



2 adults return to spawn

4,000
eggs
are laid

Salmon life cycle

800 fry
hatch

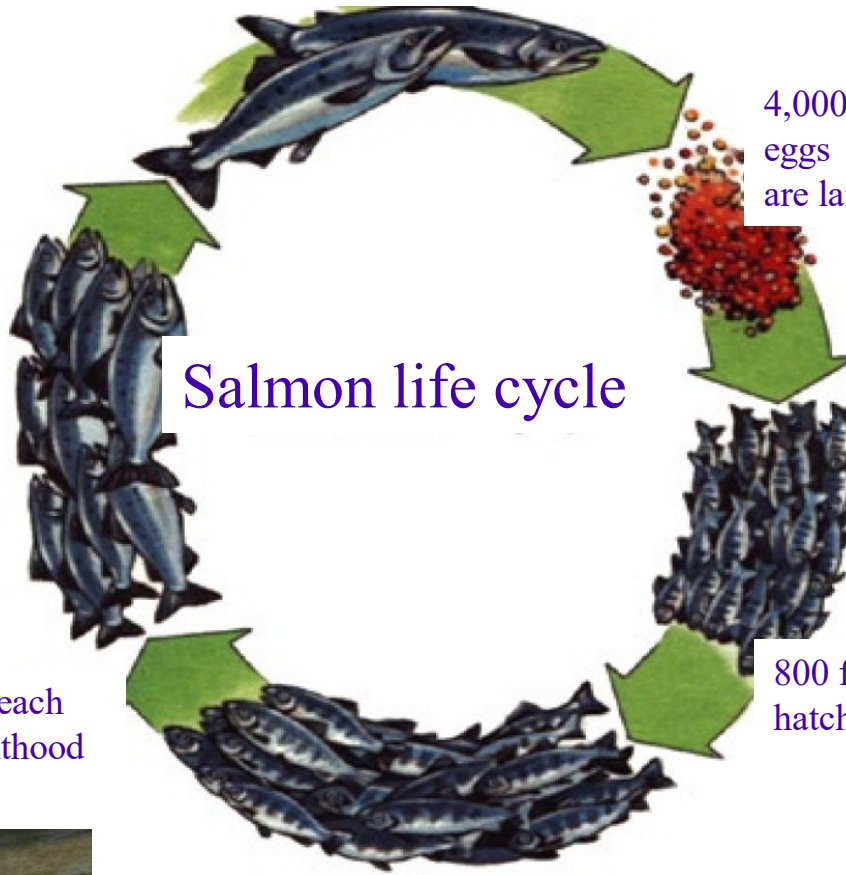
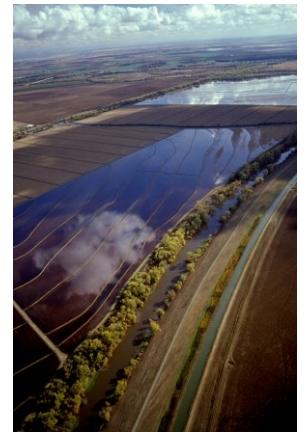
200 smolts go to sea

10 reach
adulthood

Ocean

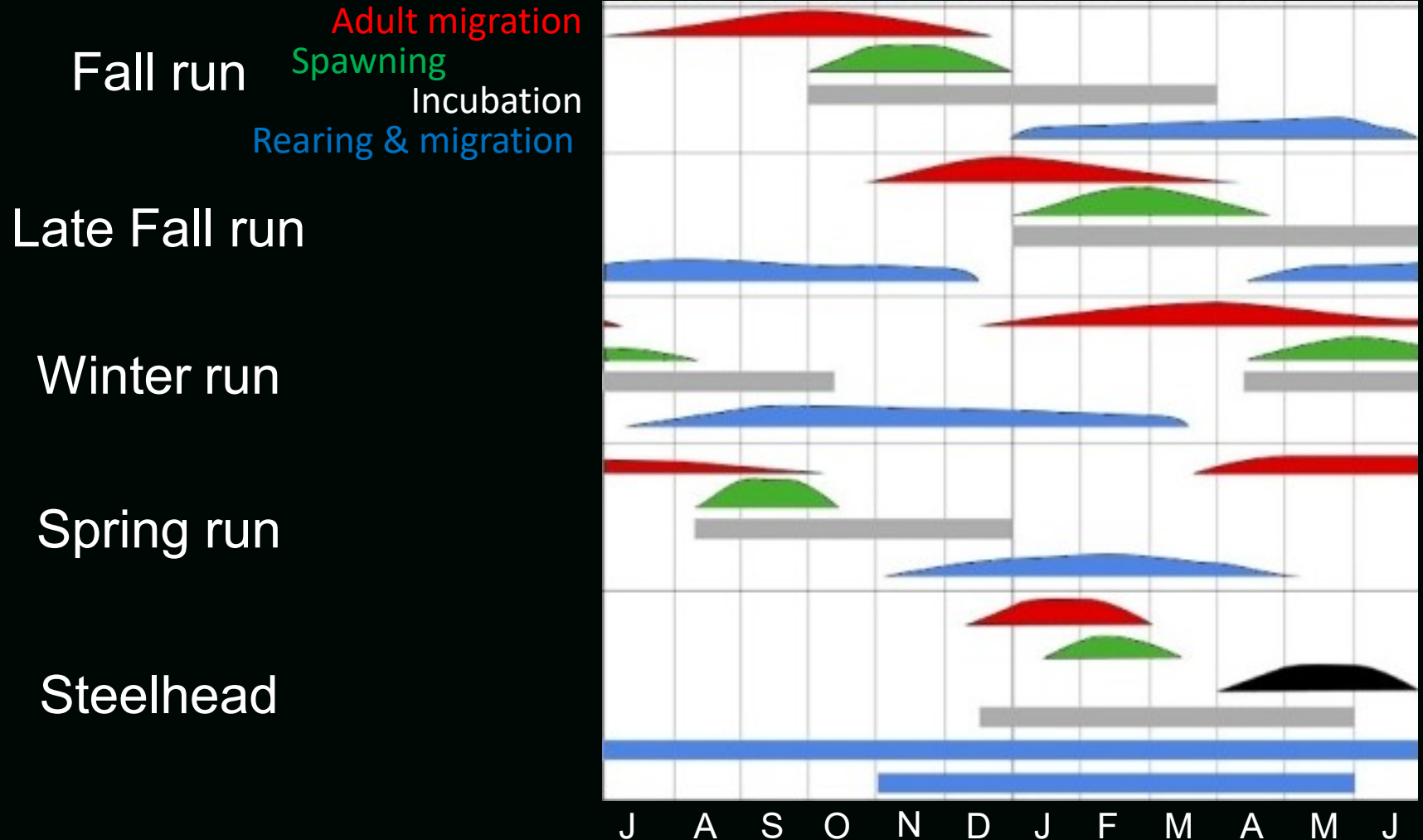
Freshwater

Estuary



Salmon

Diversity spreads risk in space & time





MAP
OF THE
**SAN JOAQUIN, SACRAMENTO
TULARE VALLEYS**
STATE OF CALIFORNIA

PREPARED UNDER THE ACT OF THE

BOARD OF SUPERVISORS OF CALIFORNIA

PASADENA, CALIF., 1884

PRINTED BY THE STATE OF CALIFORNIA

AT THE STATE PRINTING OFFICE

SACRAMENTO, CALIF.

1884

PUBLISHED BY THE STATE OF CALIFORNIA

AT THE STATE PRINTING OFFICE



Scale of Distances

Scale	Feet	Miles
1 inch	63,360	1.2
2 inches	126,720	2.4
3 inches	190,080	3.6
4 inches	253,440	4.8
5 inches	316,800	6.0
6 inches	380,160	7.2
7 inches	443,520	8.4
8 inches	506,880	9.6
9 inches	570,240	10.8
10 inches	633,600	12.0

1884

Published by the State of California
at the State Printing Office
Sacramento, California

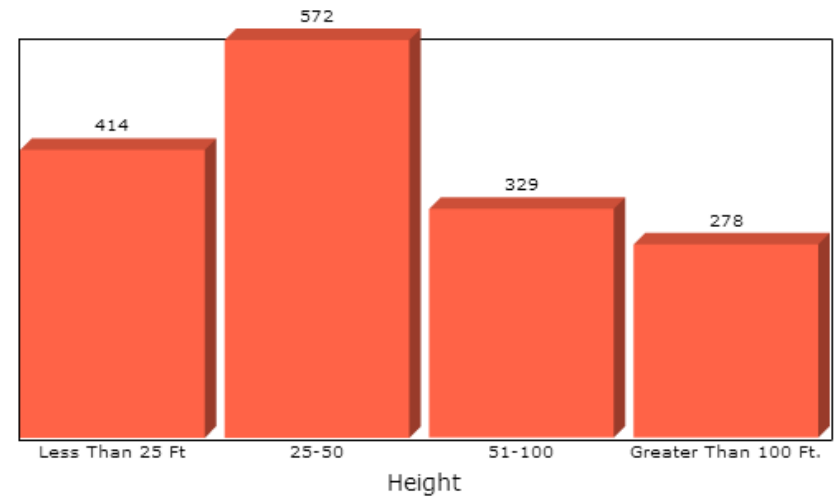
Select from the following Map Views

-  Major Rivers
-  State Projects
-  Federal Projects
-  Local Projects
-  All Water Projects

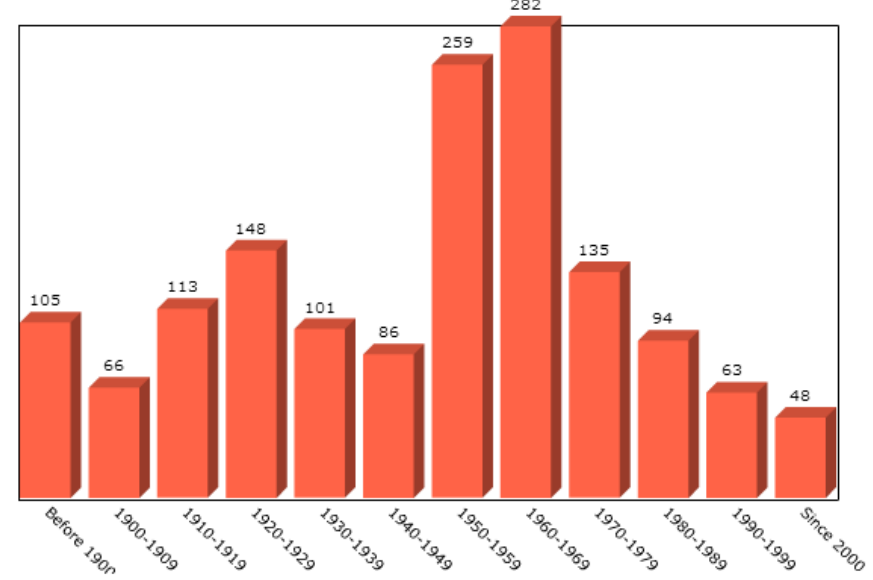




Dams by Height



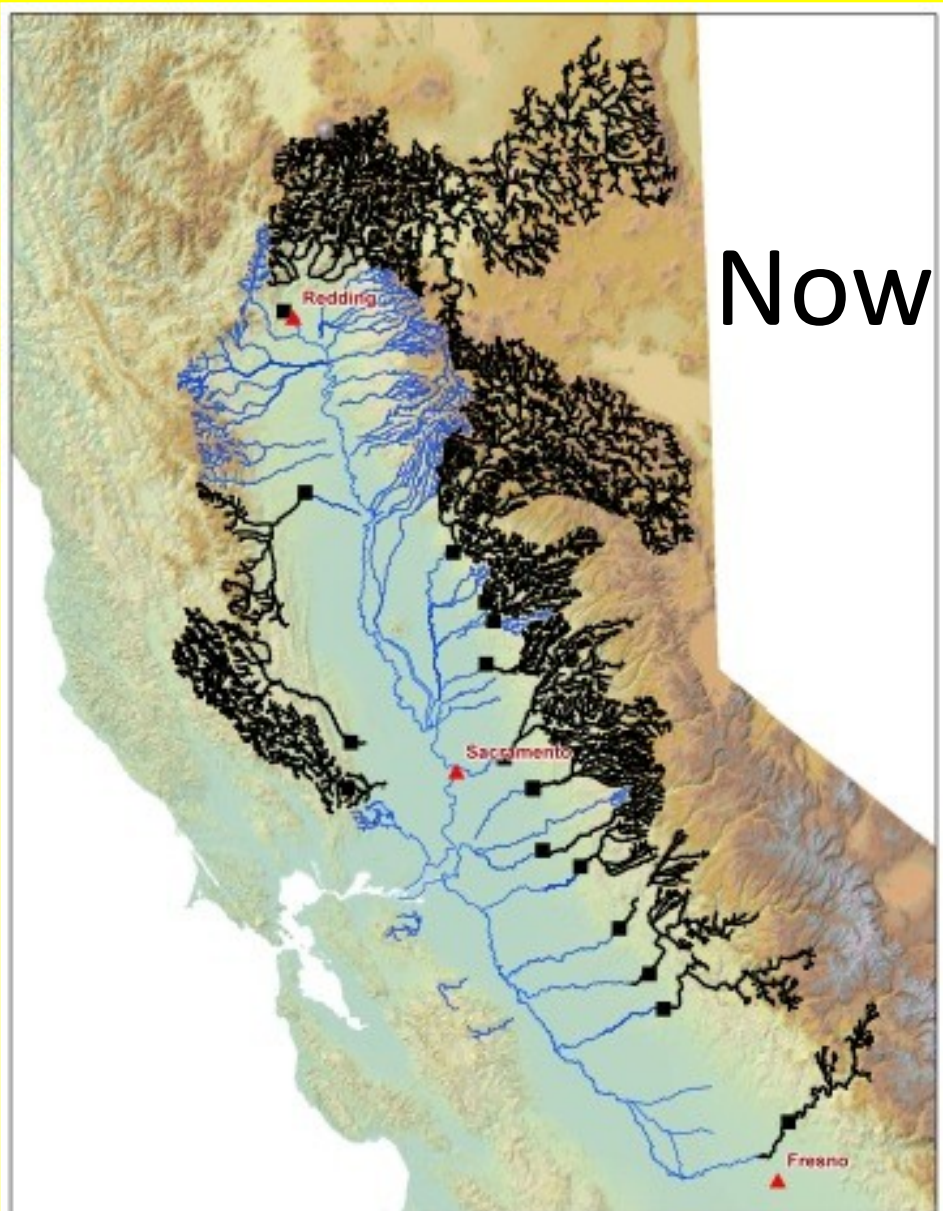
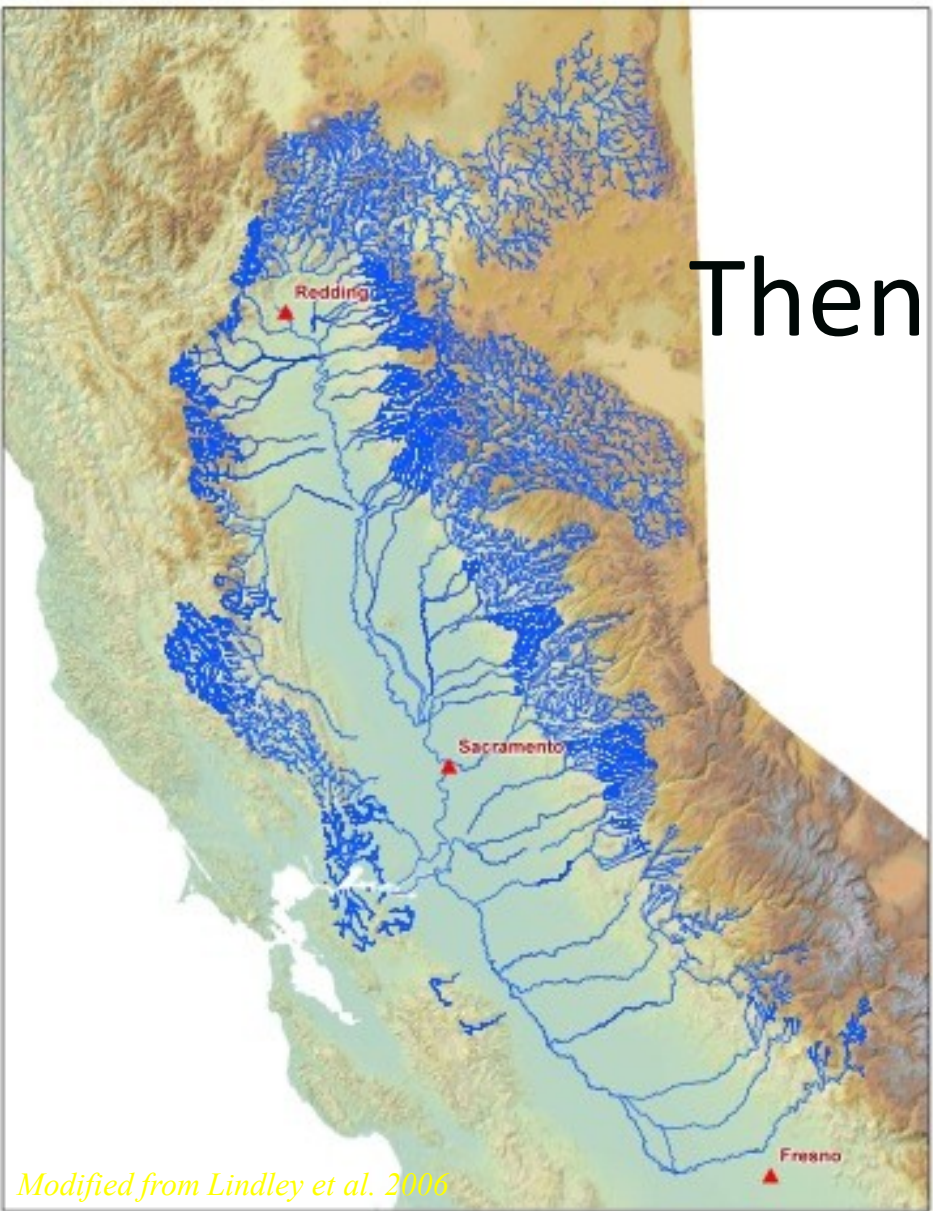
Dams By Completion Date



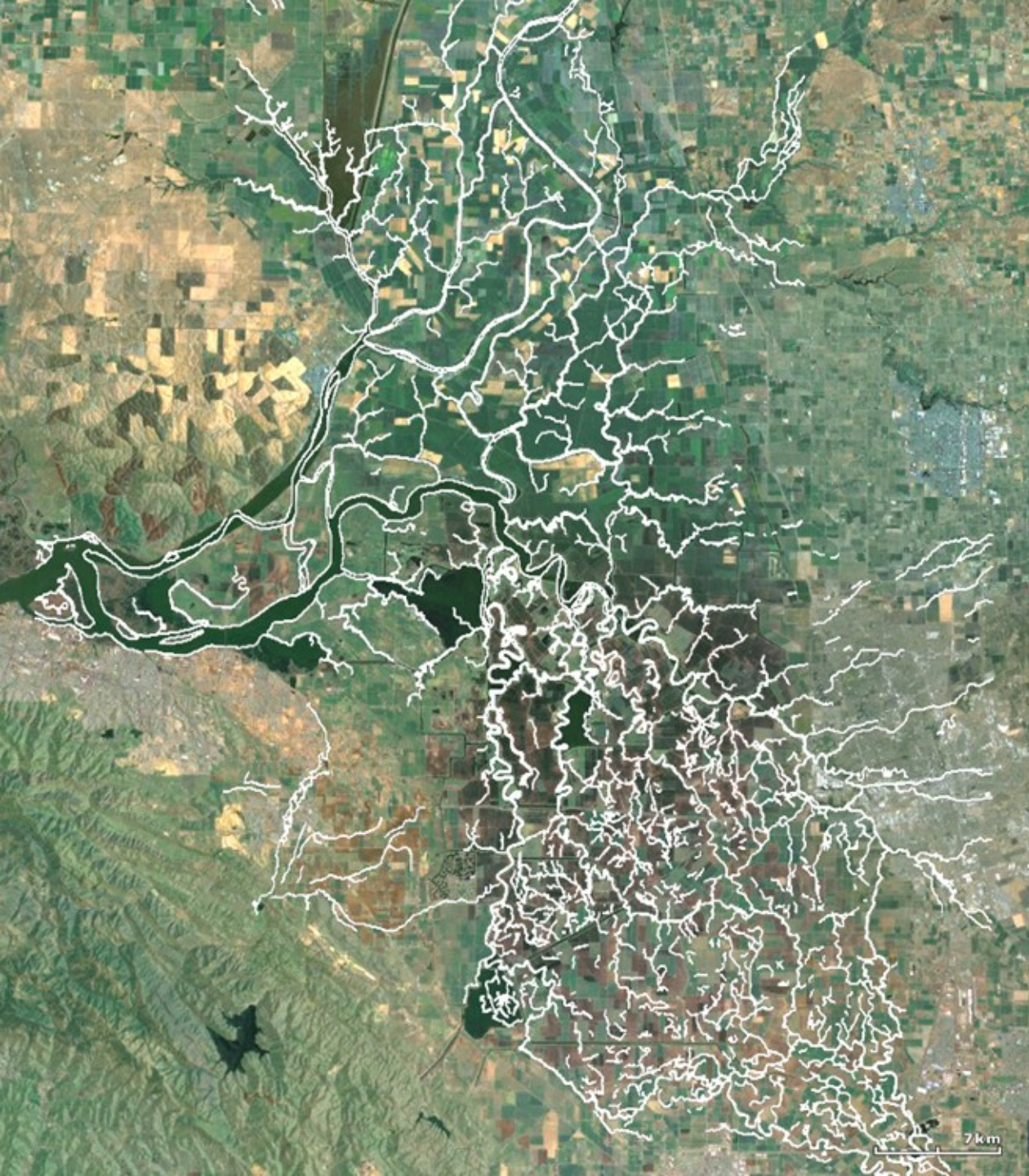
1594 Dams in California
 National Inventory of Dams, Army Corps

Then

Now



Modified from Lindley et al. 2006



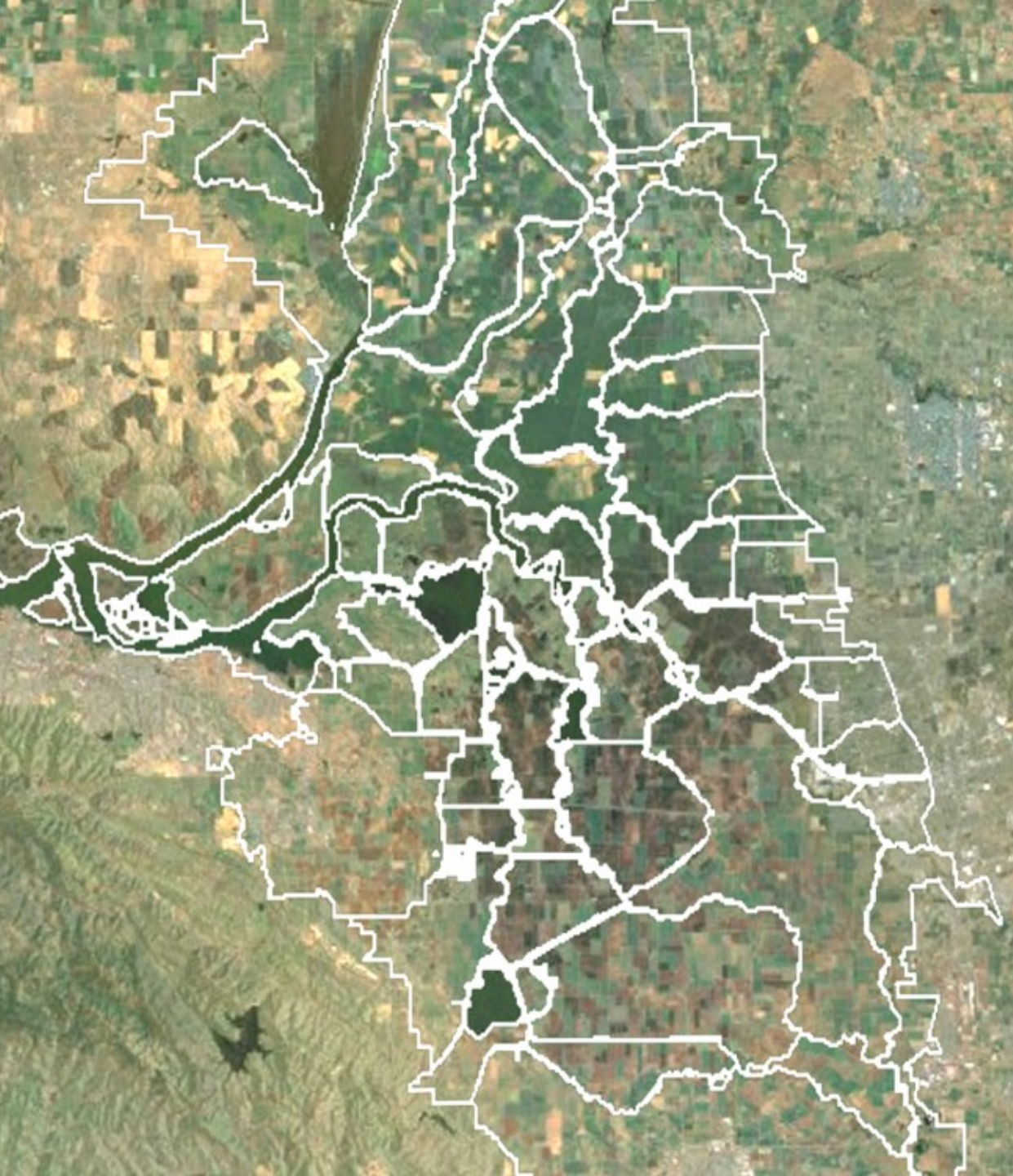
1873 Delta:

Long residence time

Marsh connections

Two rivers connect
to bay

Waterways dendritic



Modern delta

Short residence times

Rip-rapped

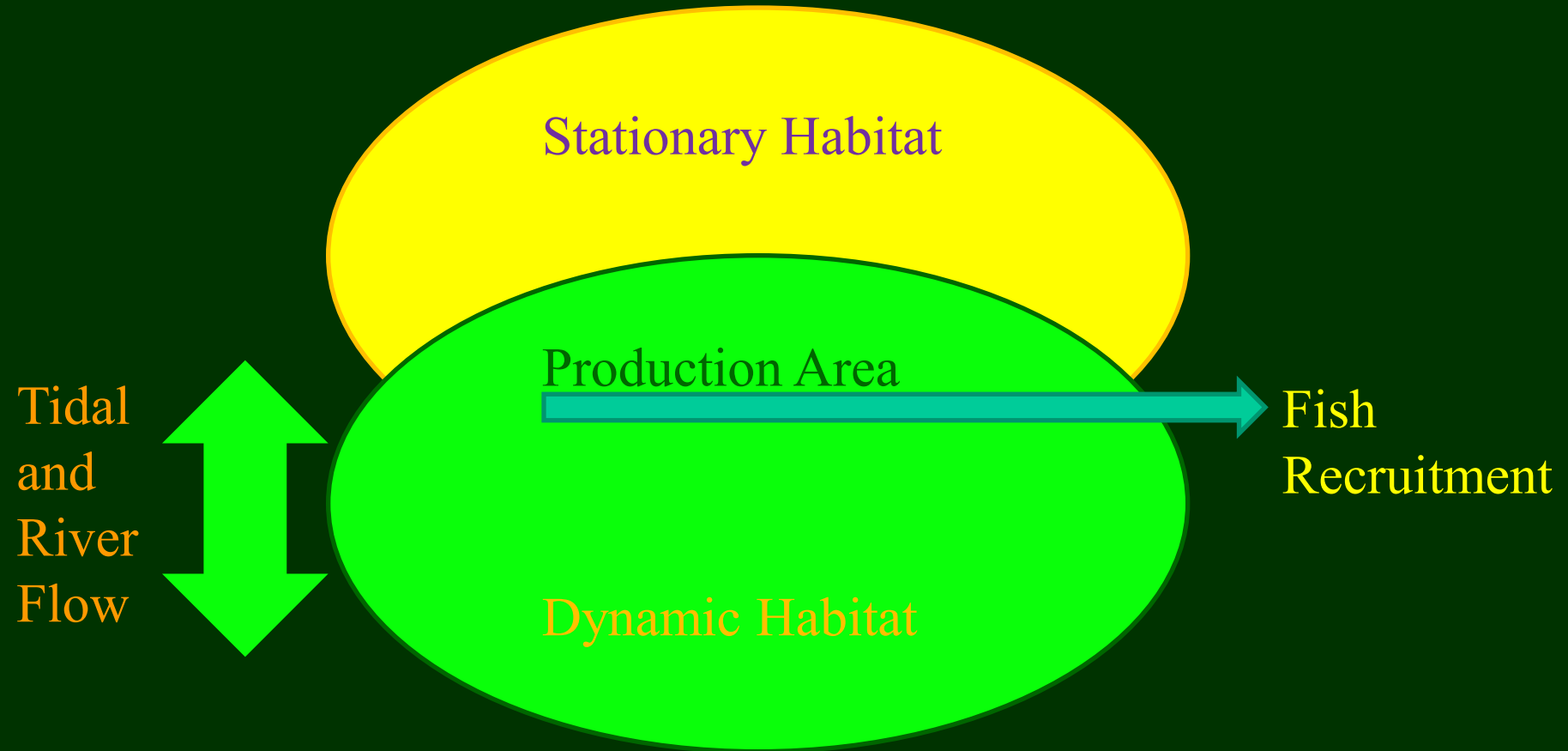
Cross Delta flows

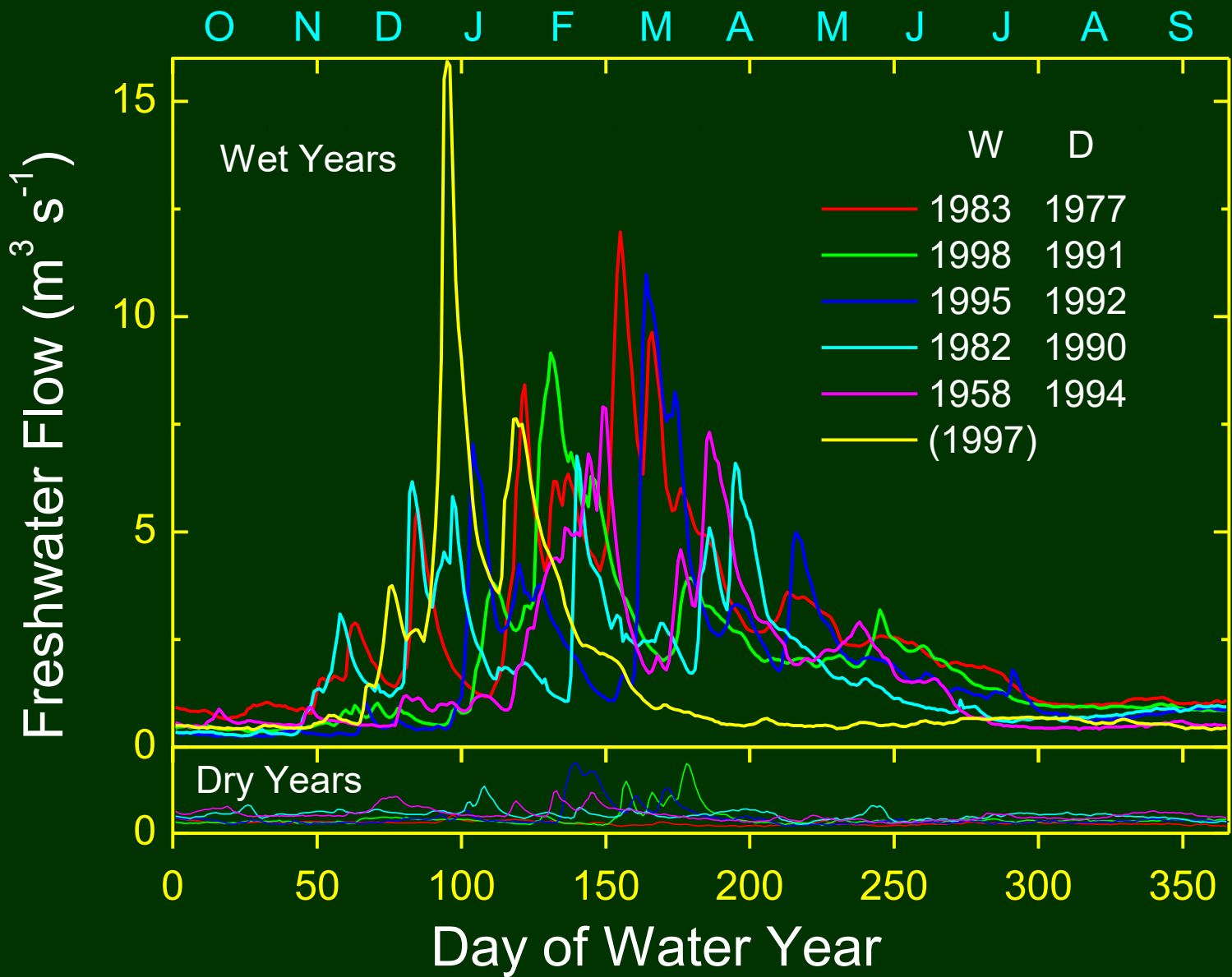
Rare San Joaquin
connection to bay

Waterways web-like

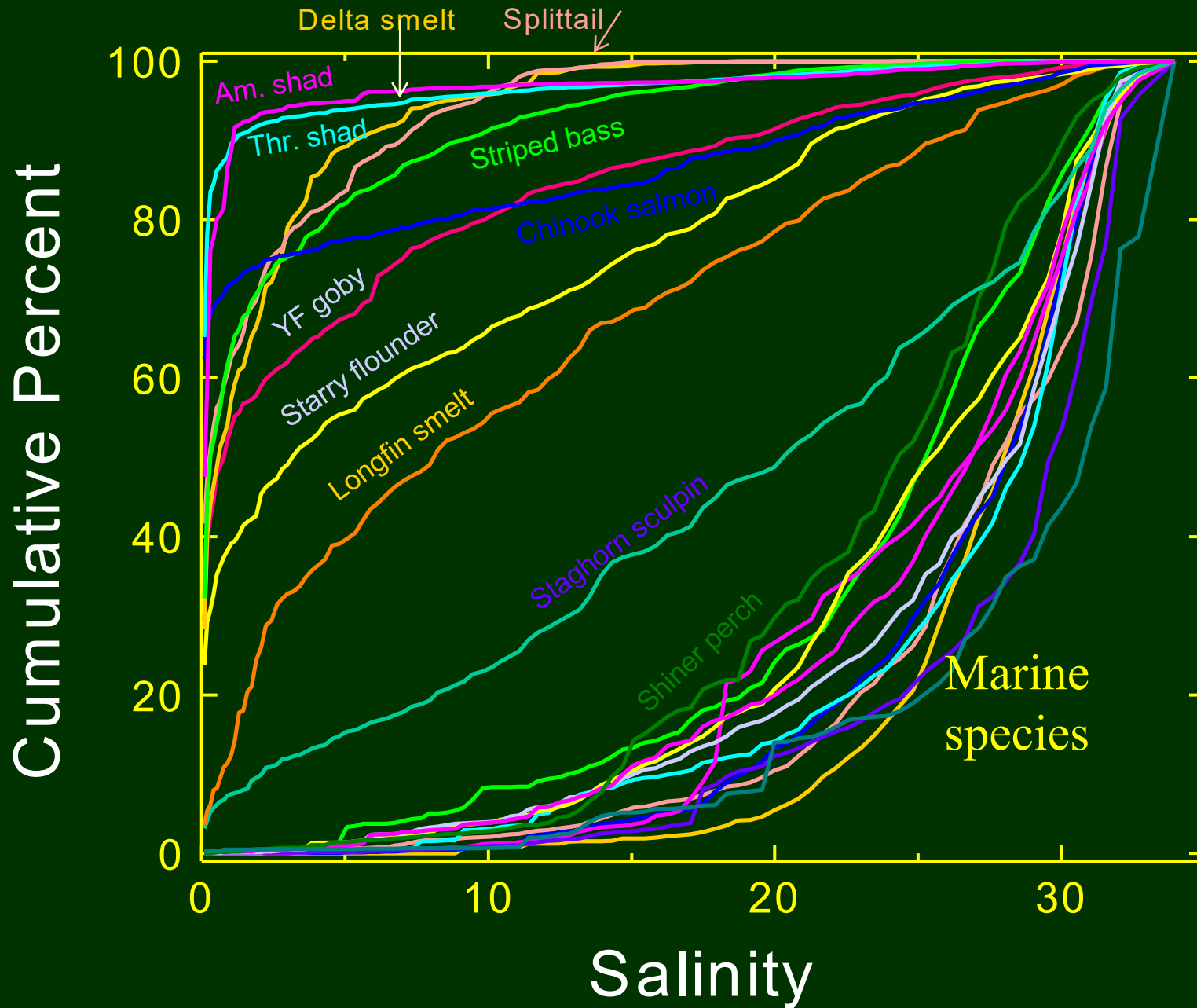
Estuarine habitat conceptual model

(Peterson 2003)





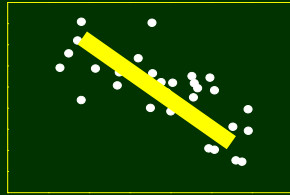
Most fishes follow salinities



[Kimmerer 2004](#)

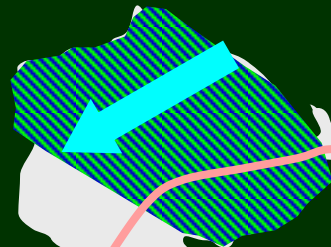
What Changes As Flow Increases?

Salinity
and X2



FLOW

Location of
Any Salinity
Range

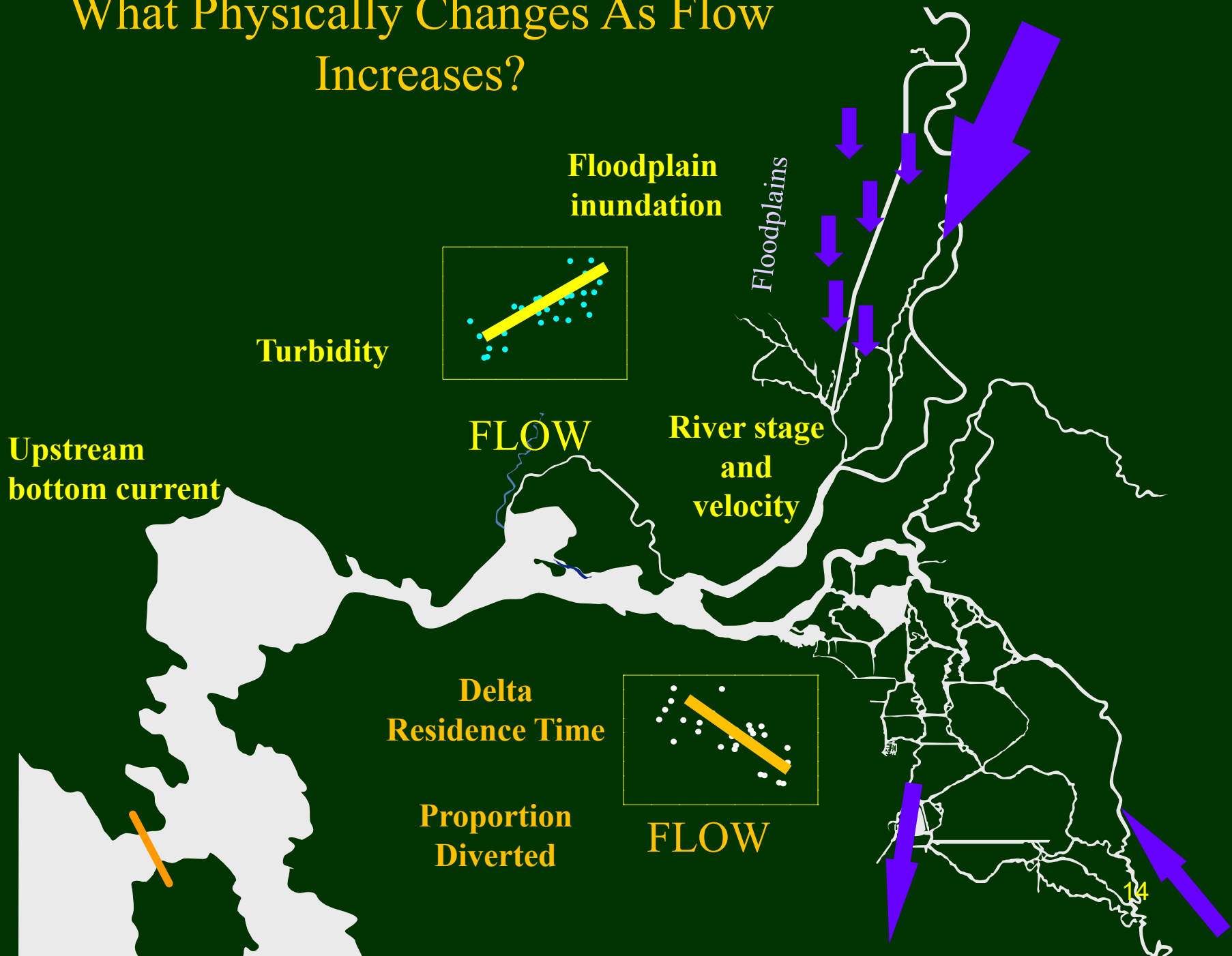


stratification

L
S
Z

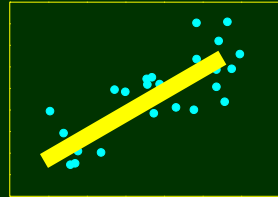


What Physically Changes As Flow Increases?



What chemically changes?

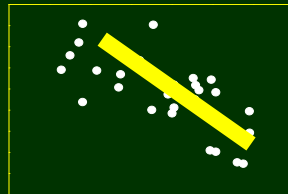
Loadings



FLOW

Nutrients
Contaminants
Organic matter
Sediment

Concentrations



FLOW

What Biologically Changes As Flow Increases?

Adult spawners move up:

Salmon

Green and White Sturgeon

Longfin smelt

Delta smelt

Splittail

American shad

Pacific herring

Young fish move down:

Salmon

Longfin smelt

Delta smelt

Splittail

American shad

Striped bass

Young Marine fish move up:

Starry flounder

White croaker

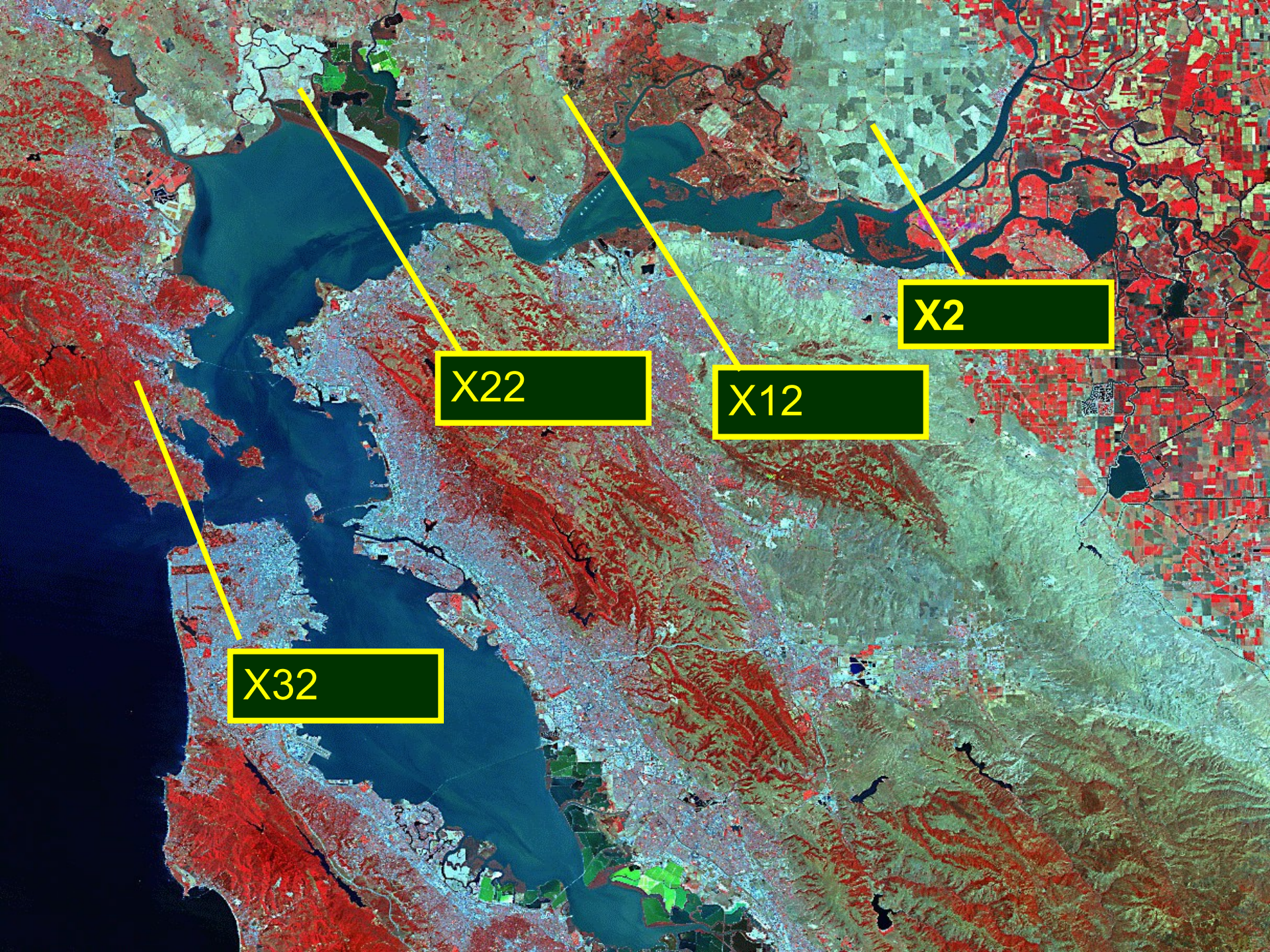
Pacific halibut



How much water do fish need?



X2

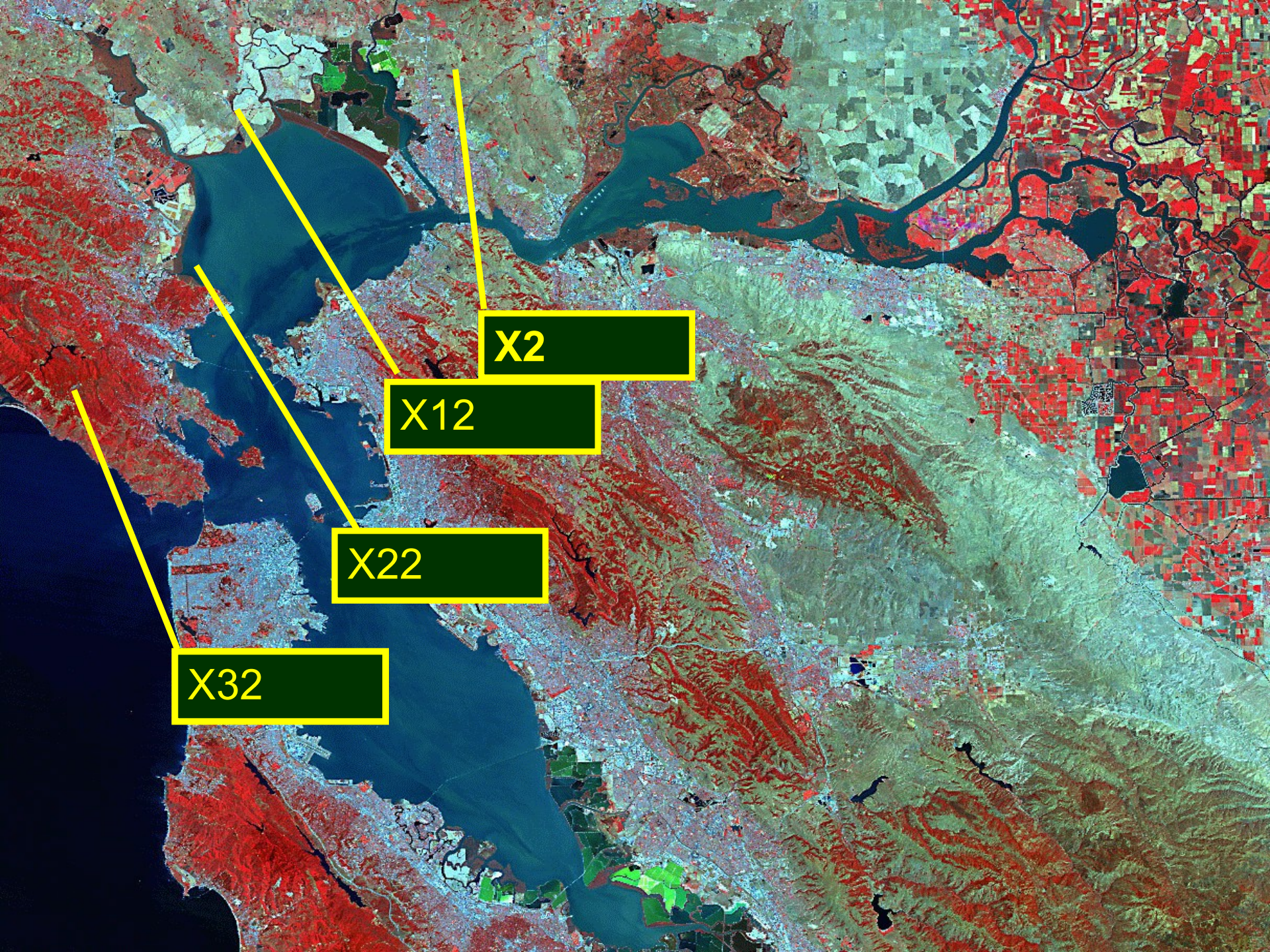


X2

X12

X22

X32

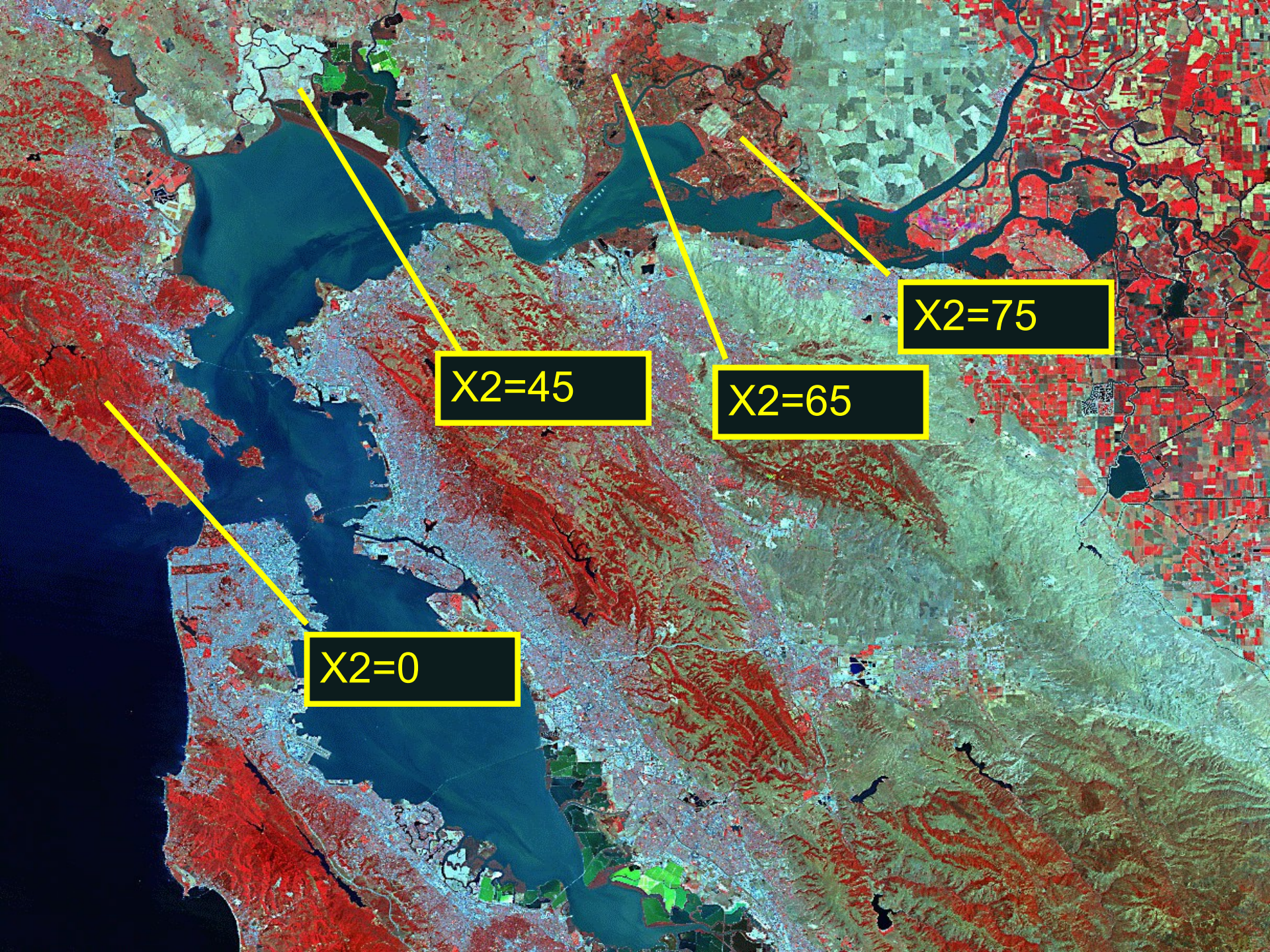


X2

X12

X22

X32



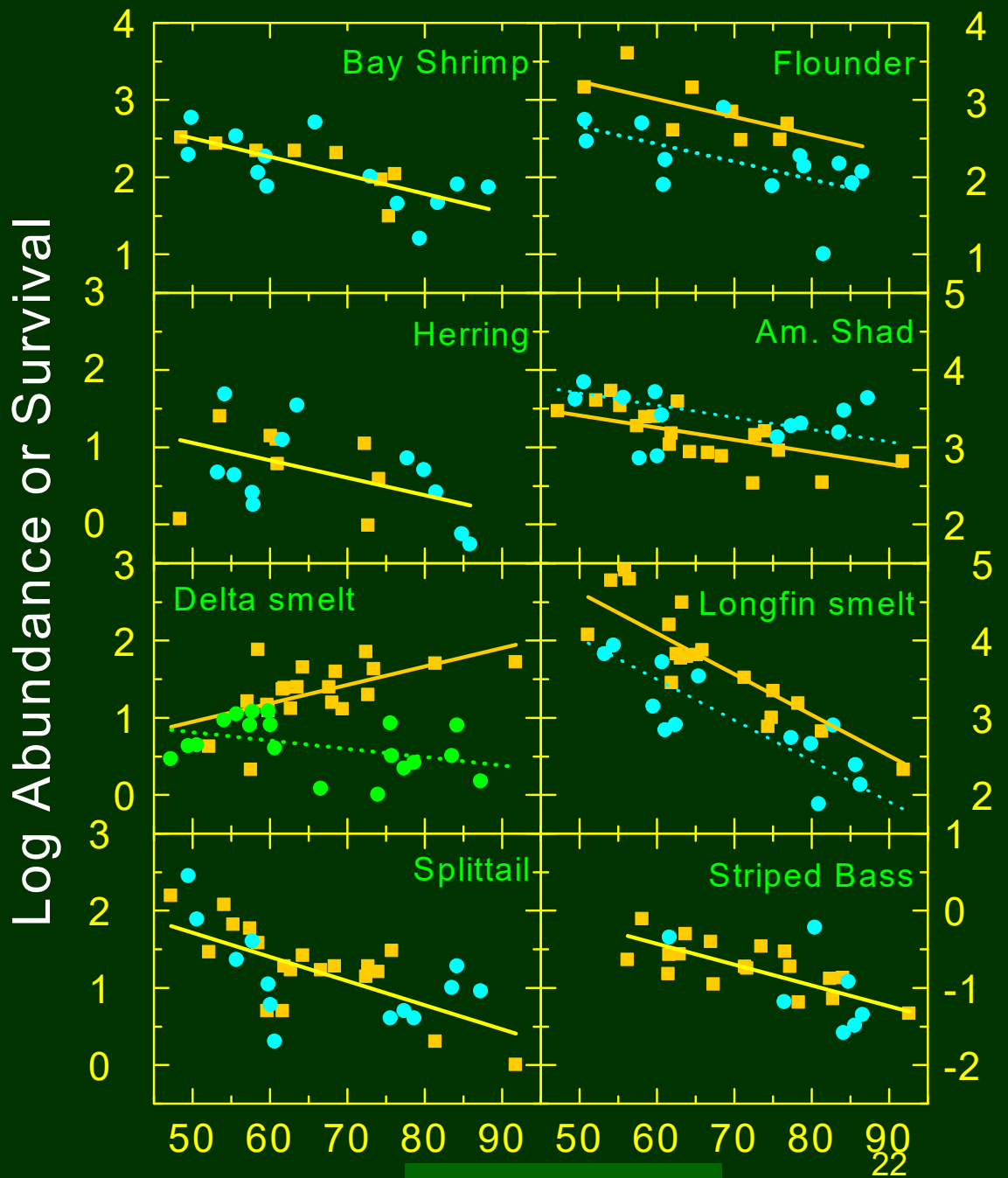
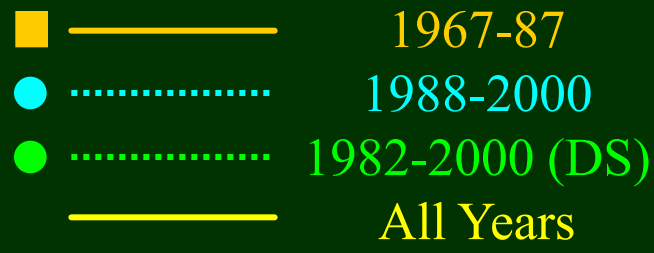
$X2=0$

$X2=45$

$X2=65$

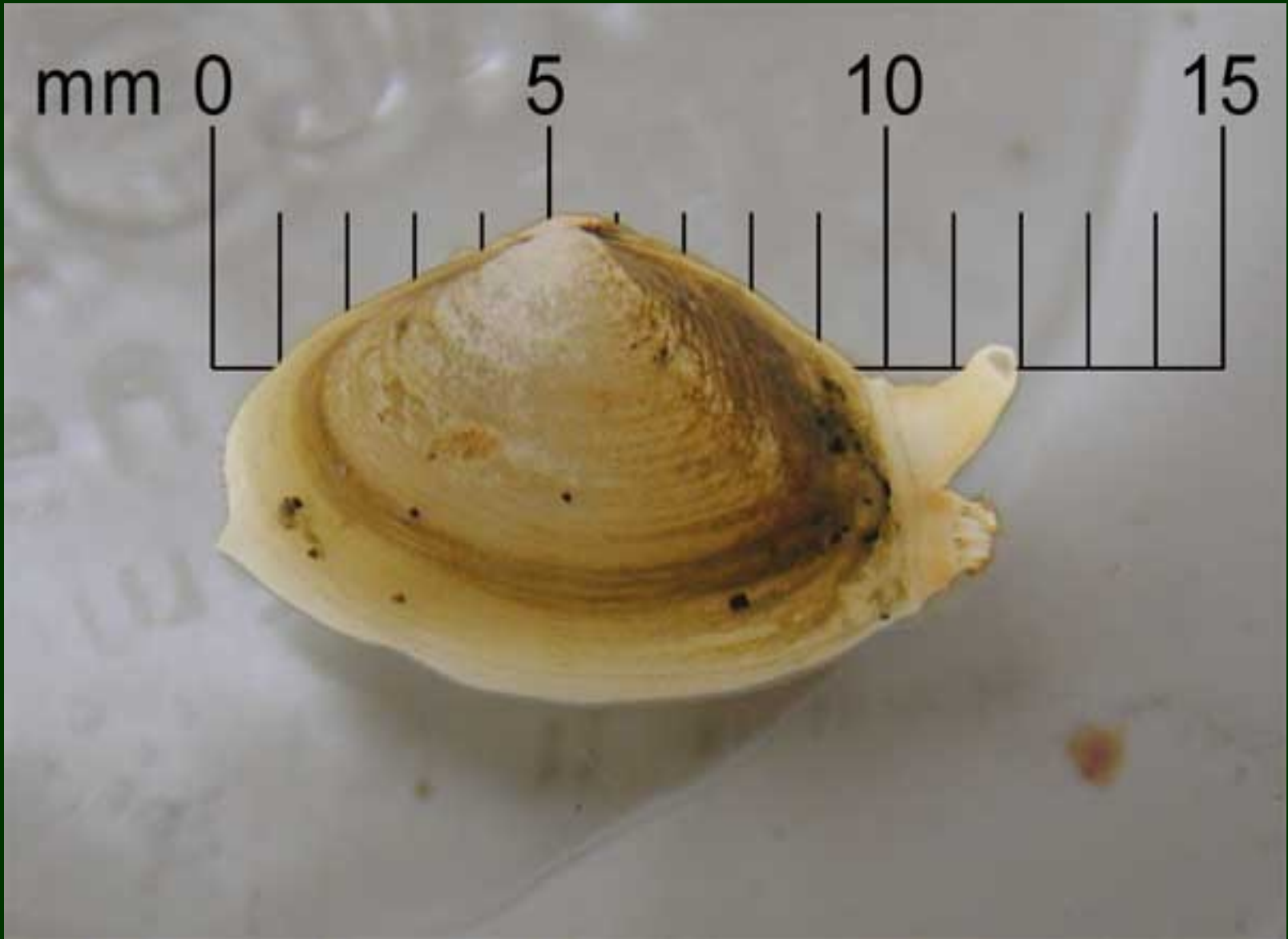
$X2=75$

Higher trophic levels show many relationships of abundance to X2



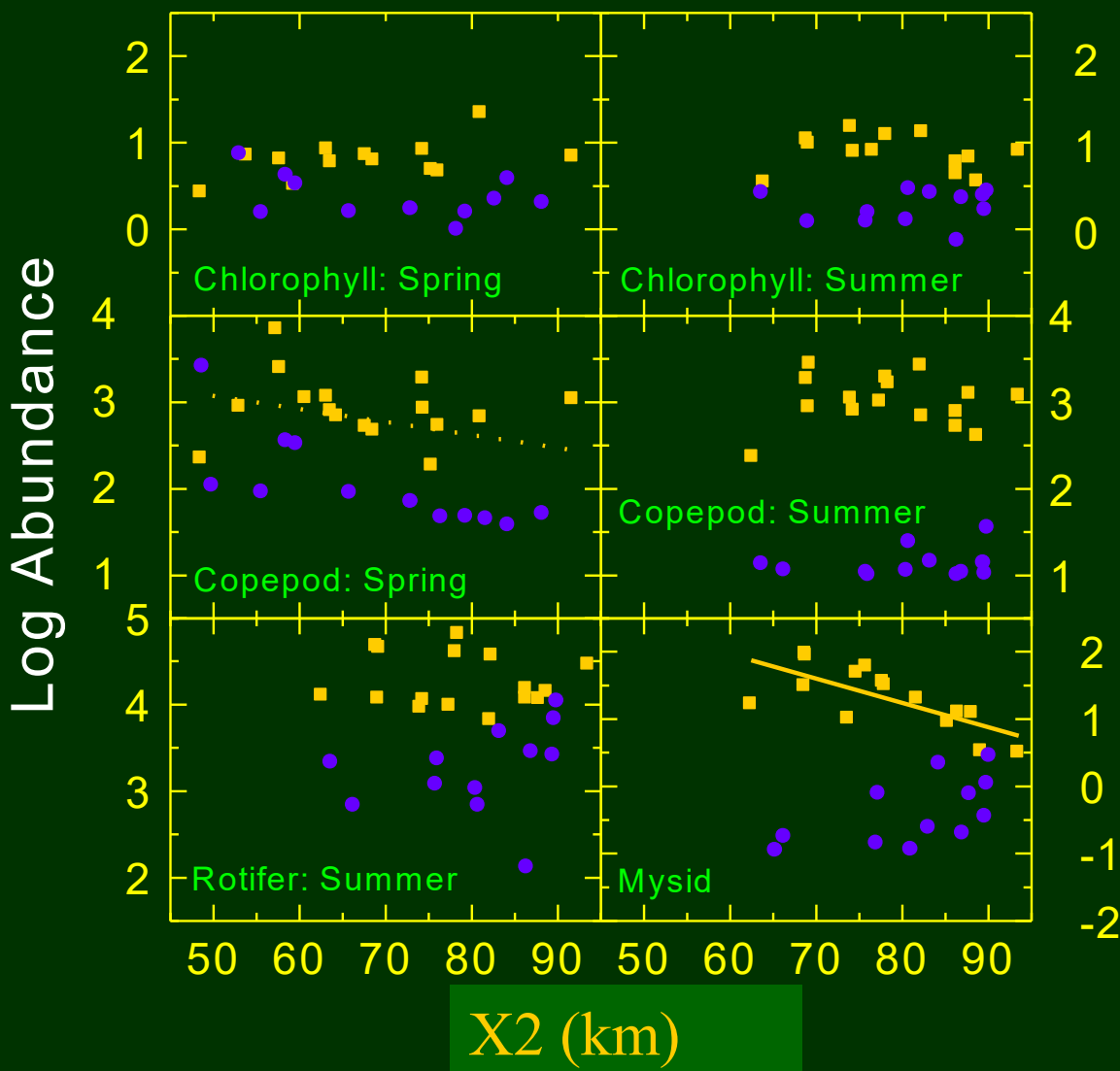
High Flow X2 (km) Low Flow

Source: Kimmerer 2002MEPS



Lower trophic levels show few relationships of abundance to X2

■ — 1972-1987
 ● 1988-2000

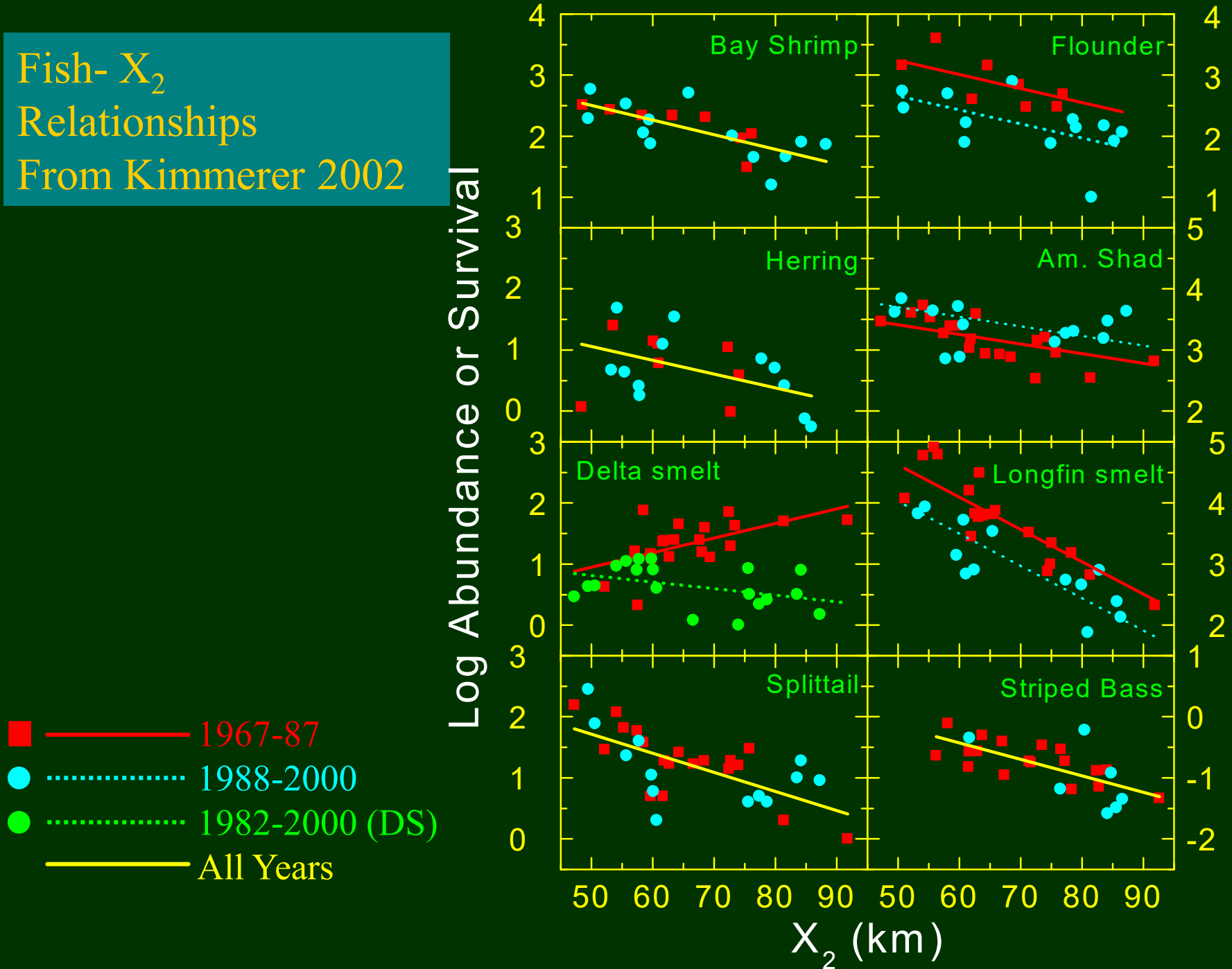


Source:
 Kimmerer 2002 MEPS

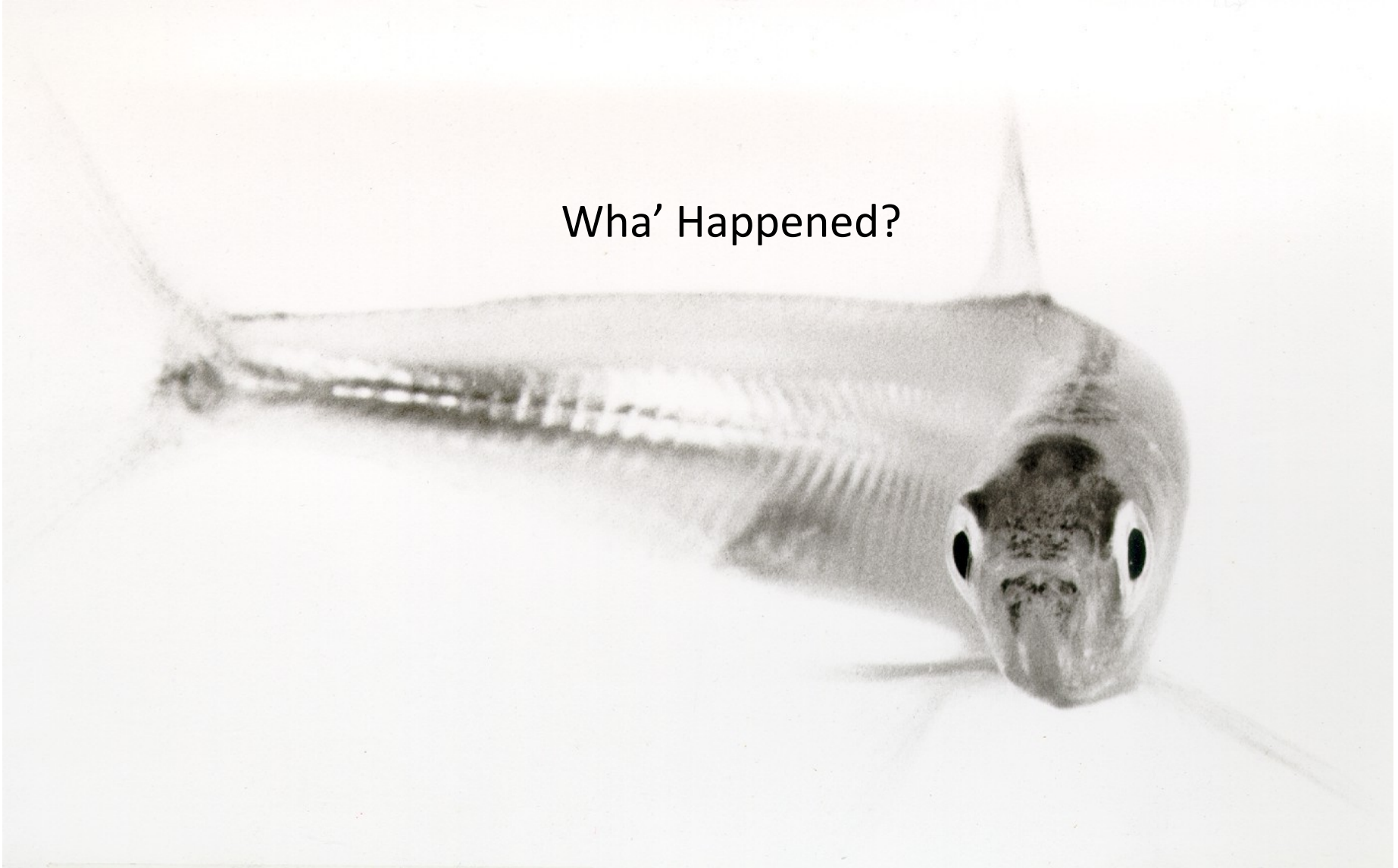
High Flow

24
 Low Flow

Fish- X_2 Relationships From Kimmerer 2002



Wha' Happened?



POD---

Pelagic

Organism

Decline

Delta smelt

Longfin smelt

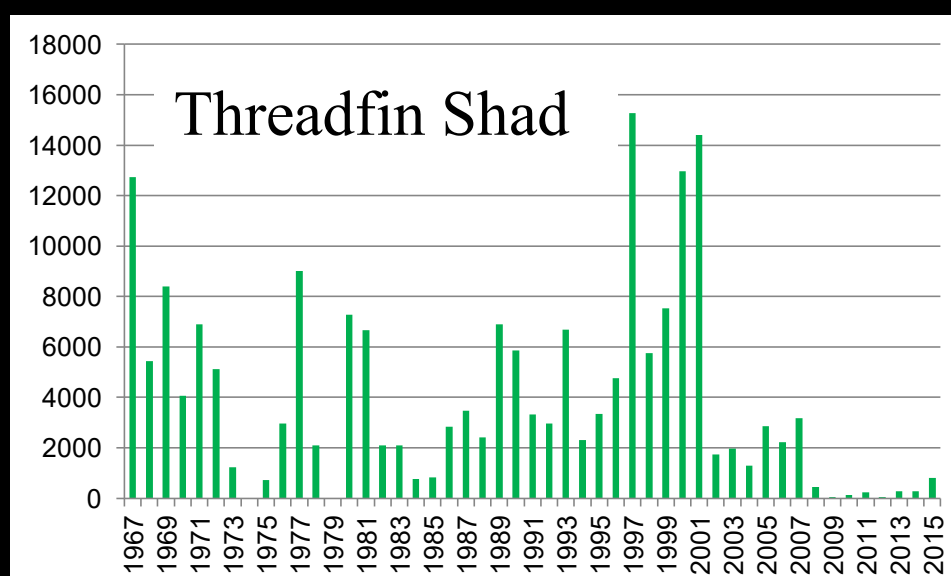
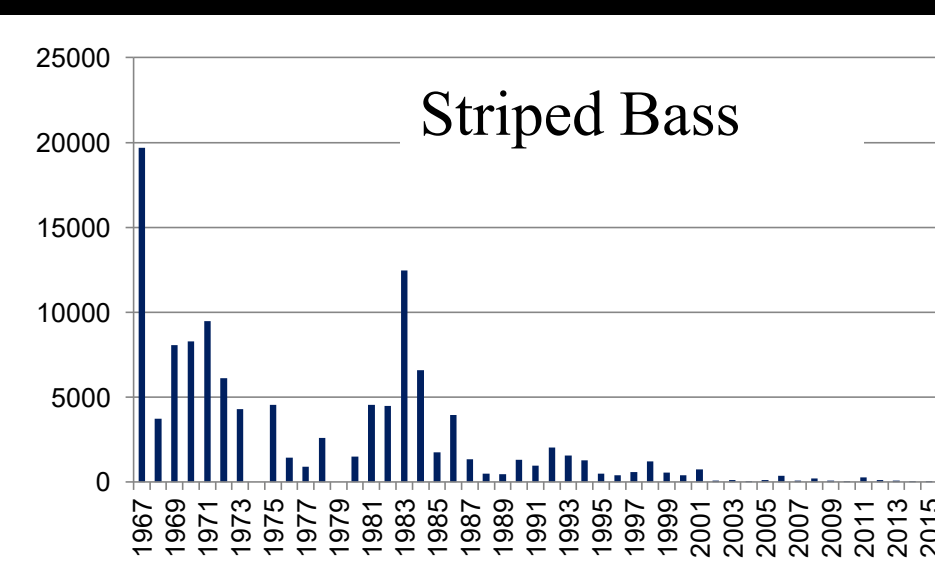
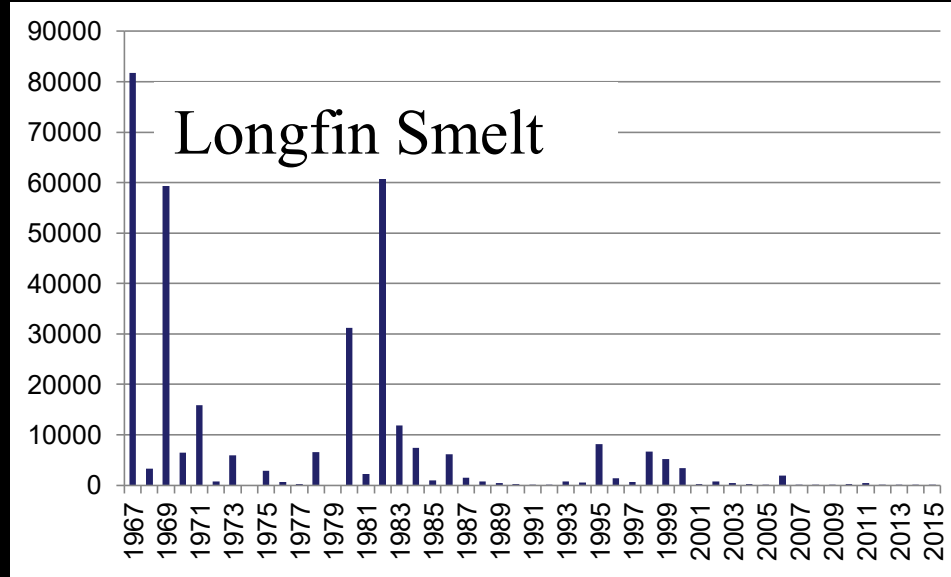
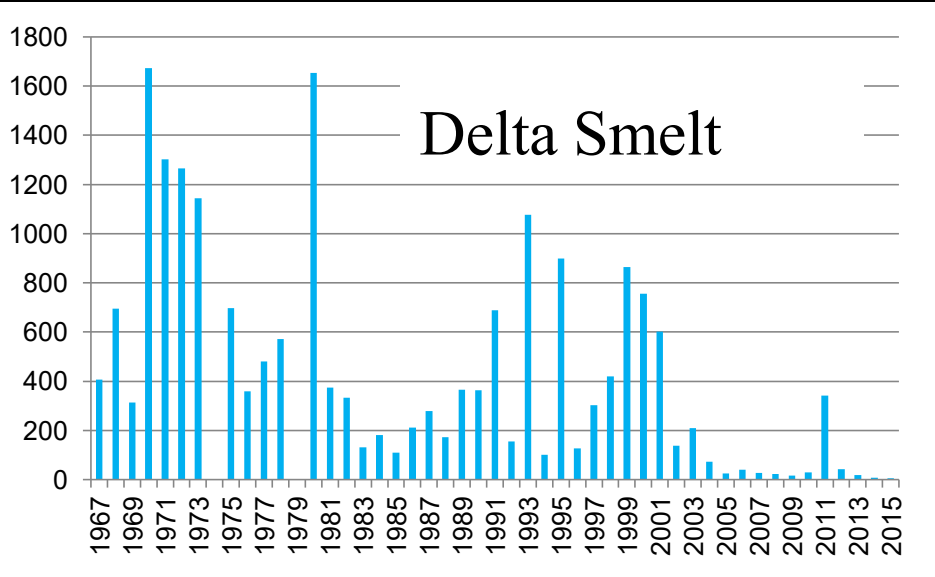


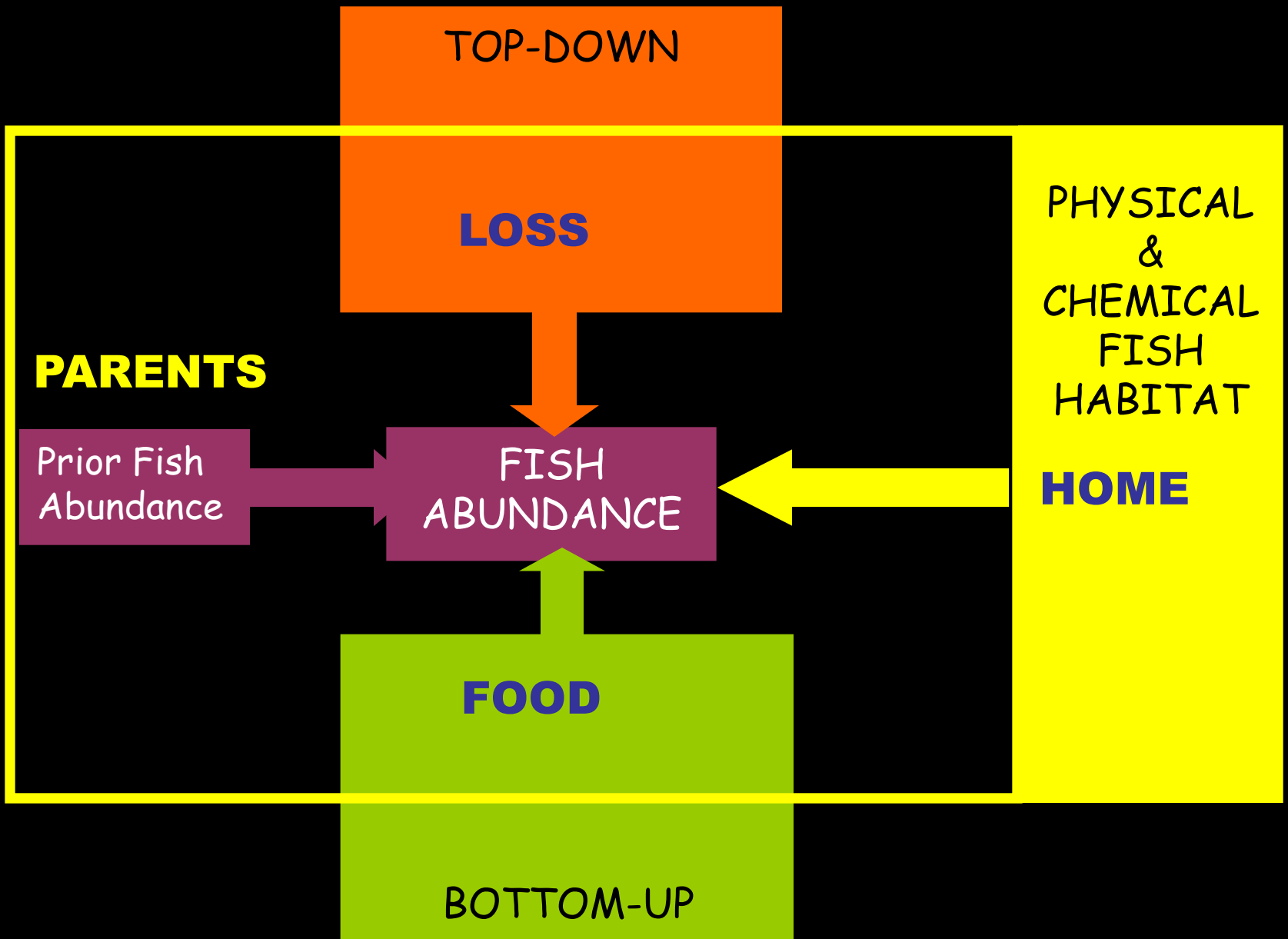
Striped bass



Threadfin shad

Fall Abundance Indices 1967-2015

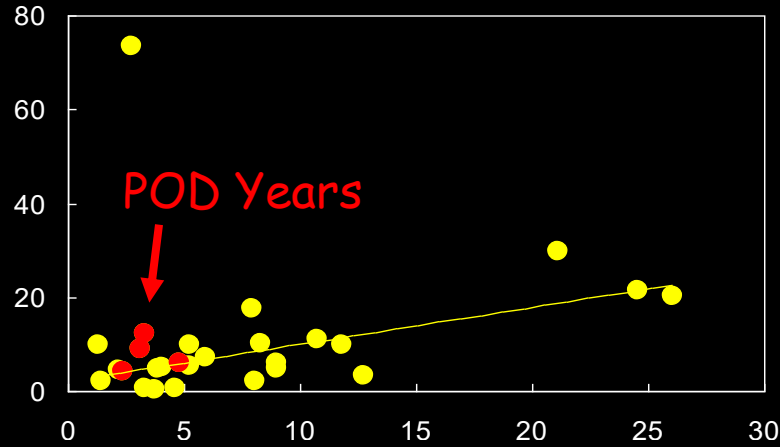




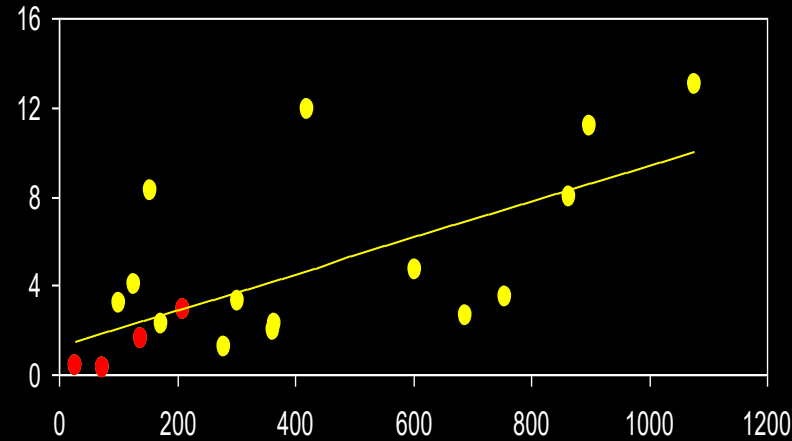
Stock - Recruitment Effects



Juvenile Production



Threadfin shad



Delta smelt

Fall Midwater Trawl (Adults)

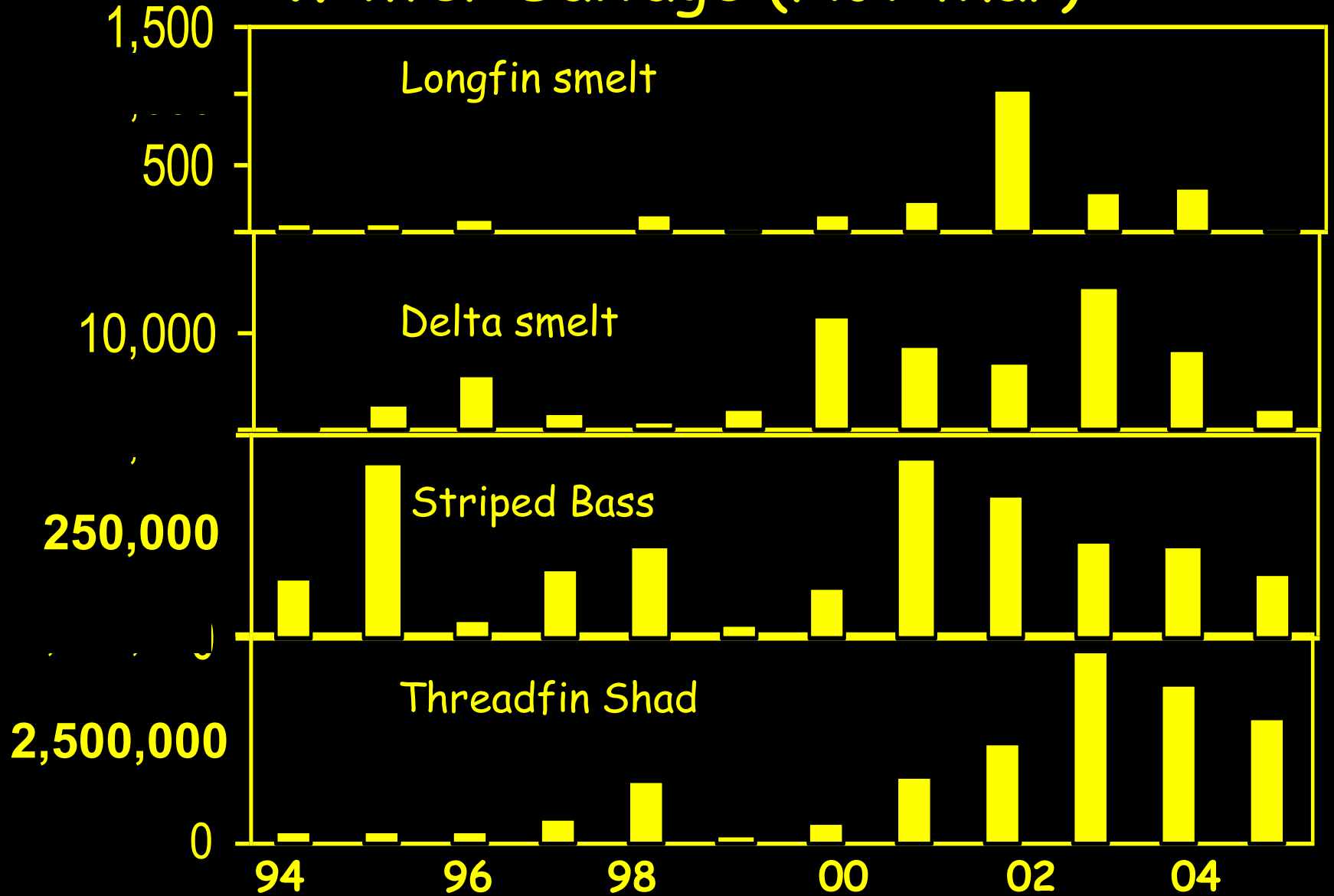


Water Project Losses



Fish Facilities Provide Data on Numbers “Salvaged”

Winter Salvage (Nov-Mar)

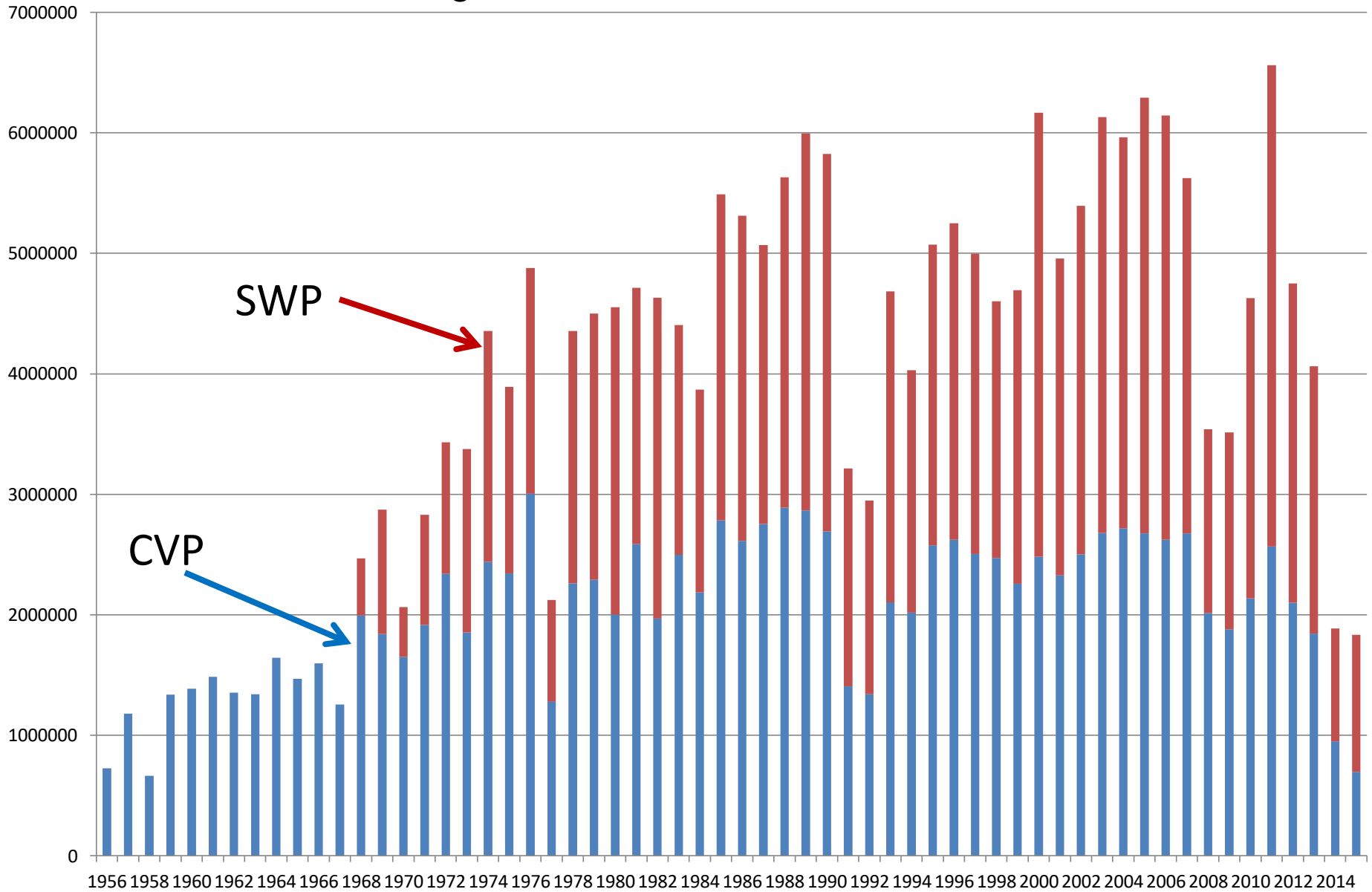


Exports in acre-feet

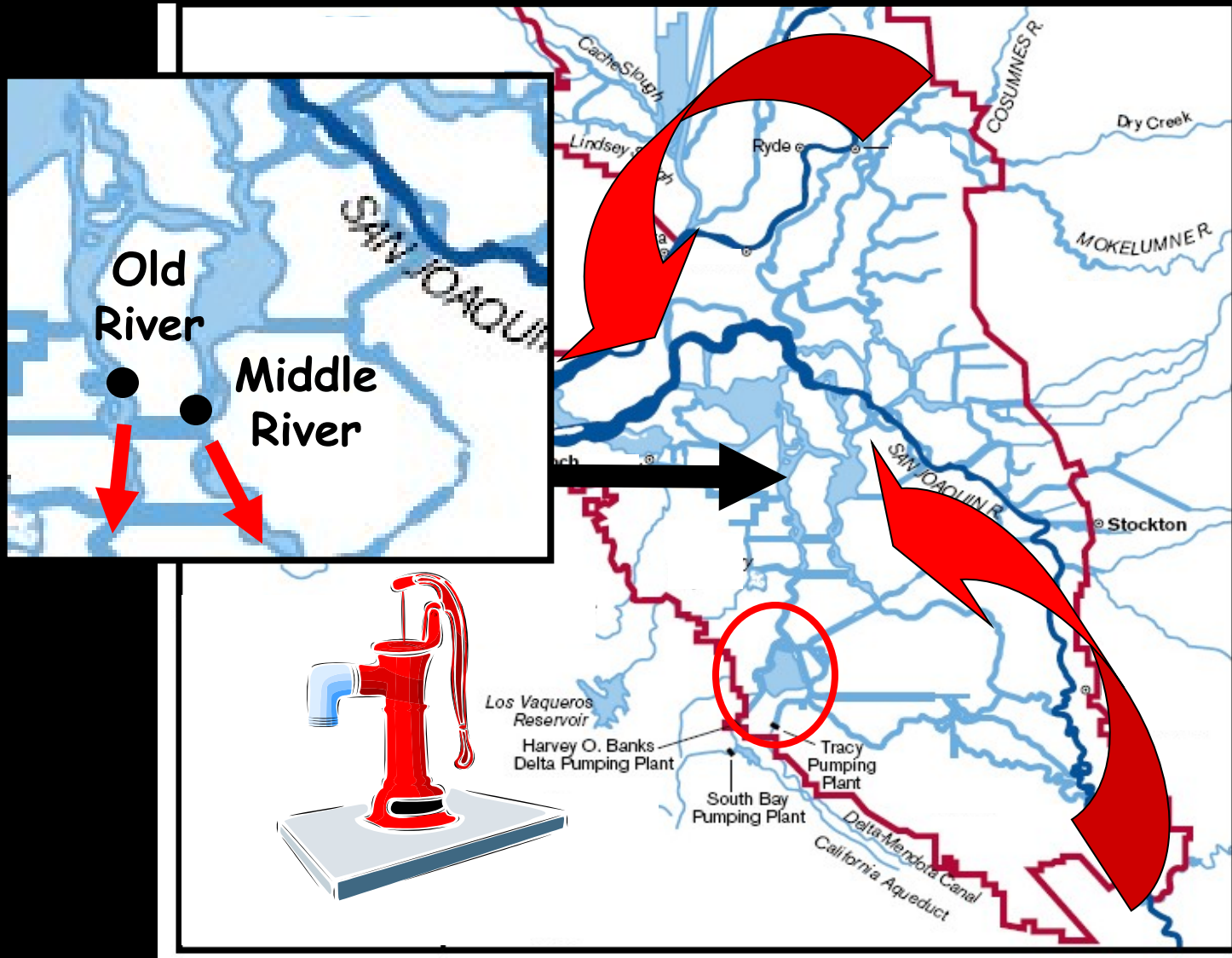
1 acre-foot = 325,851 gallons

OR 1233 kiloliters

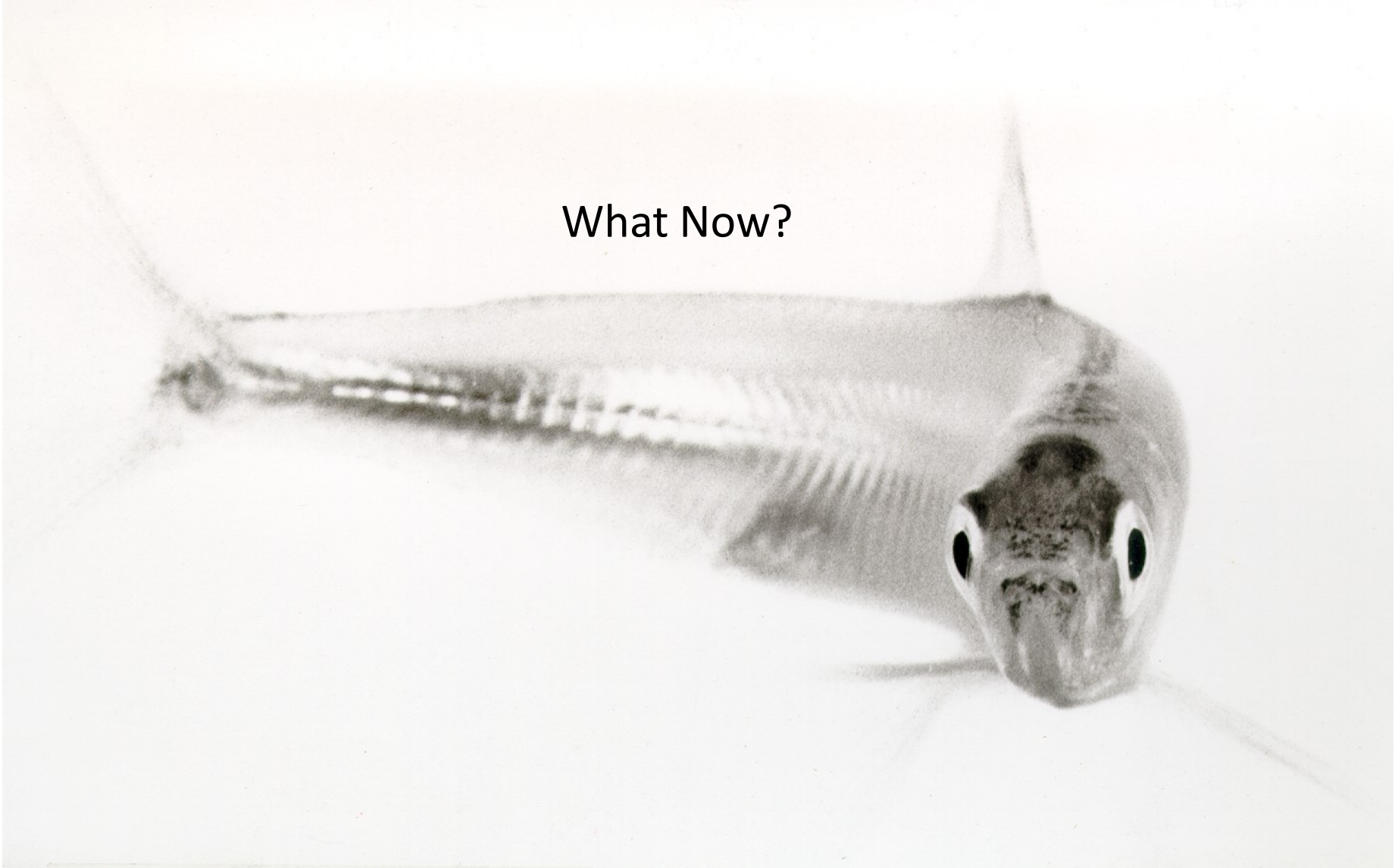
OR 1 cfs for 12 hours



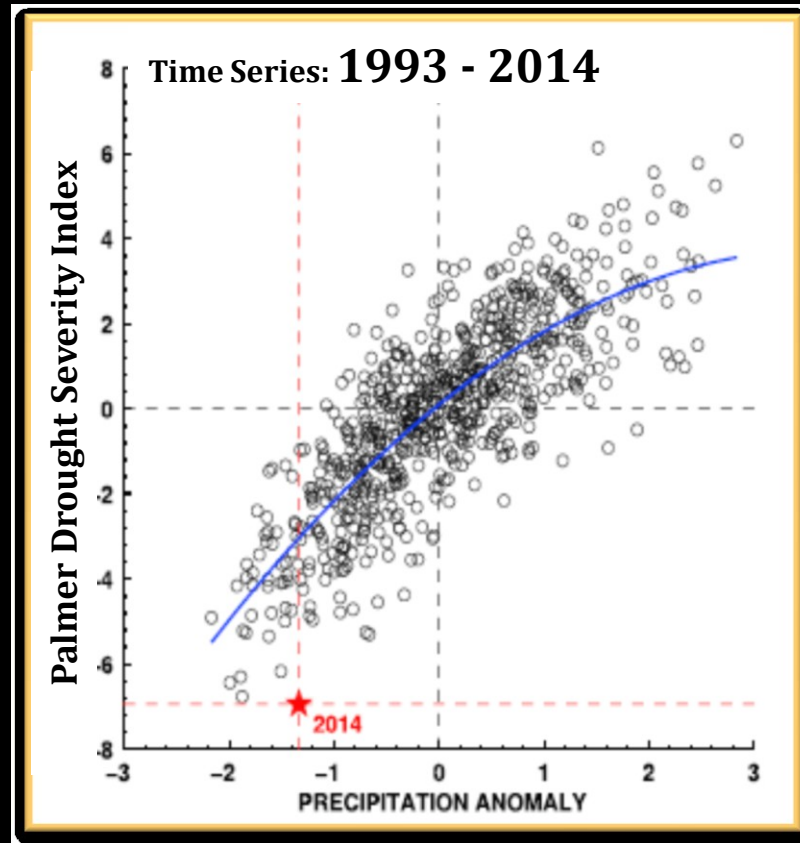
OMR = Old and Middle River flows



What Now?



Drought Effects on Delta Smelt Application of a Conceptual Model



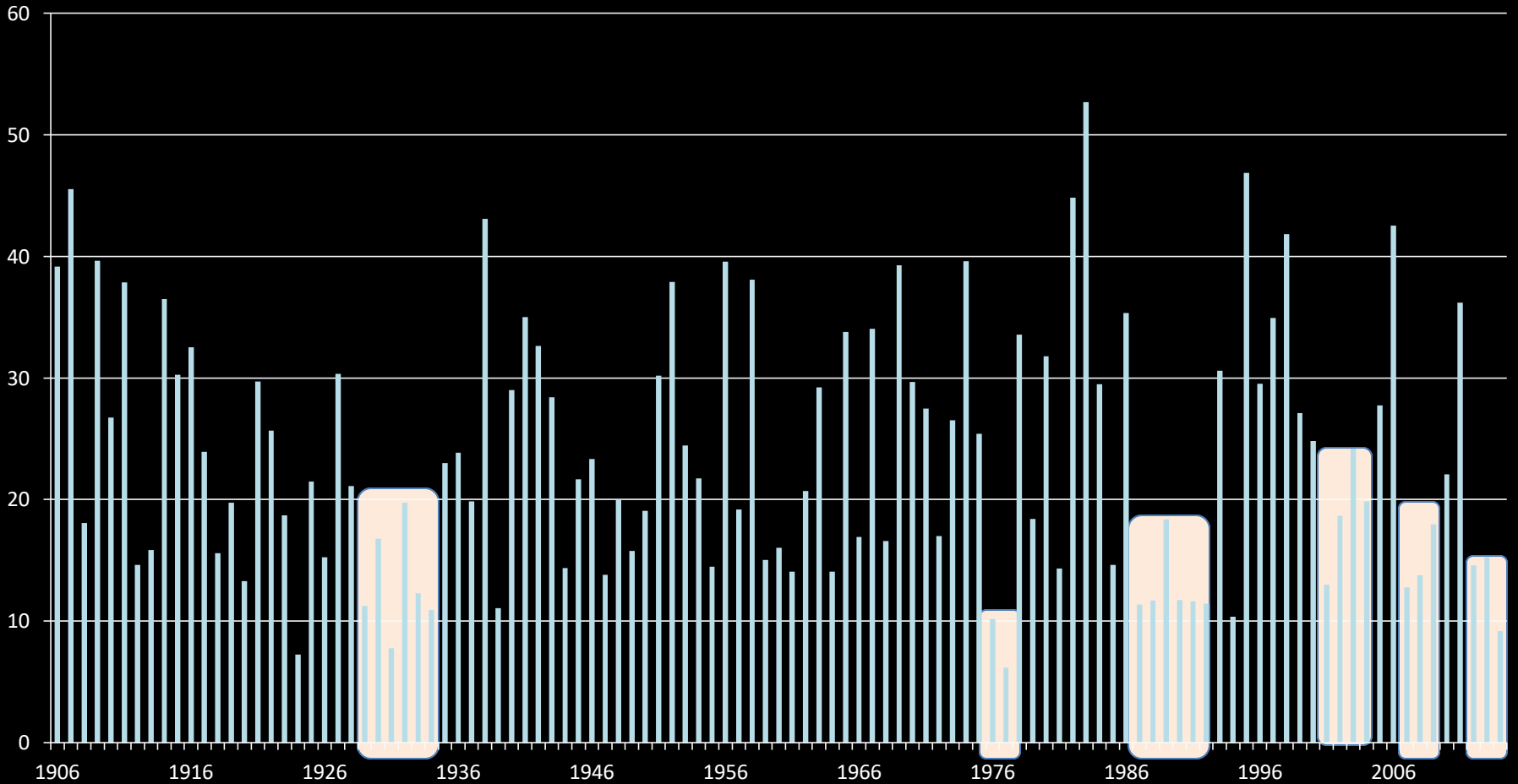
Griffin & Anchukaitis, 2014

Geophysical Research Letters, 41: 1-7.

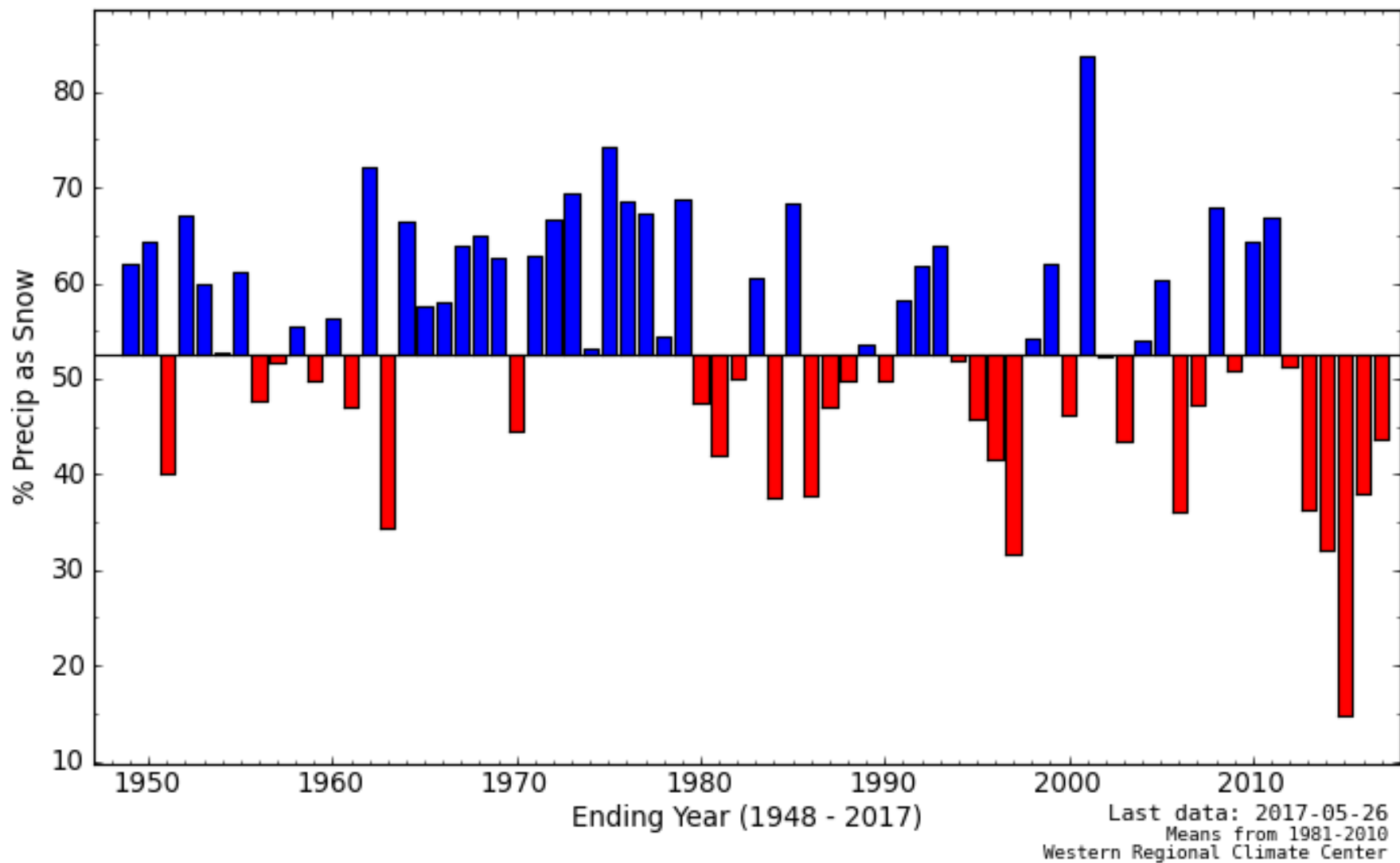
Thanks to Louise Conrad, DWR



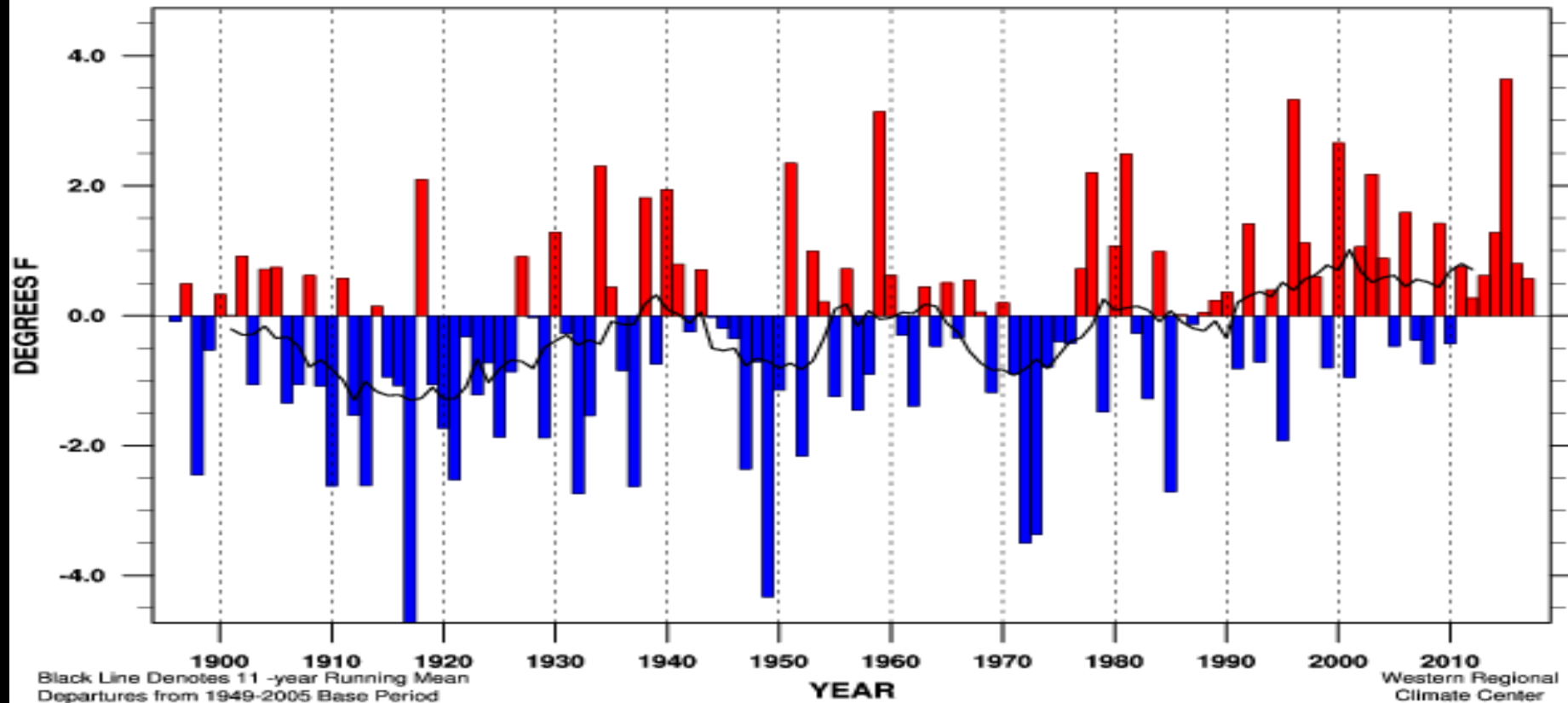
Central Valley Runoff MAF



7 Months Ending in May % of Precip as Snow 39.28°N, 120.37°W 2200m



California Statewide Mean Temperature Departure Oct-Jan



Linear Trend 1895-present	+ 1.24 ± 0.73 °F/100yr	
Linear Trend 1949-present	+ 1.94 ± 1.72 °F/100yr	
Linear Trend 1975-present	+ 2.34 ± 3.41 °F/100yr	
Warmest Year	51.1°F (+ 3.6 °F) in 2015	MEAN 47.5 °F
Coldest Year	42.7 °F (- 4.7 °F) in 1917	STDEV 1.46 °F
Oct-Jan	2017 48.0 °F (+ 0.6 °F)	RANK 84 of 122

Tier 1 - Landscape Attributes

Erodible Sediment Supply, Proximity to Ocean, Proximity to Discharges,
Proximity to Diversions, Bathymetry (Proximity to and Extent of Shallow Areas)

Tier 2 - Environmental Drivers

Air Temperature, Flows, Turbidity,
Contaminant Loading, Water Diversions

Weather, Exports, Hydrology,
Turbidity, Contaminants

Tier 3 - Habitat Attributes

Food, Predation, Temperature,
Entrainment, Toxicity

Food, Predation, Temperature,
Transport, Entrainment, Toxicity

Tier 4 - Delta Smelt Responses

Adults

Spawning

**Eggs &
Larvae**

Survival

Tier 5 - Life Stage Seasons

December-May
(Winter)

March-June
(Spring)

Growth

September-December
(Fall)

June-September
(Summer)

Survival

Subadults

Survival

Growth

Juveniles

Food, Predation, Size and
Location of LSZ, Toxicity

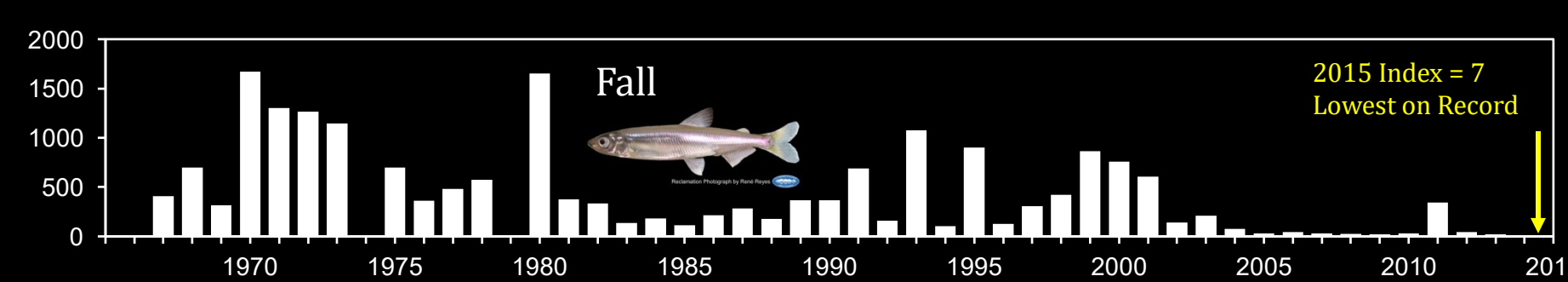
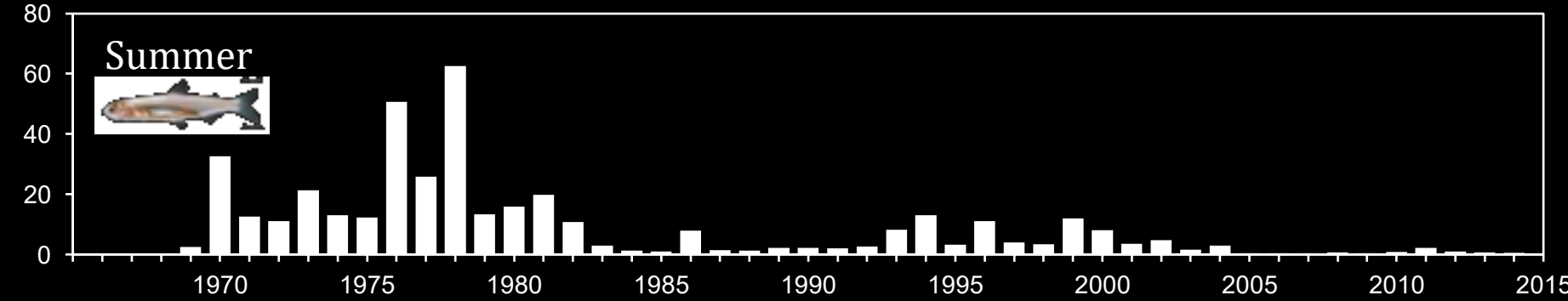
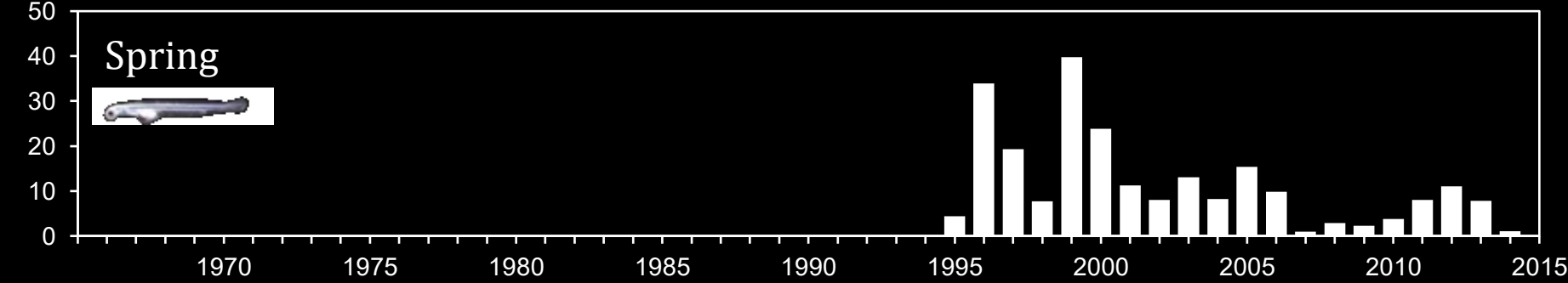
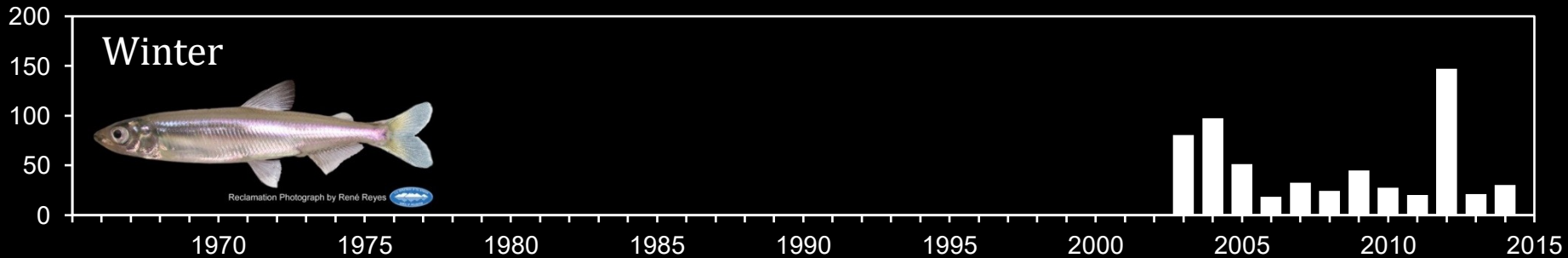
Food, Predation, Temperature
Harmful Algal Blooms, Toxicity

Weather, Outflow, Turbidity, Clam Grazing,
Nutrients, Contaminants

Weather, Hydrology, Turbidity, Clam Grazing,
Nutrients, Contaminants



Abundance Indices at Historic Lows



Seasonally Clearer Water...

Jan - Mar

Apr - Jun

July - Aug

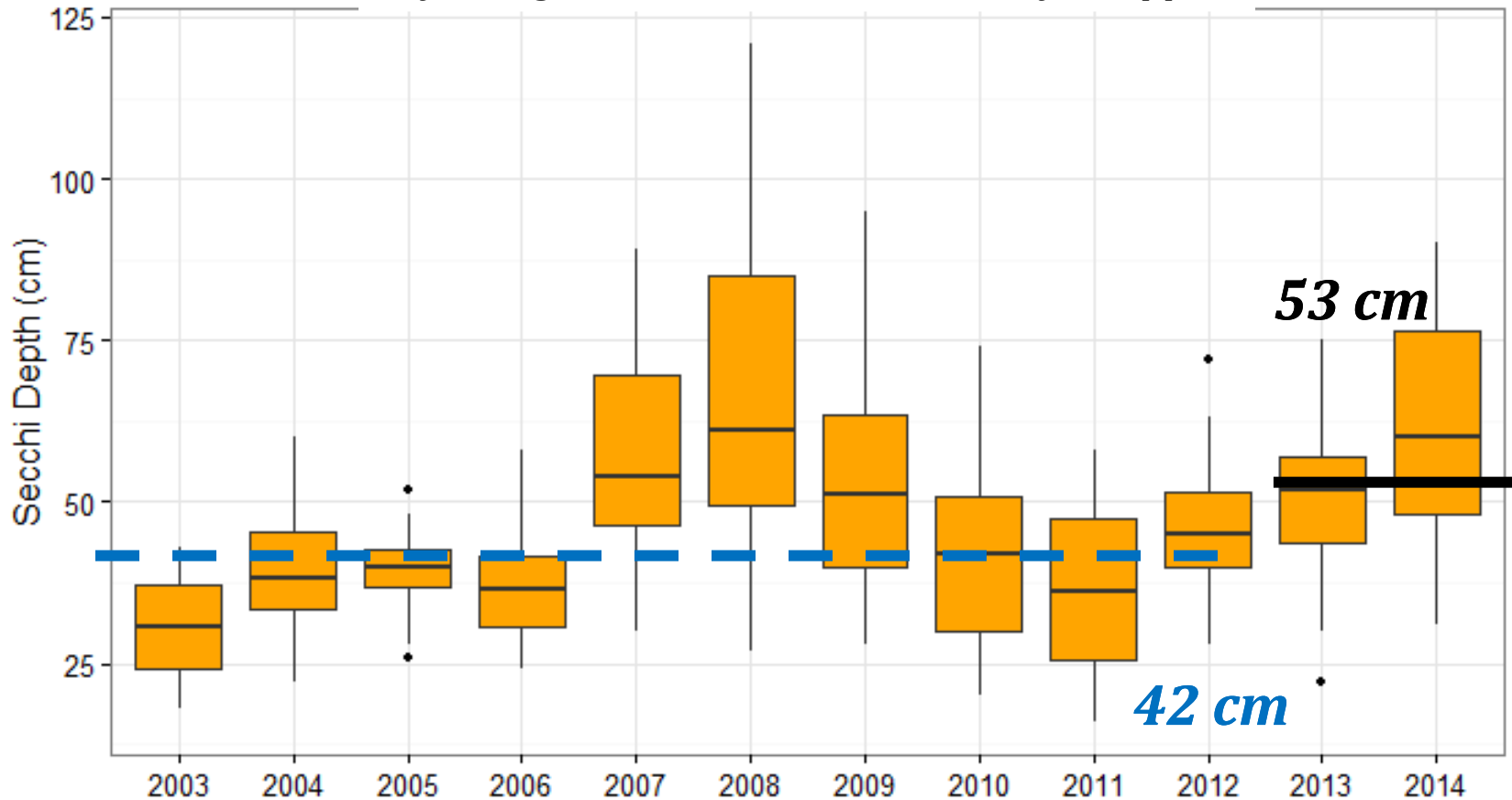
Sept - Dec

Results

Water Clarity



July - August, Summer Towntet Survey, 1-6ppt



CDFW Summer Towntet Survey

Sharp Increase in Mississippi Silverside Abundance

Jan - Mar

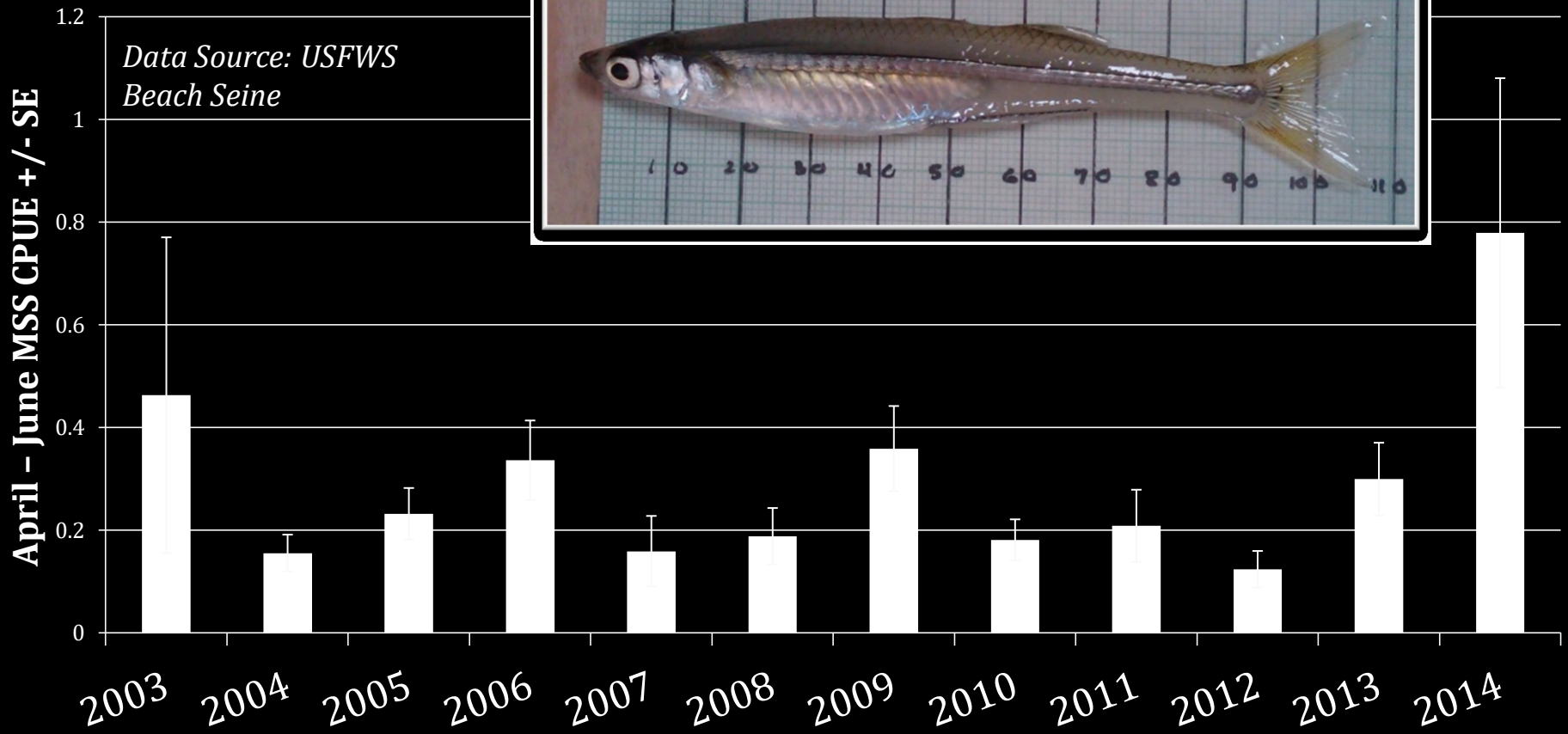
Apr - Jun

July - Aug

Sept - Dec

Results

Mississippi Silverside



Black bass densities increased in 2014

Jan - Mar

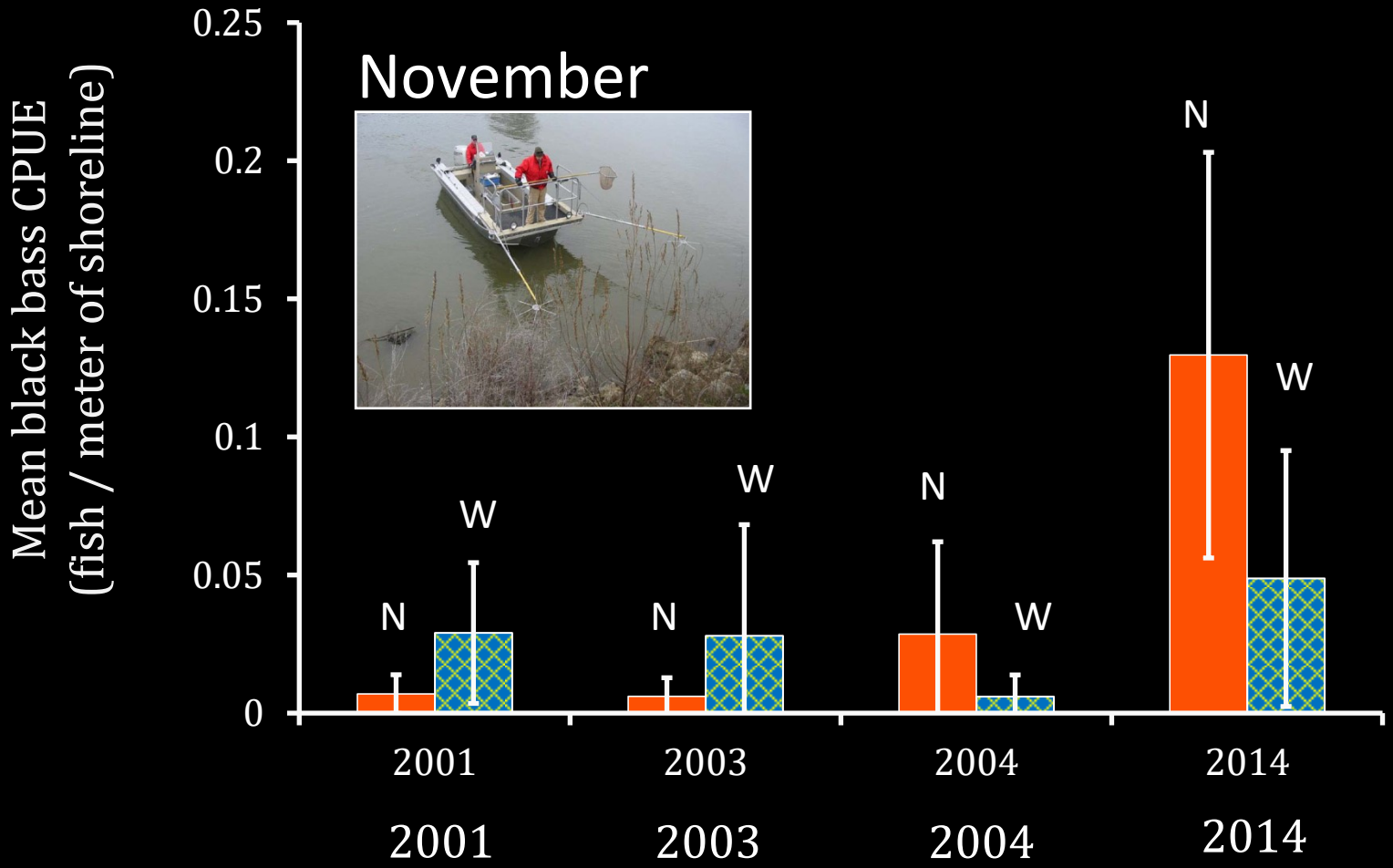
Apr - Jun

July - Aug

Sept - Dec

Results

Black Bass



Water Temperatures Warmer All Year Long

Jan - Mar

Apr - Jun

Jul - Aug

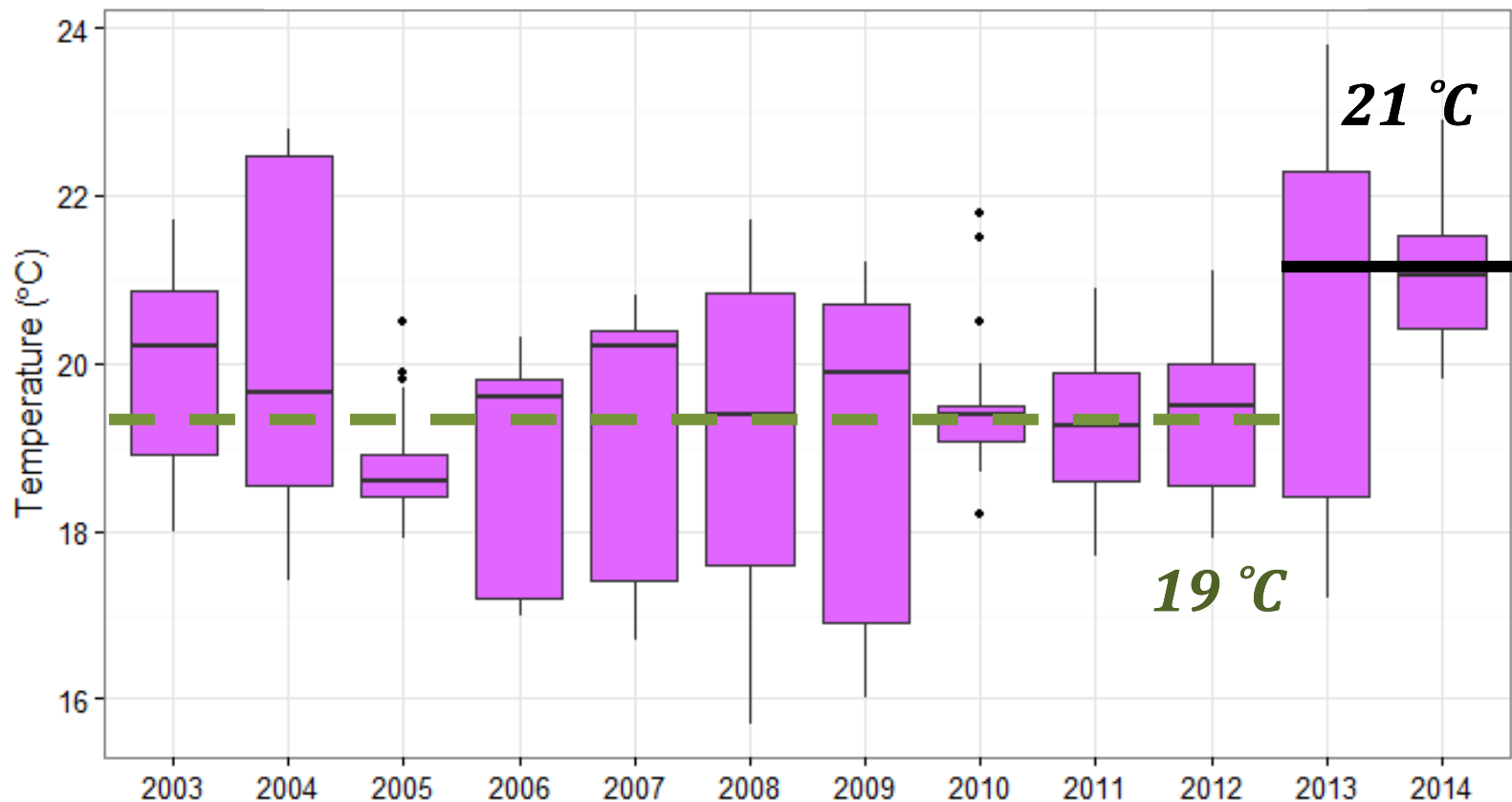
Sept - Dec

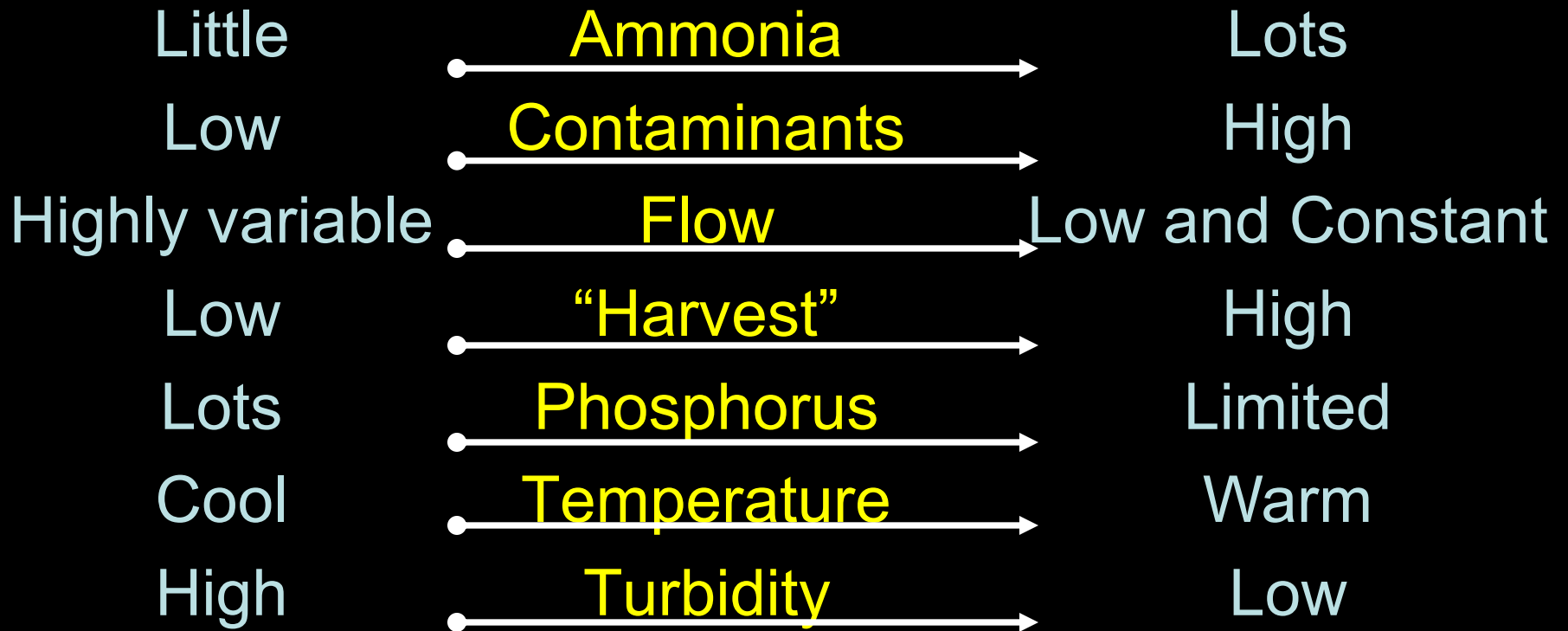
Results

Water Temp



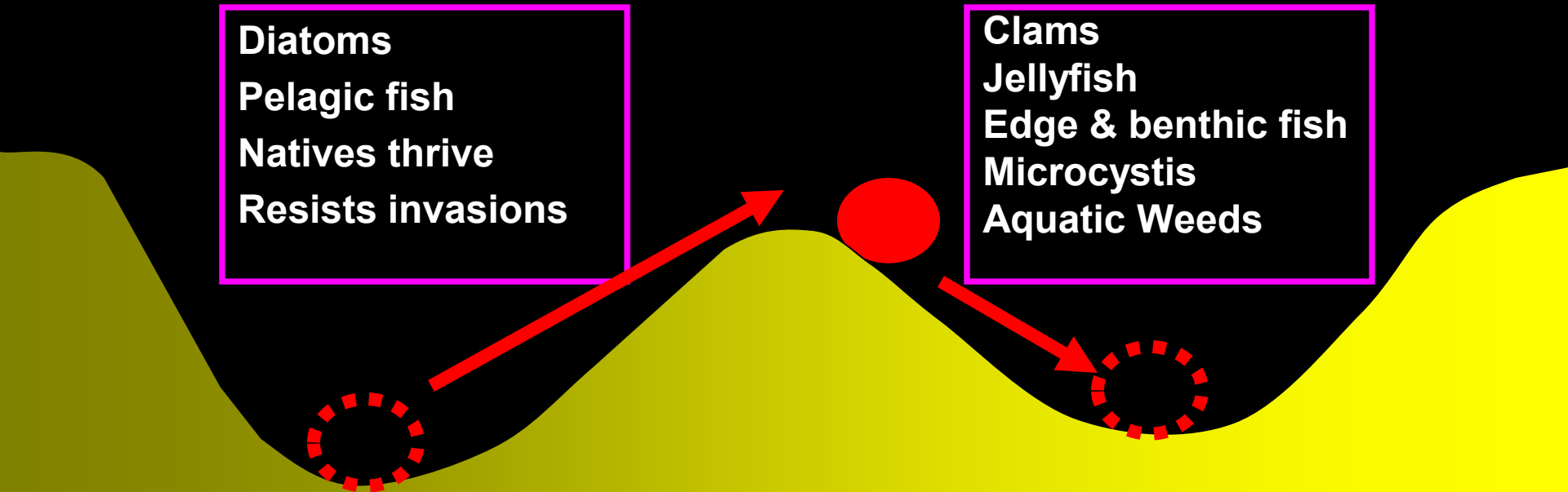
September - October only, Fall Midwater Trawl, 1-6 ppt



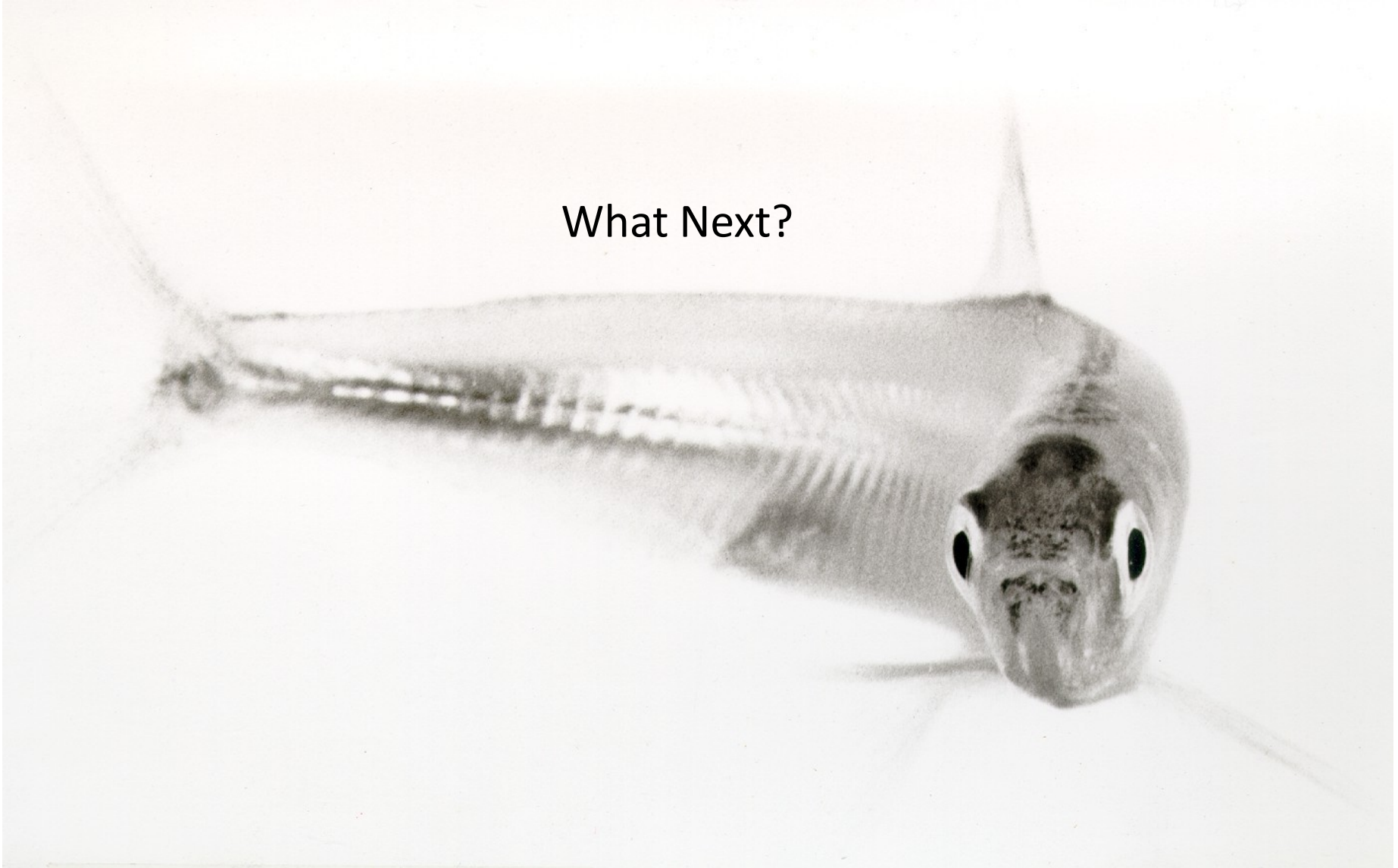


Diatoms
Pelagic fish
Natives thrive
Resists invasions

Clams
Jellyfish
Edge & benthic fish
Microcystis
Aquatic Weeds



What Next?





**Water Hyacinth, San Joaquin River @
Connection Slough; December 2014.**

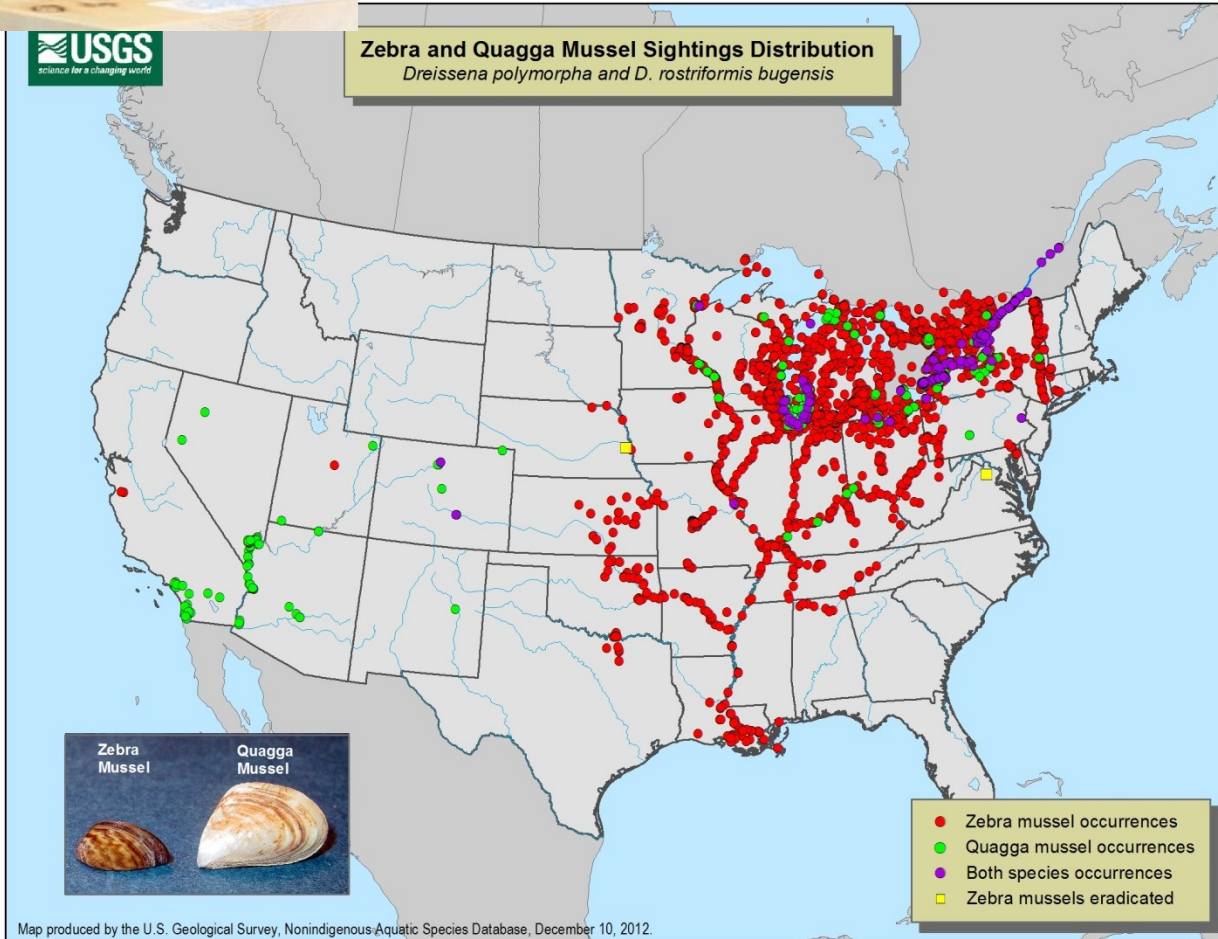
Photo: Roger Kelly for Bay Nature Magazine

**South American Sponge Plant @ Brannon Island
2011 Lars Anderson**

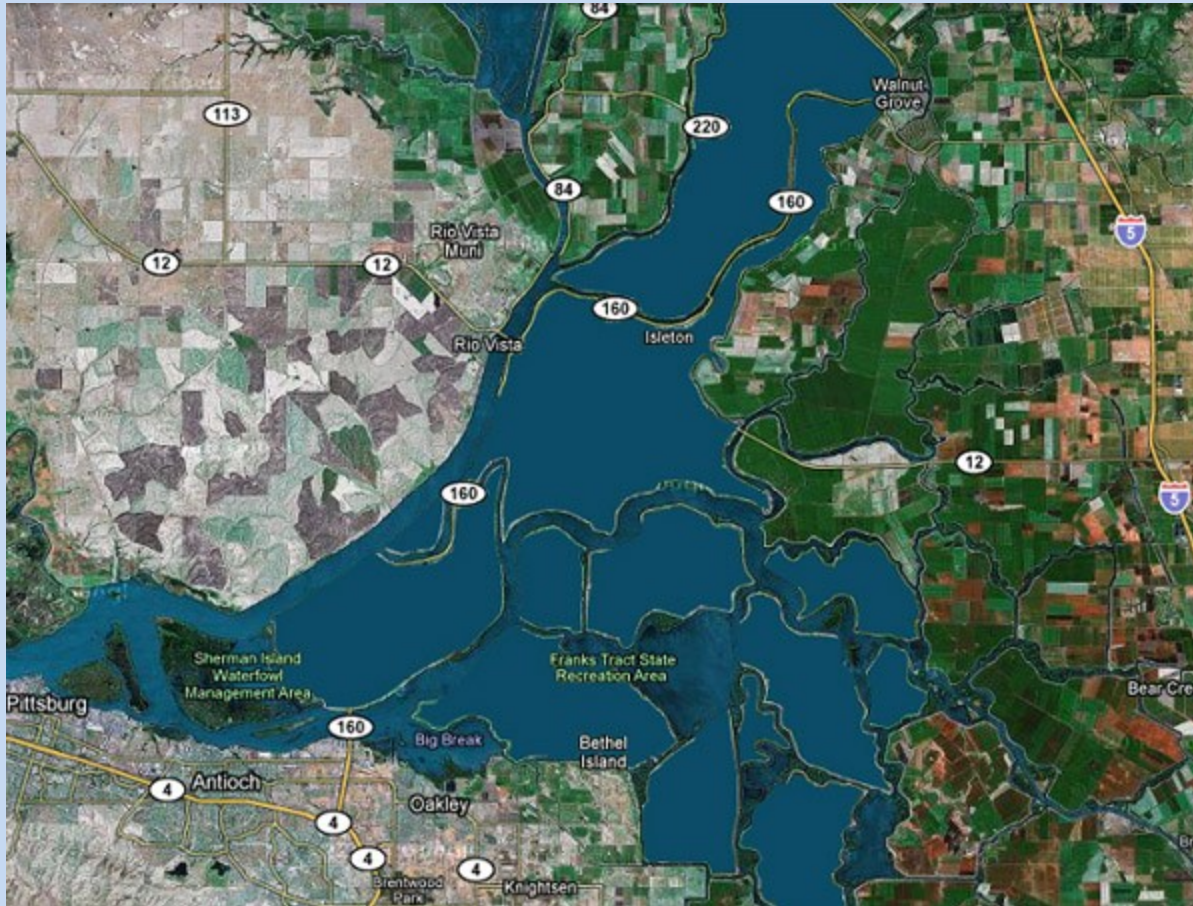


**Loach: San Joaquin River near
Fresno, Fall 2014.**

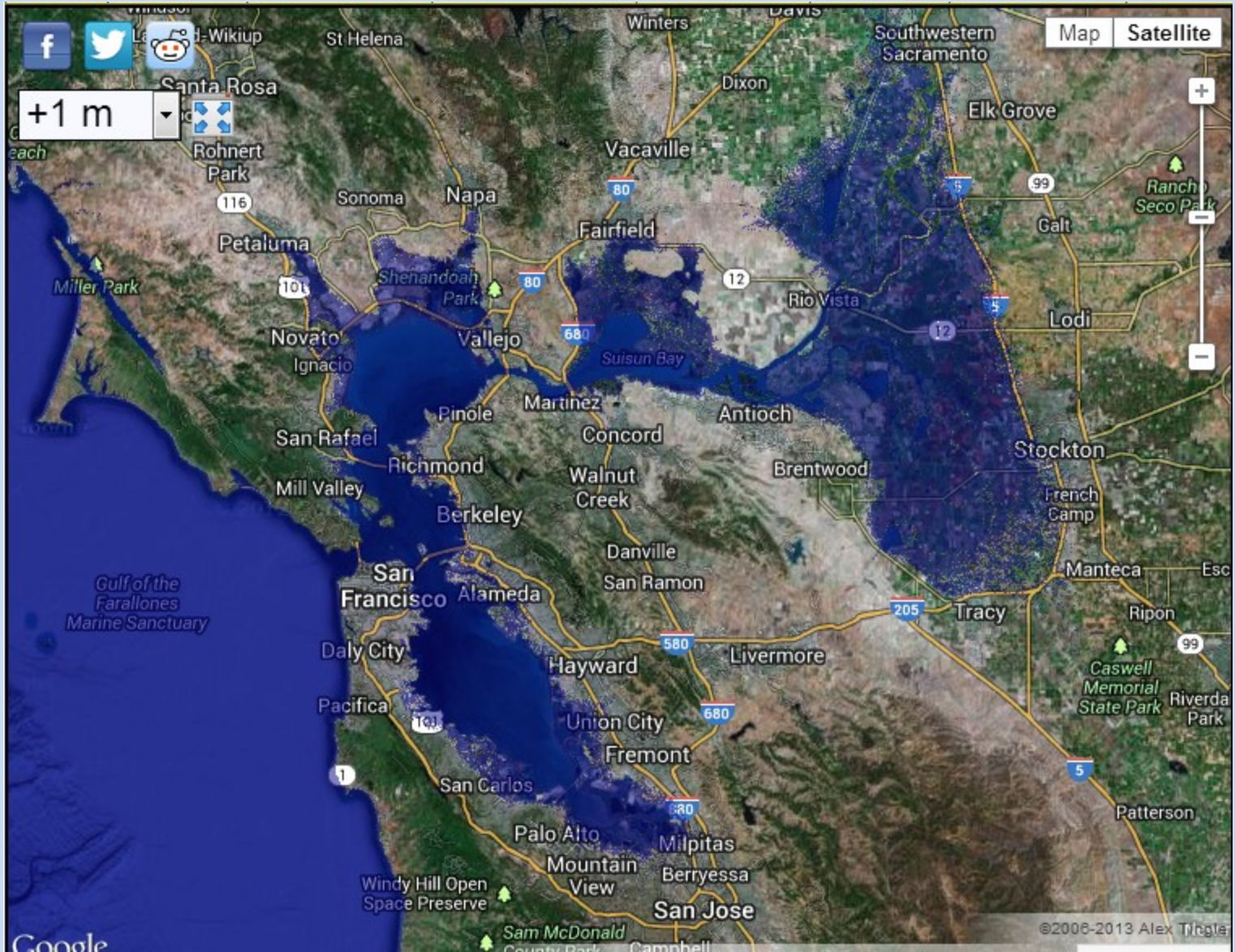
Today?

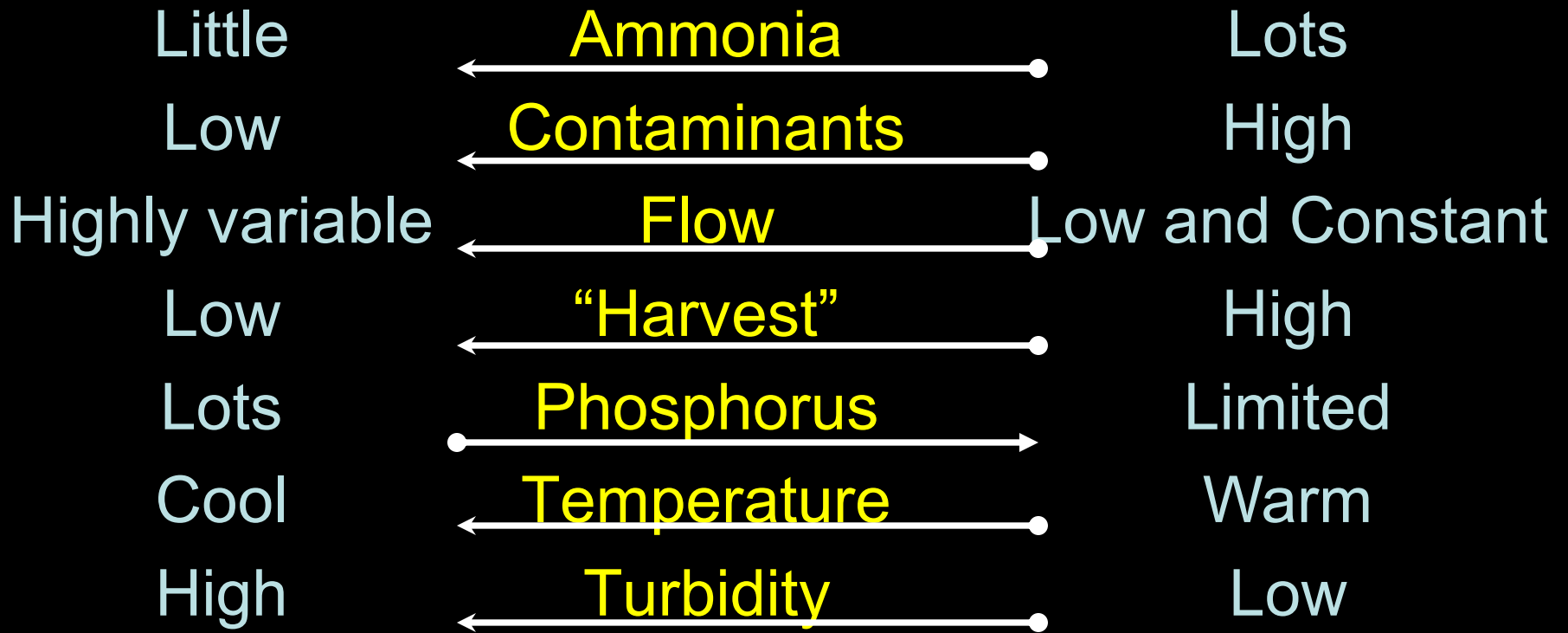


Earthquake or flood



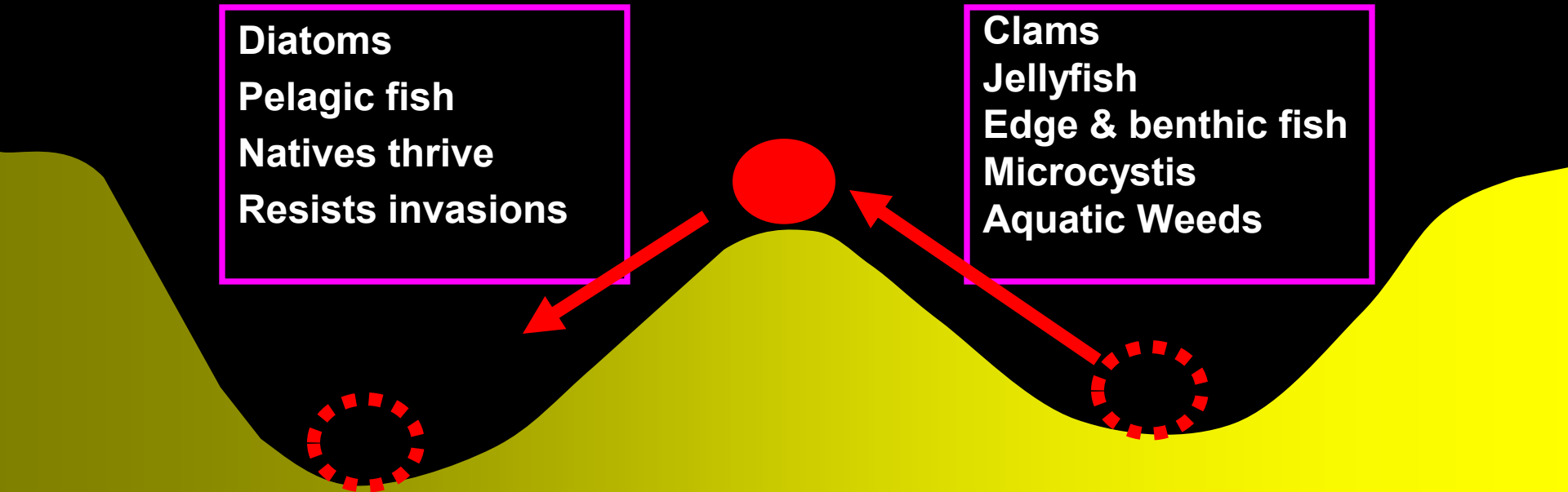
1 M sea level rise (2100?)





Diatoms
Pelagic fish
Natives thrive
Resists invasions

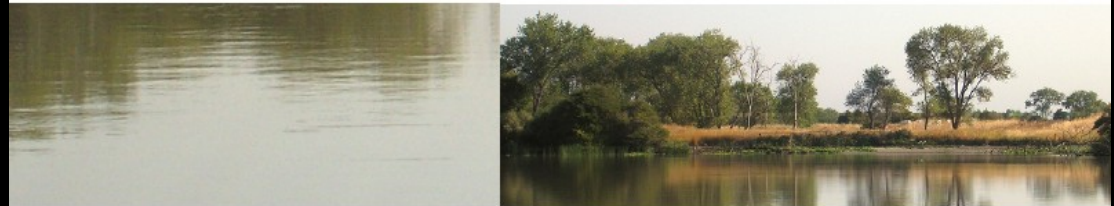
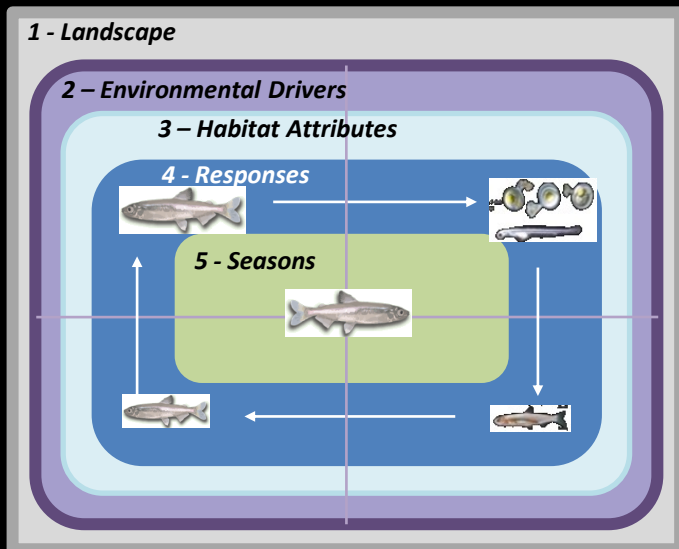
Clams
Jellyfish
Edge & benthic fish
Microcystis
Aquatic Weeds



Delta Smelt MAST Report: Completed January 2015

INTERAGENCY ECOLOGICAL PROGRAM, MANAGEMENT, ANALYSIS, AND SYNTHESIS TEAM

An updated conceptual model
of Delta Smelt biology:
our evolving understanding of an estuarine fish



Technical Report 90 January, 2015

Interagency Ecological Program
for the
San Francisco Bay/Delta Estuary

A Cooperative Program of:

California Department of Water Resources
California Department of Fish and Wildlife
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

State Water Resource Control Board
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency
National Marine Fisheries Service

www.water.ca.gov/iep

Warmer Air Temperatures During Drought

Jan - Mar

Apr - Jun

July - Aug

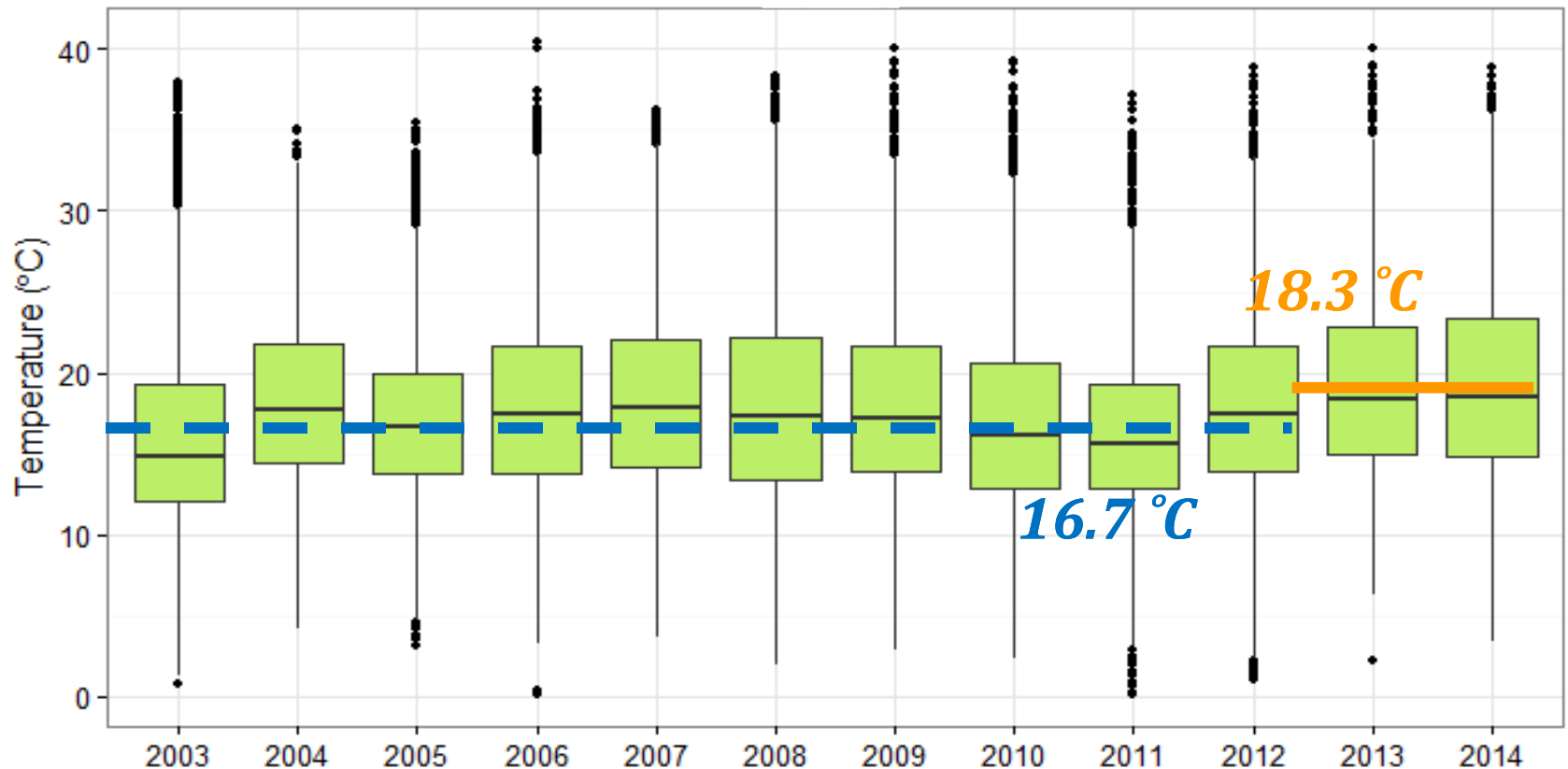
Sept - Dec

Results

Air Temperature



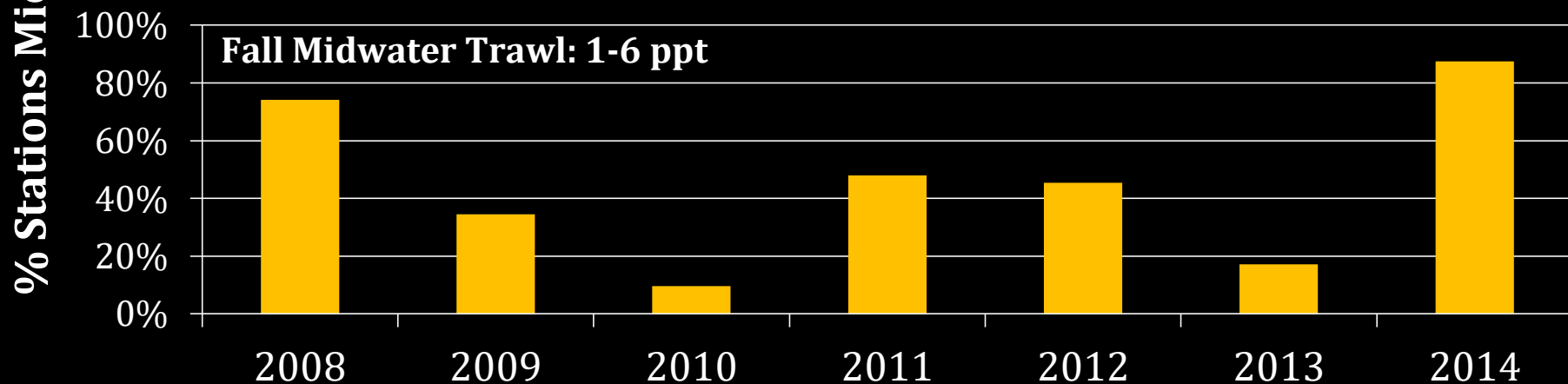
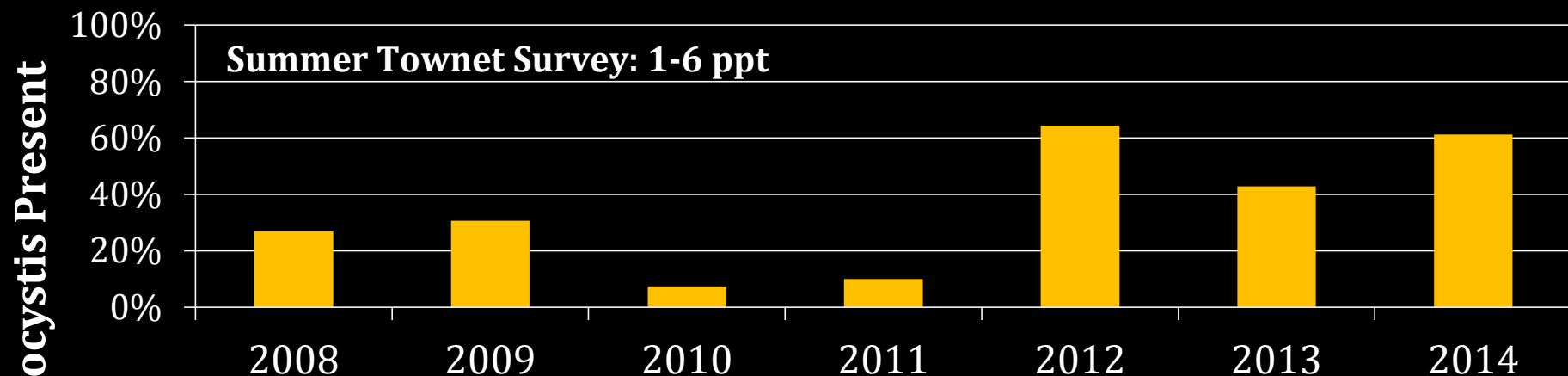
April - June



Air temperature station data pooled from: Lodi, Mossdale Bridge, Mallard, Rio Vista

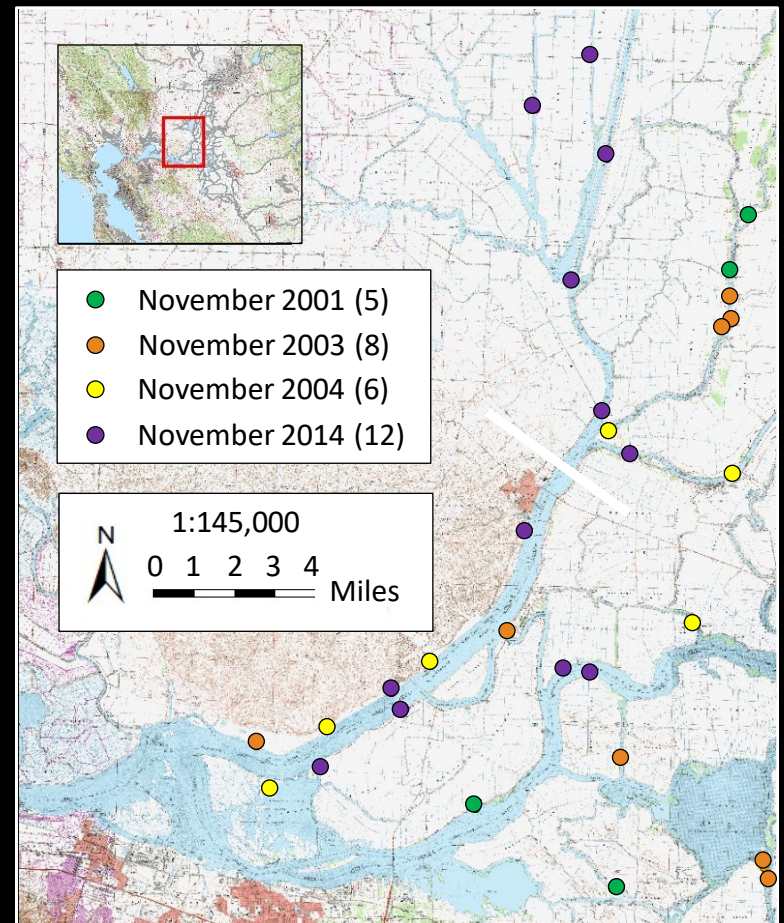
Microcystis More Prevalent

	Jan - Mar	Apr - Jun	Jul - Aug	Sept - Dec
Results				
<i>Harmful Algae Bloom</i>			↑	↑



November 2014: Boat Electrofishing Drought Survey

- Western and northern Delta



Summer Growth Reduced

