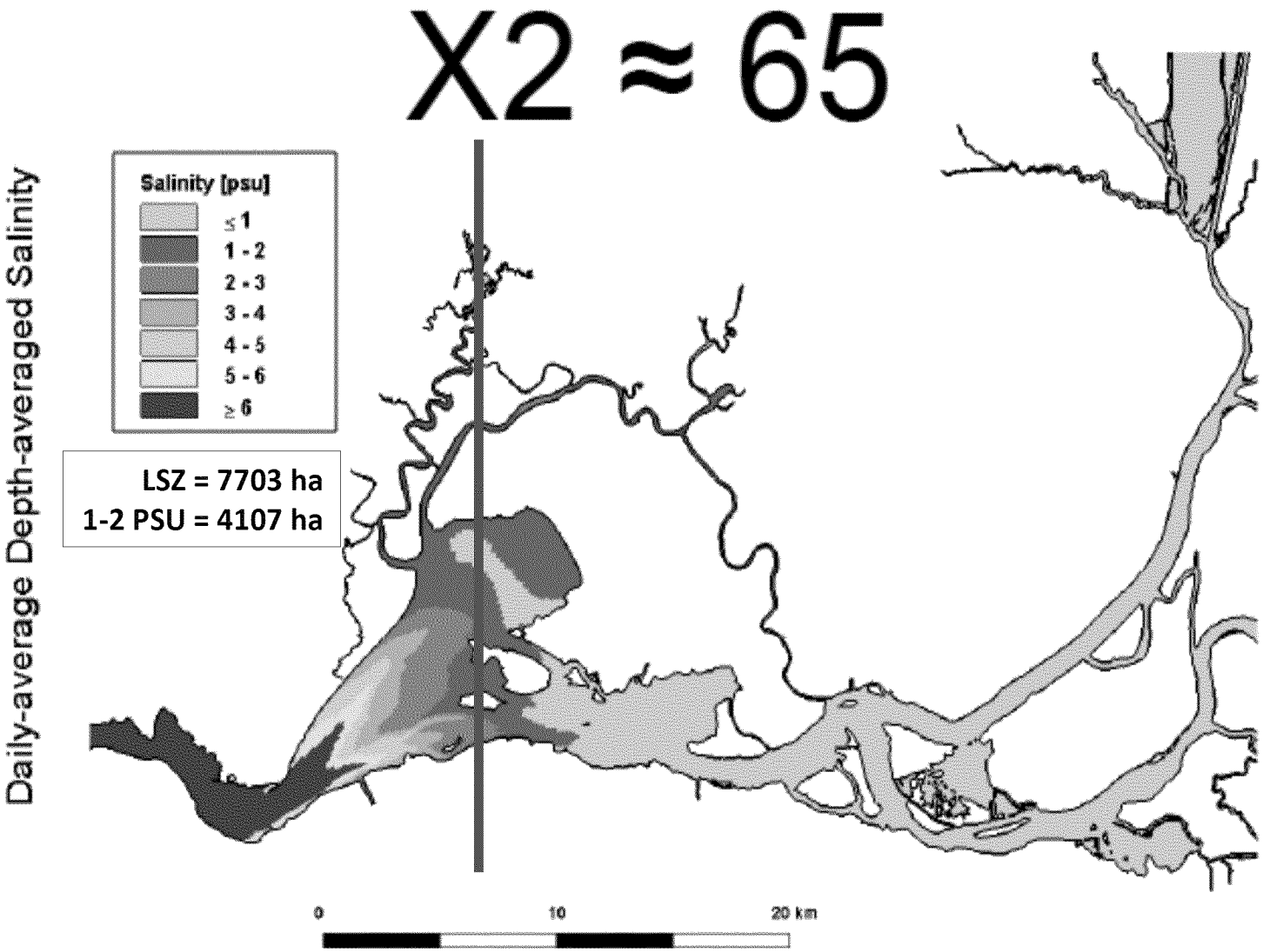

Kimmerer 2002MEPS

National Research Council (2012)

- SF Bay Delta estuarine species are more abundant when the salinity gradient is farther west.
- X2 continues to be a valid foundation for WQS in the SF Bay Delta estuary for species associated with various salinities.

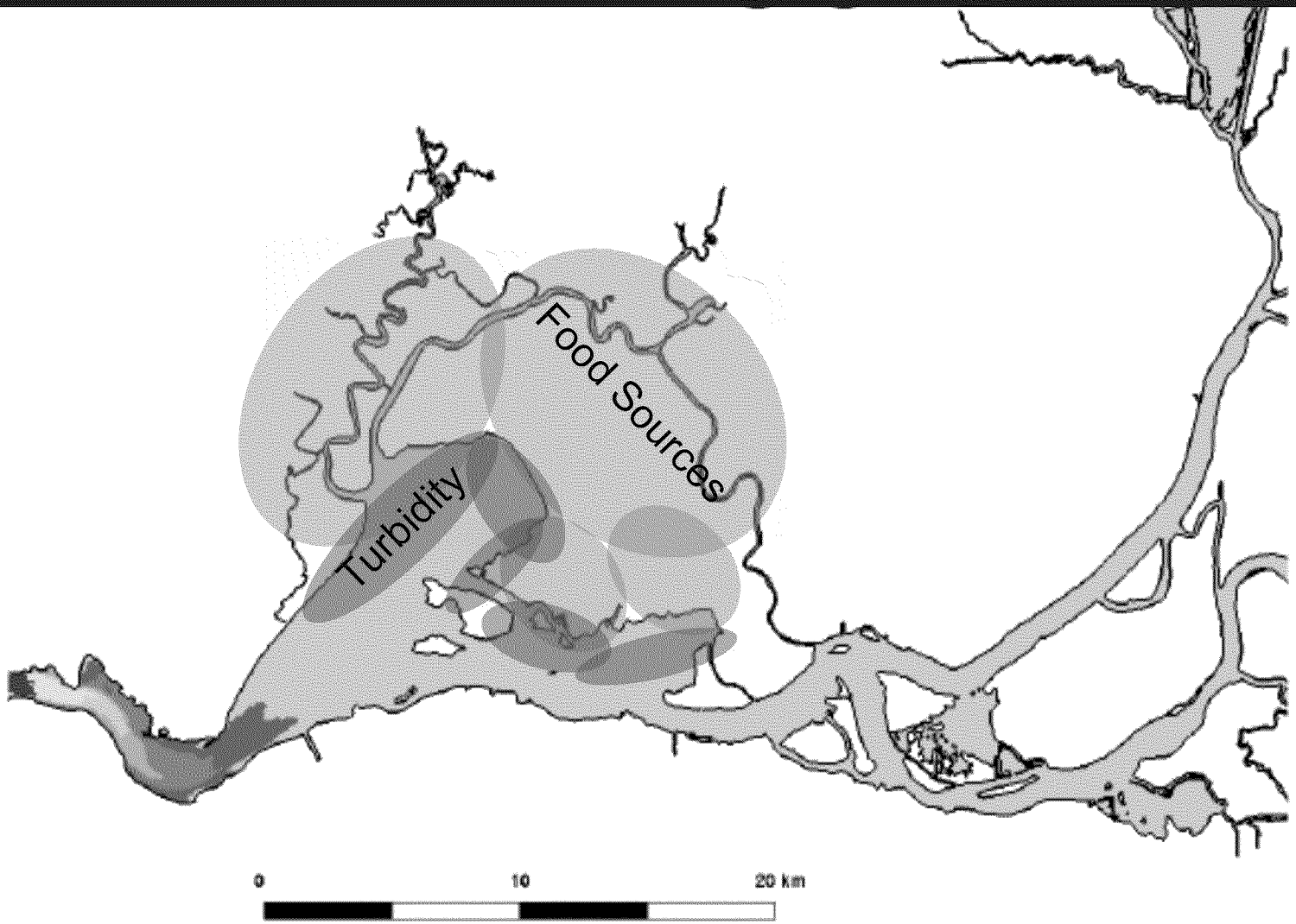
New Information

# 3D LSZ Modeling & X2



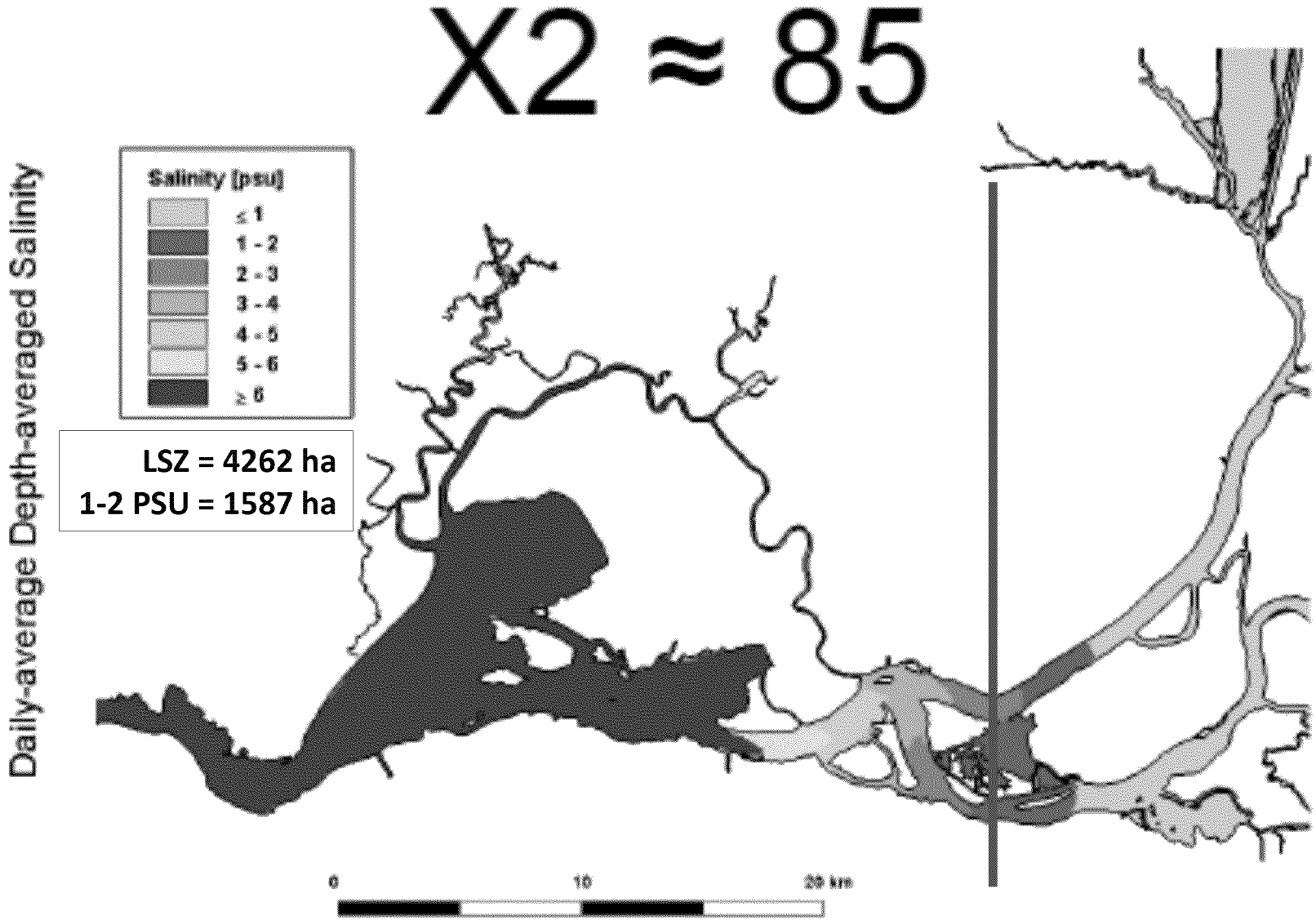

Source Delta Modeling Associates Low Salinity Flip Book. June 15, 2012. Version 0.9.

# Location of LSZ



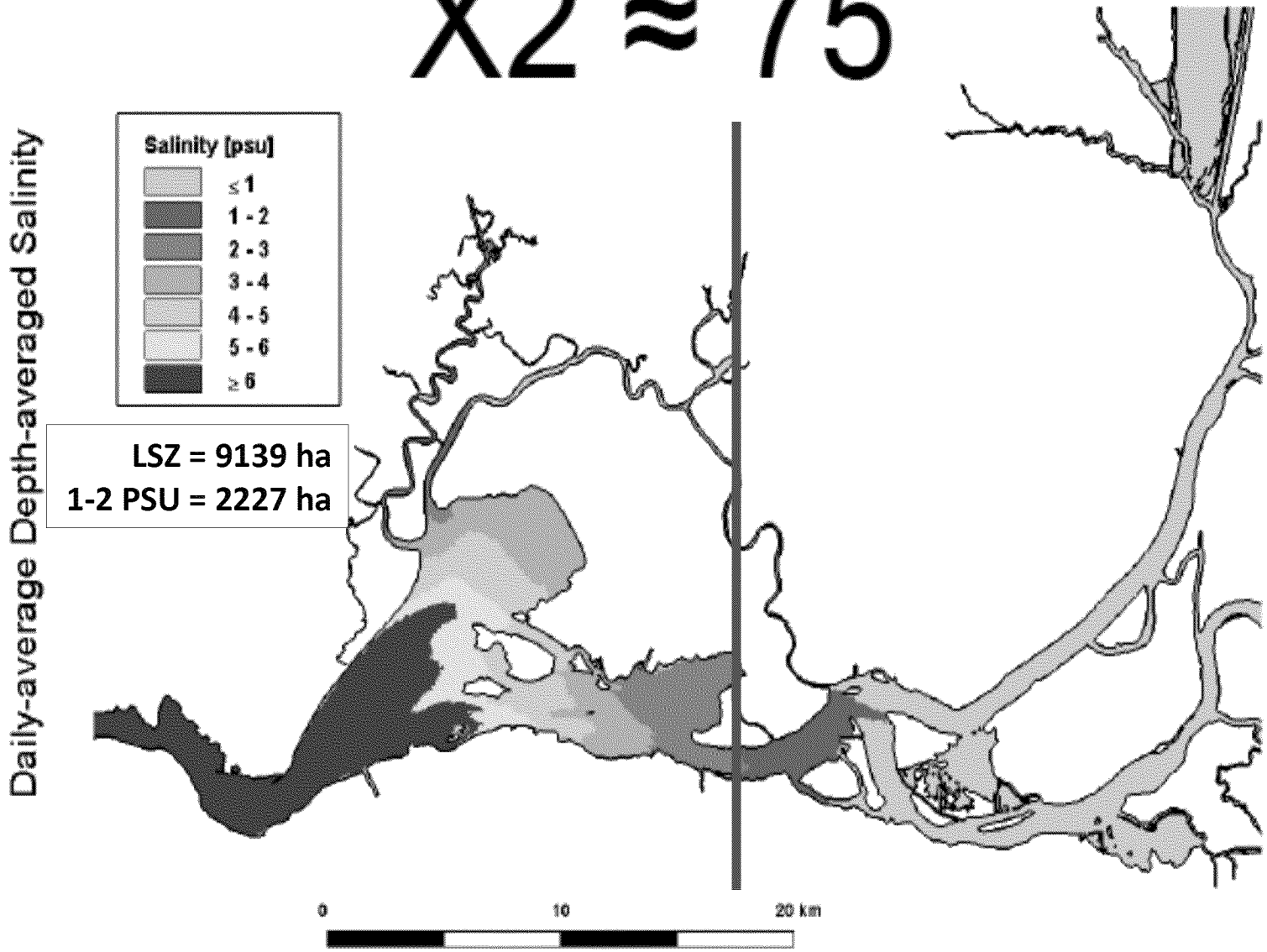

Source Delta Modeling Associates Low Salinity Flip Book. June 15, 2012. Version 0.9.

# X2 ≈ 85




Source Delta Modeling Associates Low Salinity Flip Book. June 15, 2012. Version 0.9.

# X2 ≈ 75




Source Delta Modeling Associates Low Salinity Flip Book. June 15, 2012. Version 0.9.

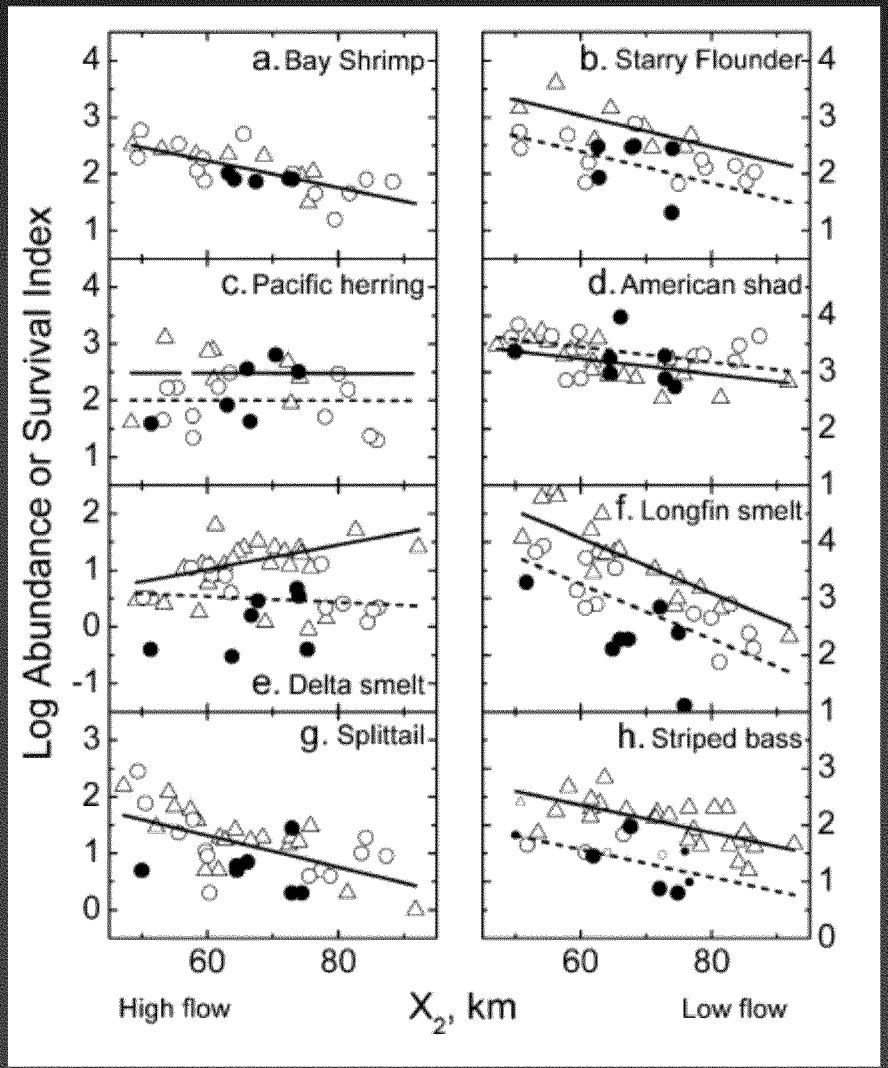
# Low Salinity Zone

- 65 km ≤ X2 ≤ 74 km
  - Access to food and turbidity are maximized
  - Surface area is maximized
- X2 > 85 km
  - Access to food and turbidity are limited
  - Surface area is minimized

New Information

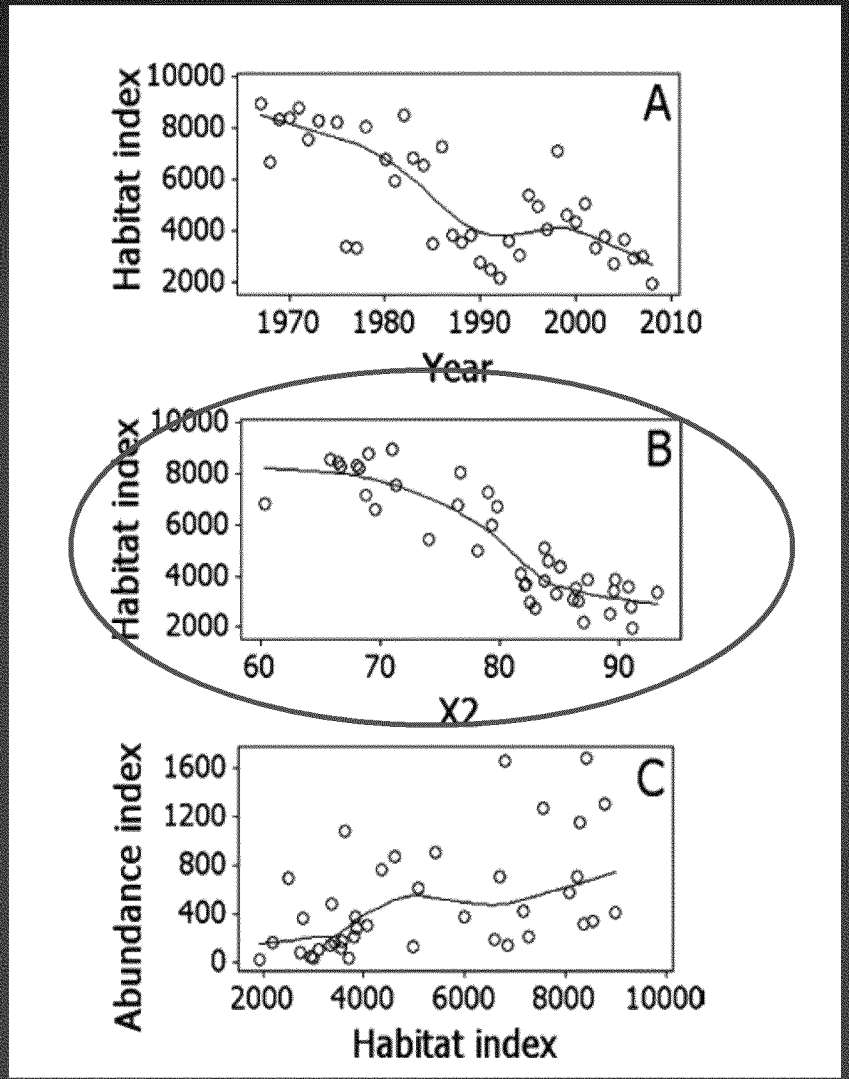
# LSZ is important year-round

Spring




Kimmerer 2002MEPS

Fall




Feyrer et al (2011)

# LSZ is important year-round

## Longfin Smelt

Highest since 2006

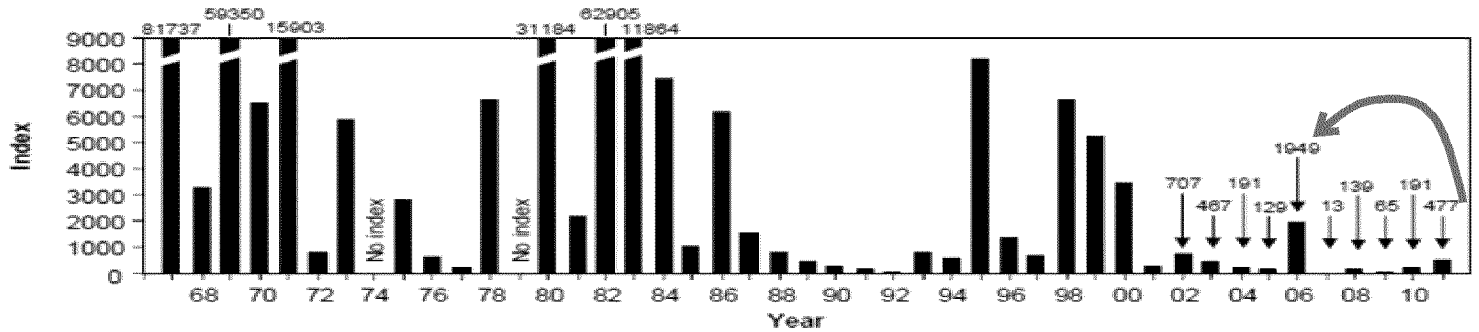
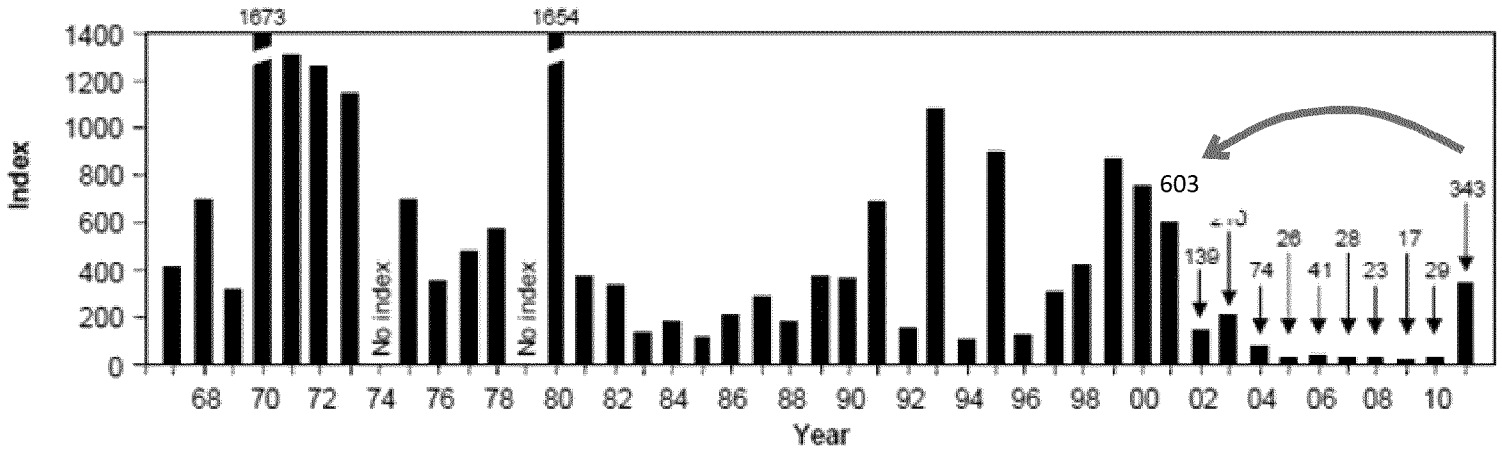



Figure 4. Longfin smelt FMWT annual abundance indices, 1967-2011.

## Delta Smelt

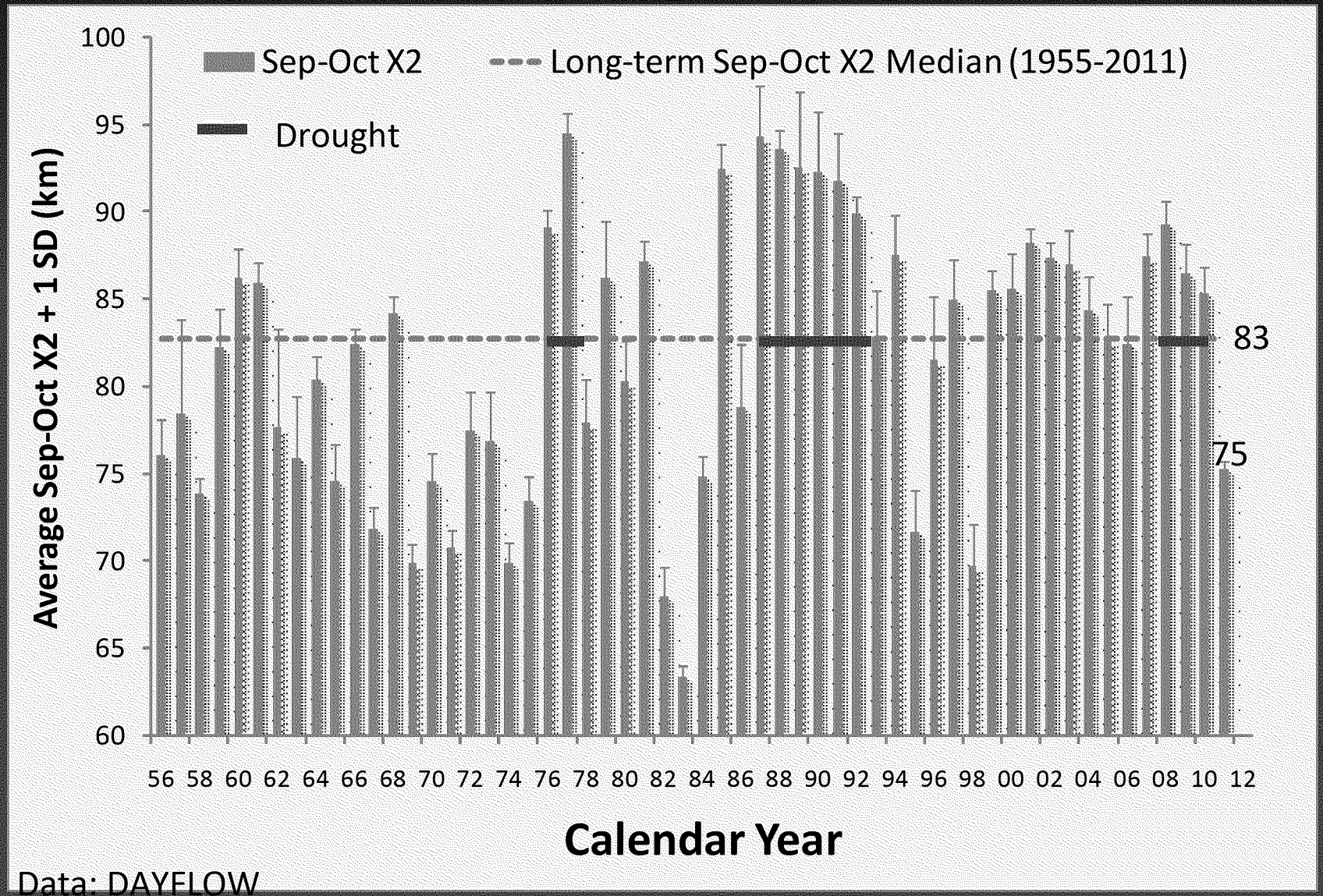
Highest since 2001




Source DFG 2008 Fall MW Trawl -- No sampling 1974 and 1979

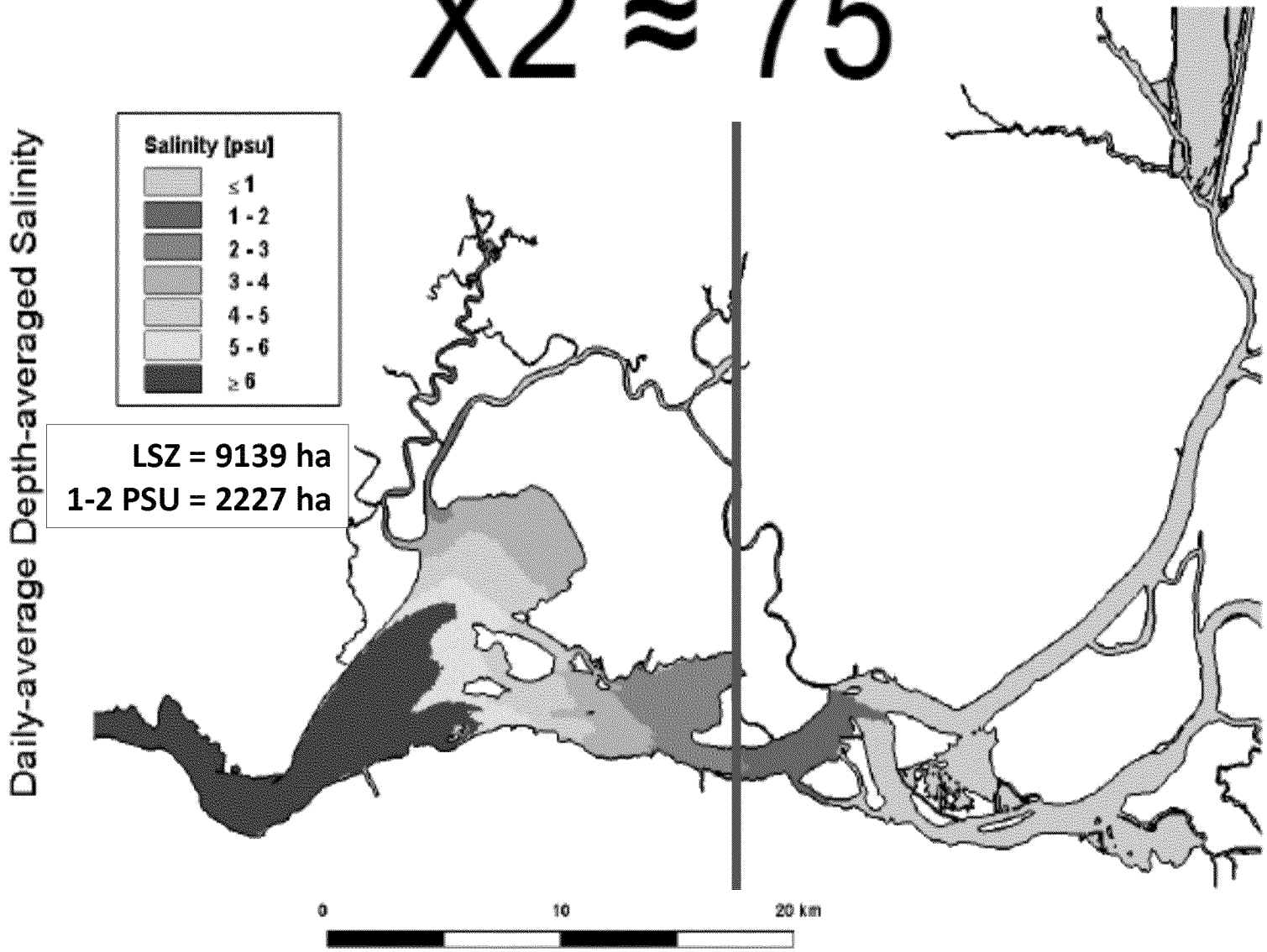
# Low Salinity Zone in the Fall.

**(September-October)**



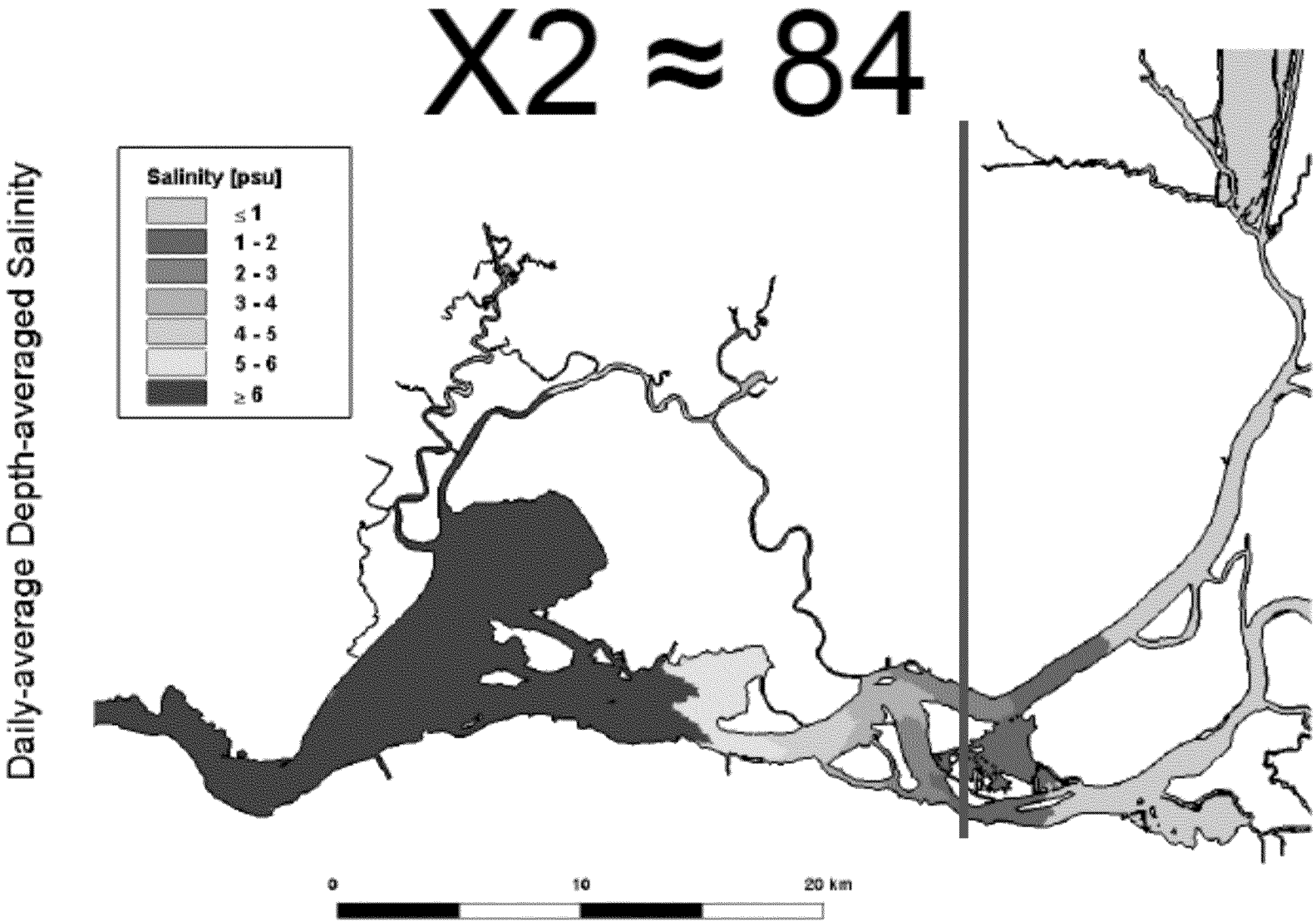

Data: DAYFLOW

# X2 ≈ 75




Source Delta Modeling Associates Low Salinity Flip Book. June 15, 2012. Version 0.9.

# X2 ≈ 84




Source Delta Modeling Associates Low Salinity Flip Book. June 15, 2012. Version 0.9.

# Changes to Bay-Delta Plan

## Start with existing recommendations

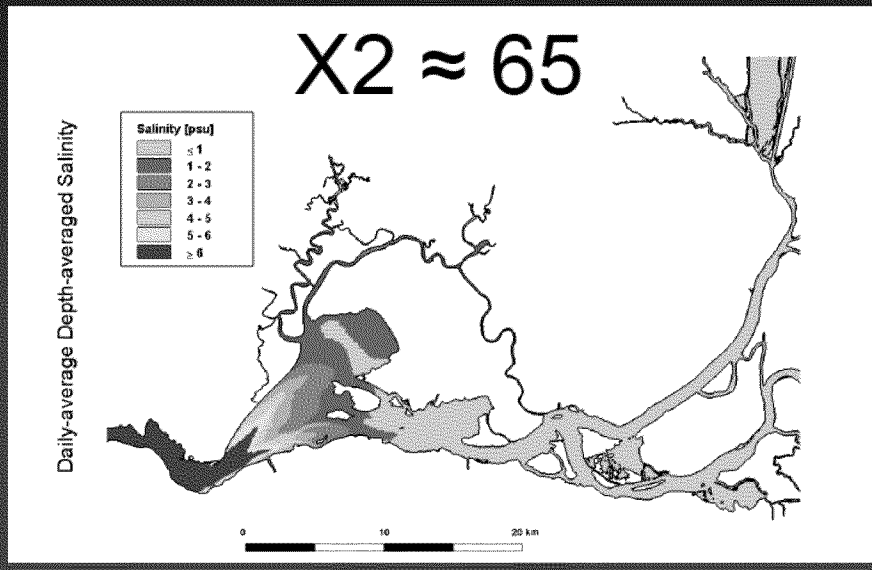
**Table 20. Delta Outflow Summary Criteria**

| Delta Outflows | |
|---|---|
| **Category A** | |
| **Water Year** (O N D J F M A M J J A S) | **Criteria** |
| | 1) Net Delta Outflows: 75% of 14-day average unimpaired flow |
| **Category B** | |
| **Water Year** (O N D J F M A M J J A S) | **Criteria** |
| | 2) Fall X2<br>a. Wet years: X2 less than 74 km (greater than approximately 12,400 cfs)<br>b. Above normal years: X2 less than 81 km (greater than approximately 7,100 cfs) |
| | 3) Net Delta Outflows: 2006 Bay-Delta Plan Delta Outflow Objectives - applies during critical, dry, and below normal years |
| **Basis for Criteria and Explanation** | |

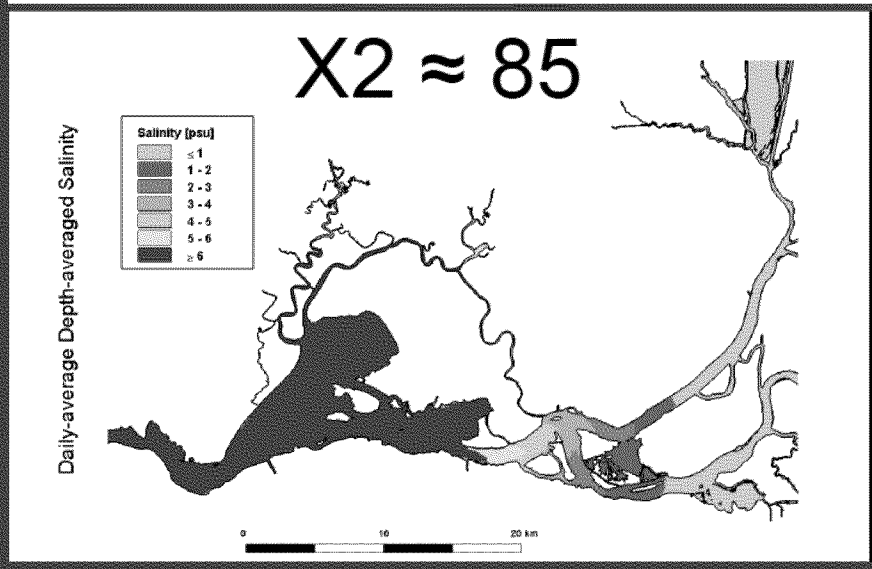
1) Promote increased abundance and improved productivity (positive population growth) for longfin smelt and other desirable estuarine species
2) Increase quantity and quality of habitat for delta smelt; fall X2 requirement limited to above normal and wet years to reduce potential conflicts with cold water pool storage, while promoting variability with respect to fall flows and habitat conditions in above normal and wet water year types; expected to result in improved conditions for delta smelt, however, the statistical relationship between fall X2 and abundance is not strong; note 2) above regarding need for improved understanding concerning the fall X2 action also applies
3) Fish and wildlife beneficial use protection

# Connect Flow to Essential Habitat Elements

Net Delta Outflow at
65 % Unimpaired flow




Net Delta Outflow at
35 % Unimpaired flow



# EPA Summary

- Aquatic life beneficial uses are not adequately protected.
- X2 relationships have overwhelming scientific support, but details of some have changed through time.
- Resident species require year-round habitat.
- Connect percent unimpaired flows to habitat elements.
- The Bay-Delta Plan update needs to provide better protection for aquatic habitat.