

2 adults return to spawn

4,000  
eggs  
laid

# Salmon life cycle

800 fry  
hatch

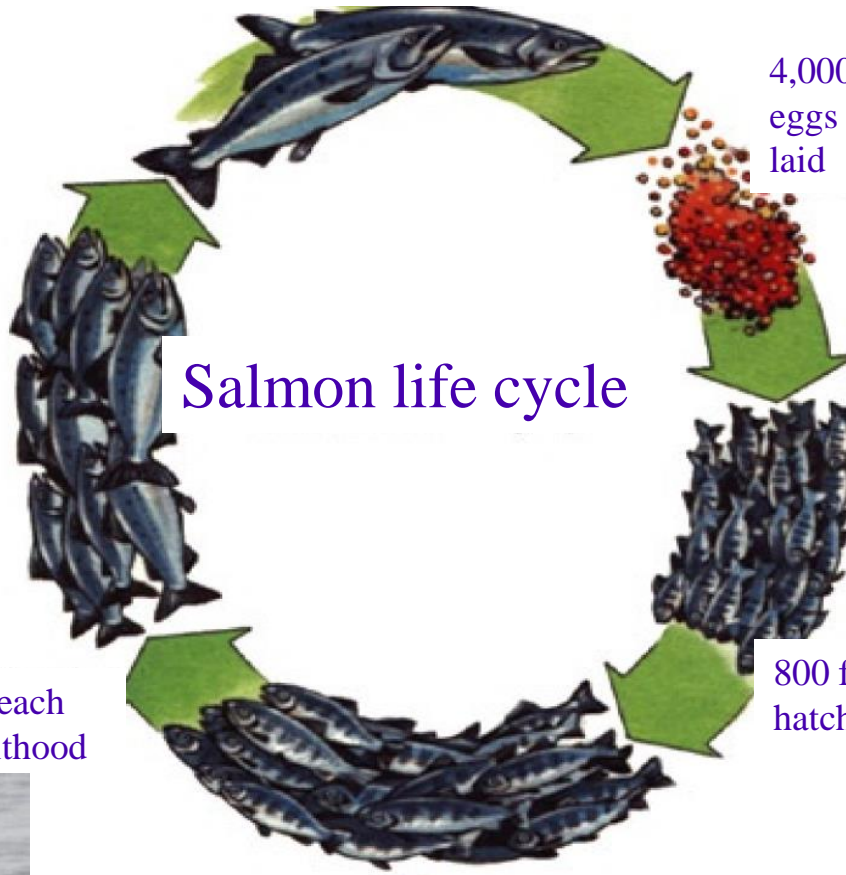
10 reach  
adulthood

200 smolts go to sea

# Estuary

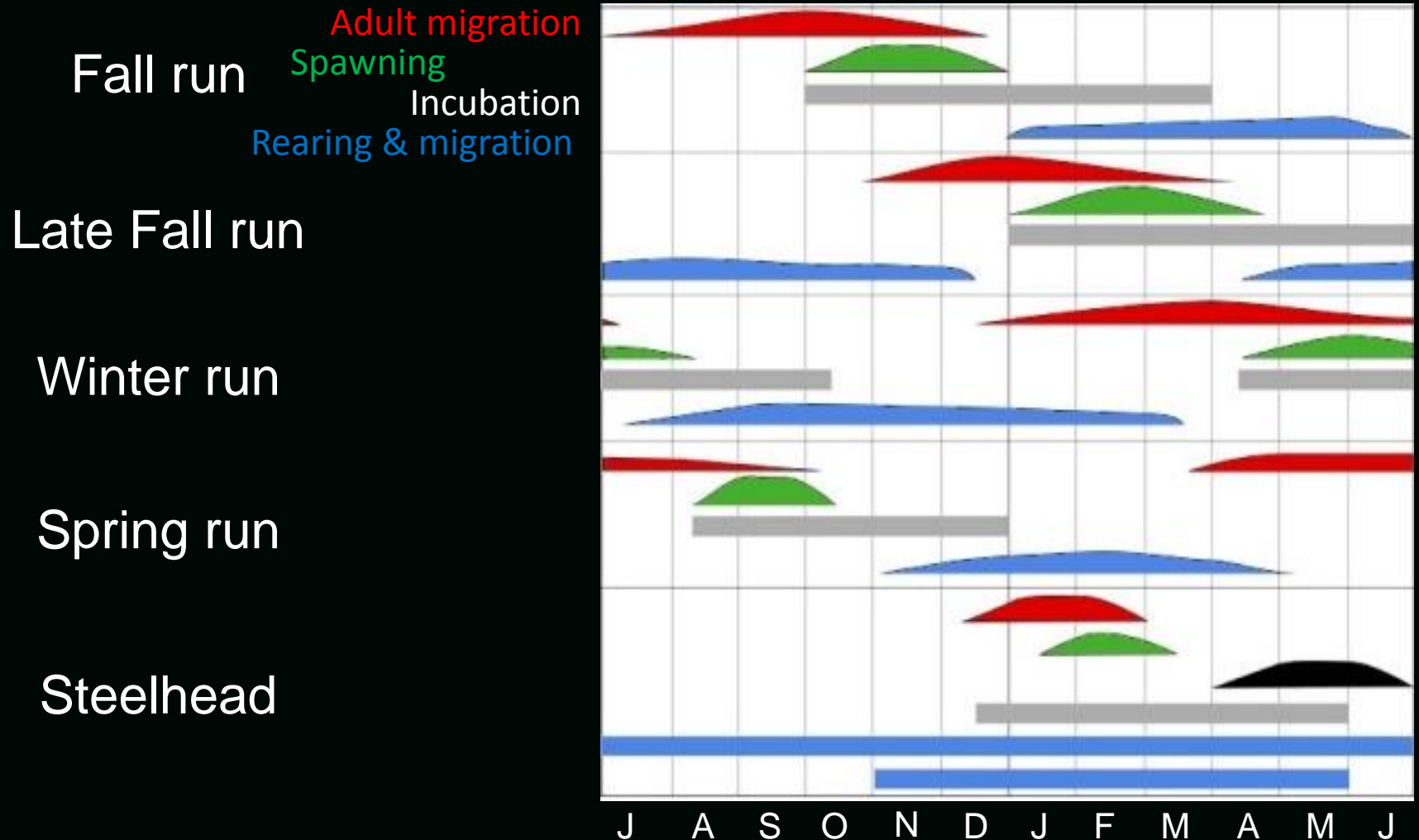
# Ocean

# Freshwater

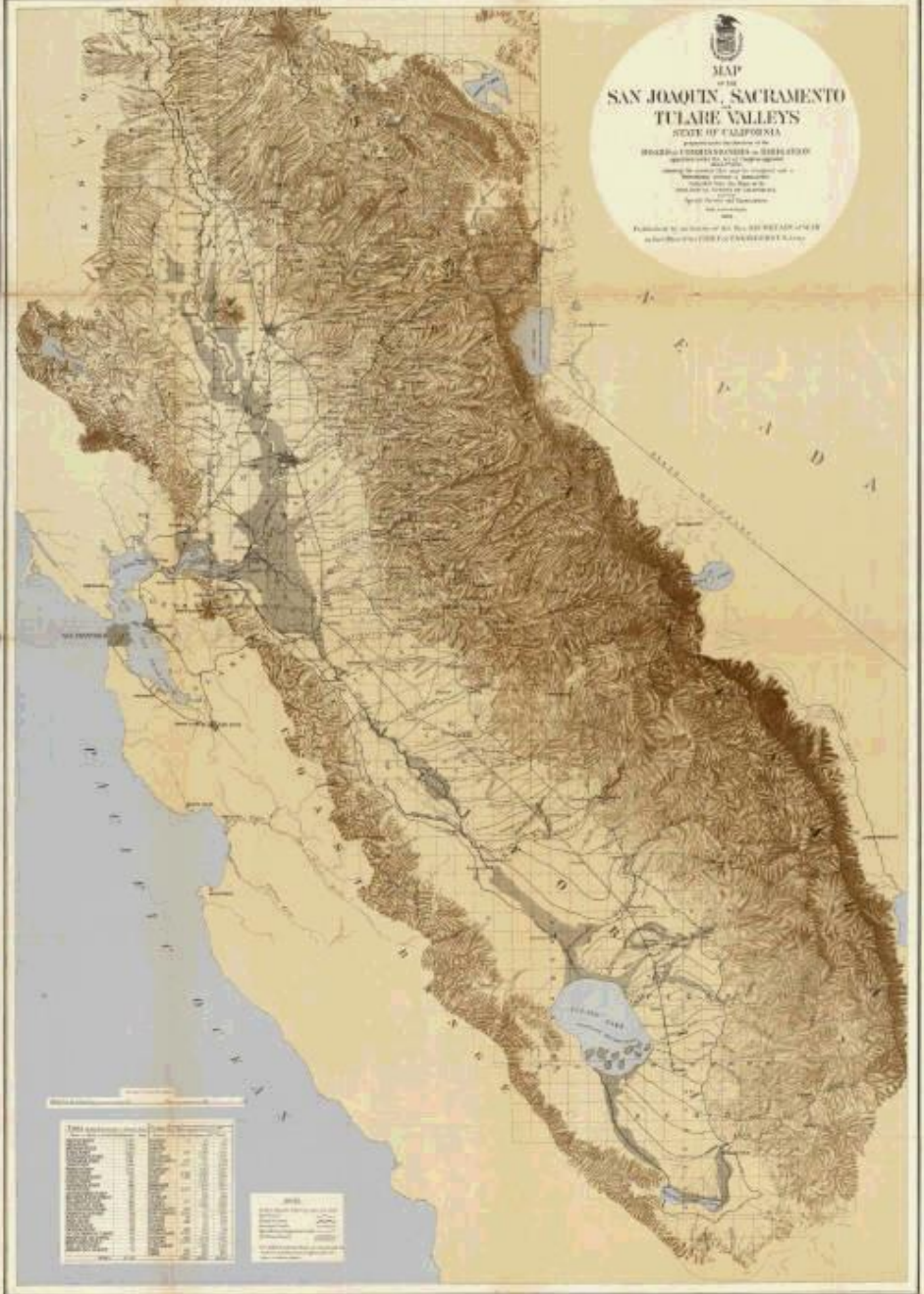


# Salmon

Diversity spreads risk in space & time



  
**MAP**  
 OF THE  
**SAN JOAQUIN, SACRAMENTO**  
**TULARE VALLEYS**  
 STATE OF CALIFORNIA  
 PREPARED UNDER THE ACT OF  
 MARCH 3, 1854, CHAP. 113, SECT. 1  
 BY  
 W. H. KELLOGG, U. S. GEOLOGICAL SURVEY  
 ASSISTANT GEOLOGIST  
 UNDER THE SUPERVISION OF  
 G. W. WOODRUFF, CHIEF OF THE  
 SURVEY OF THE TULARE VALLEYS  
 AND SACRAMENTO VALLEY  
 1874  
 Published by the Order of the BOARD OF STATE PRINTERS  
 at San Francisco: 1874. For CHAS. H. BENTLEY & Co.



**Vertical Scale**

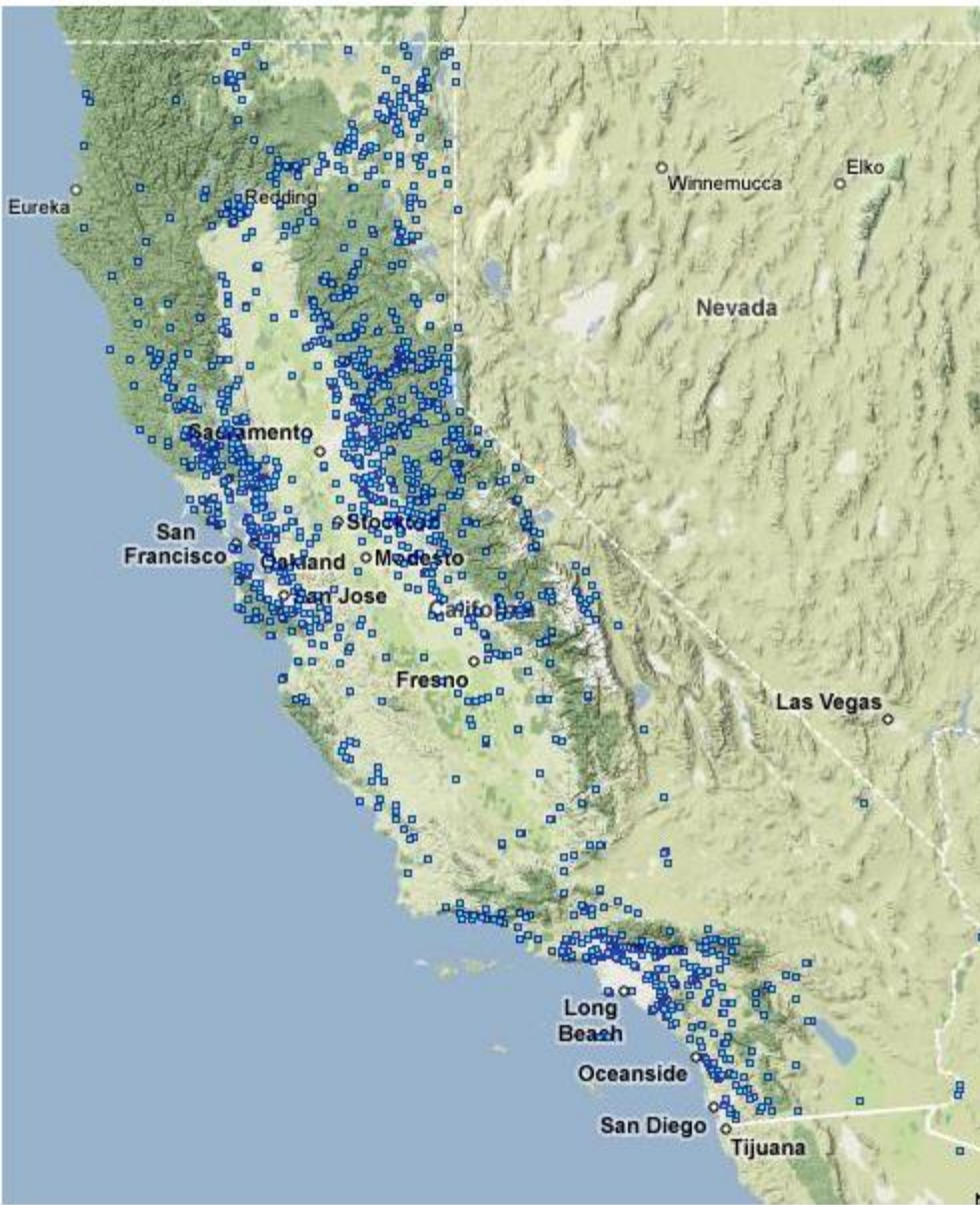
0	0
10	10
20	20
30	30
40	40
50	50
60	60
70	70
80	80
90	90
100	100
110	110
120	120
130	130
140	140
150	150
160	160
170	170
180	180
190	190
200	200
210	210
220	220
230	230
240	240
250	250
260	260
270	270
280	280
290	290
300	300
310	310
320	320
330	330
340	340
350	350
360	360
370	370
380	380
390	390
400	400
410	410
420	420
430	430
440	440
450	450
460	460
470	470
480	480
490	490
500	500
510	510
520	520
530	530
540	540
550	550
560	560
570	570
580	580
590	590
600	600
610	610
620	620
630	630
640	640
650	650
660	660
670	670
680	680
690	690
700	700
710	710
720	720
730	730
740	740
750	750
760	760
770	770
780	780
790	790
800	800
810	810
820	820
830	830
840	840
850	850
860	860
870	870
880	880
890	890
900	900
910	910
920	920
930	930
940	940
950	950
960	960
970	970
980	980
990	990
1000	1000

**Scale**  
 1 inch = 1 mile  
 1 centimeter = 1000 feet  
 1 meter = 3280 feet  
 1 kilometer = 3280 meters  
 1 mile = 1.6 kilometers  
 1 kilometer = 0.62 miles

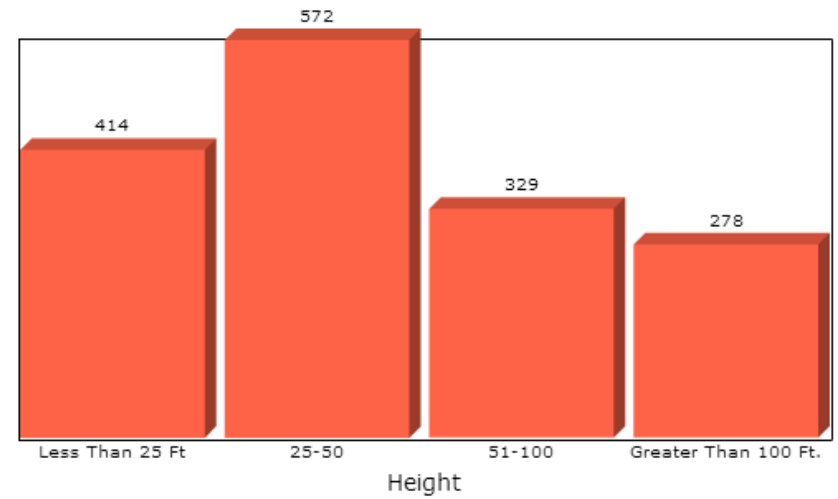
## Select from the following Map Views

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

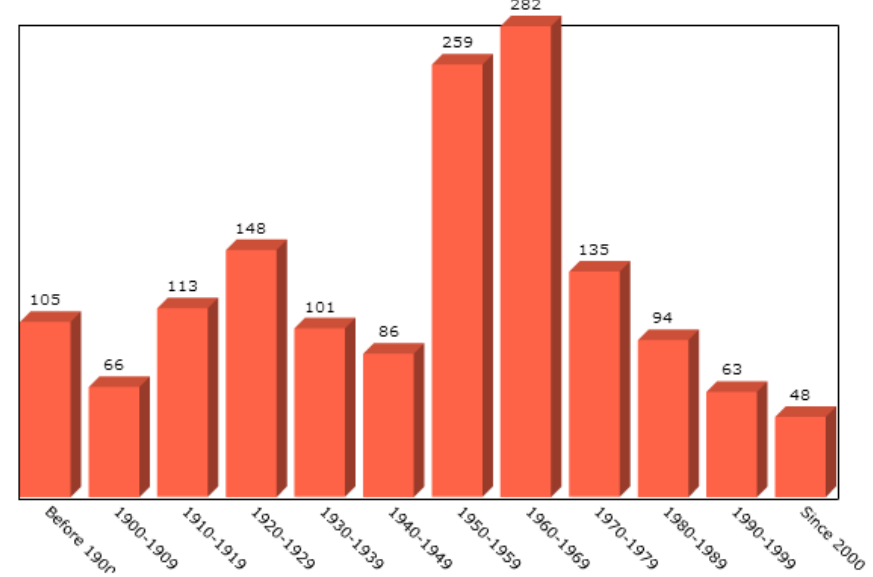




Dams by Height



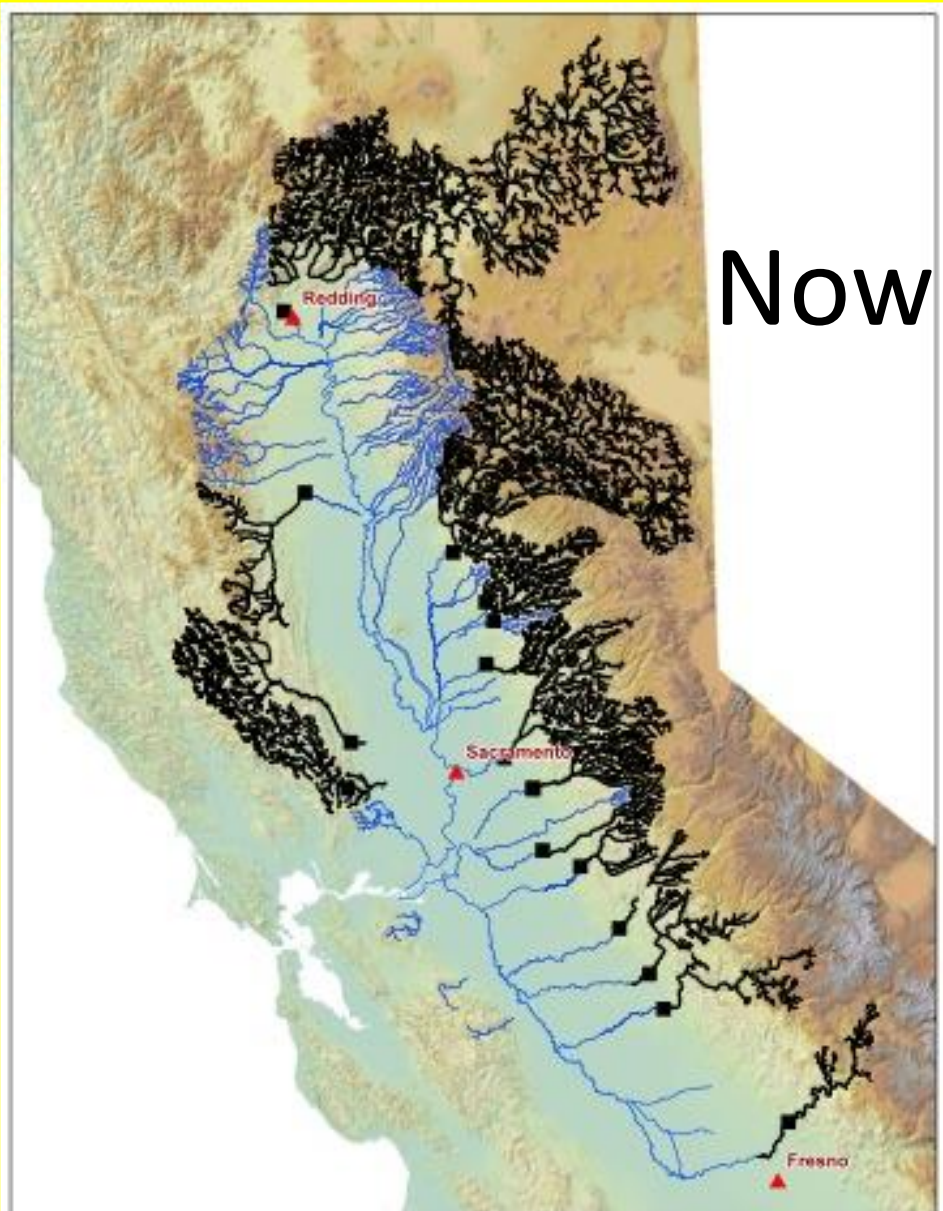
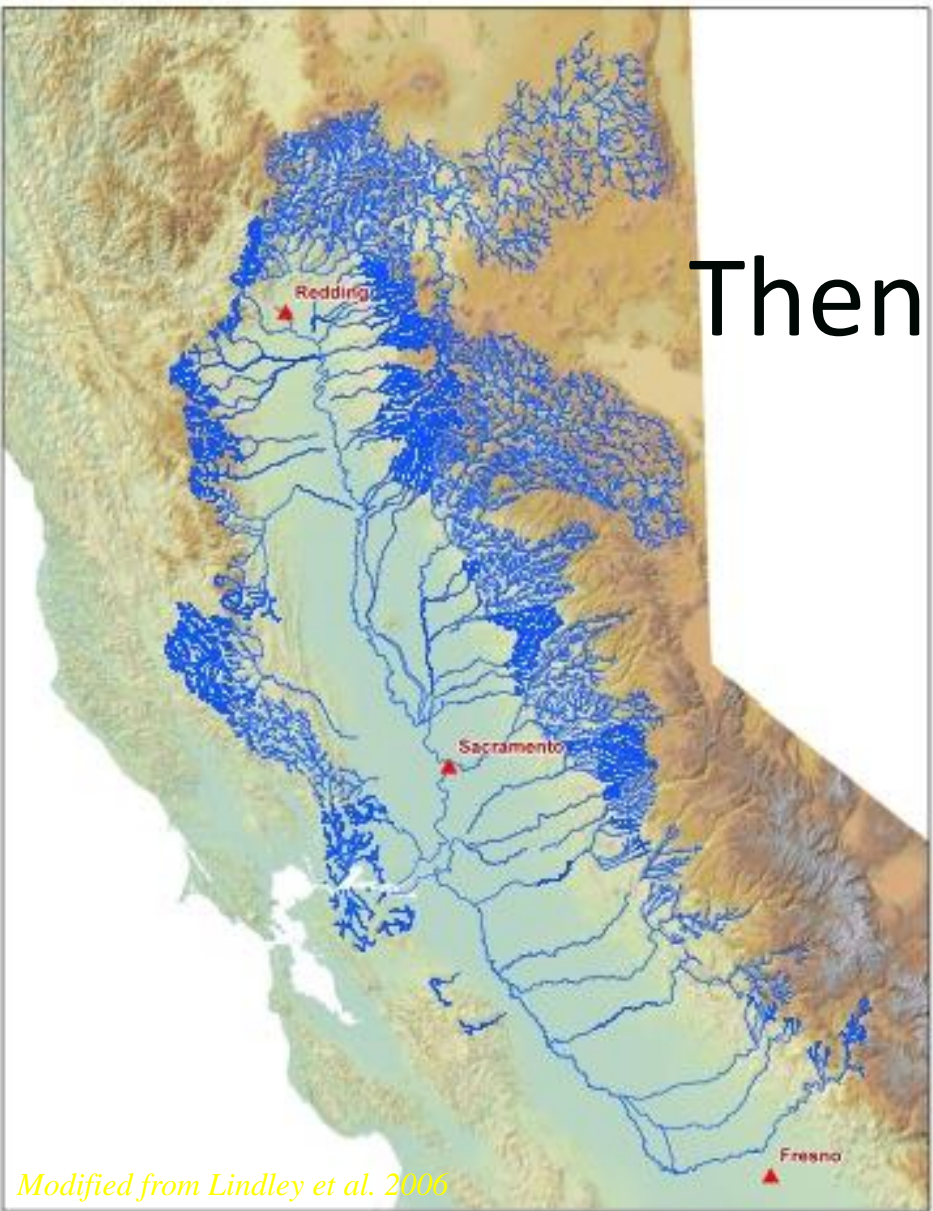
Dams By Completion Date



**1594 Dams in California**  
 National Inventory of Dams, Army Corps

Then

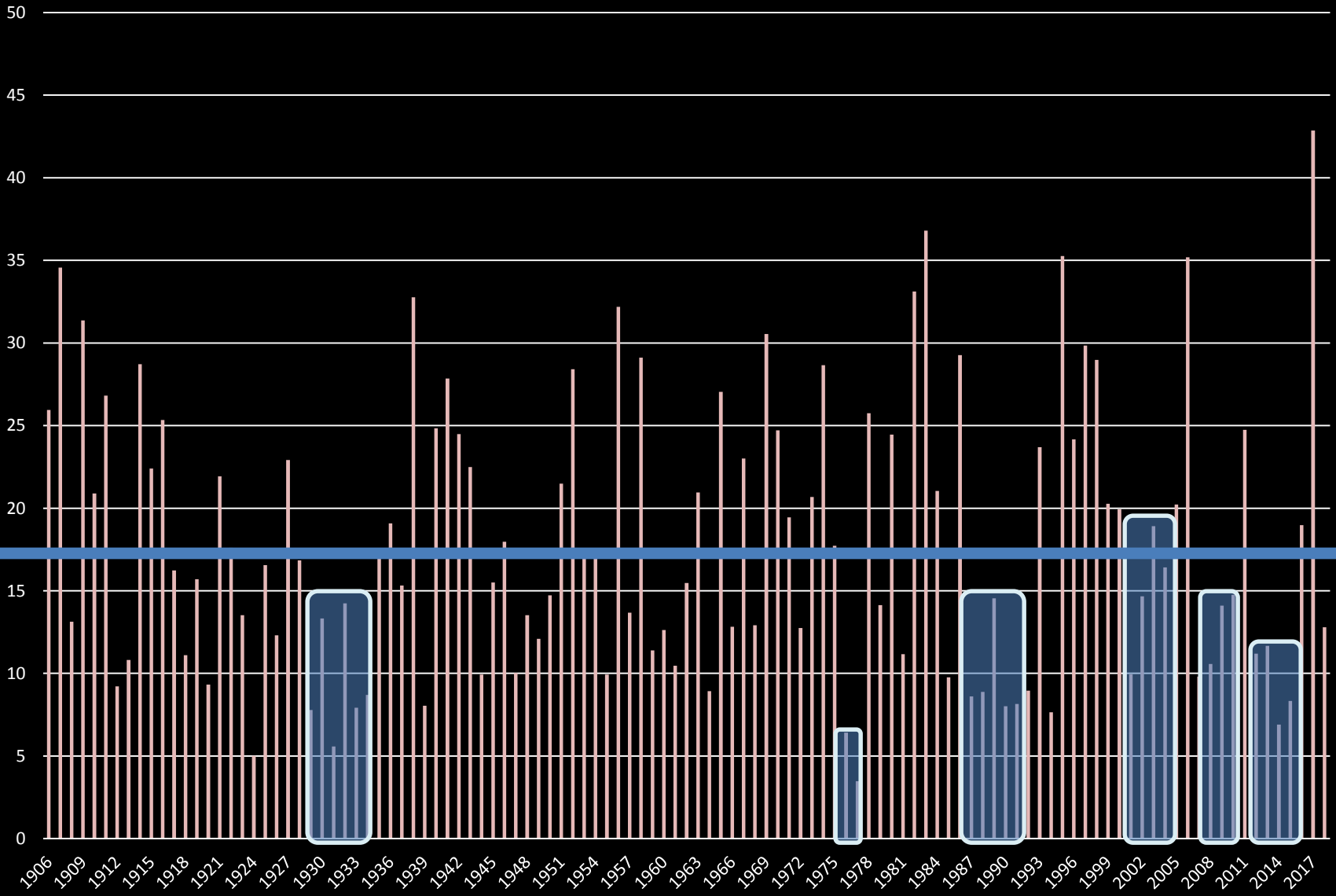
Now



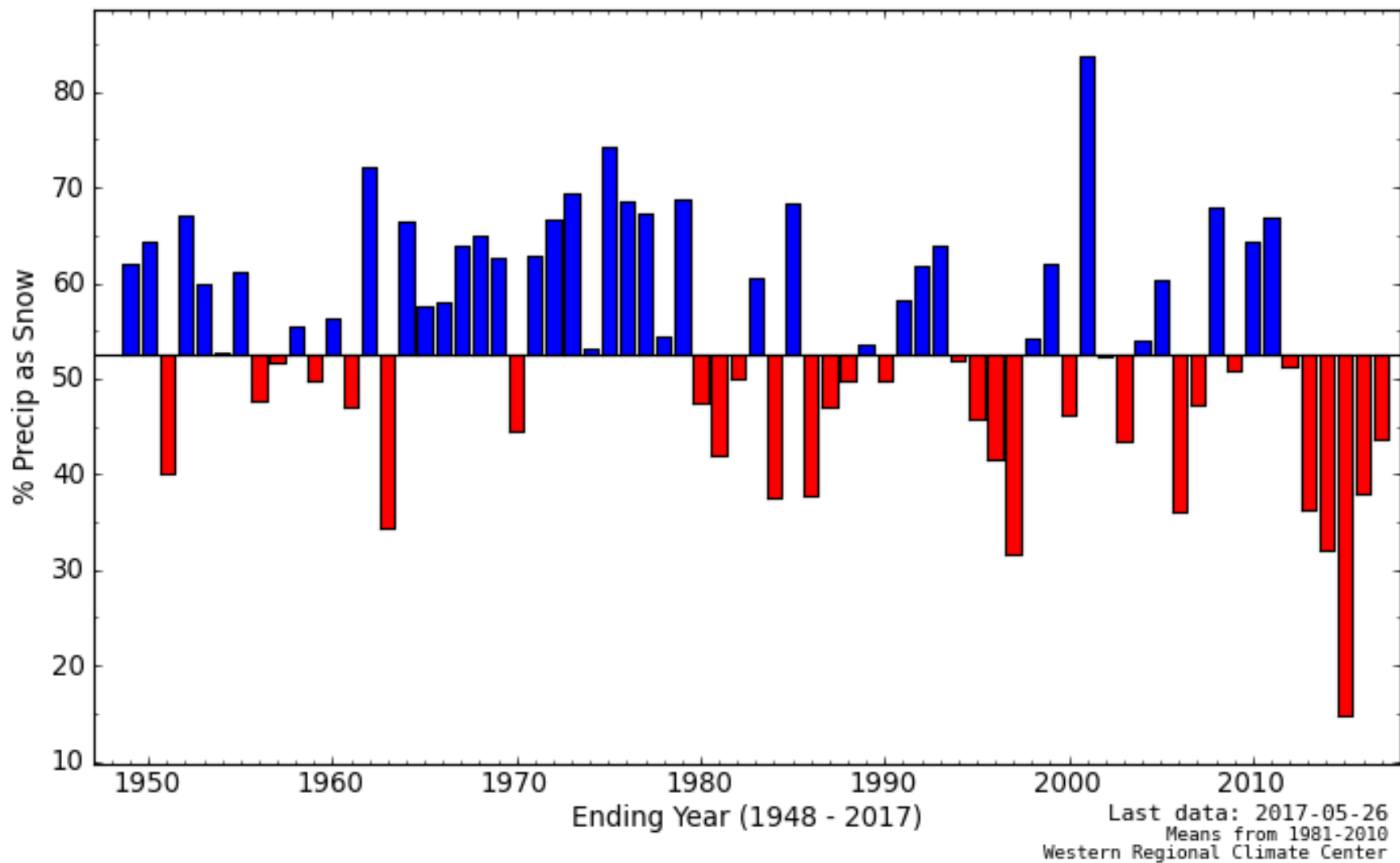
*Modified from Lindley et al. 2006*



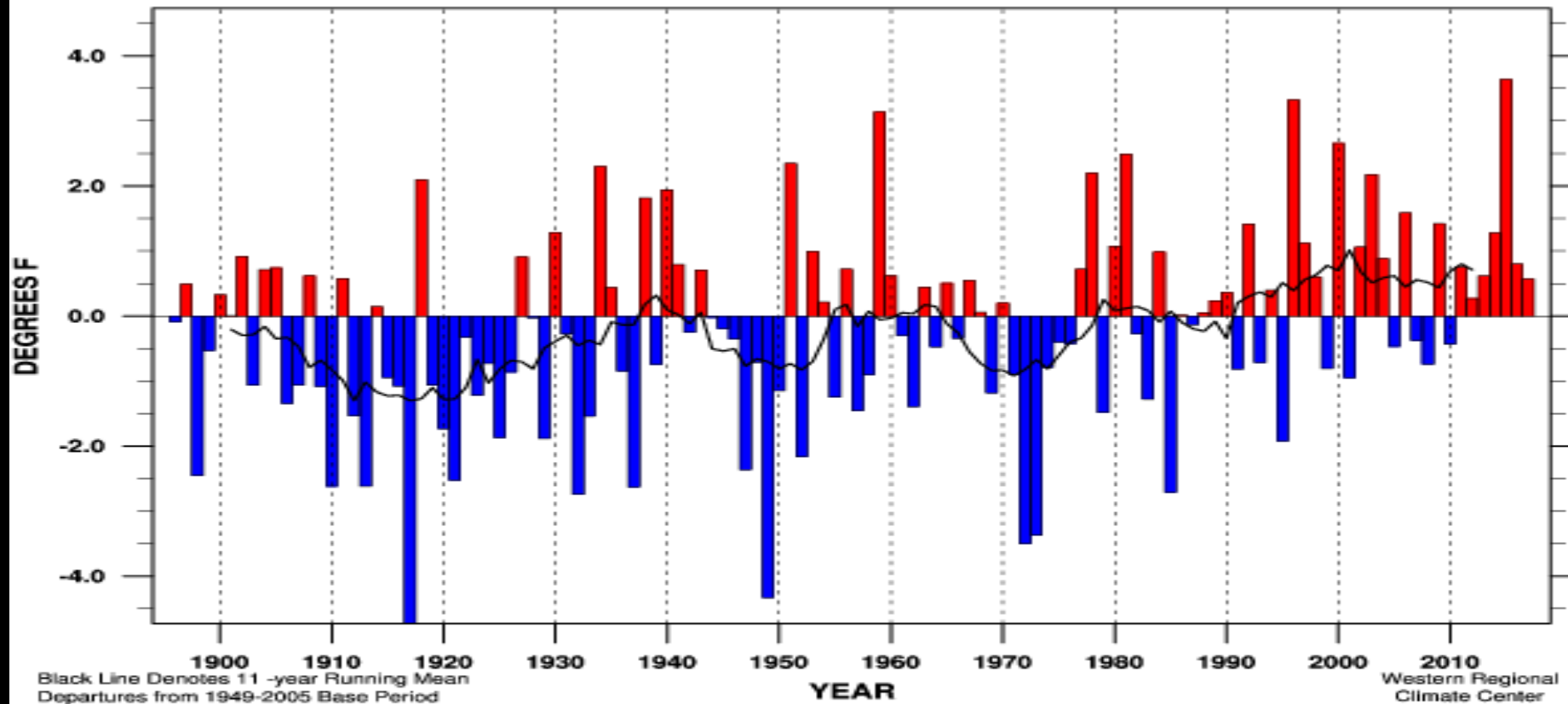
# Central Valley Runoff (MAF)



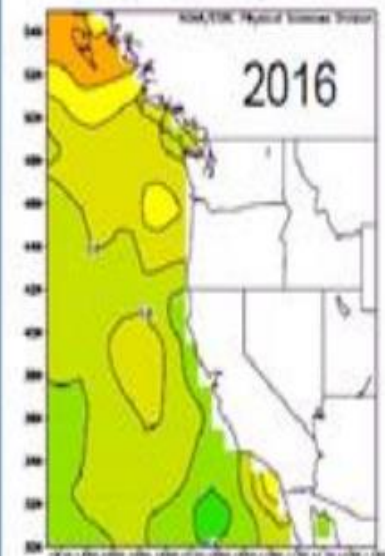
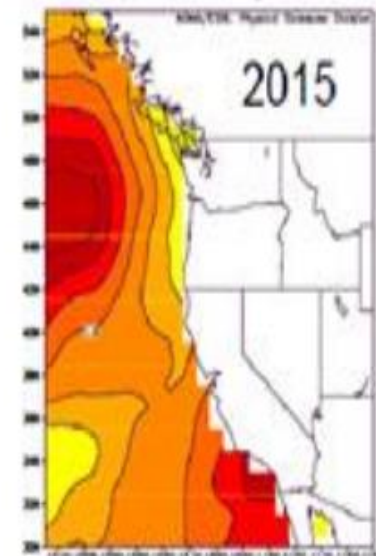
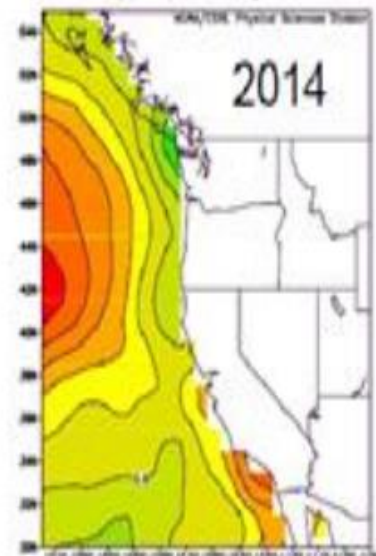
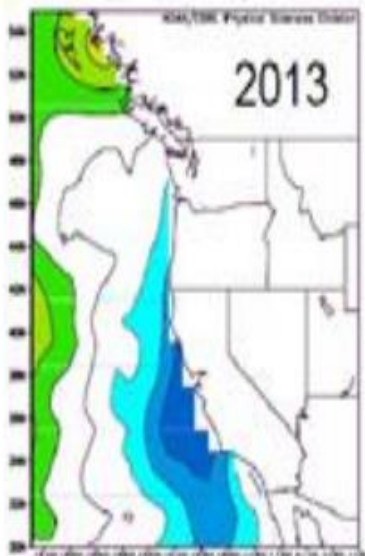
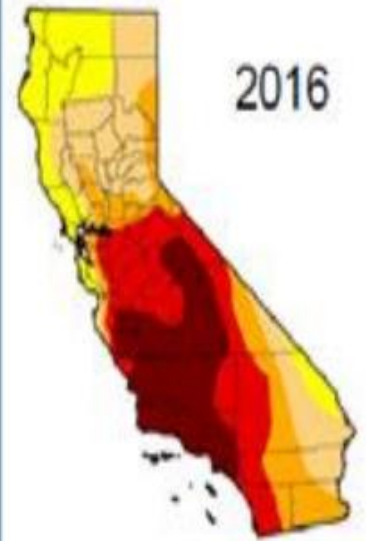
# 7 Months Ending in May % of Precip as Snow 39.28°N, 120.37°W 2200m



# 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



Delta Smelt

Longfin Smelt

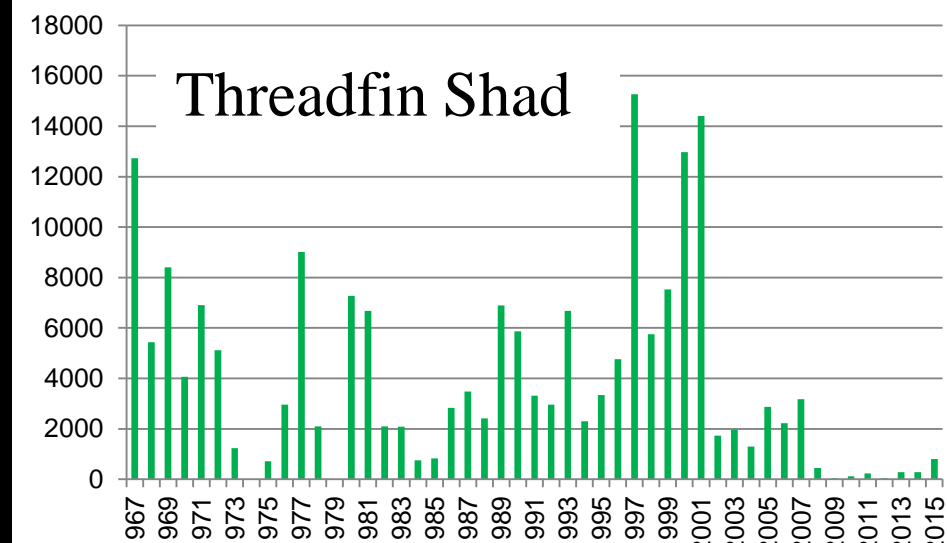
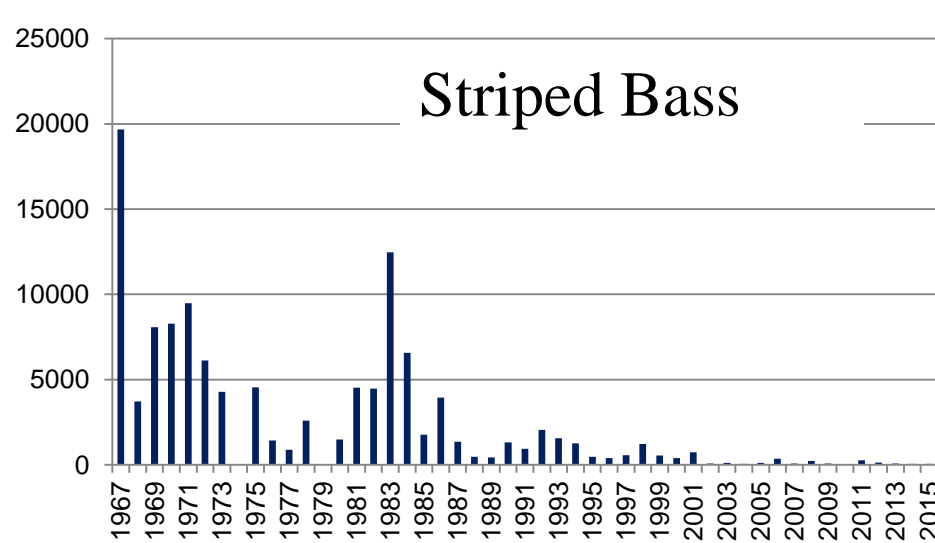
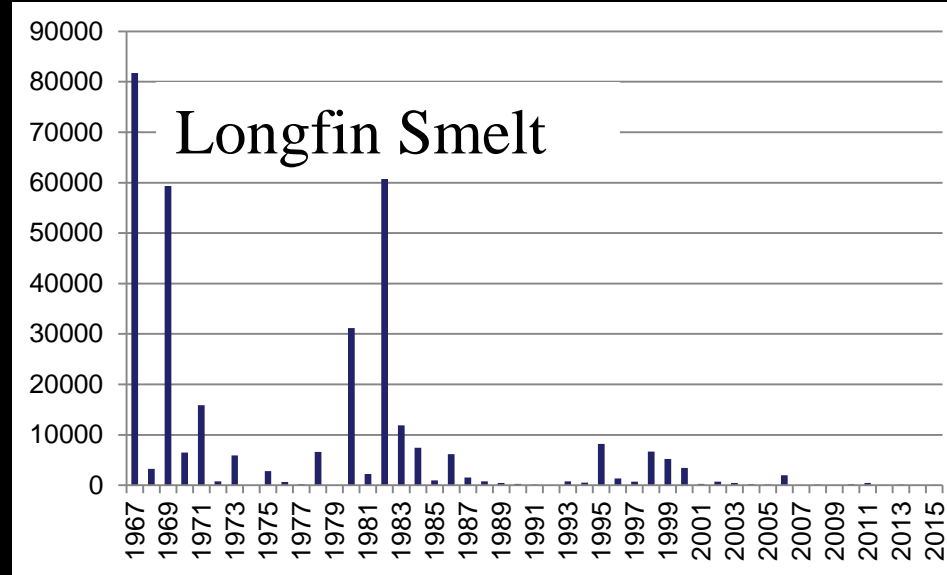
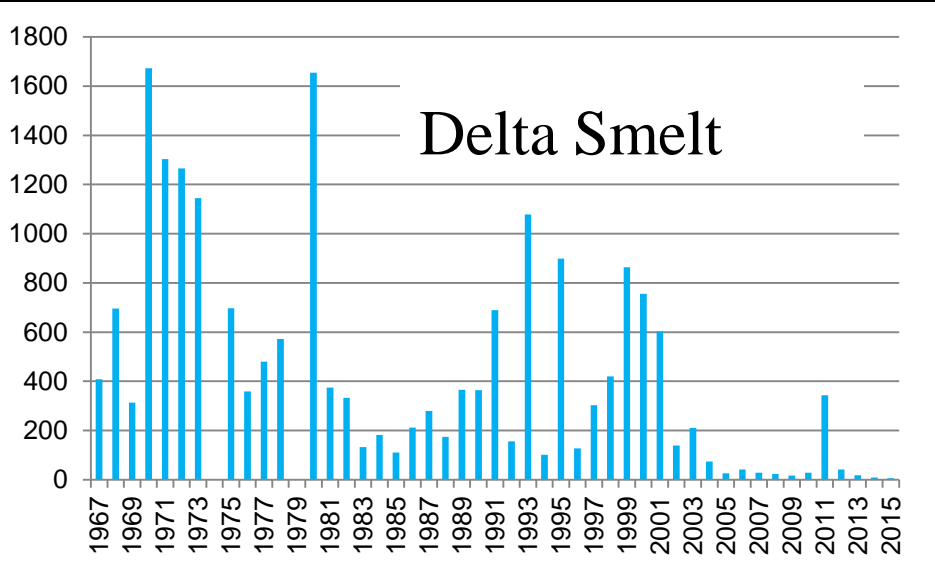


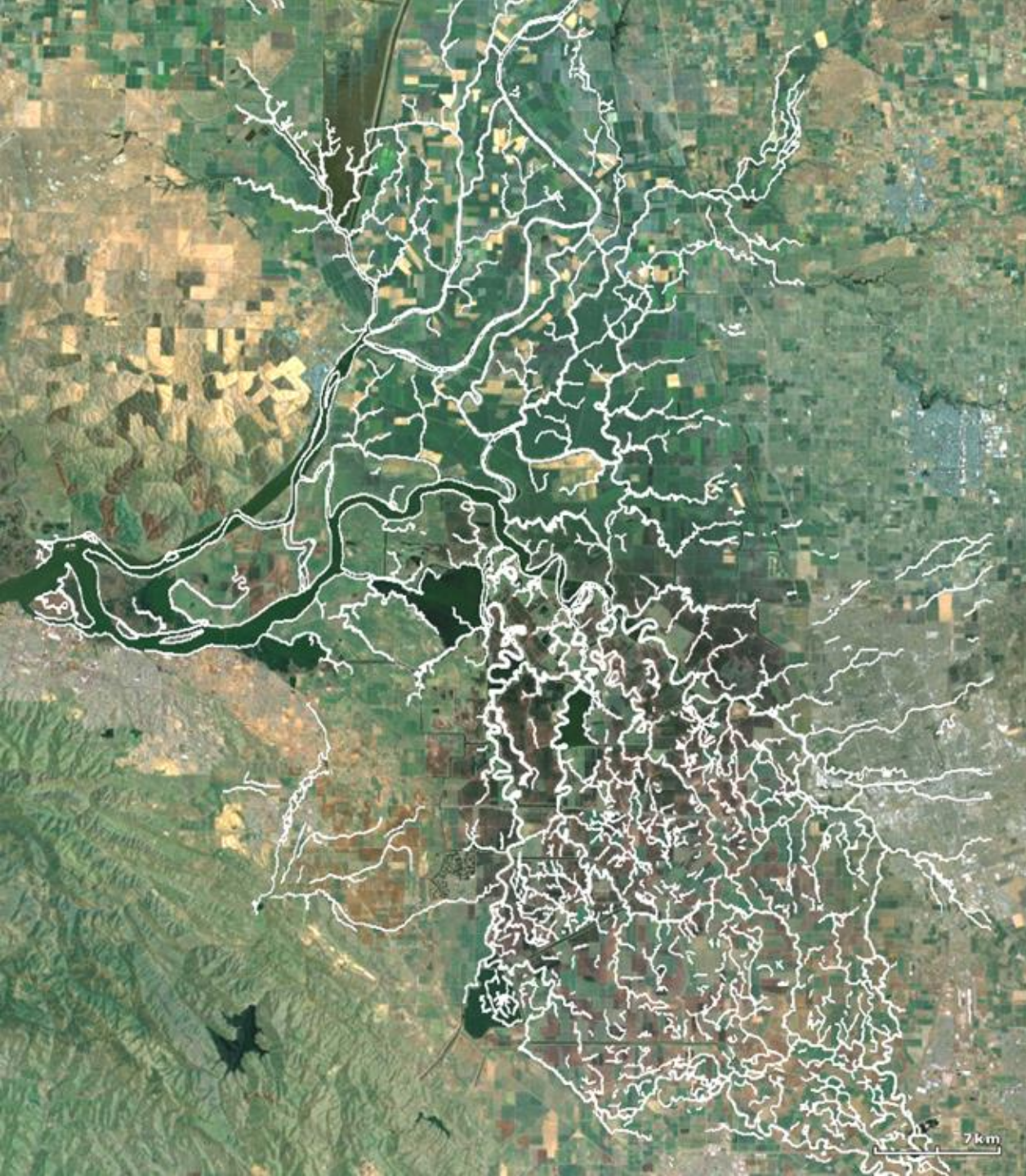
Striped Bass



Threadfin Shad

# Fall Abundance Indices 1967-2015





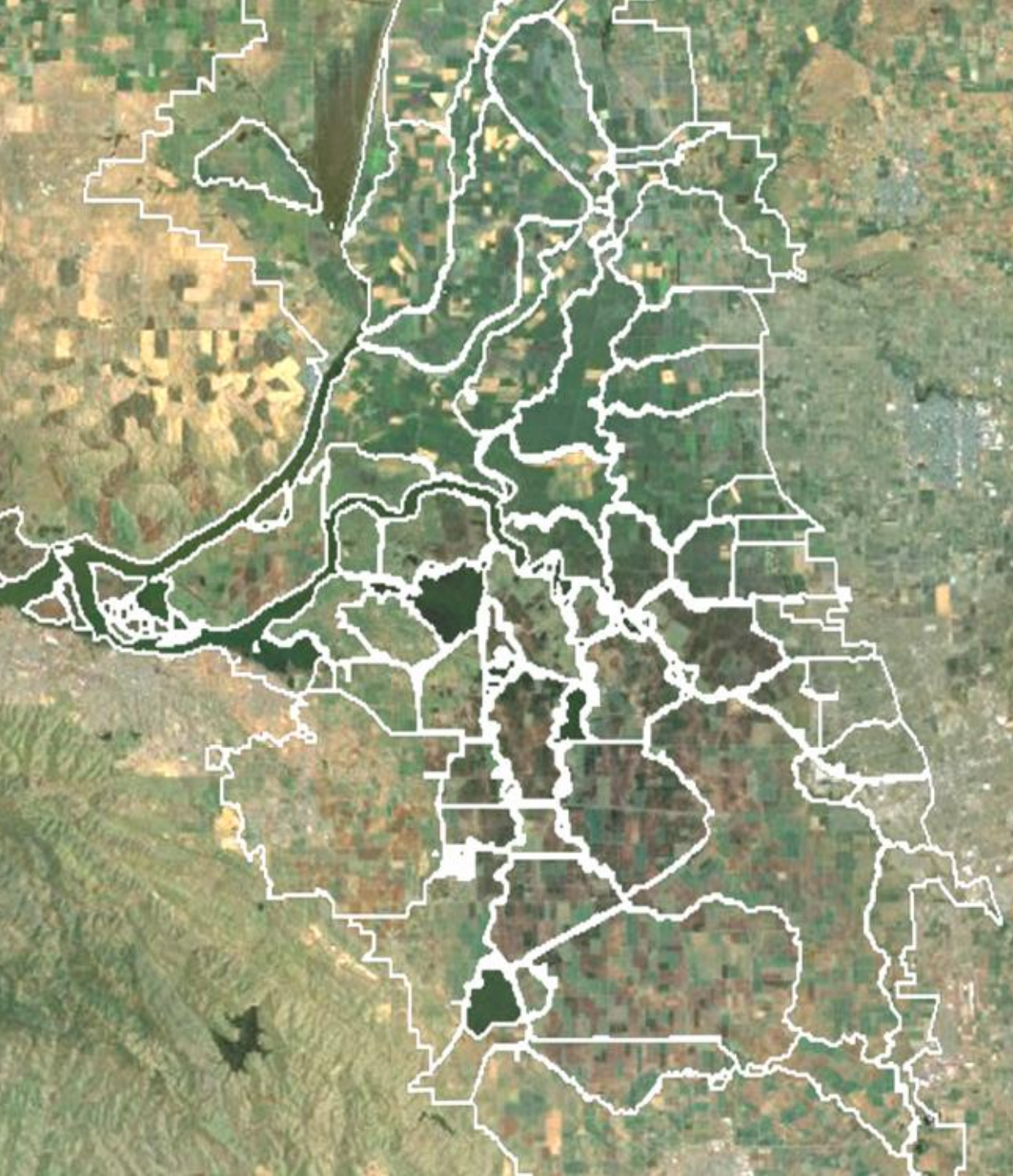
1873 Delta:

Long residence time

Marsh connections

Two rivers connect  
to bay

Waterways dendritic



Modern delta

Short residence times

Rip-rapped

Cross Delta flows

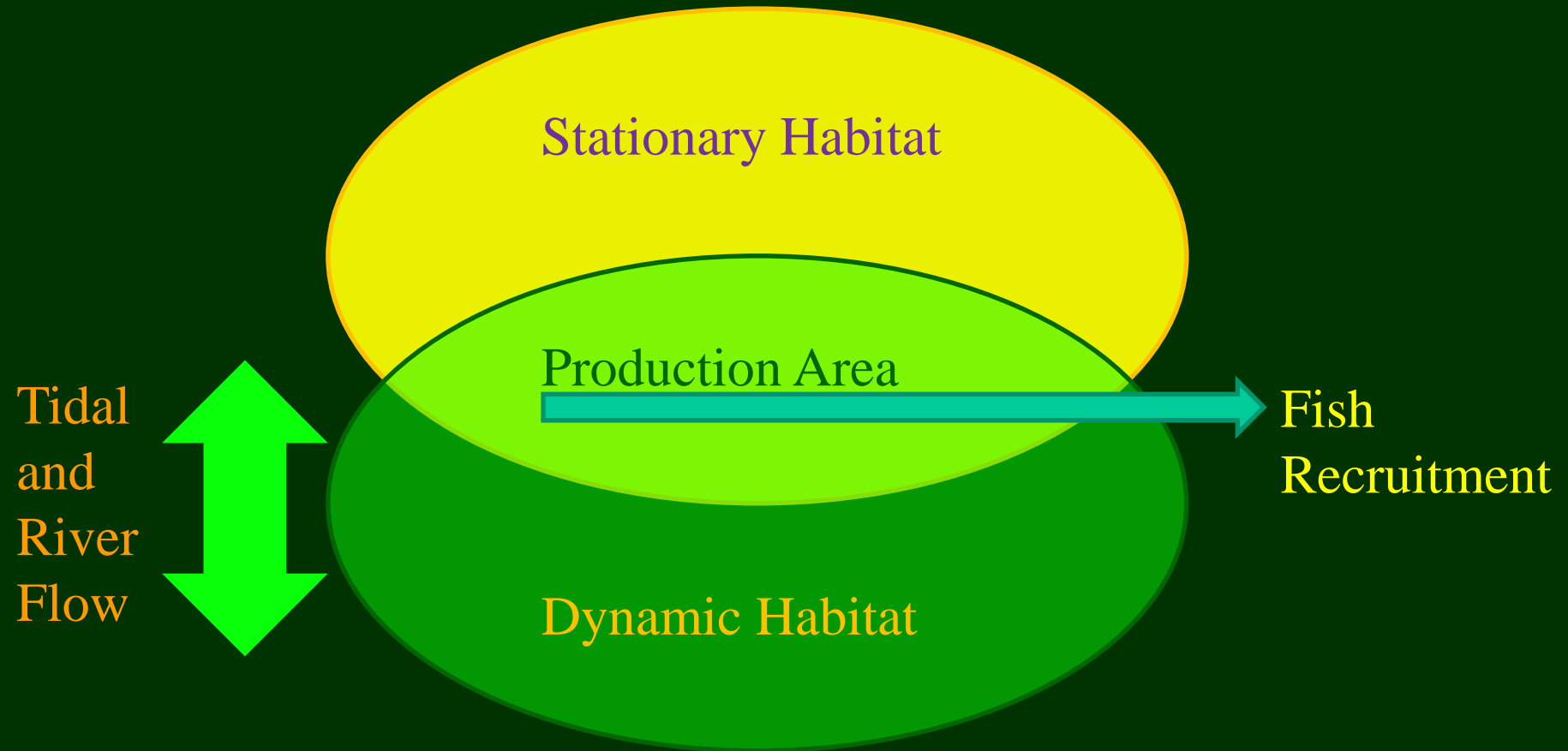
Rare San Joaquin  
connection to bay

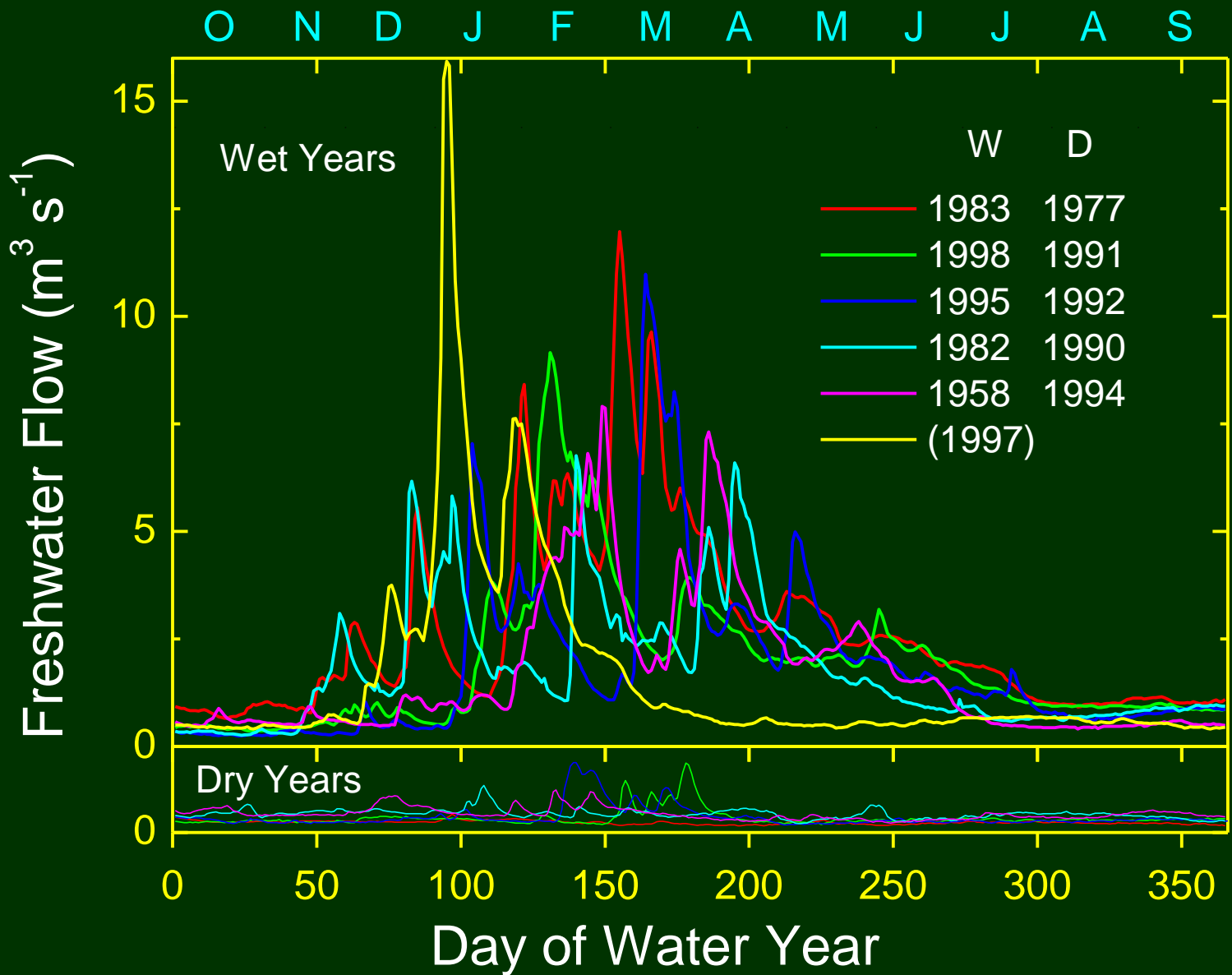
Waterways web-like



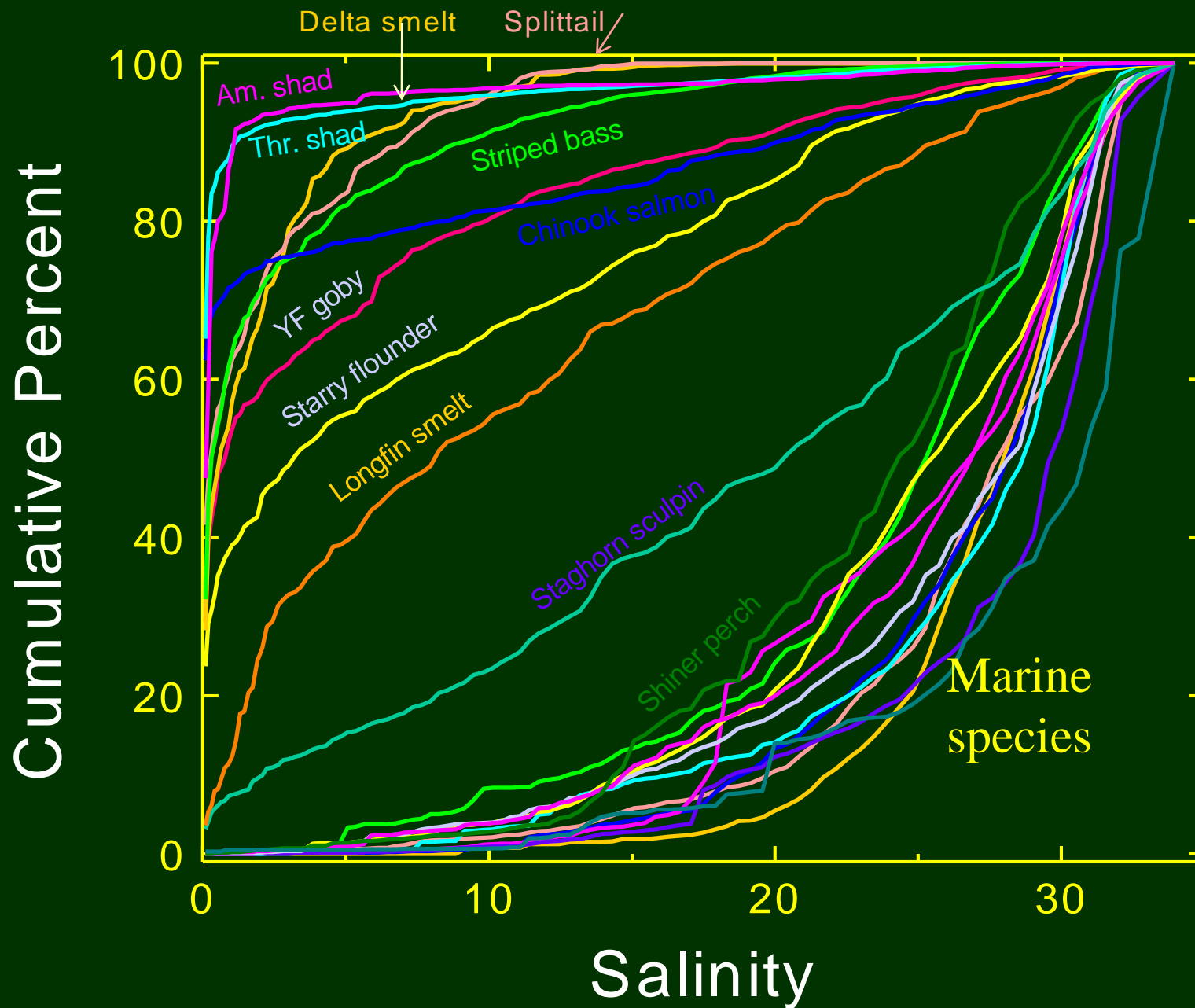
# Estuarine habitat conceptual model

(Peterson 2003)





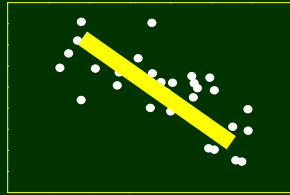
# Most fishes follow salinities



[Kimmerer 2004](#)

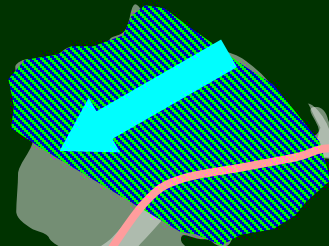
# What Changes As Flow Increases?

Salinity  
and X2



FLOW

Location of  
Any Salinity  
Range

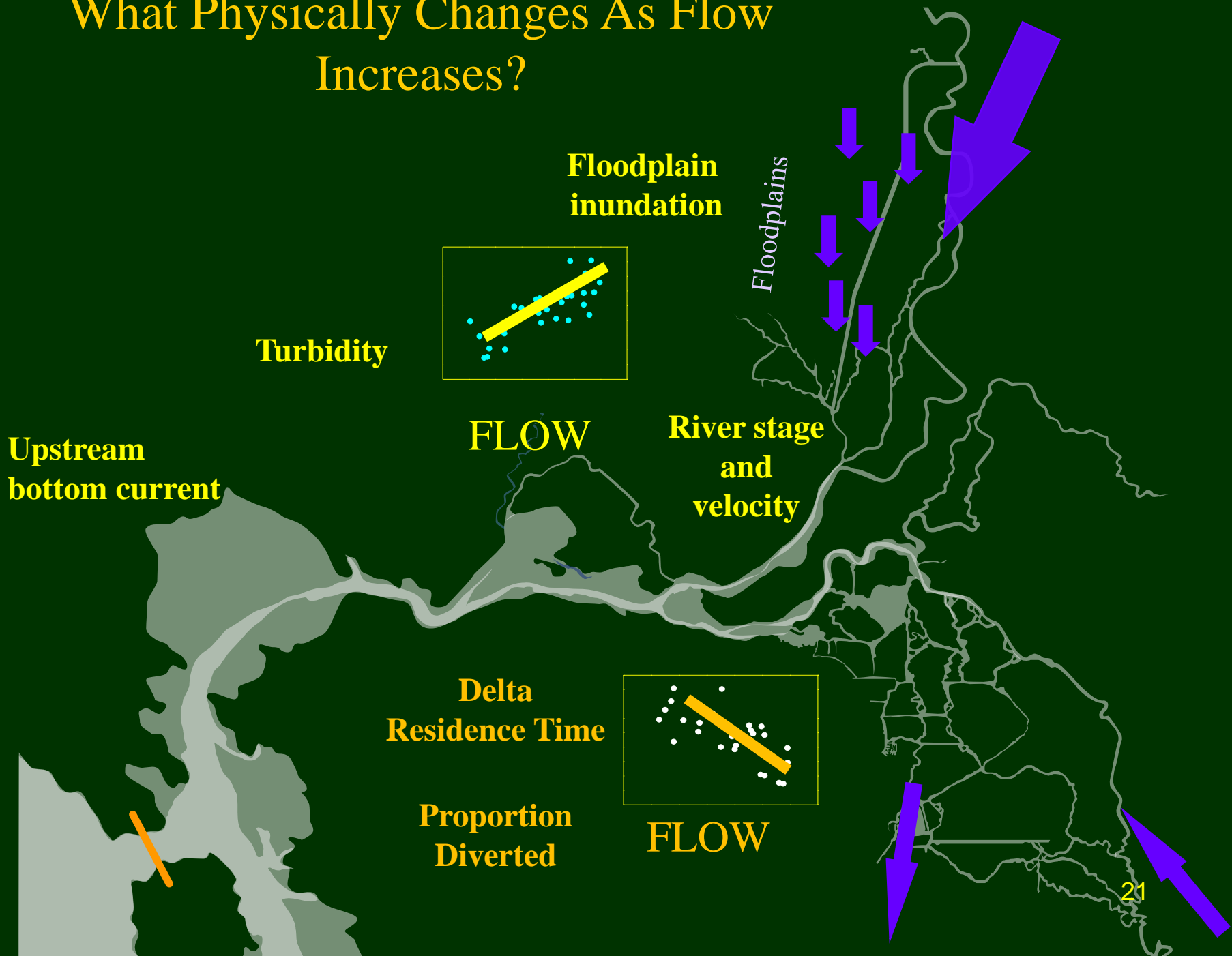


stratification

L  
S  
Z

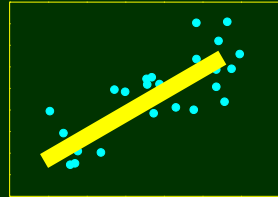


# What Physically Changes As Flow Increases?



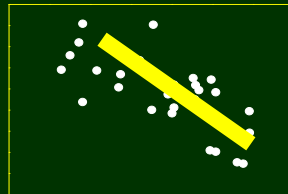
# What chemically changes?

**Loadings**



**FLOW**

**Concentrations**



**FLOW**

**Nutrients  
Contaminants  
Organic matter  
Sediment**

# 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

# Exports in acre-feet

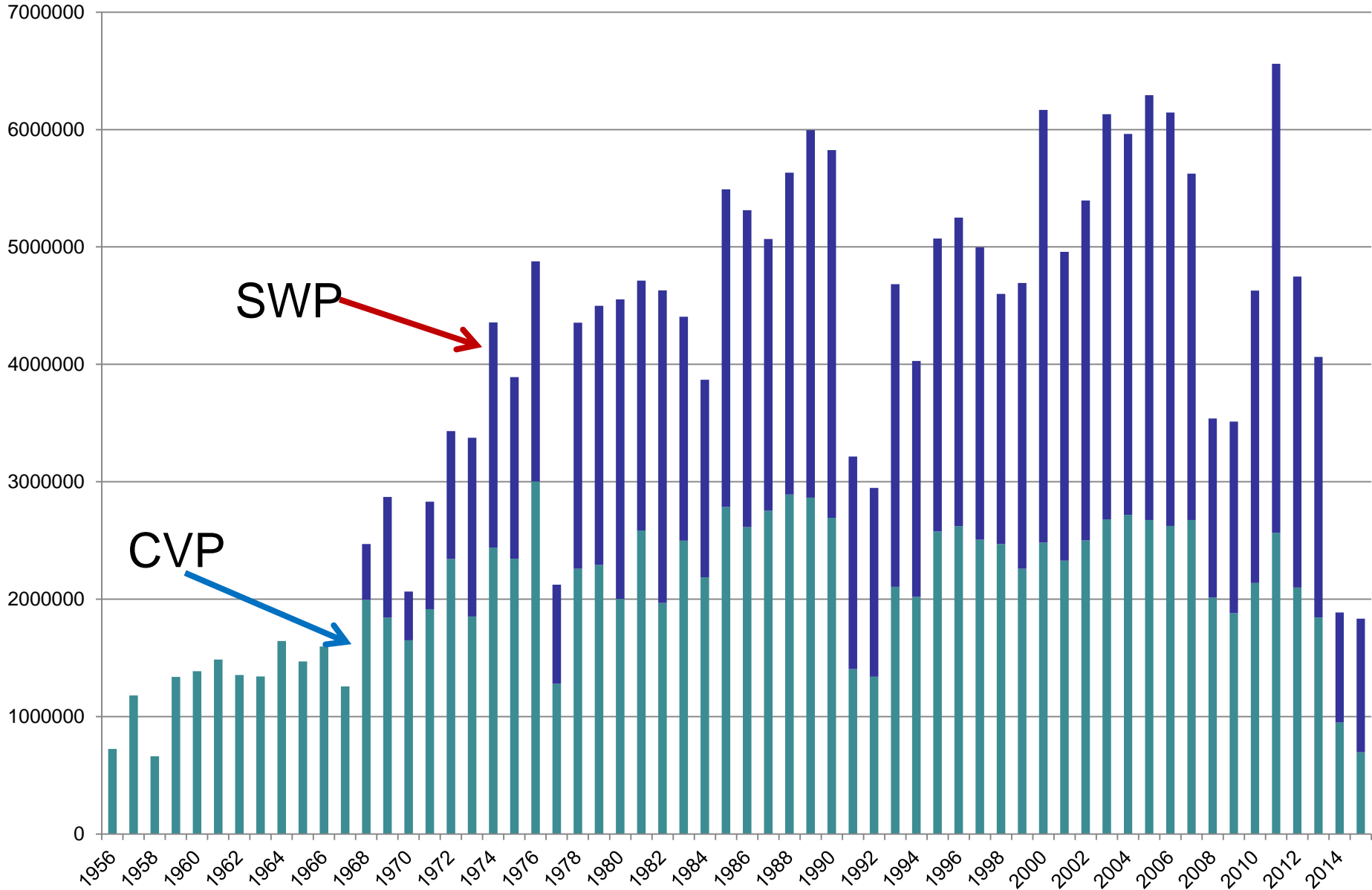
1 acre-foot = 325,851 gallons

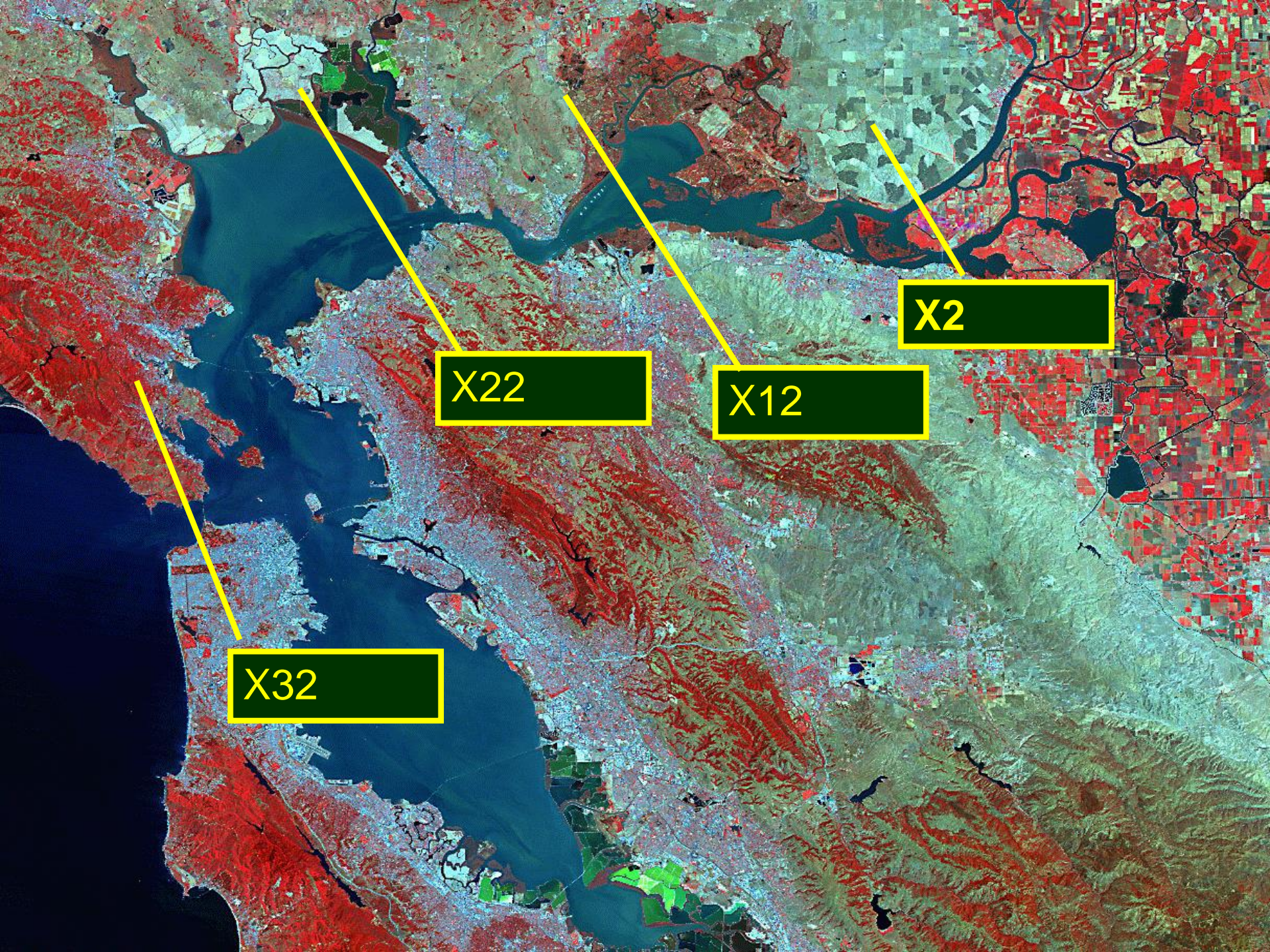
OR

1233 kiloliters

OR

1 cfs for 12 hours



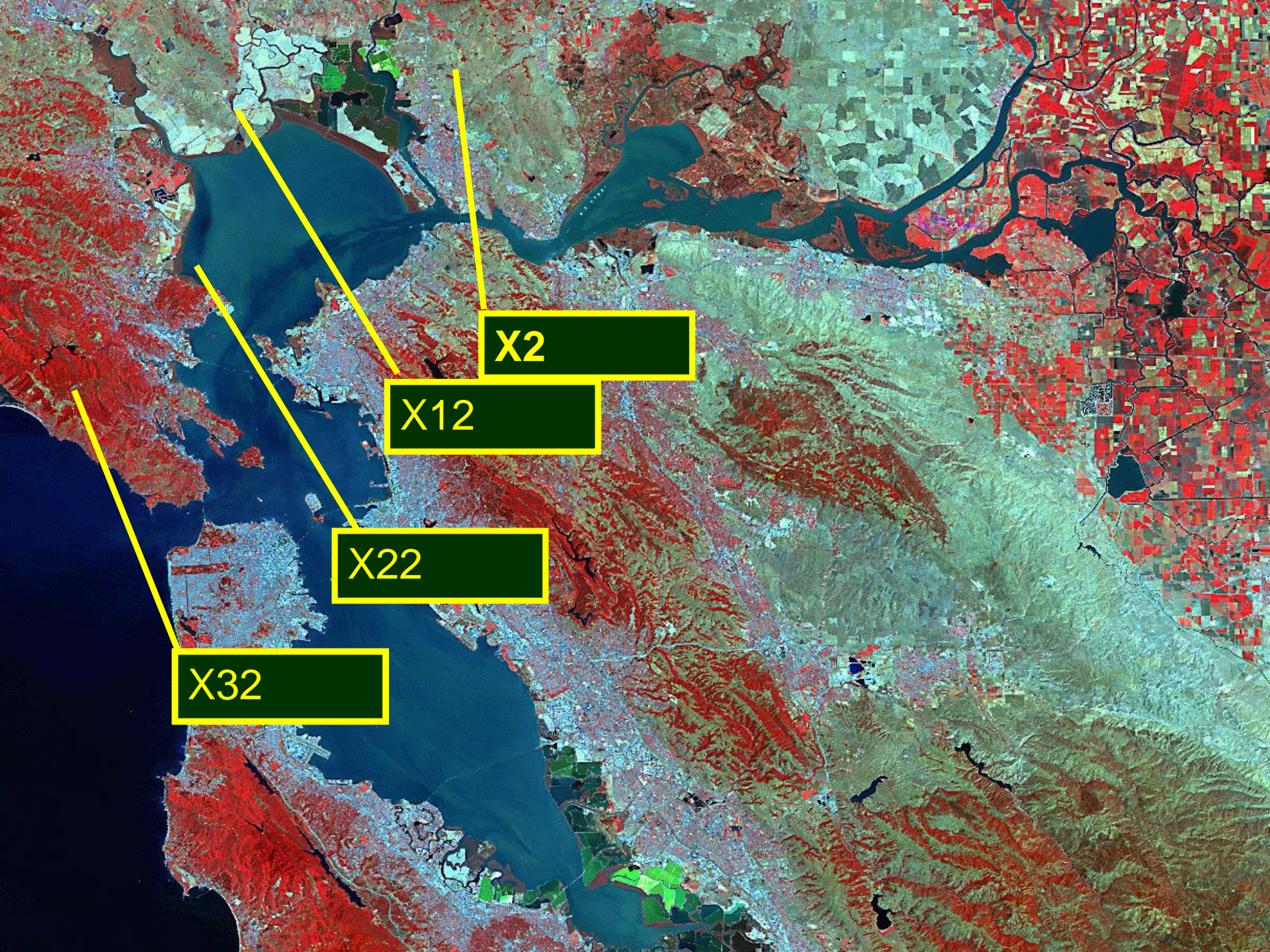


X2

X12

X22

X32

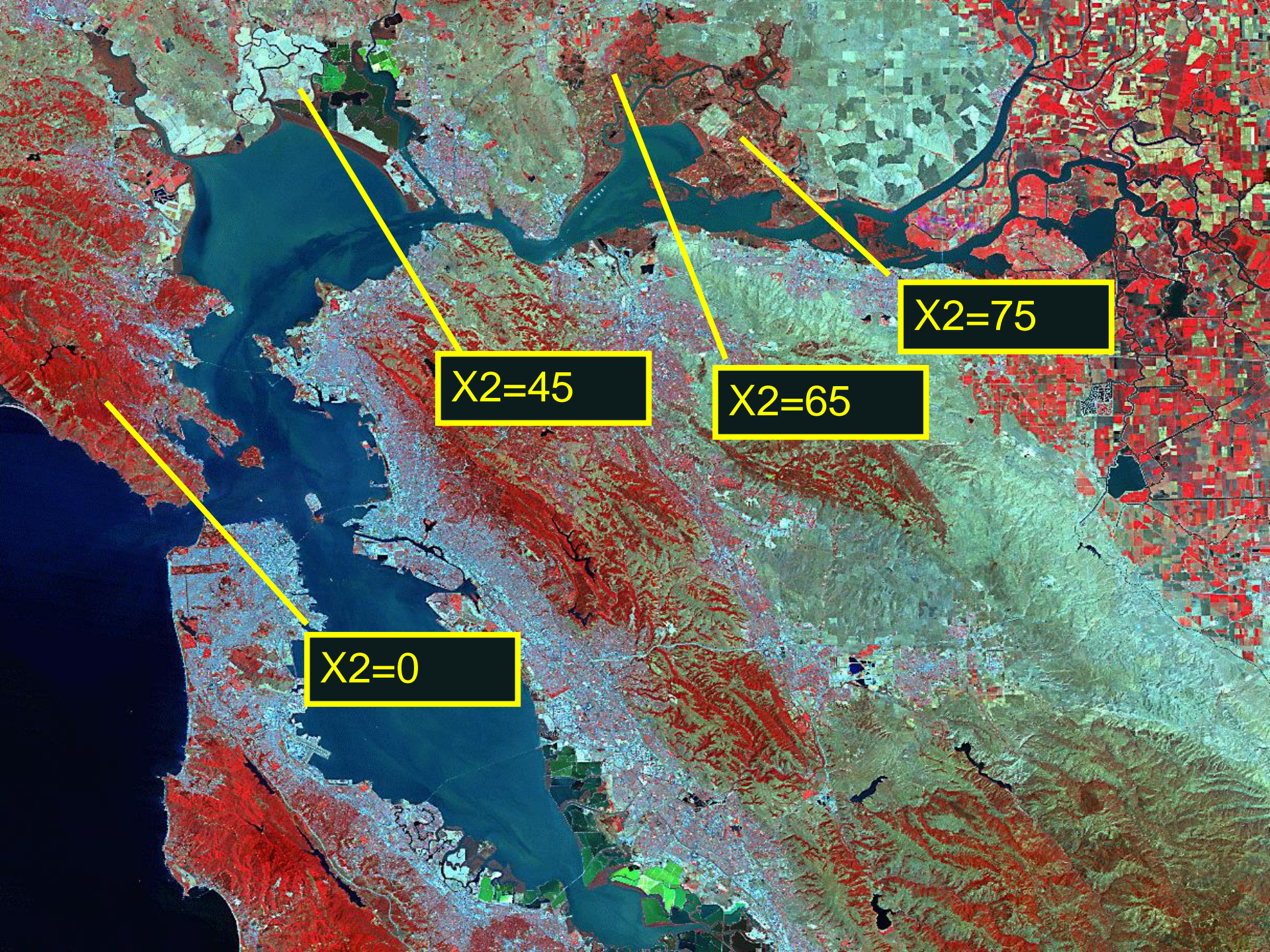


X2

X12

X22

X32



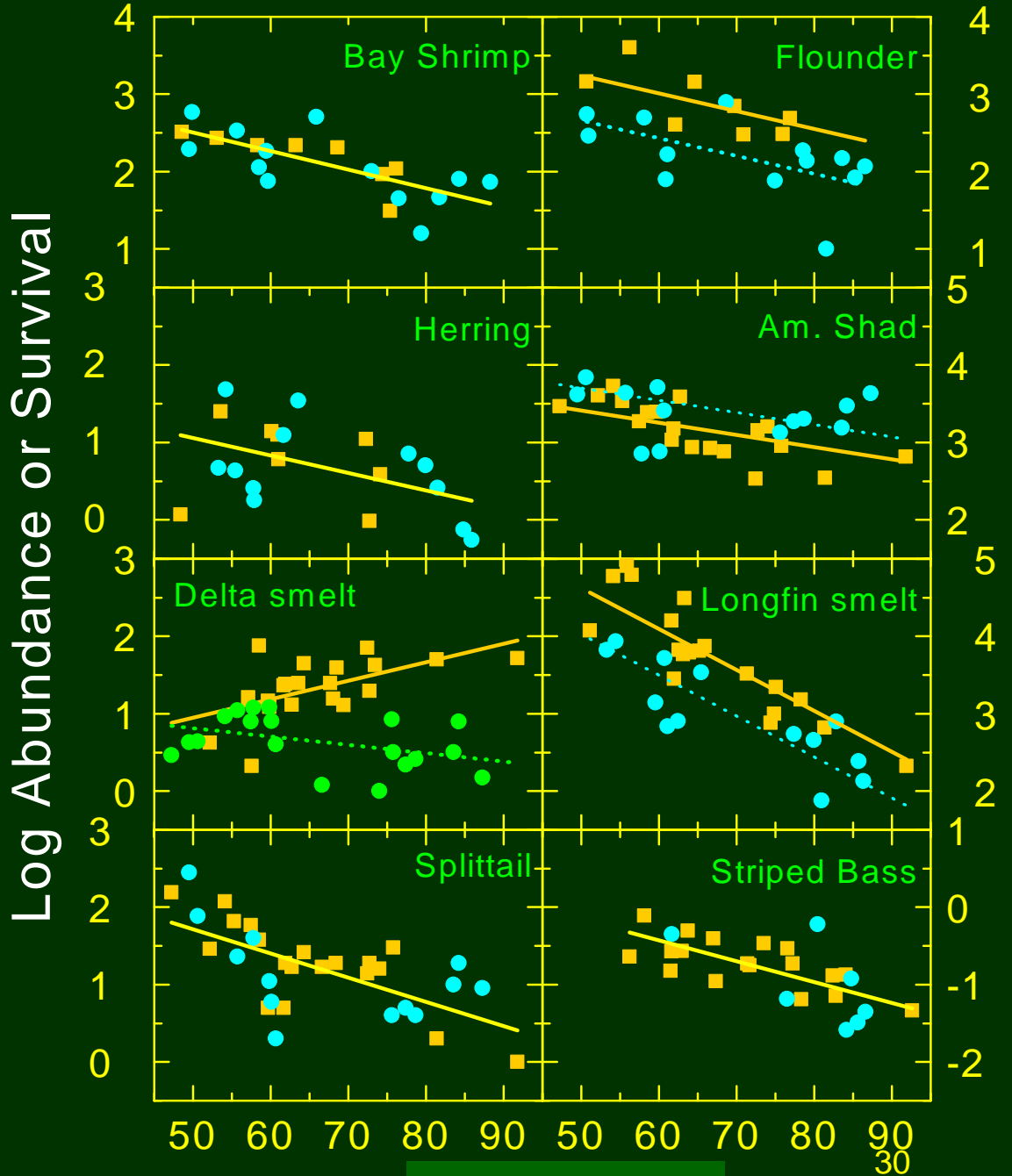
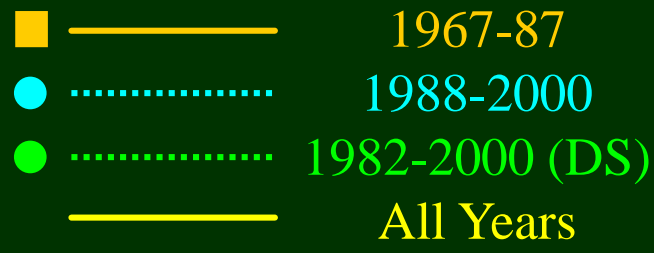
X2=0

X2=45

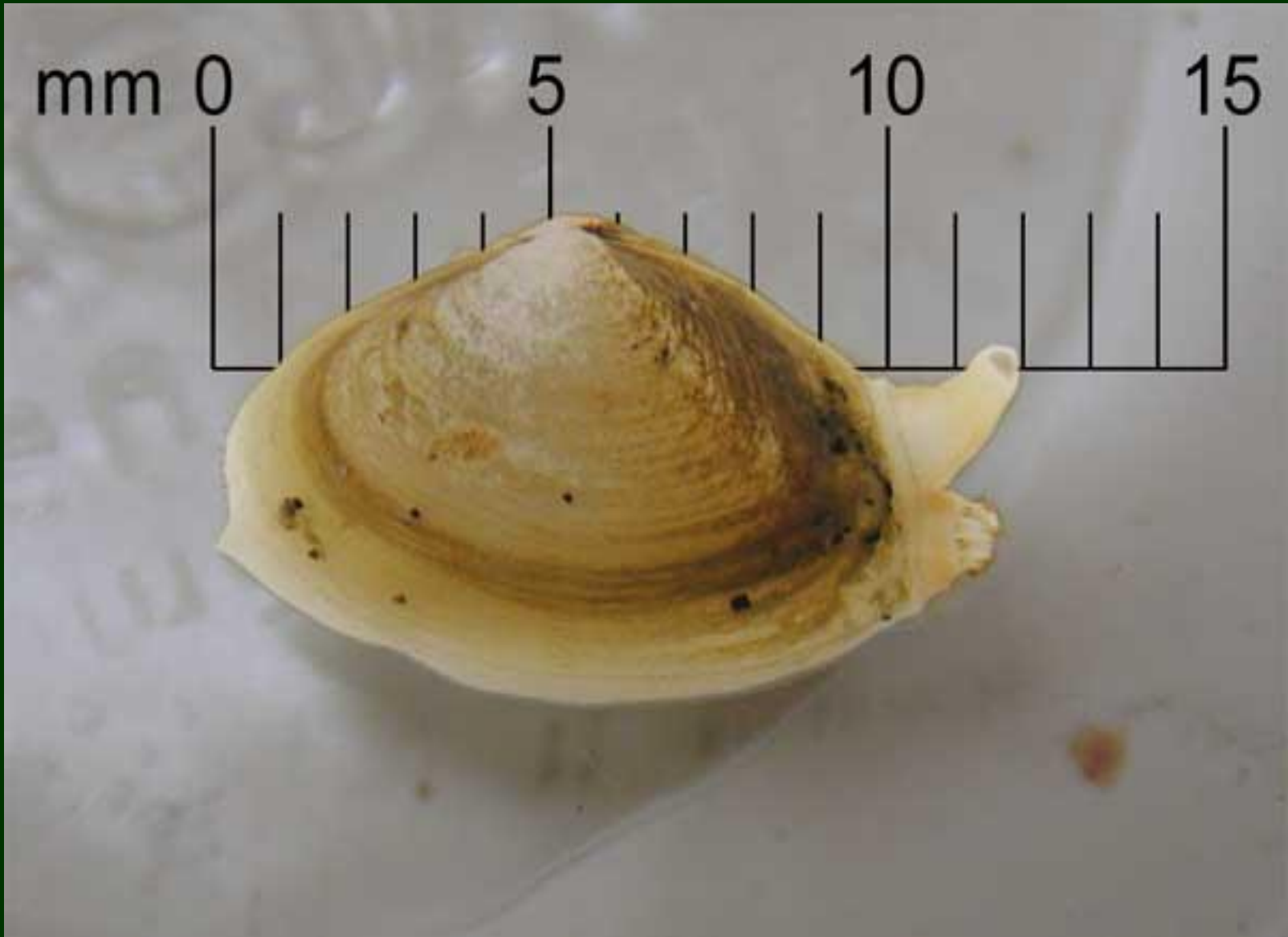
X2=65

X2=75

Higher trophic levels show many relationships of abundance to X2

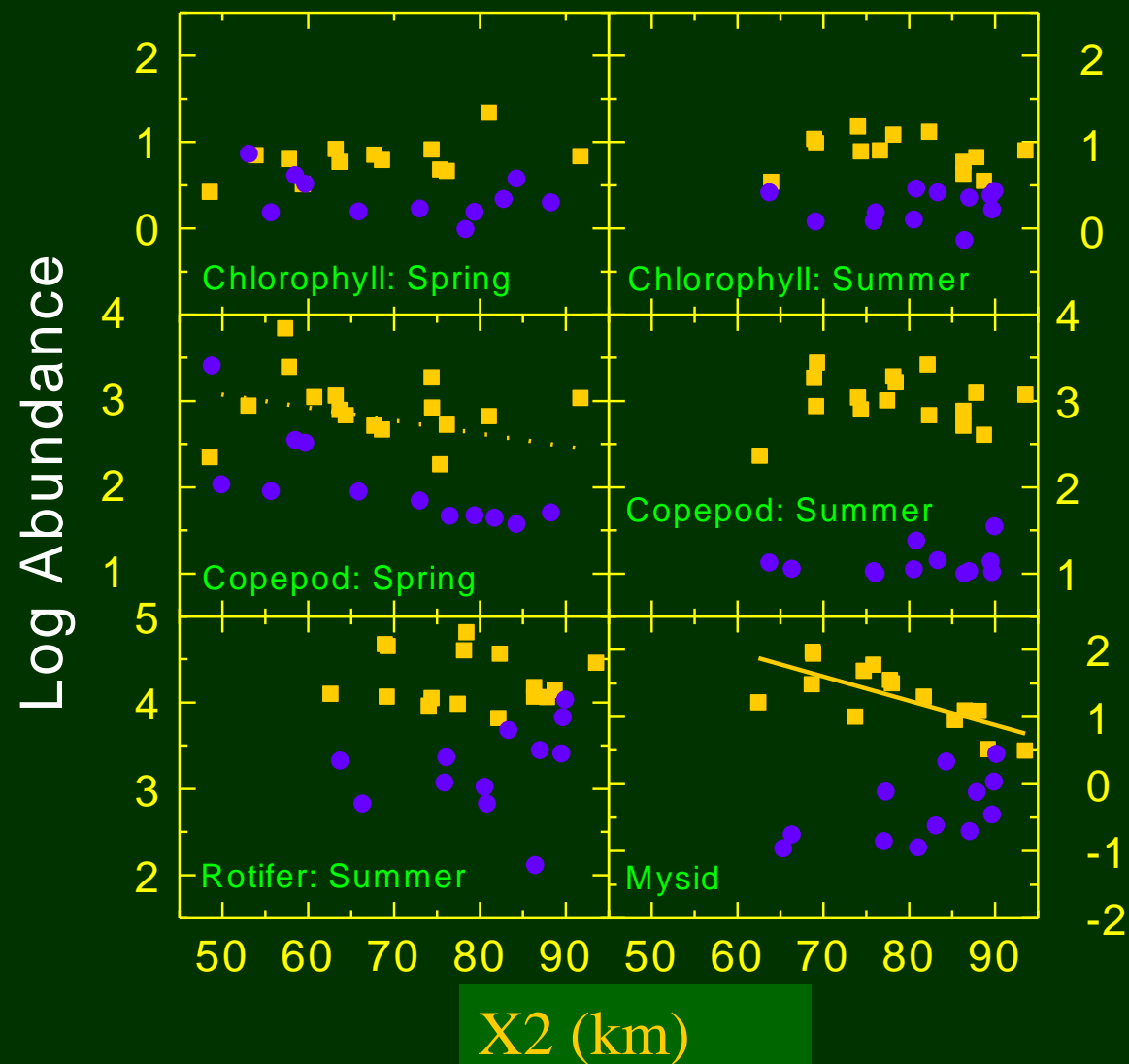


Source: Kimmerer 2002MEPS



Lower trophic levels show few relationships of abundance to X2

■ ————— 1972-1987  
● ..... 1988-2000



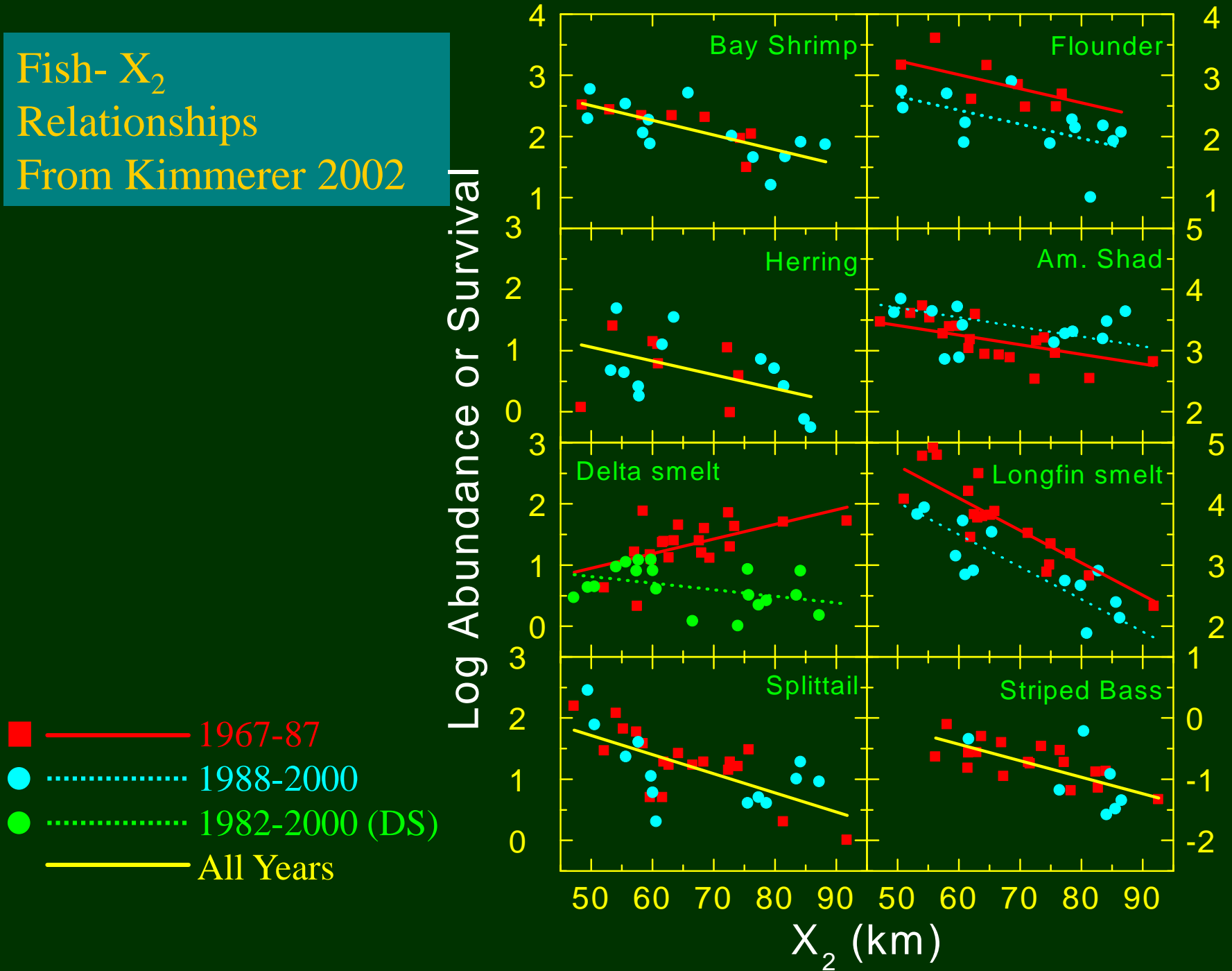
Source: Kimmerer 2002 MEPS

High Flow

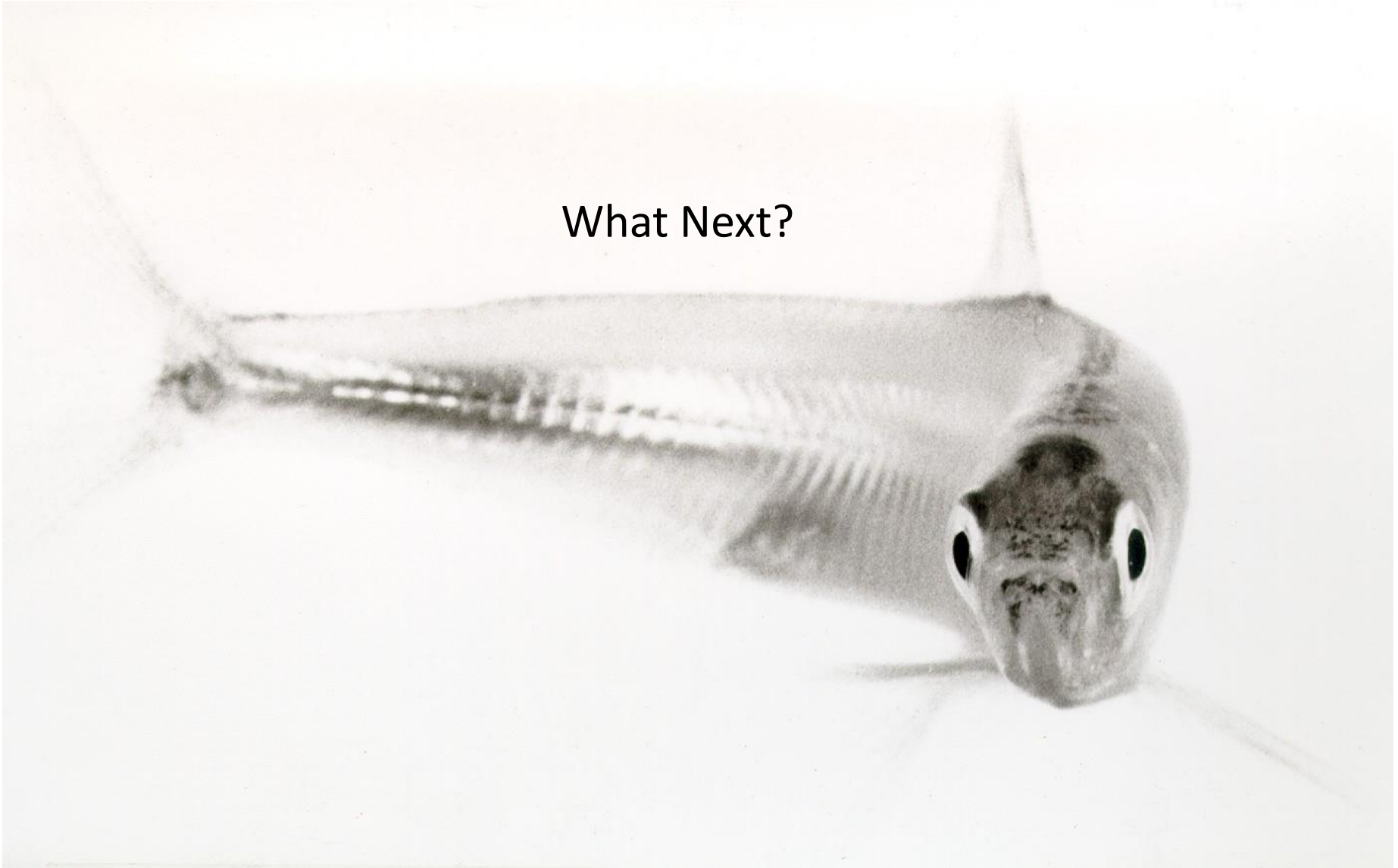
32  
Low Flow



Fish-  $X_2$   
Relationships  
From Kimmerer 2002



What Next?





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

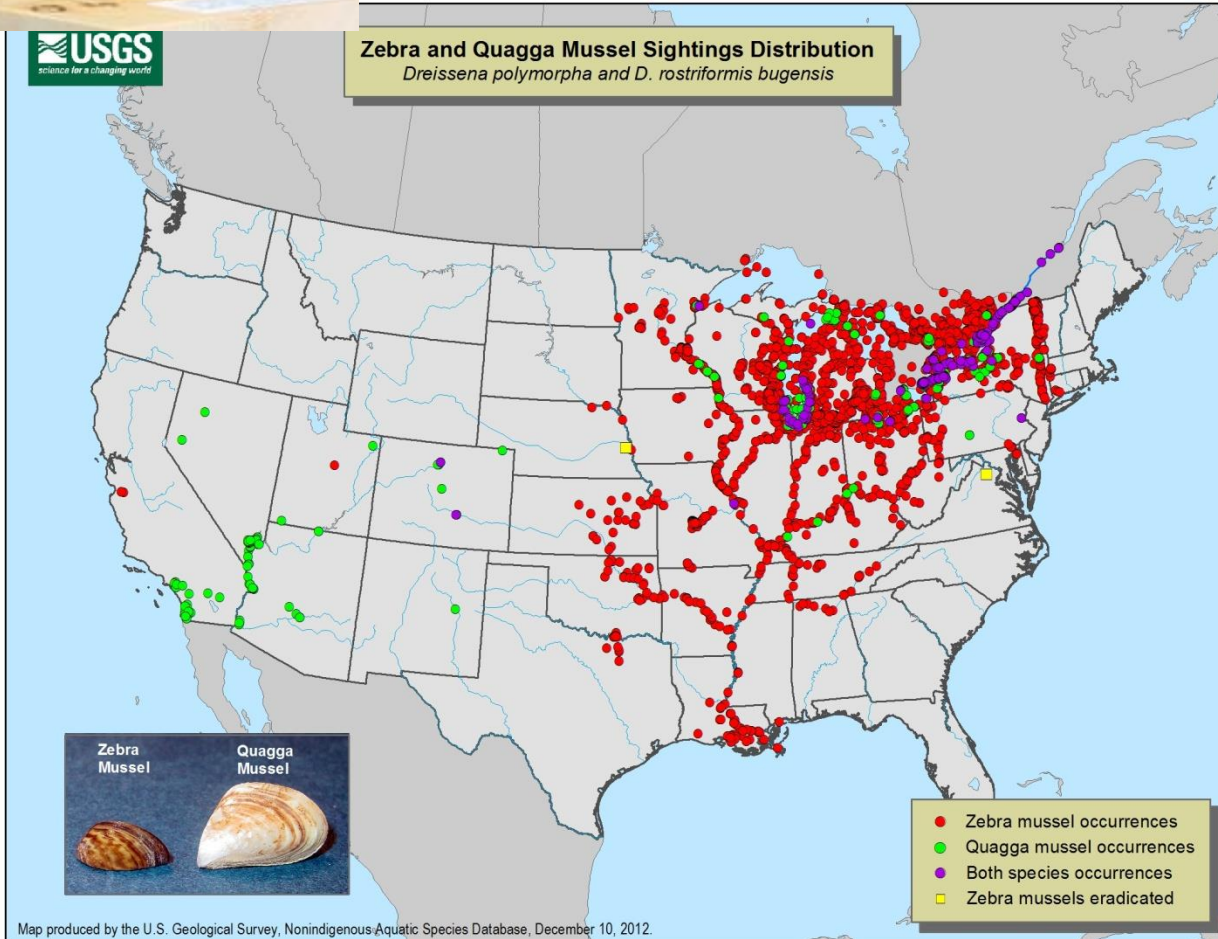
Photo: Roger Kelly for Bay Nature Magazine

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

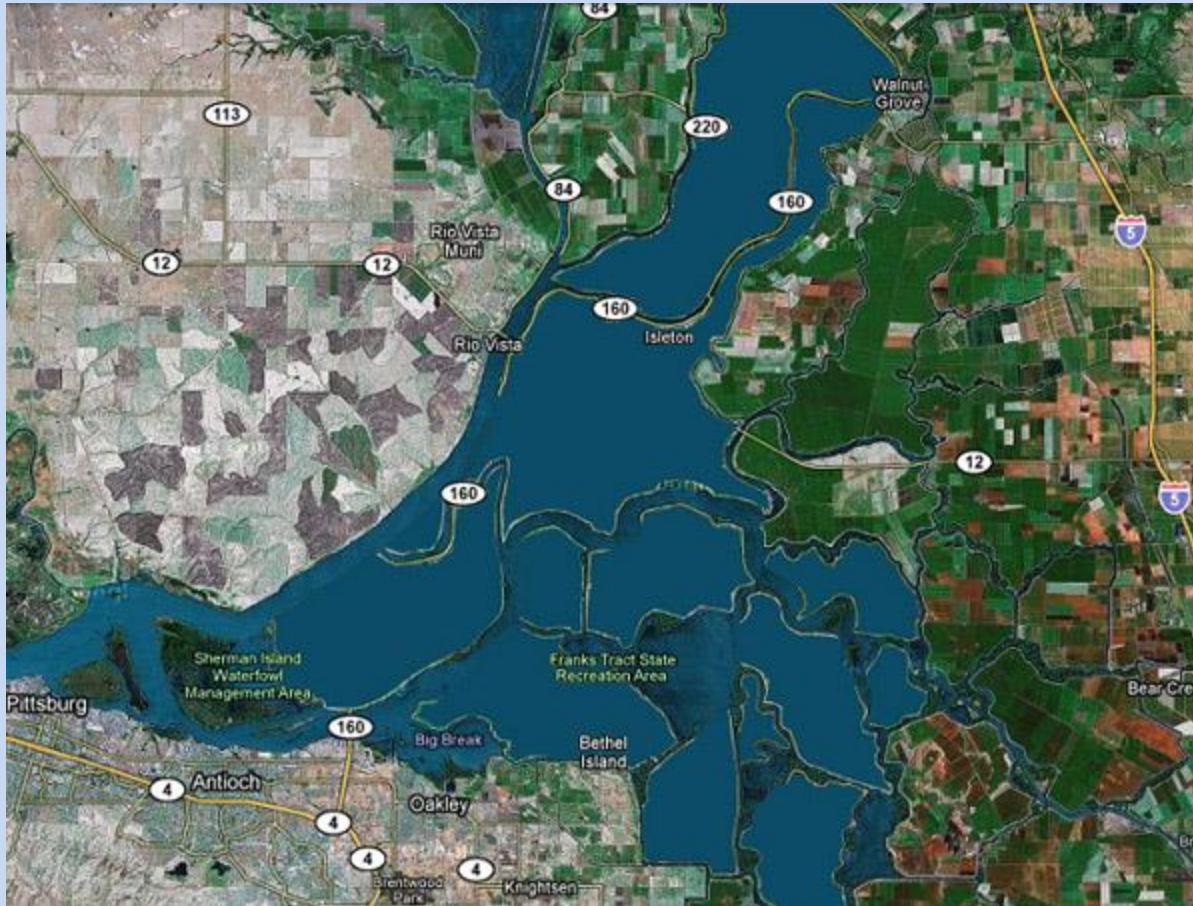


**Loach: San Joaquin River near  
Fresno, Fall 2014.**

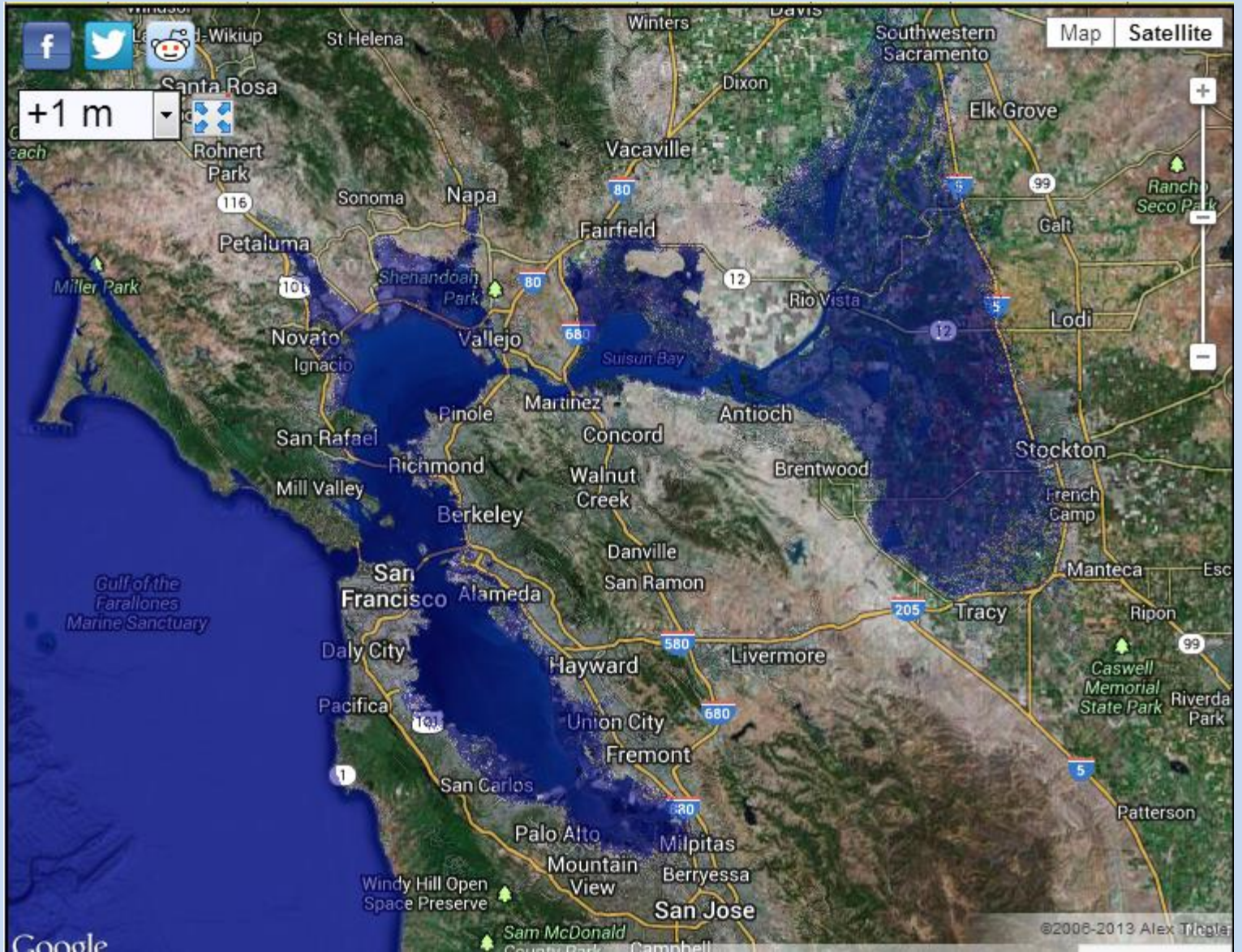
# Today?

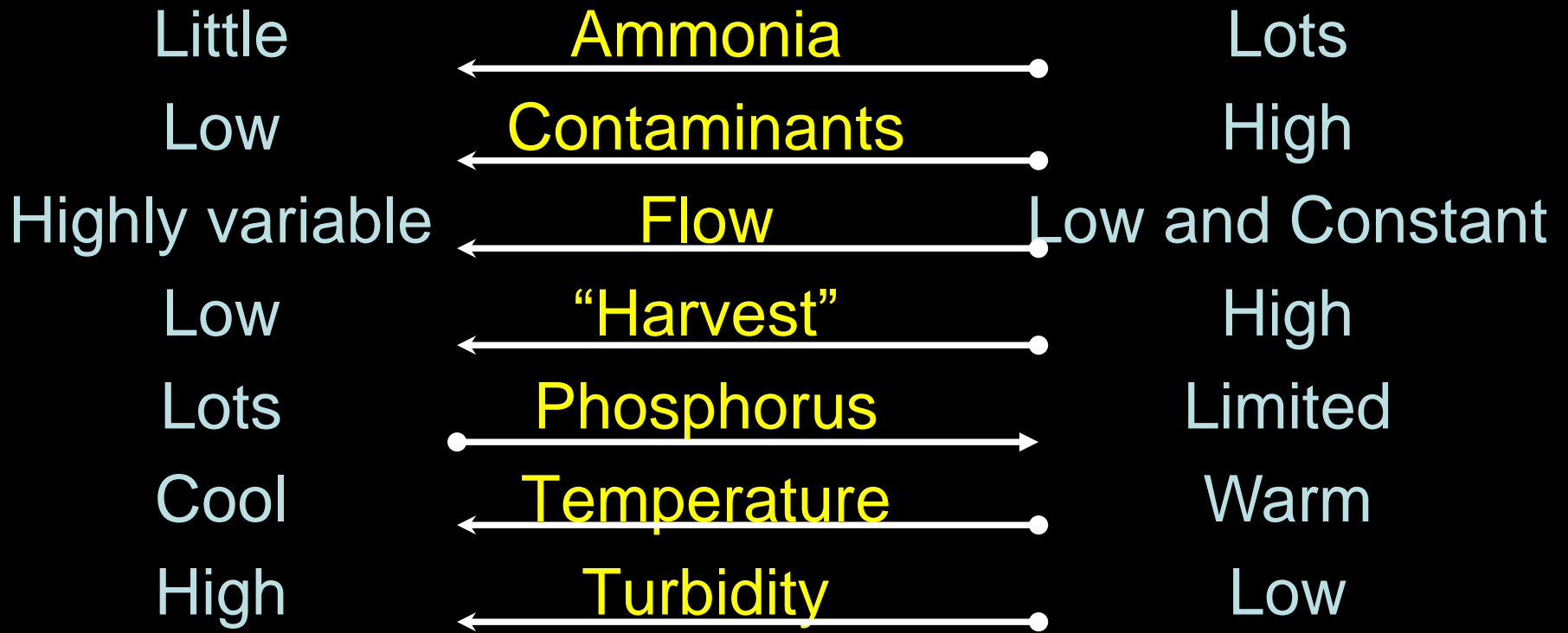


# Earthquake or flood



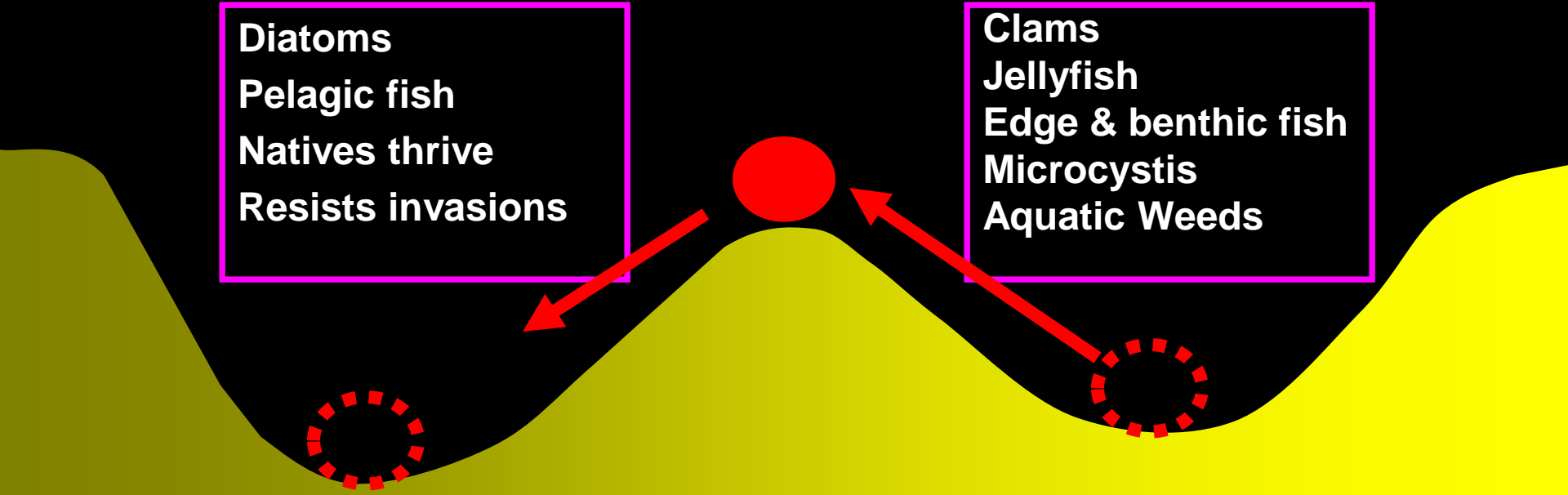
# 1 M sea level rise (2100?)





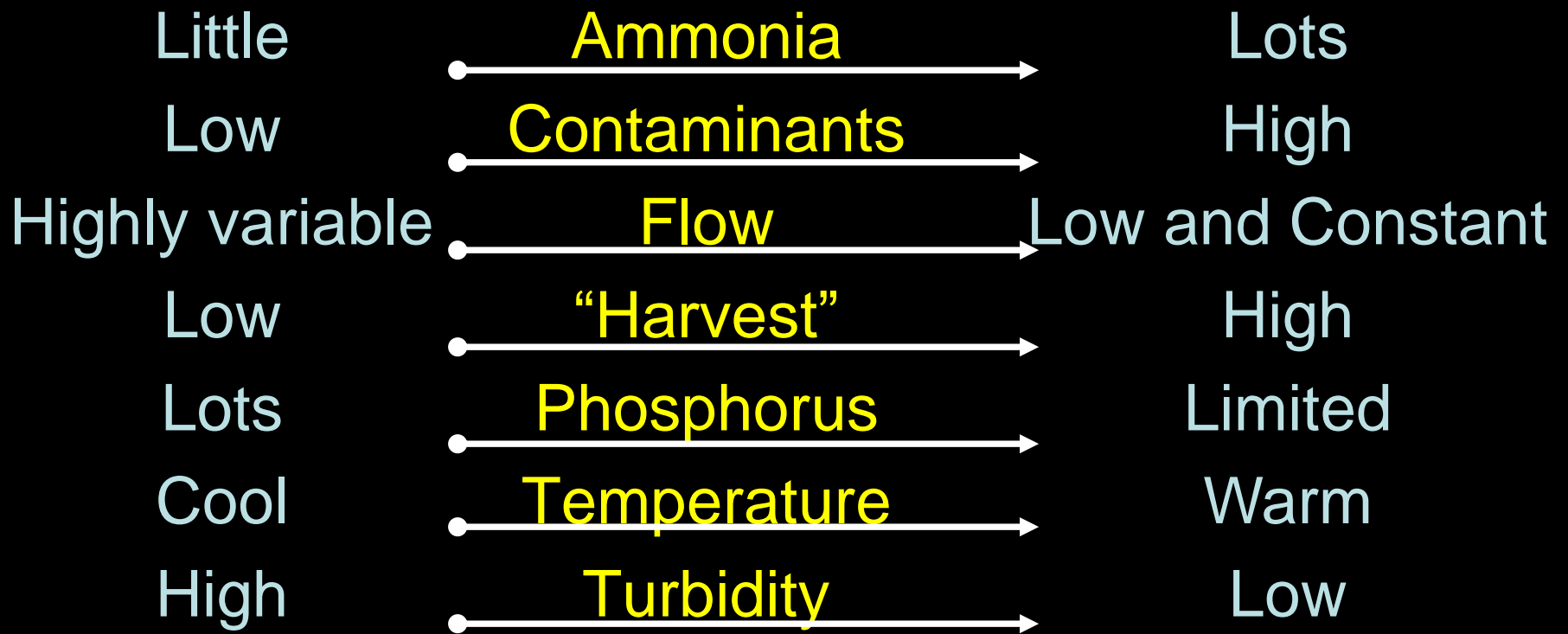
**Diatoms**  
**Pelagic fish**  
**Natives thrive**  
**Resists invasions**

**Clams**  
**Jellyfish**  
**Edge & benthic fish**  
**Microcystis**  
**Aquatic Weeds**



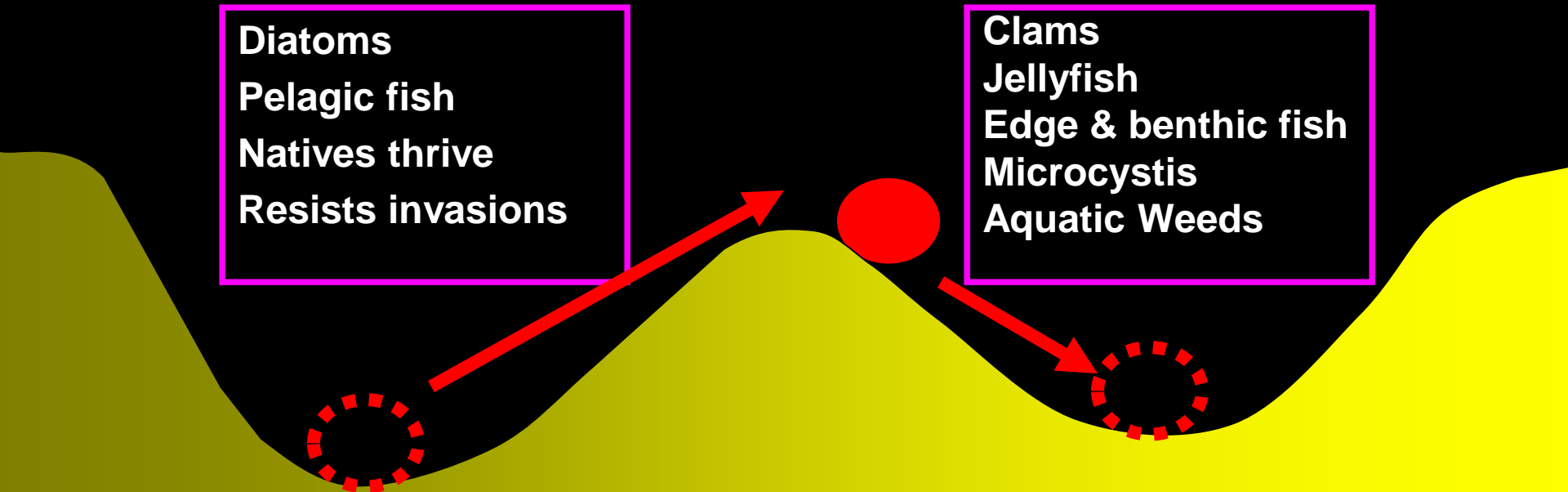




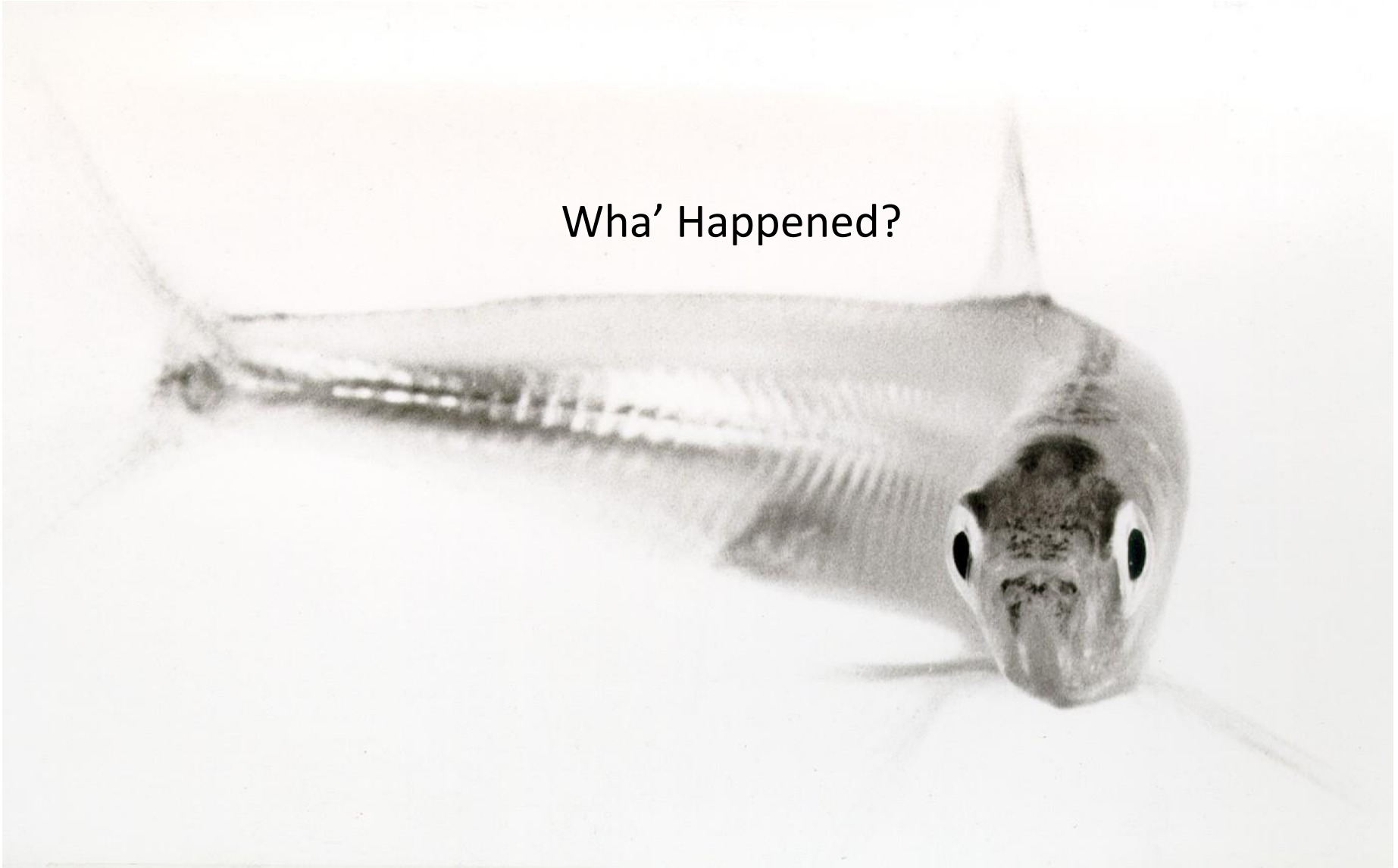


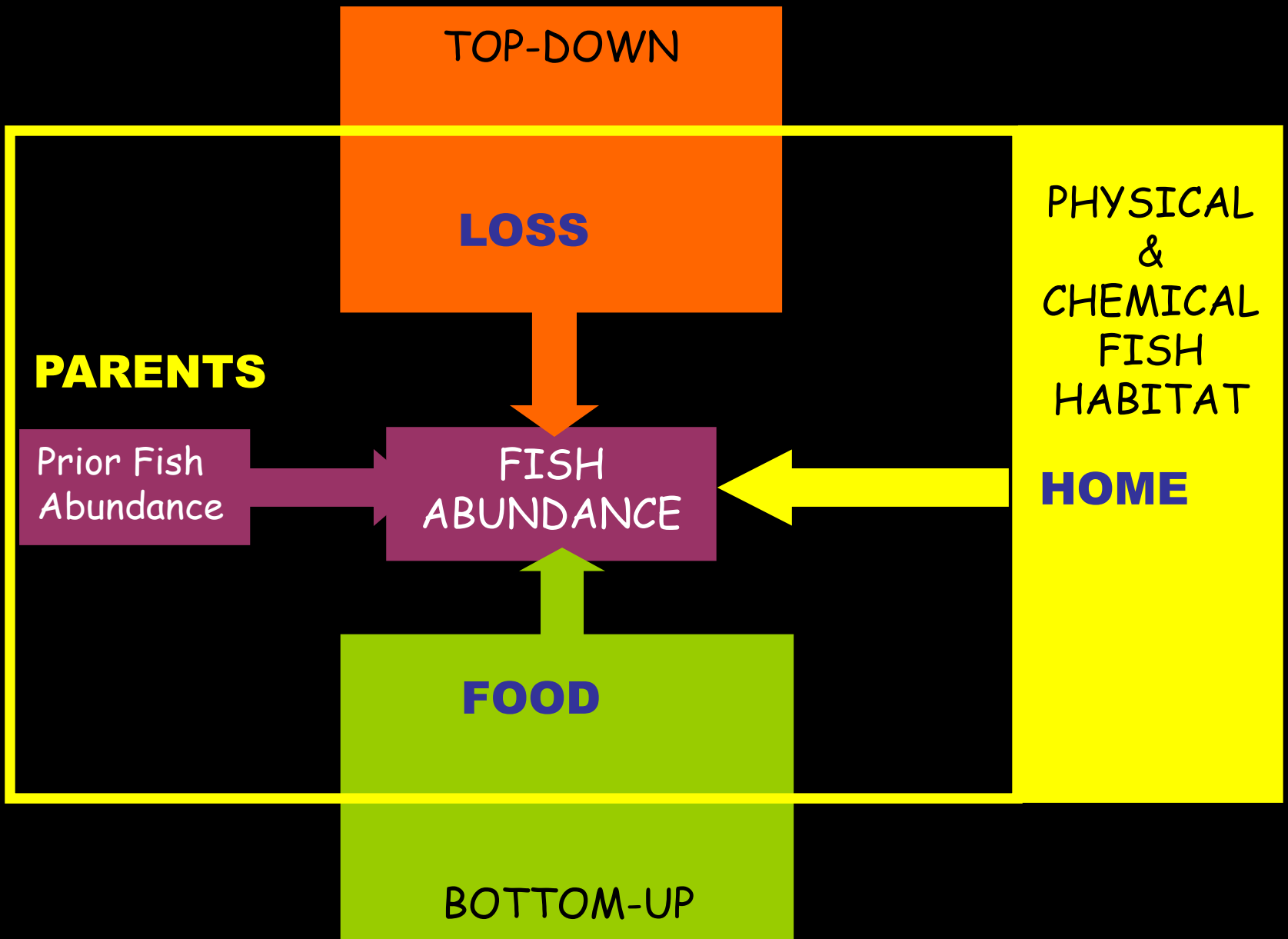
**Diatoms**  
**Pelagic fish**  
**Natives thrive**  
**Resists invasions**

**Clams**  
**Jellyfish**  
**Edge & benthic fish**  
**Microcystis**  
**Aquatic Weeds**



Wha' Happened?

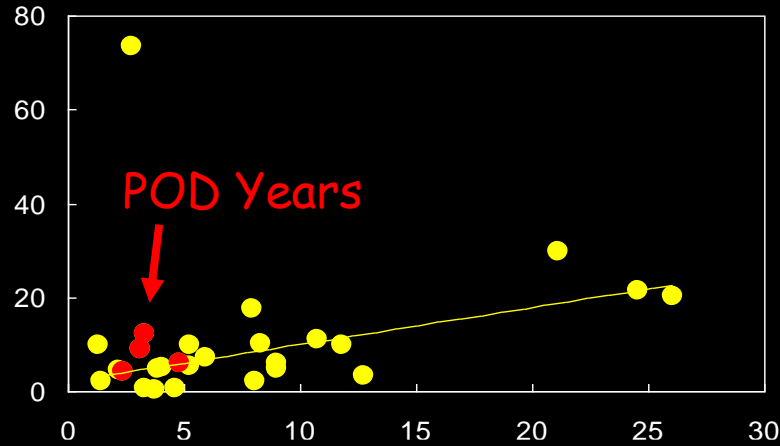




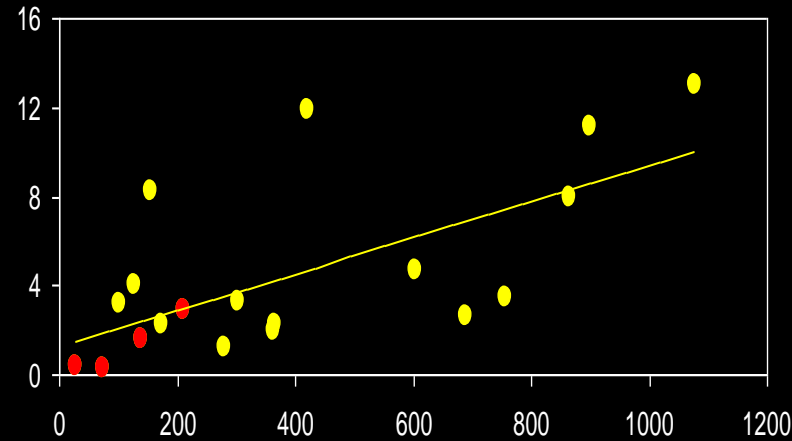
# Stock - Recruitment Effects



Juvenile Production



Threadfin shad



Delta smelt

Fall Midwater Trawl (Adults)

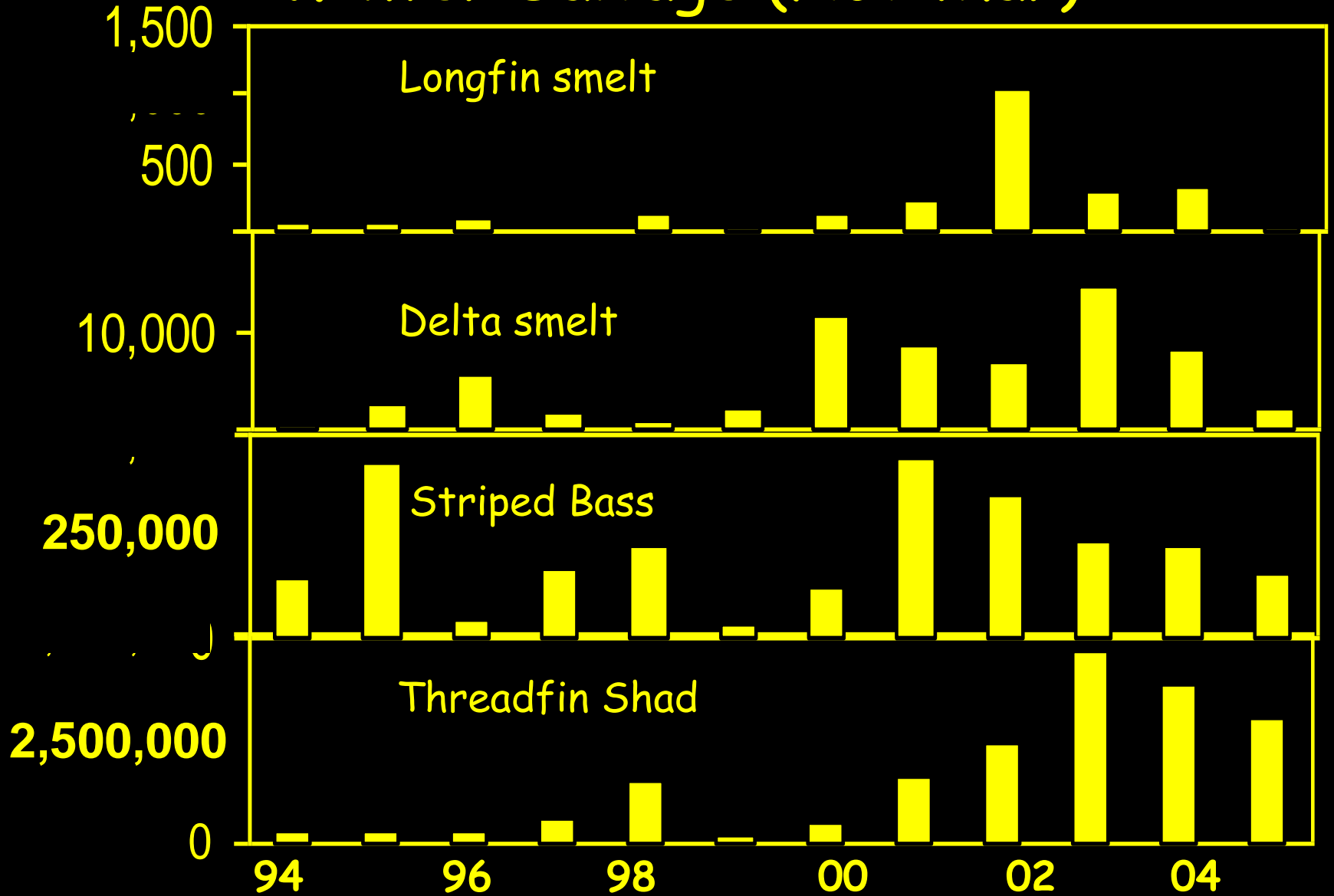


# Water Project Losses

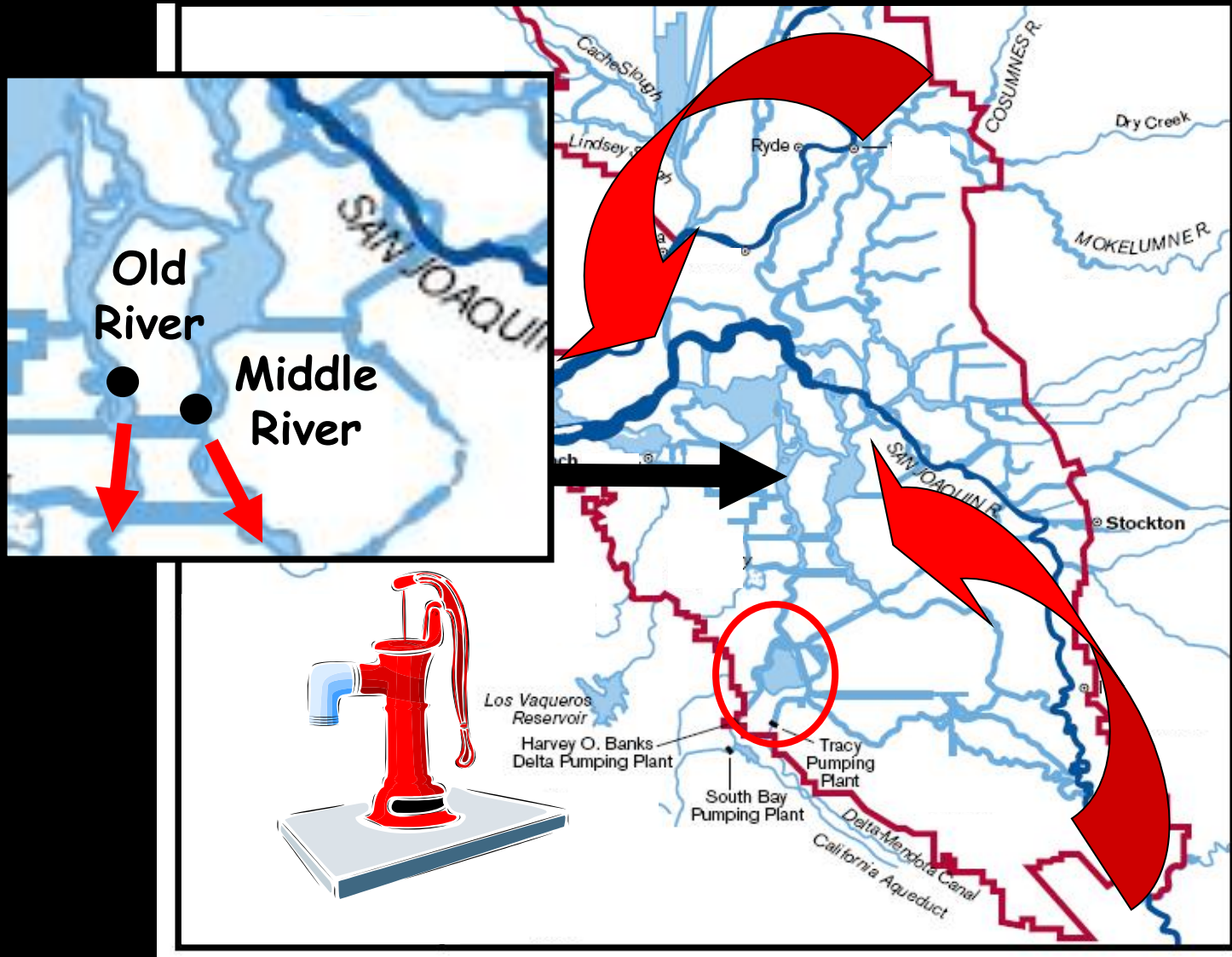


Fish Facilities Provide Data on Numbers “Salvaged”

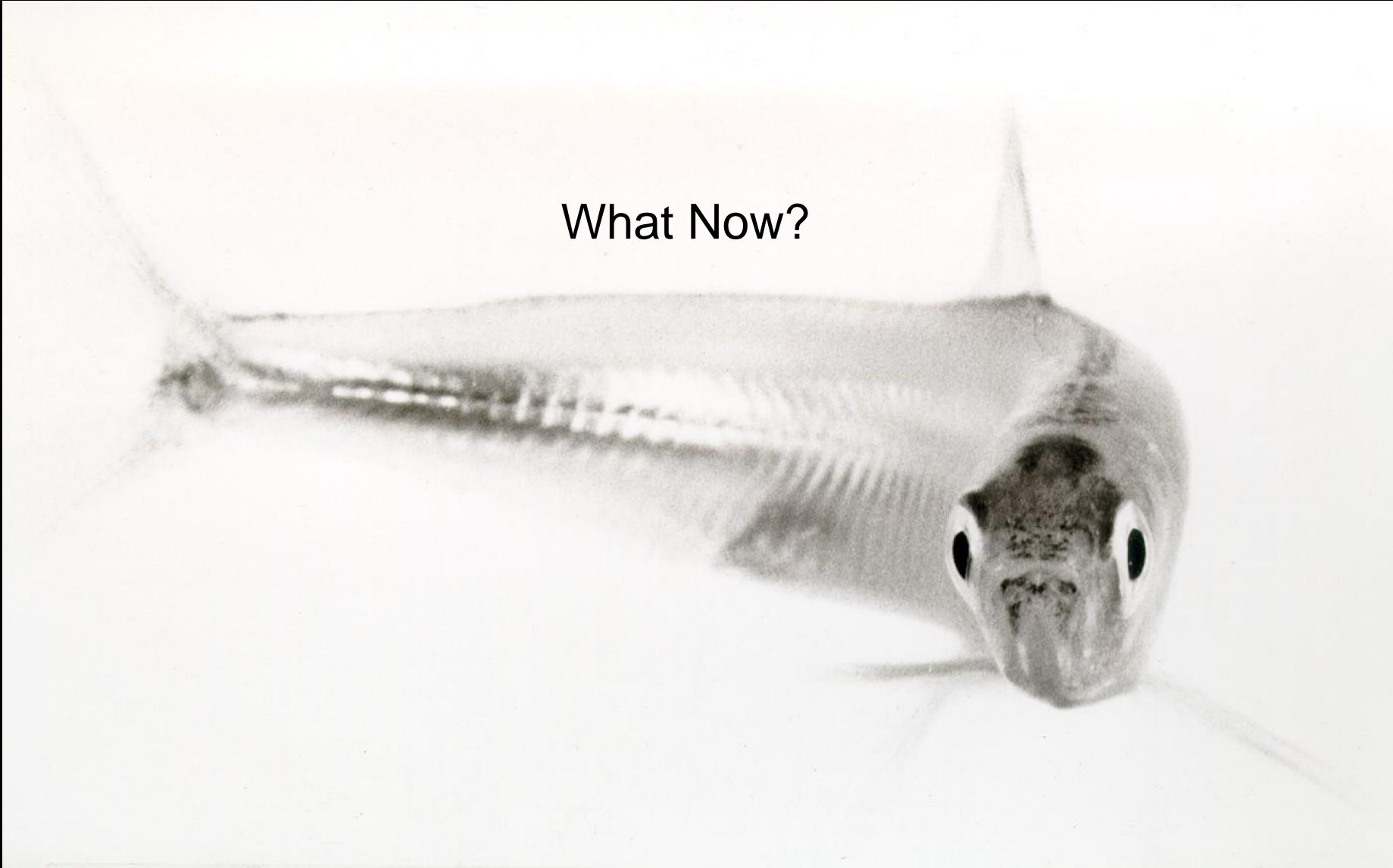
# Winter Salvage (Nov-Mar)



# OMR = Old and Middle River flows



What Now?

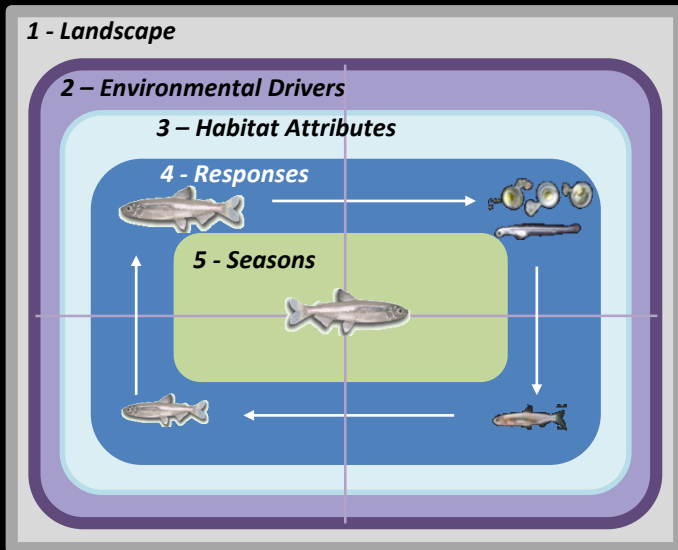




# Delta Smelt MAST Report: Completed January 2015

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](http://www.water.ca.gov/iep)

# Warmer Air Temperatures During Drought

Jan - Mar

Apr - Jun

July - Aug

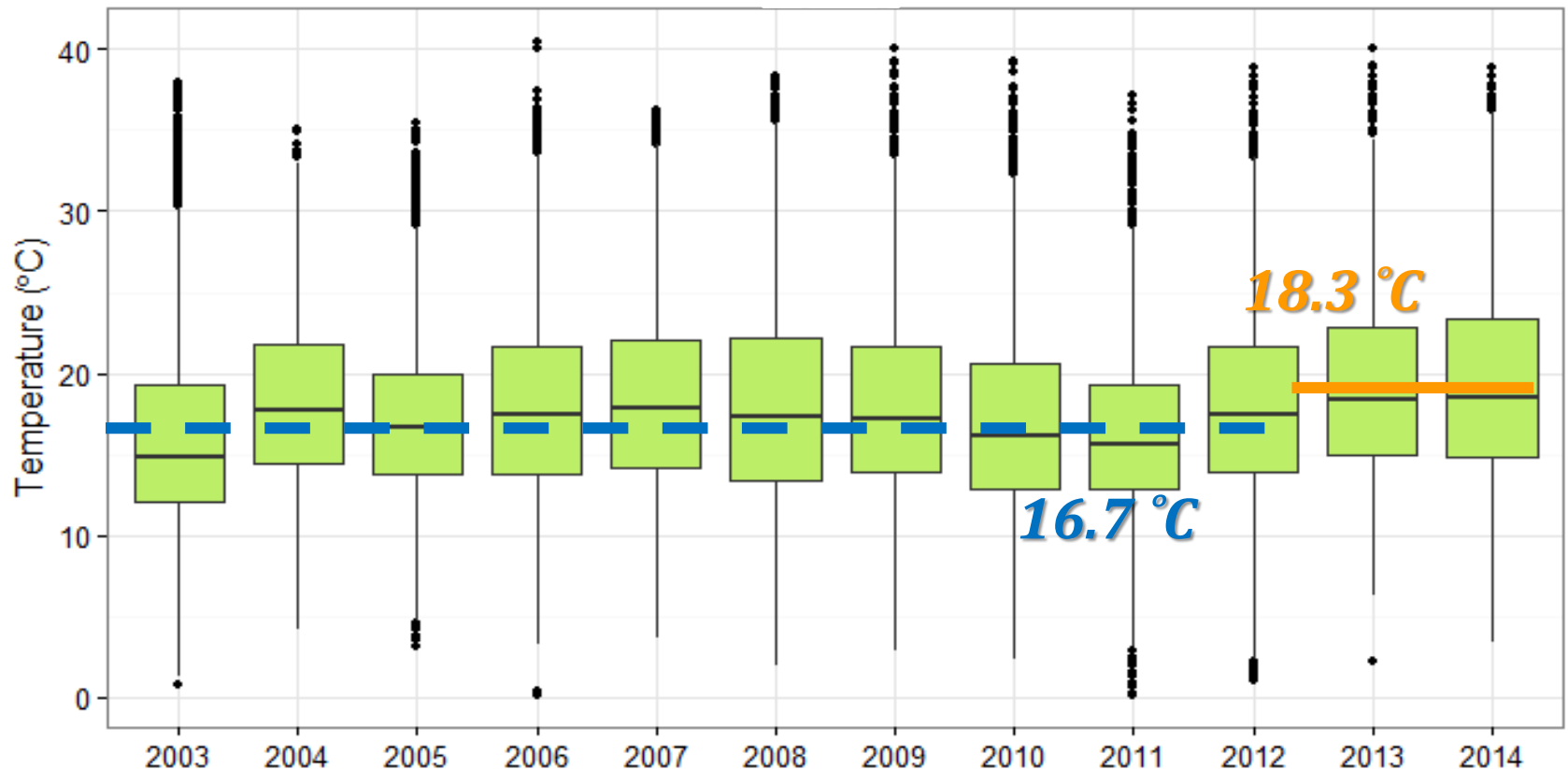
Sept - Dec

*Results*

*Air Temperature*



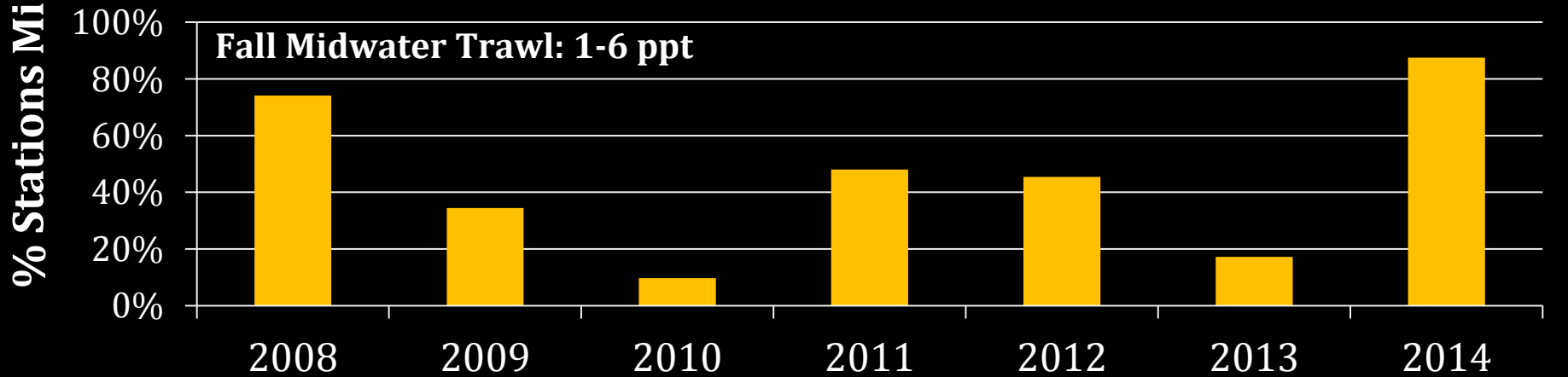
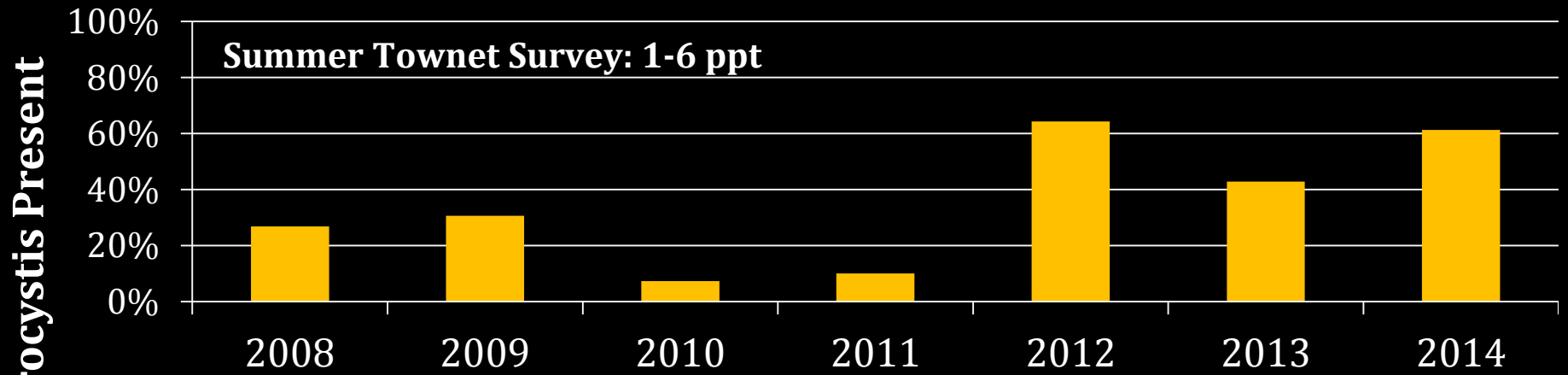
*April - June*



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

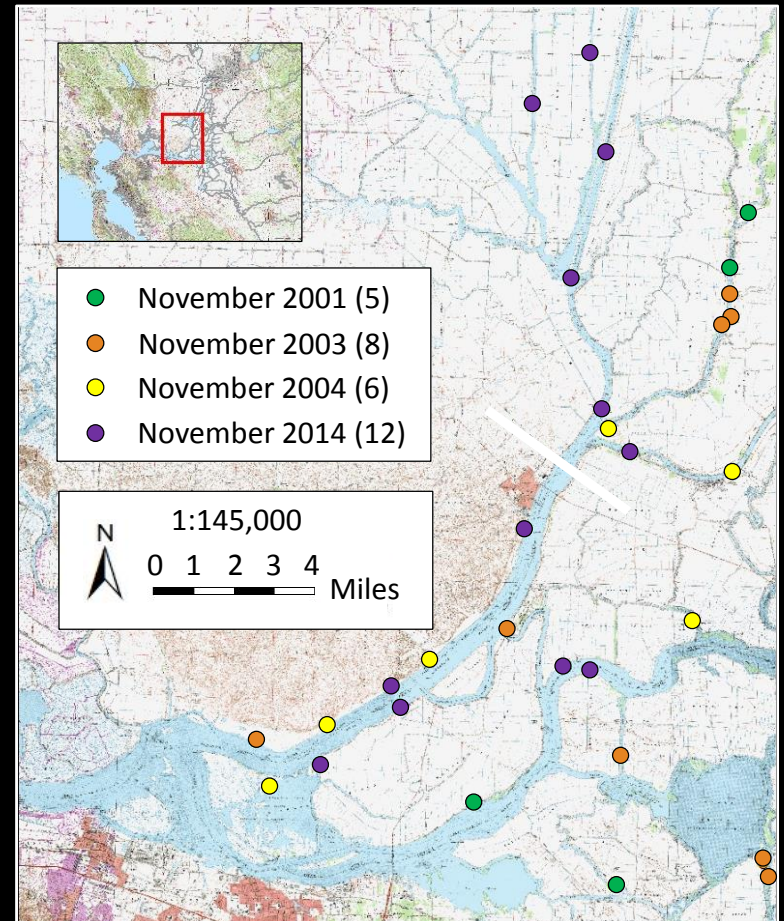
# Microcystis More Prevalent

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

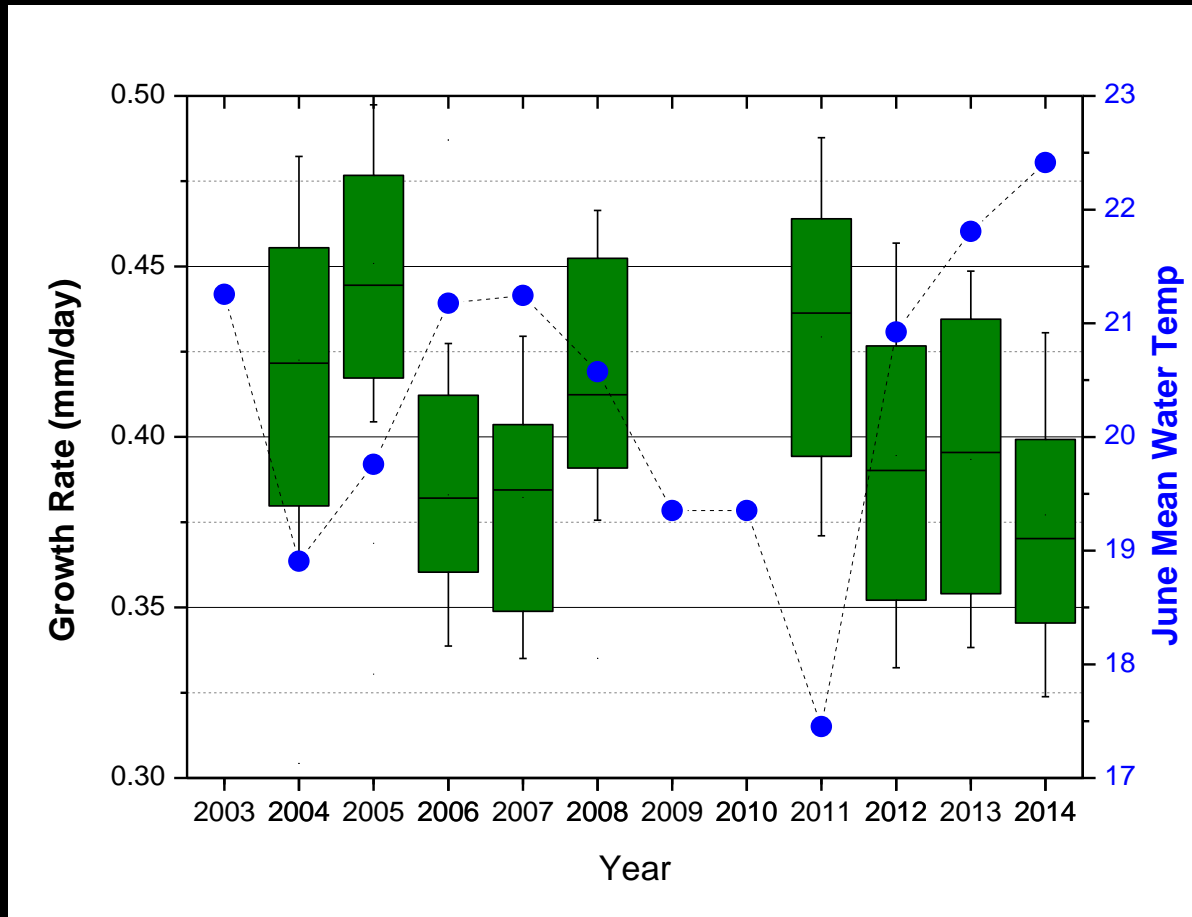


# November 2014: Boat Electrofishing Drought Survey

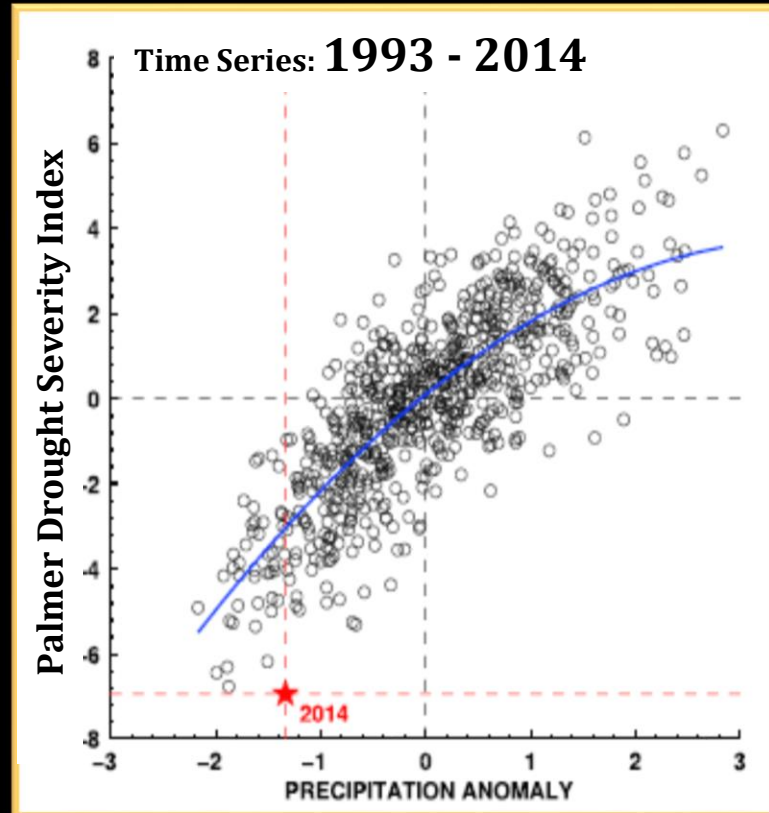
- Western and northern Delta



# Summer Growth Reduced



# Drought Effects on Fish



Griffin & Anchukaitis, 2014  
*Geophysical Research Letters*, 41: 1-7.

*Thanks to Louise Conrad, DWR*

**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**

**Tier 5 - Life Stage Seasons**

Survival

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

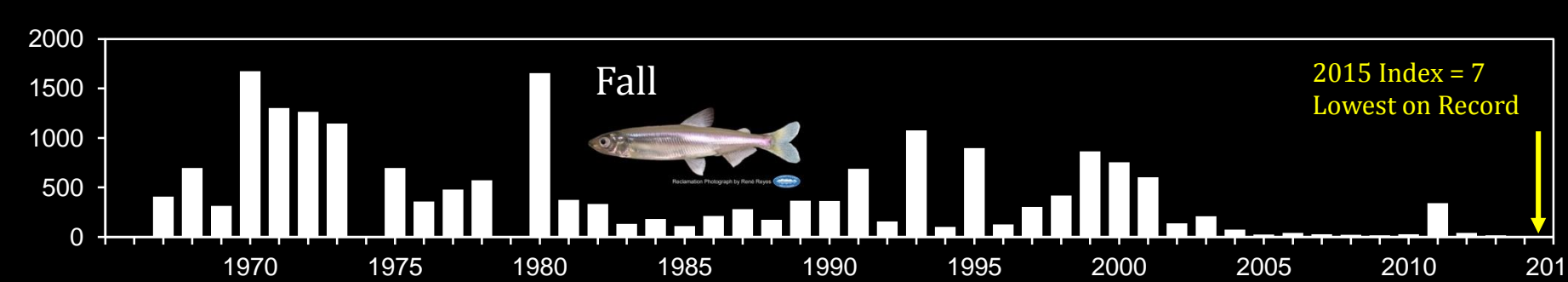
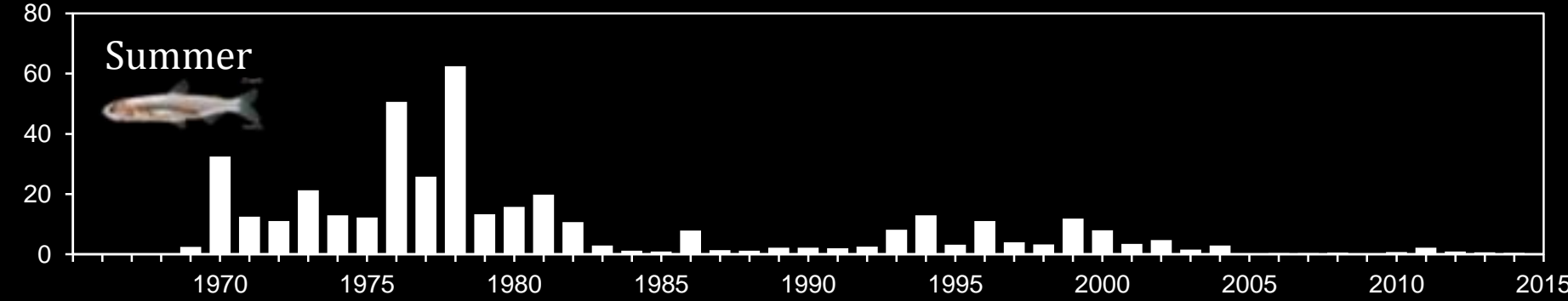
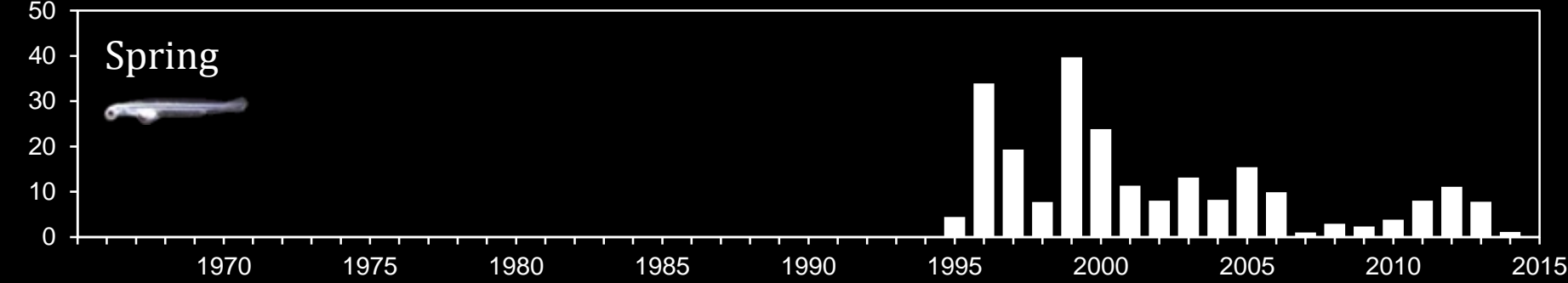
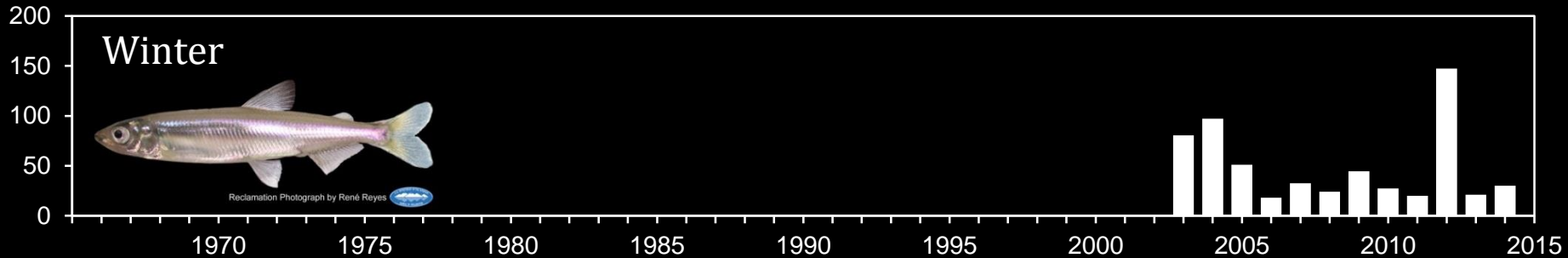
Food, Predation, Temperature  
Harmful Algal Blooms, Toxicity

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

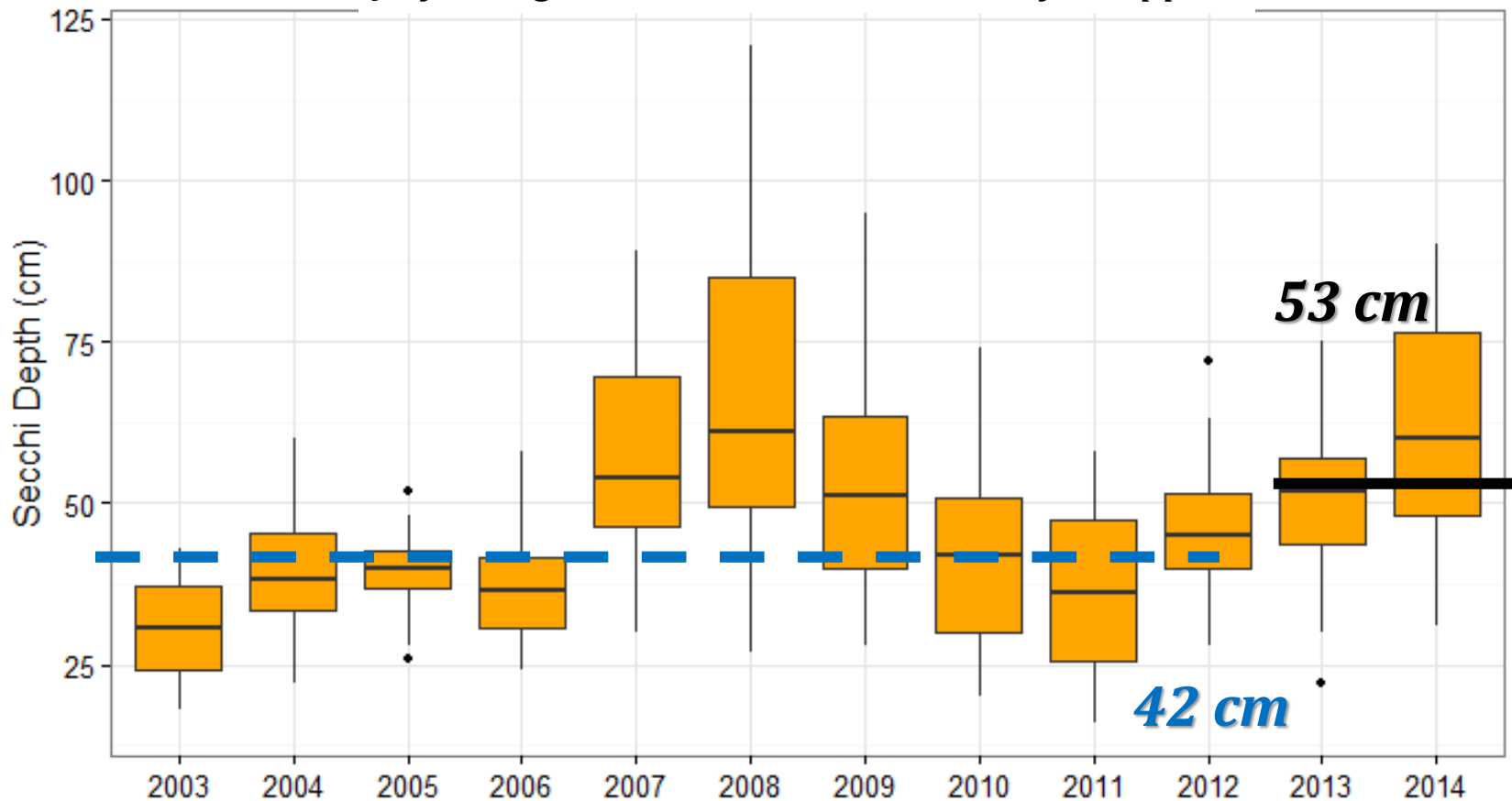
Sept - Dec

## Results

Water Clarity



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



CDFW Summer Townet Survey

# Sharp Increase in Mississippi Silverside Abundance

Jan - Mar

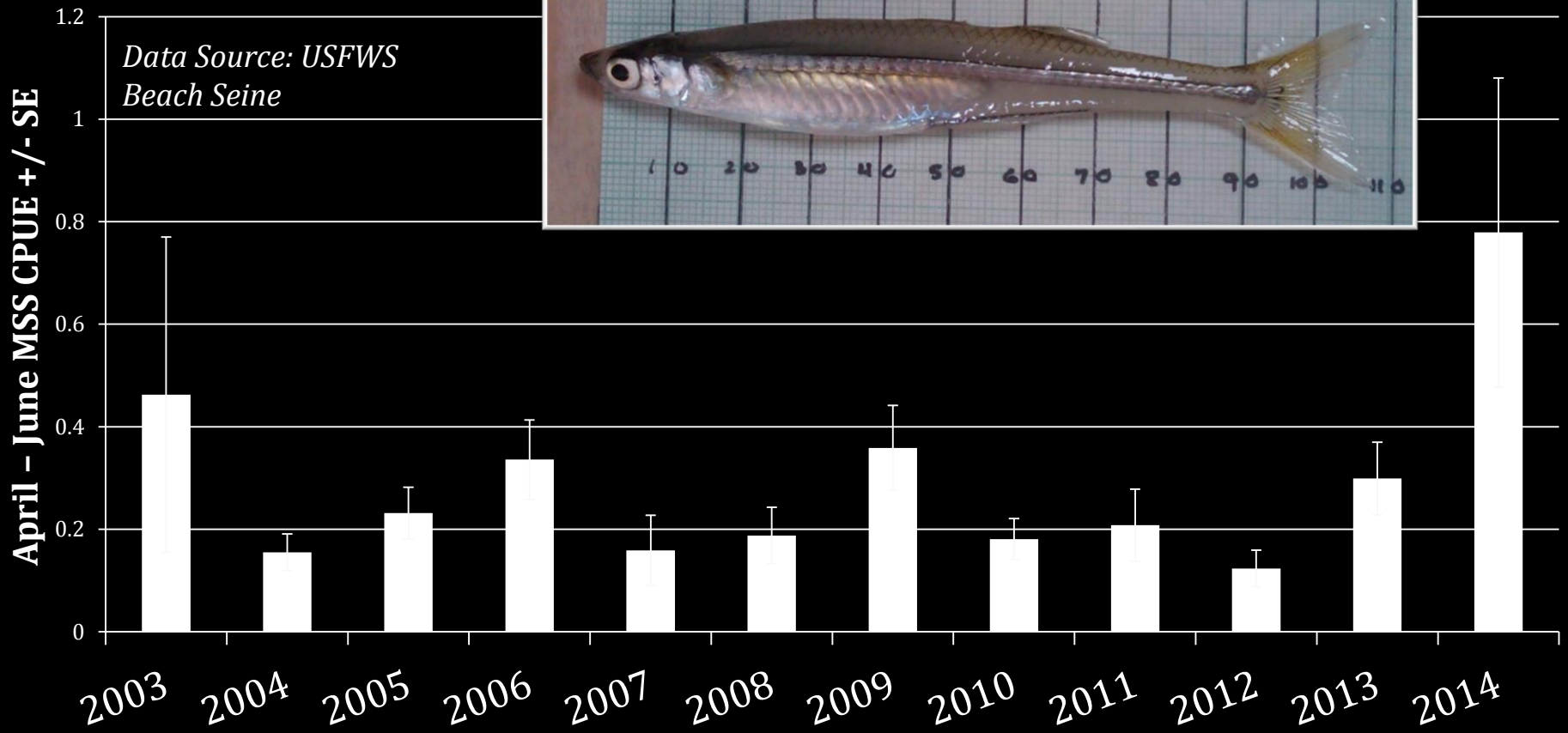
Apr - Jun

July - Aug

Sept - Dec

## Results

Mississippi Silverside



# Black bass densities increased in 2014

Jan - Mar

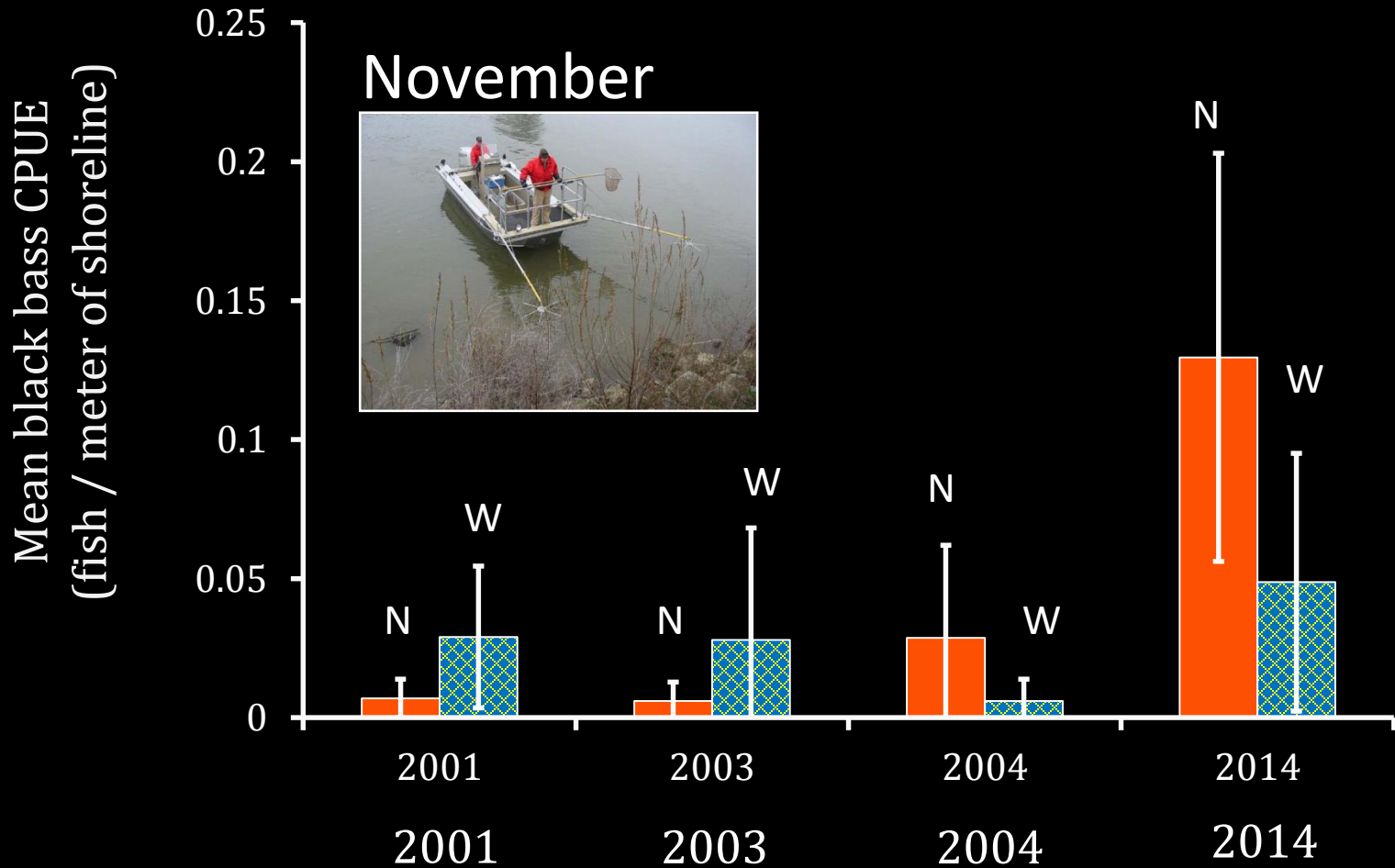
Apr - Jun

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

