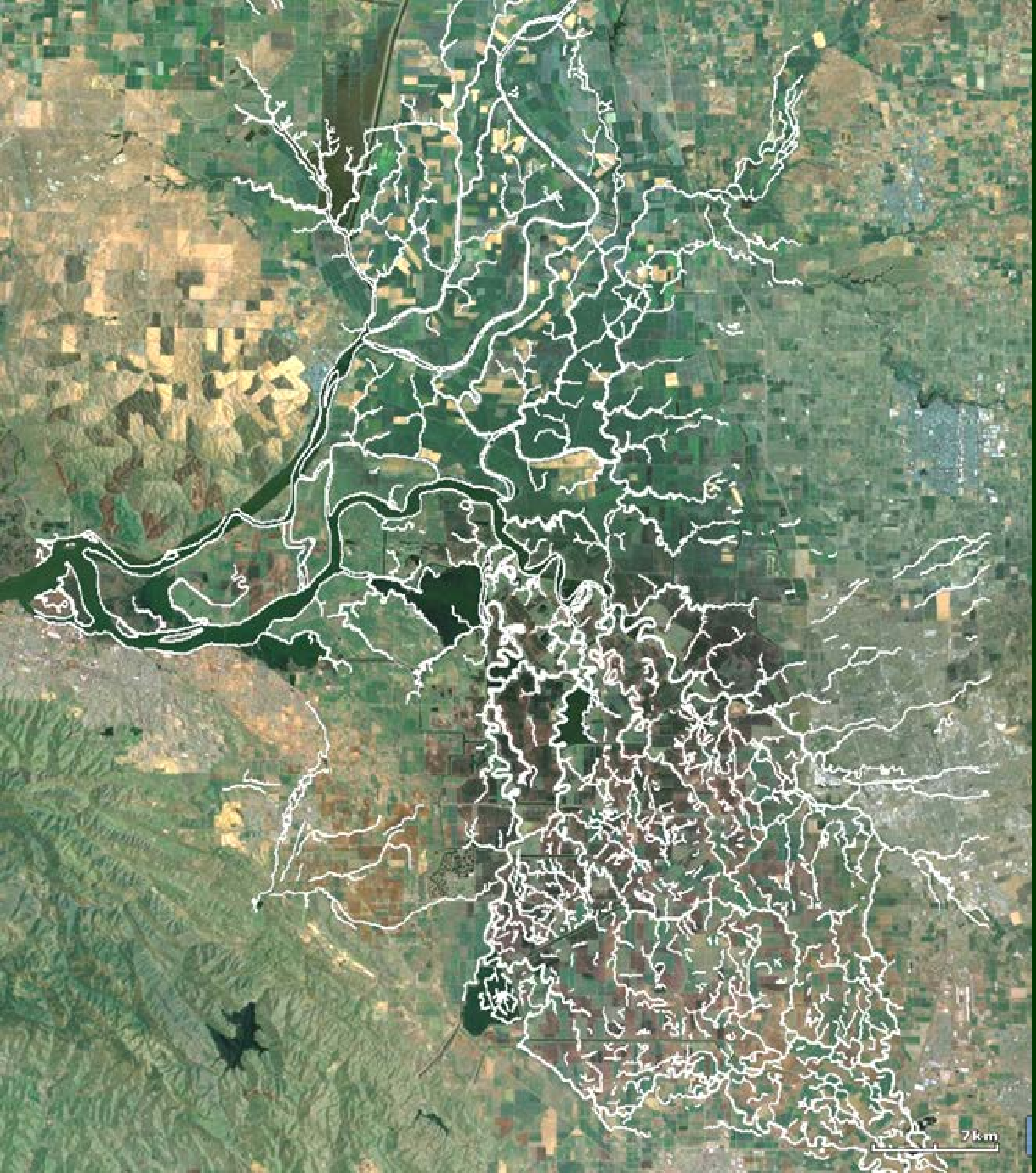

MAP
SAN JOAQUIN, SACRAMENTO
TULARE VALLEYS
STATE OF CALIFORNIA

Select from the following Map Views

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



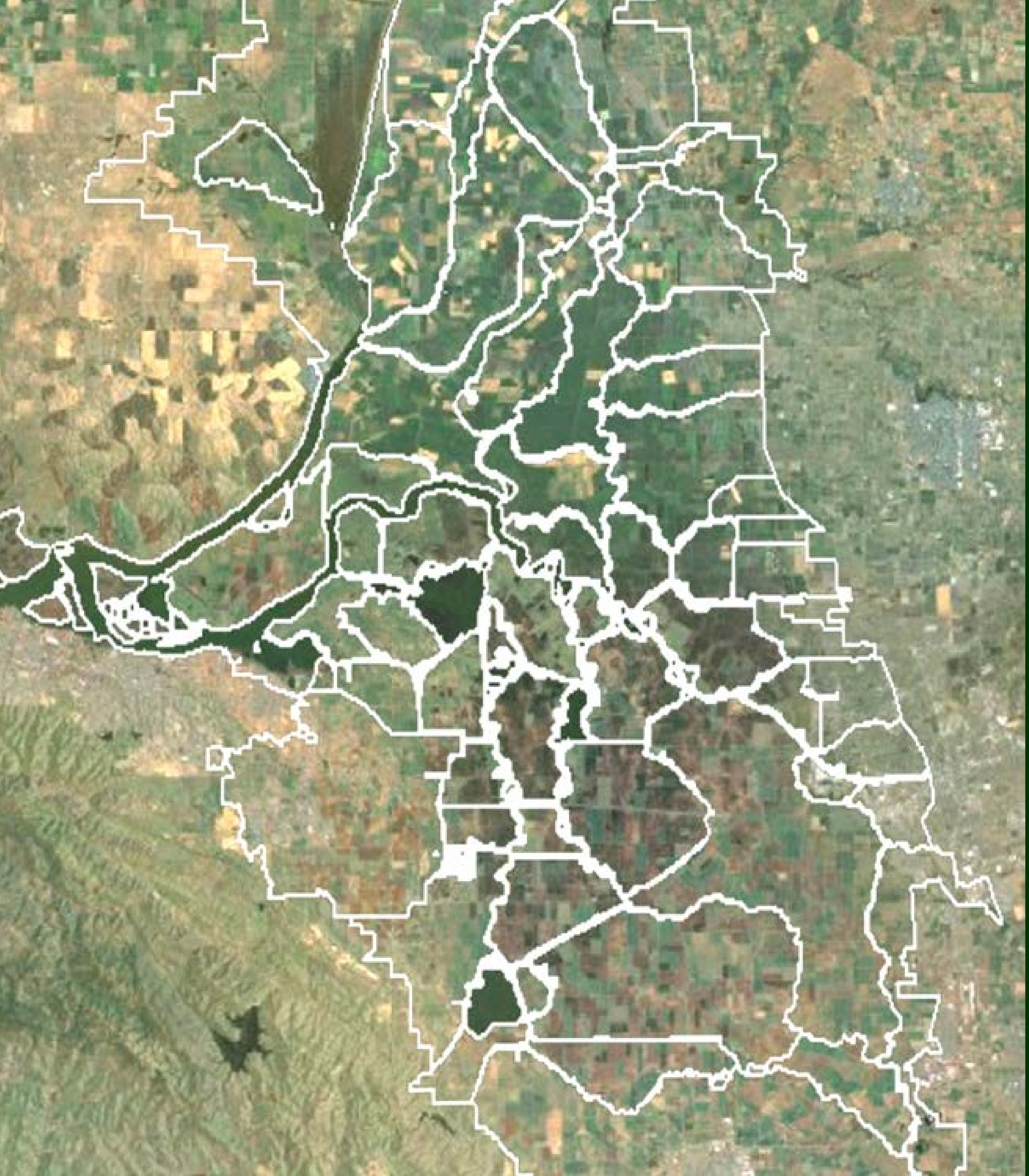
1873 Delta:

Long residence time

Marsh connections

Two rivers connect
to bay

Waterways dendritic



Modern delta

Short residence times

Rip-rapped

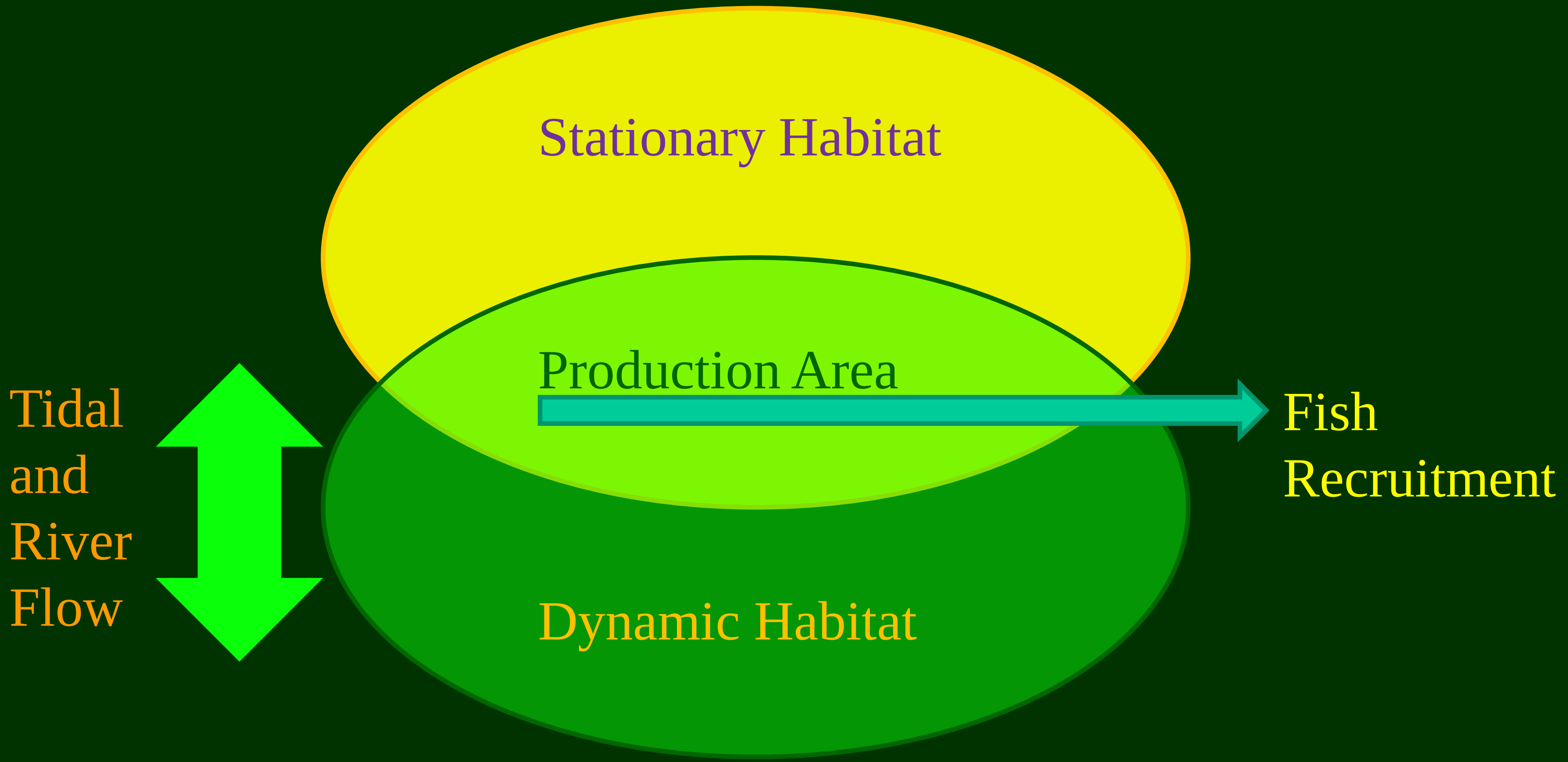
Cross Delta flows

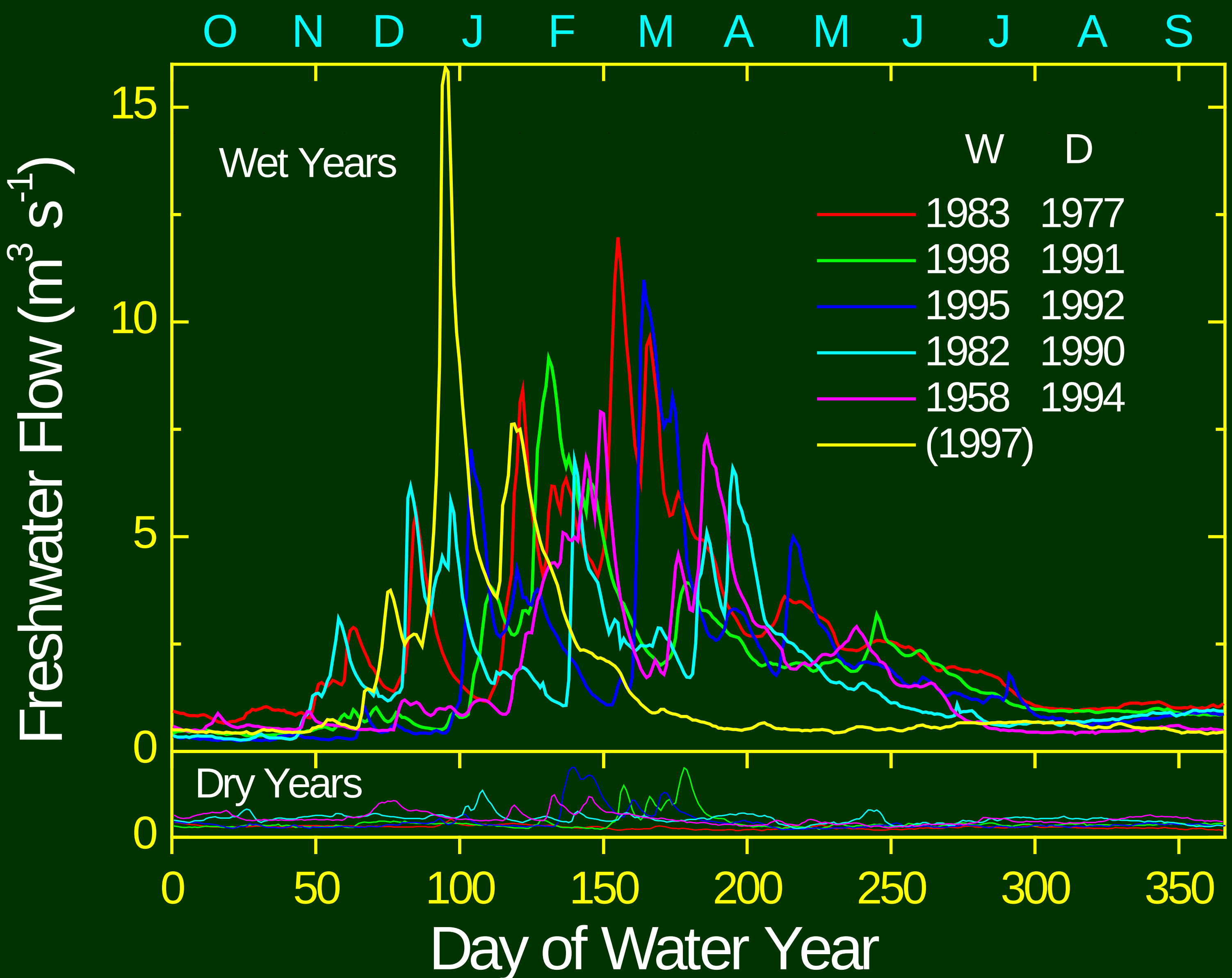
Rare San Joaquin connection to bay

Waterways web-like

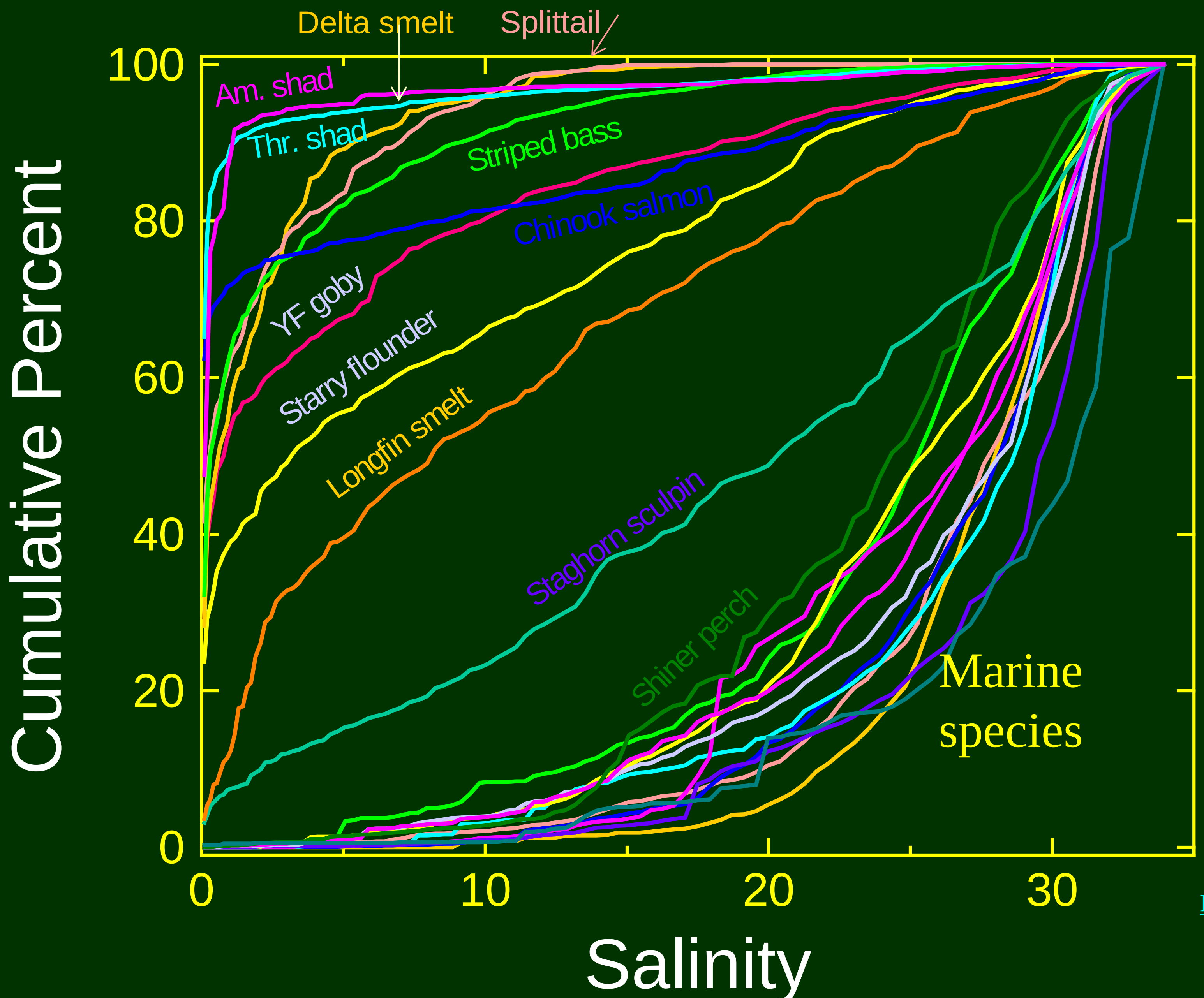
Estuarine habitat conceptual model

(Peterson 2003)



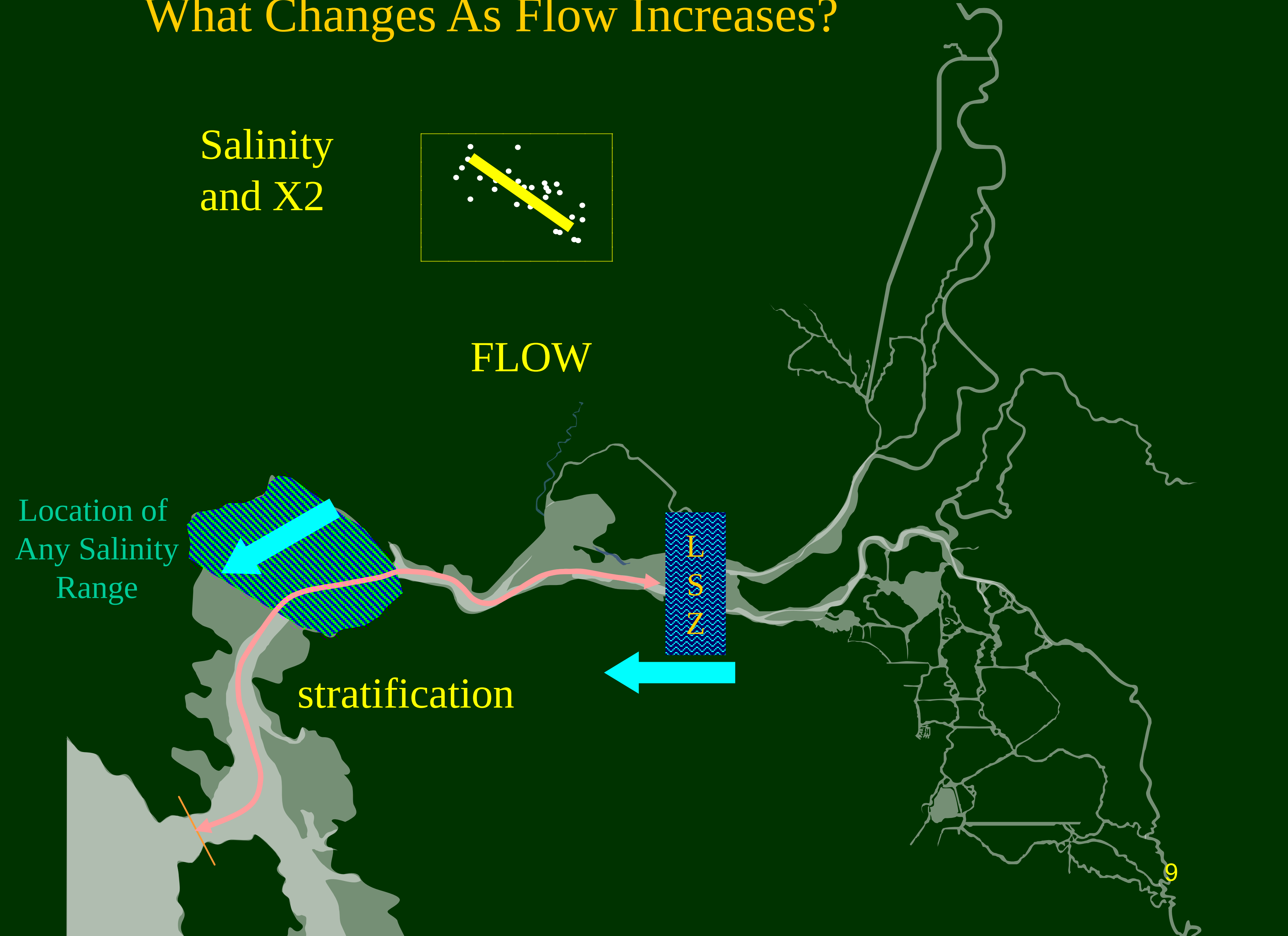

O N D J F M A M J J A S
Wet Years
W D
1983 1977
1998 1991
1995 1992
1982 1990
1958 1994
(1997)
Dry Years
Freshwater Flow (m3 s-1)
Day of Water Year
0
5
10
15
0
0
50
100
150
200
250
300
350

Most fishes follow salinities

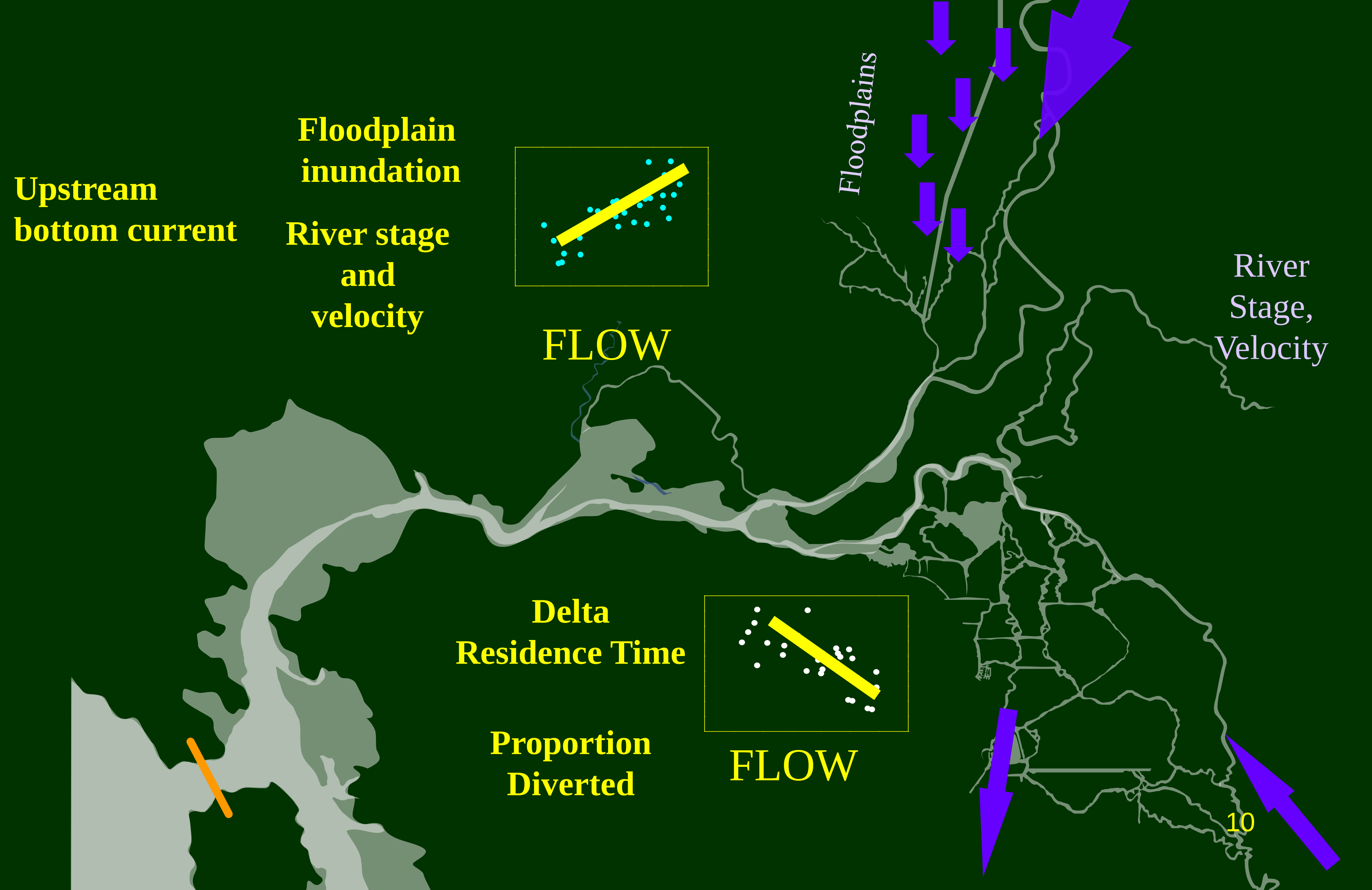


Kimmerer 2004

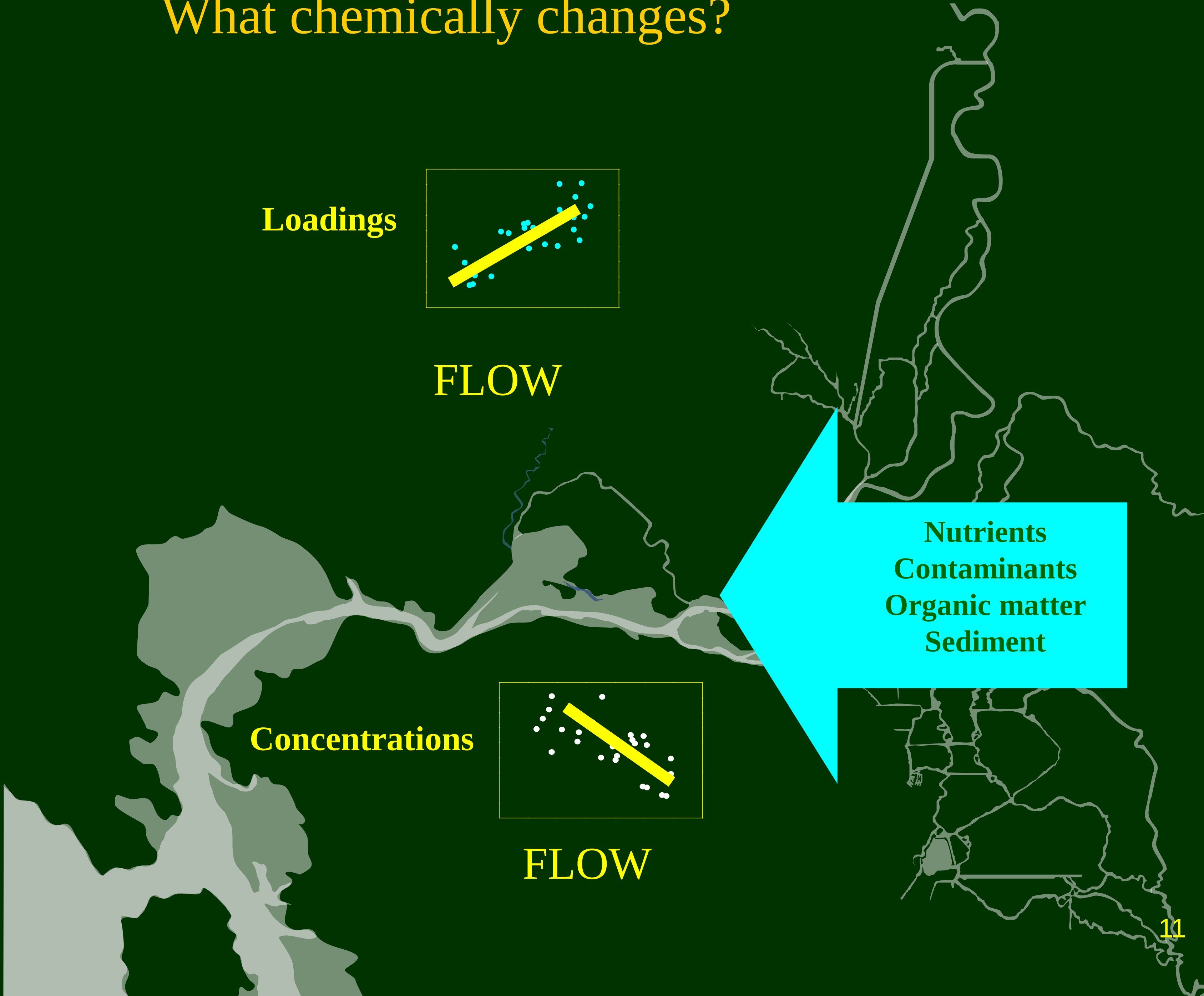
What Changes As Flow Increases?



What Physically Changes As Flow Increases?



What chemically changes?

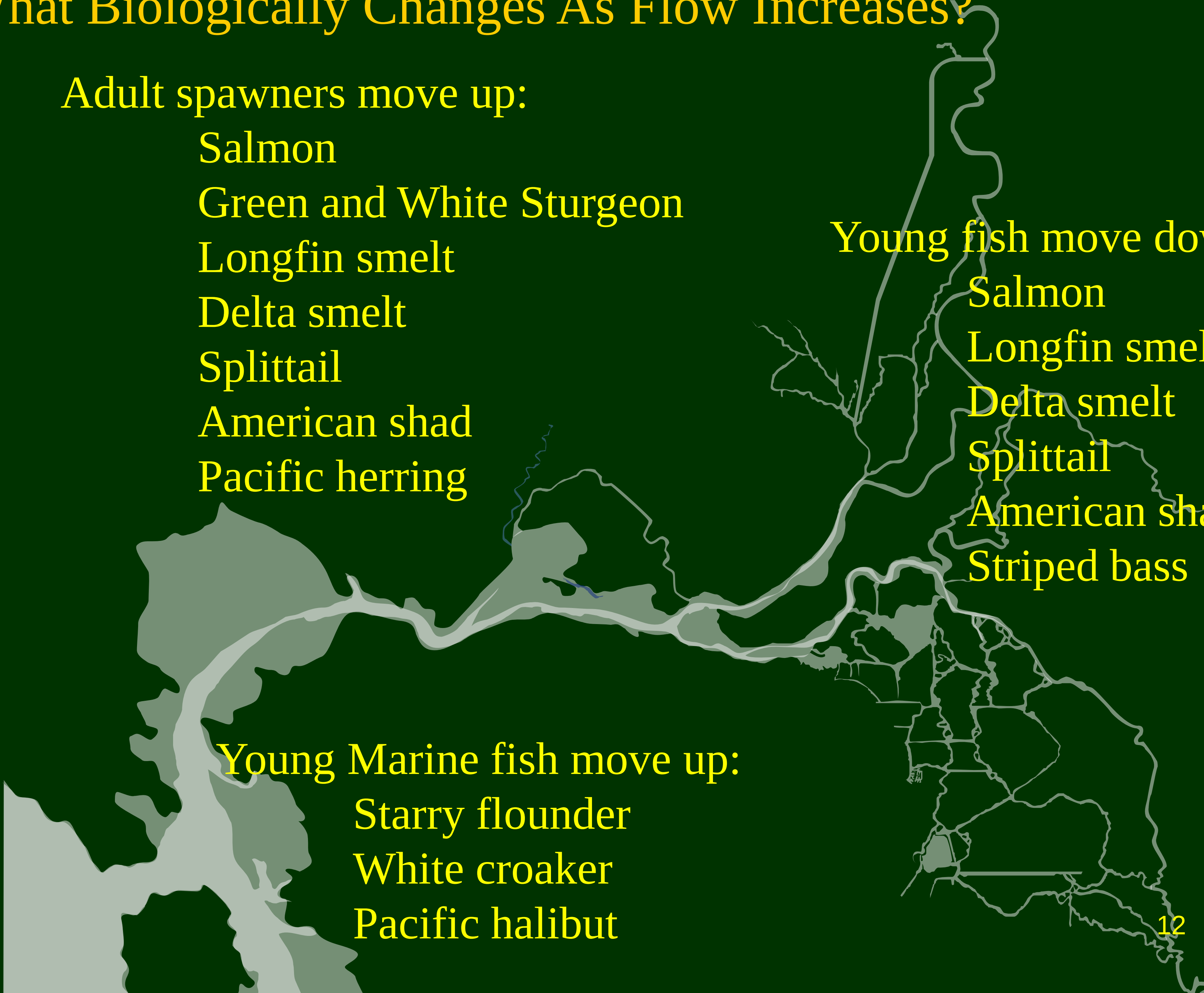


What Biologically Changes As Flow Increases?

Adult spawners move up:
- Salmon
- Green and White Sturgeon
- Longfin smelt
- Delta smelt
- Splittail
- American shad
- Pacific herring

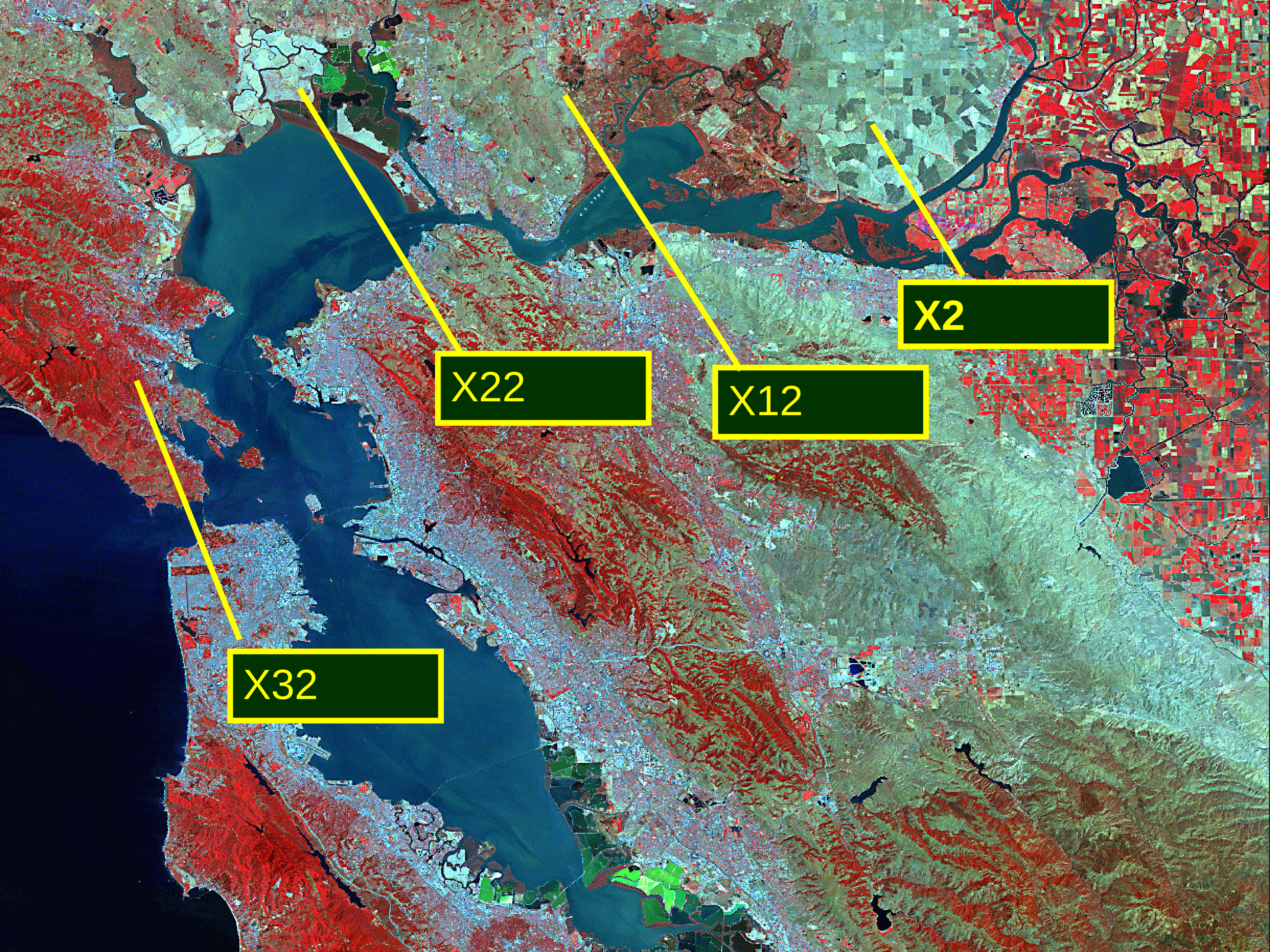
Young fish move down:
- Salmon
- Longfin smelt
- Delta smelt
- Splittail
- American shad
- Striped bass

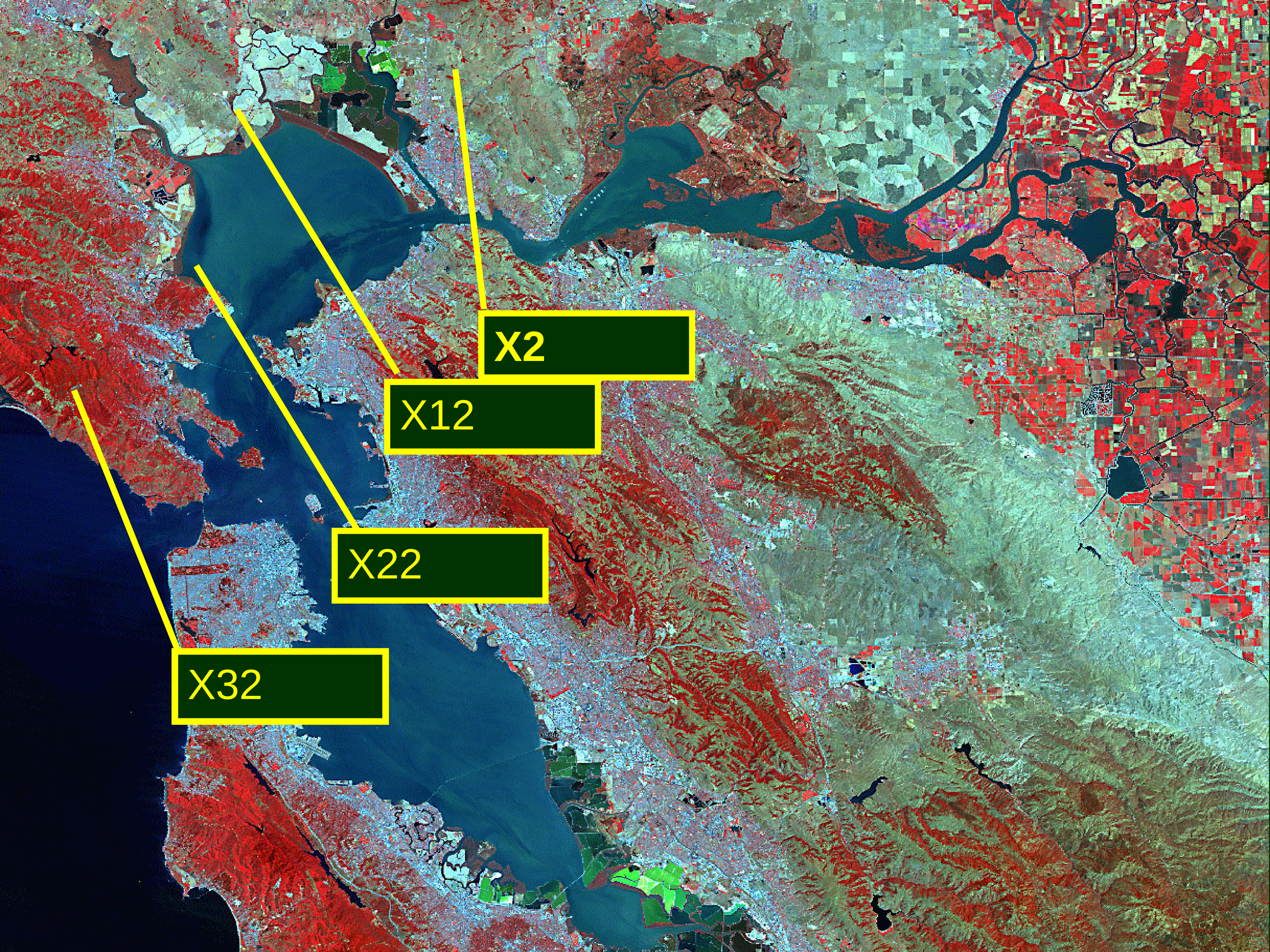
Young Marine fish move up:
- Starry flounder
- White croaker
- Pacific halibut

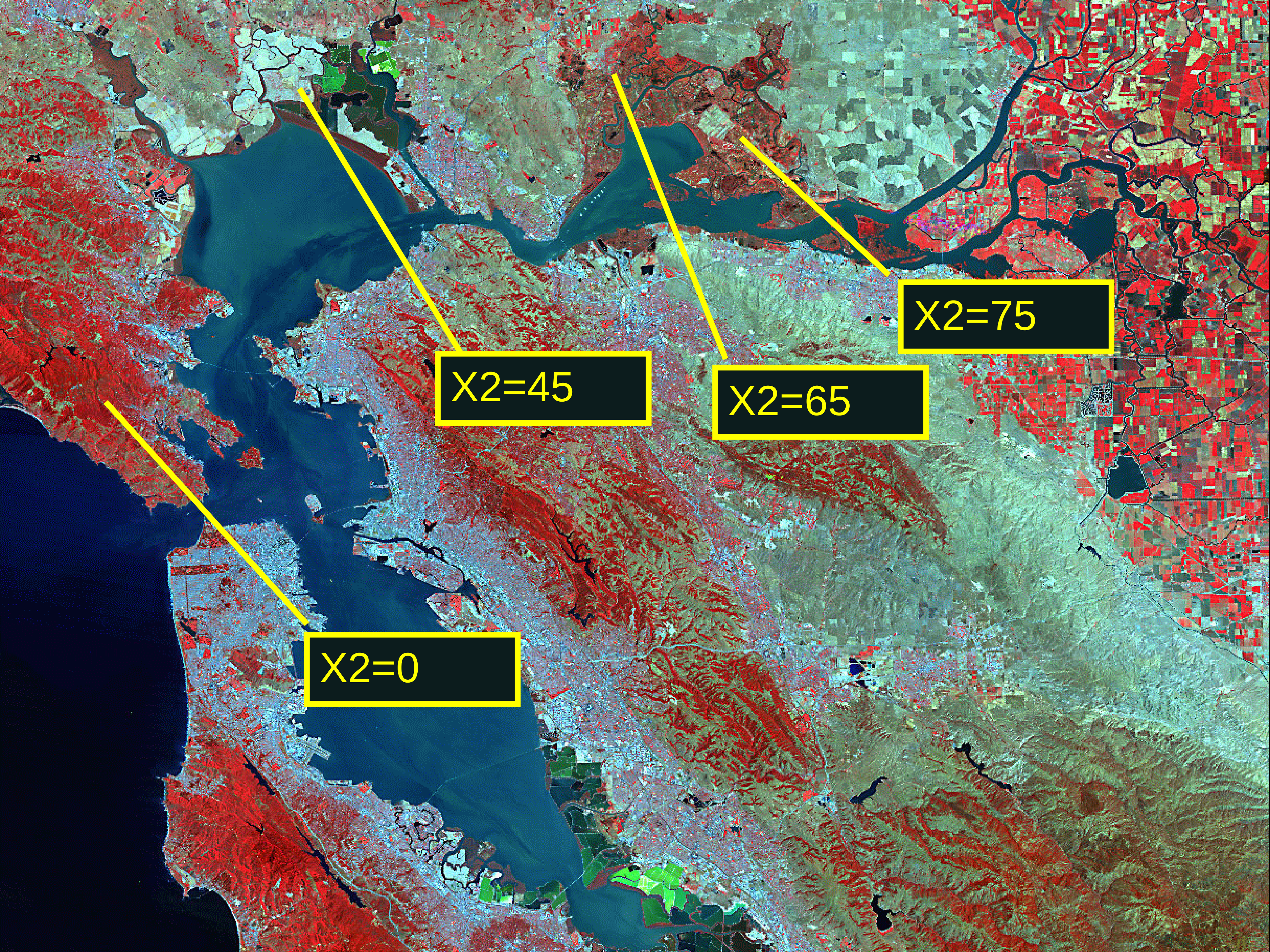


How much water do fish need?

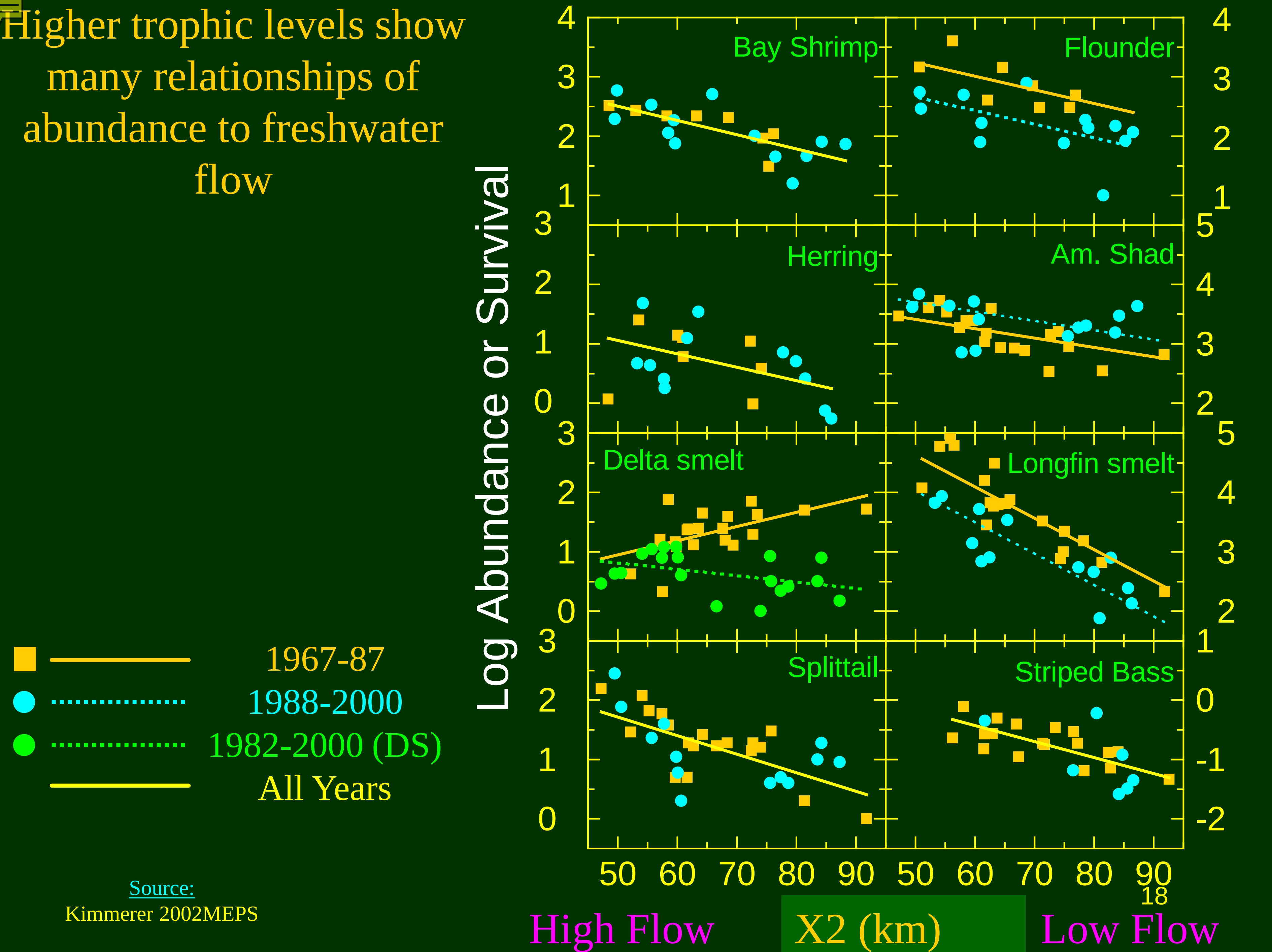
X2


X22
X12
X2
X32


X2
X12
X22
X32

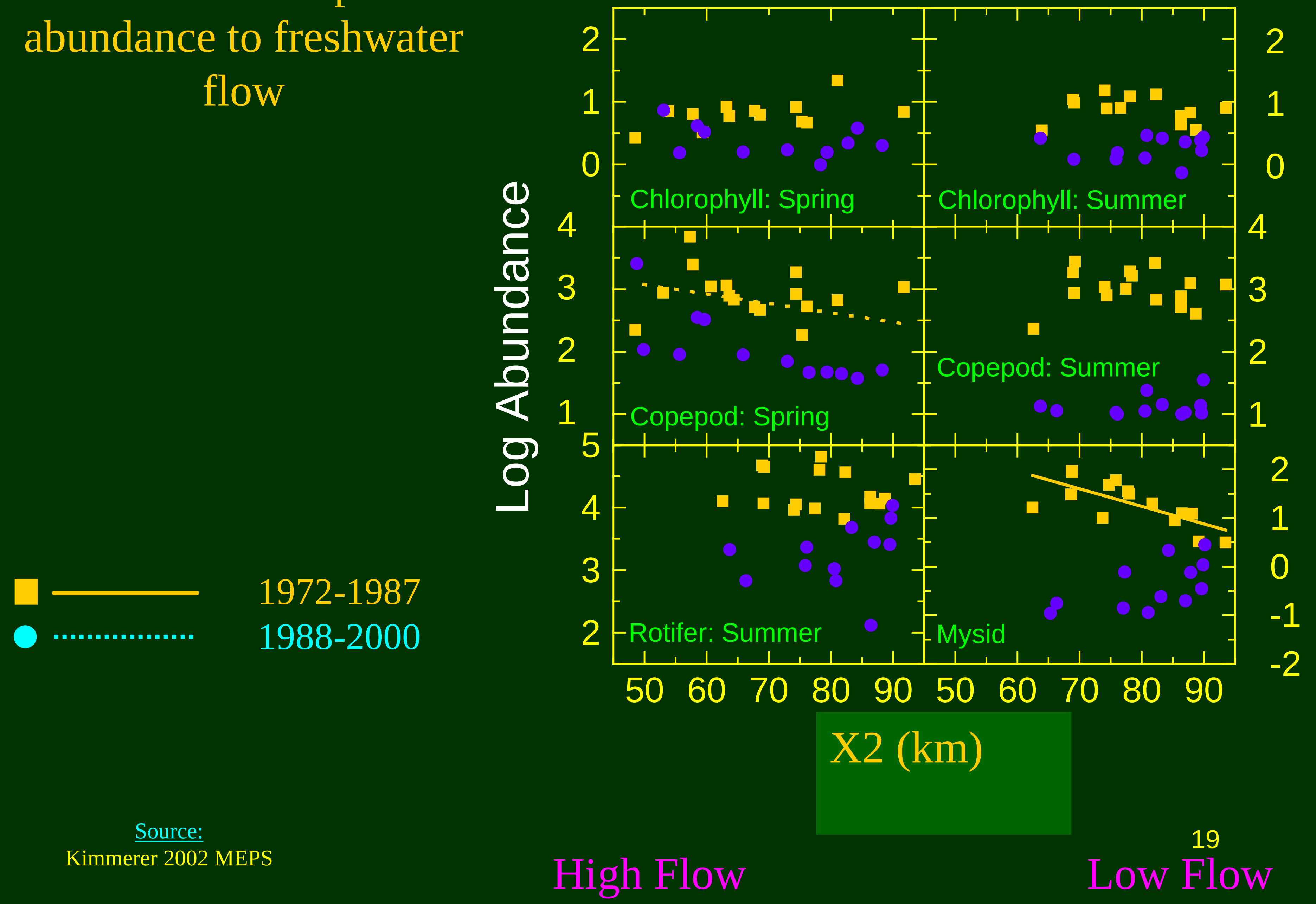

X2=45
X2=65
X2=75
X2=0

Higher trophic levels show many relationships of abundance to freshwater flow

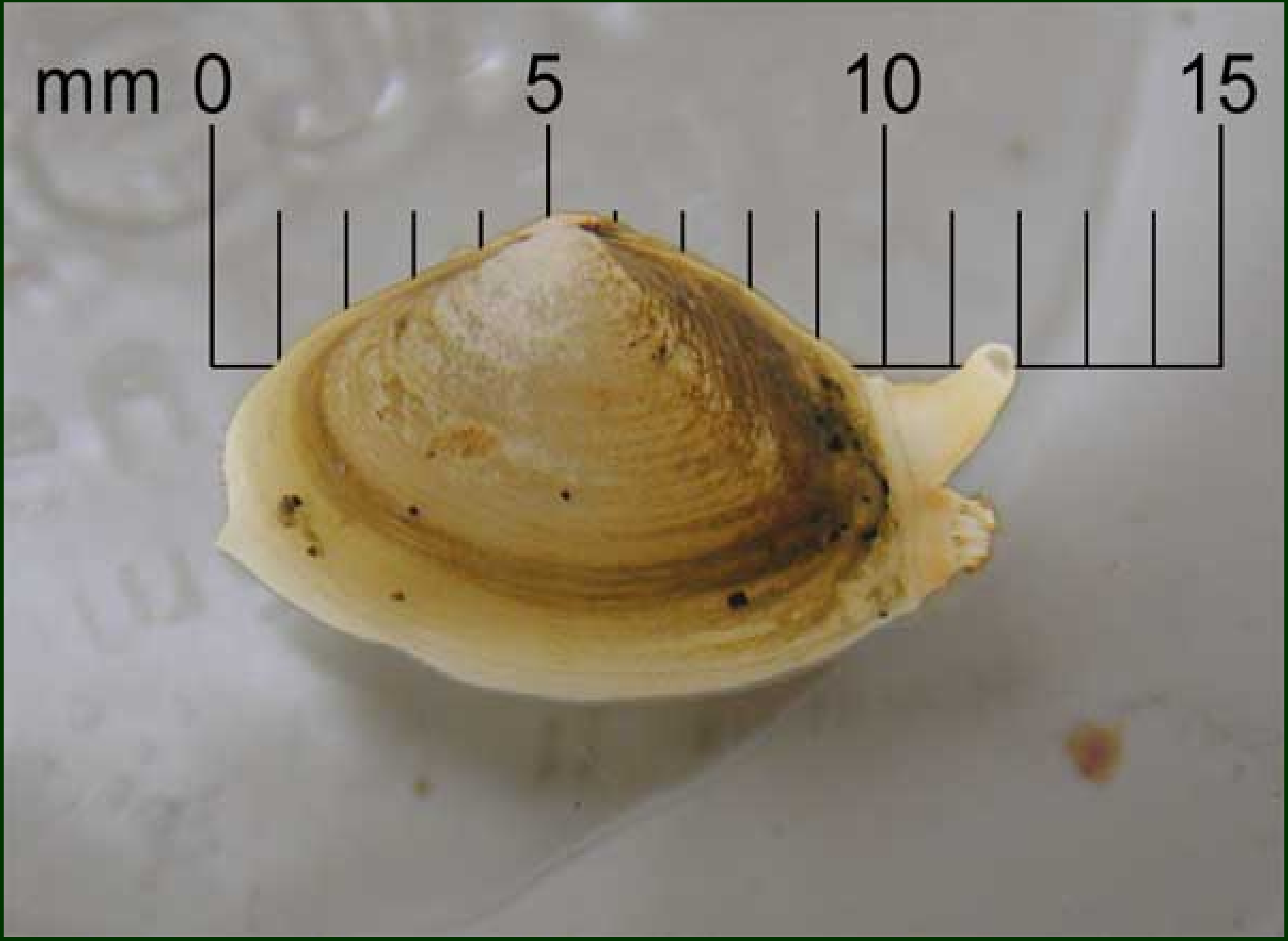


Source:
Kimmerer 2002MEPS

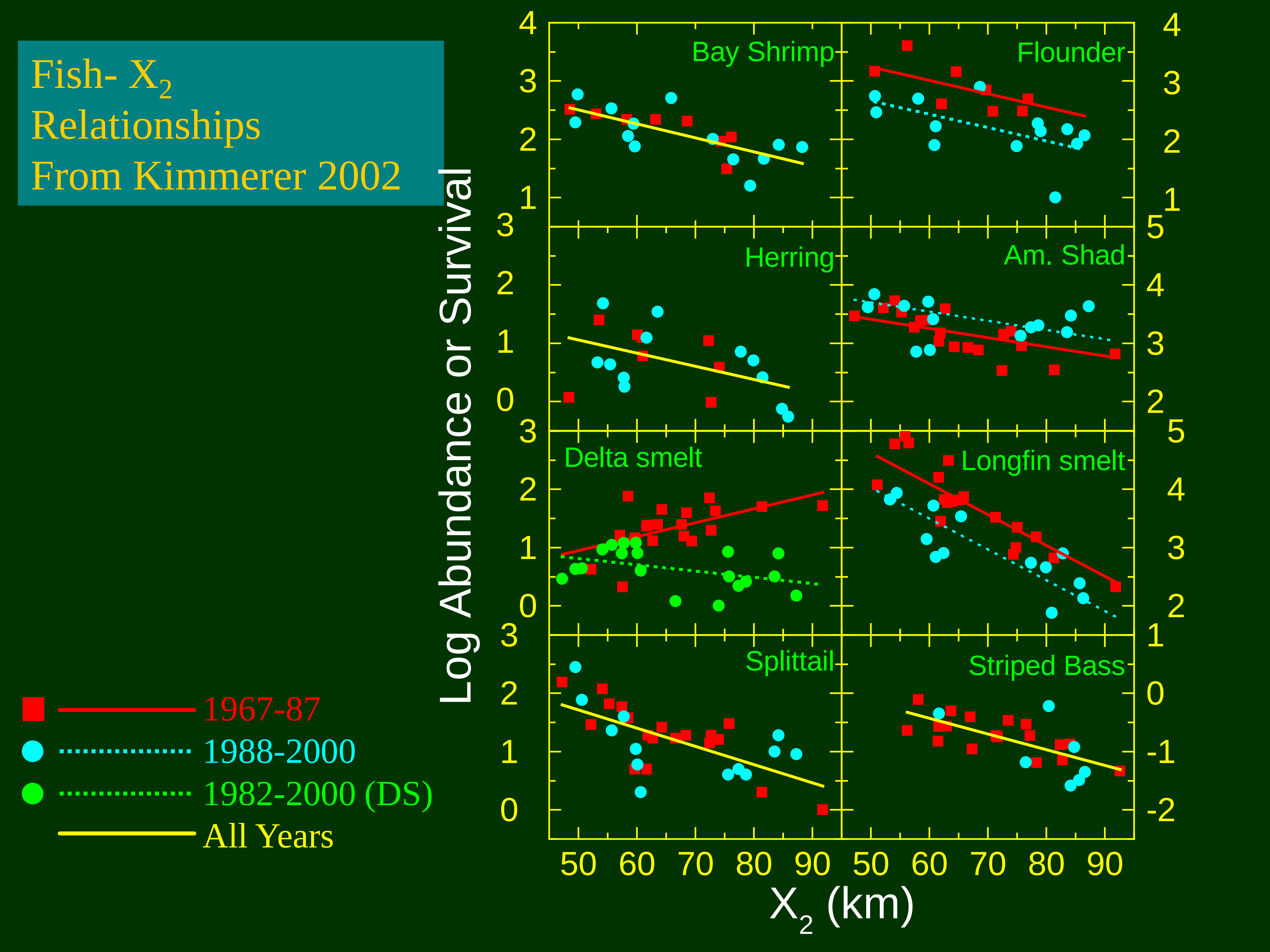
Lower trophic levels show few relationships of abundance to freshwater flow



Source:
Kimmerer 2002 MEPS


mm 0
5
10
15

Fish- X_2
Relationships
From Kimmerer 2002



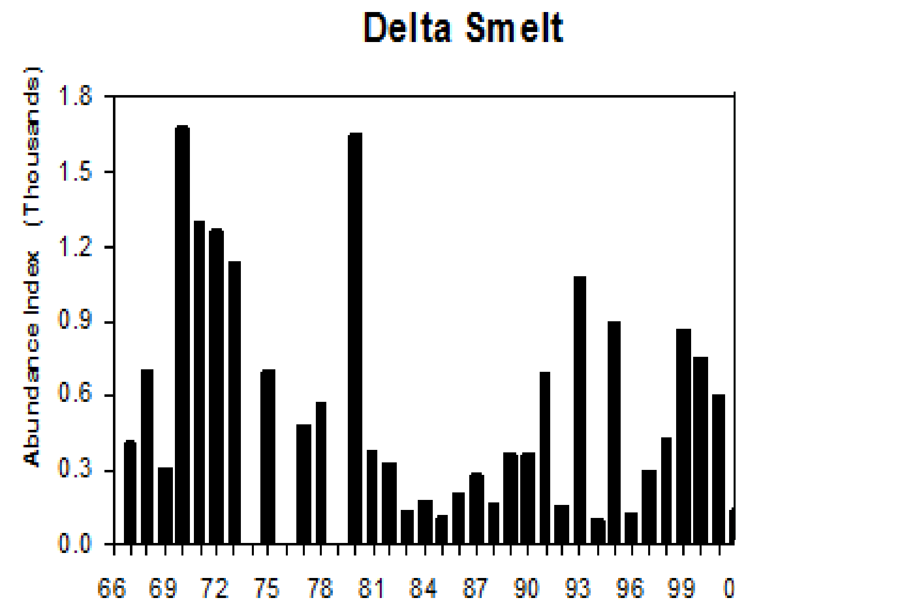
POD

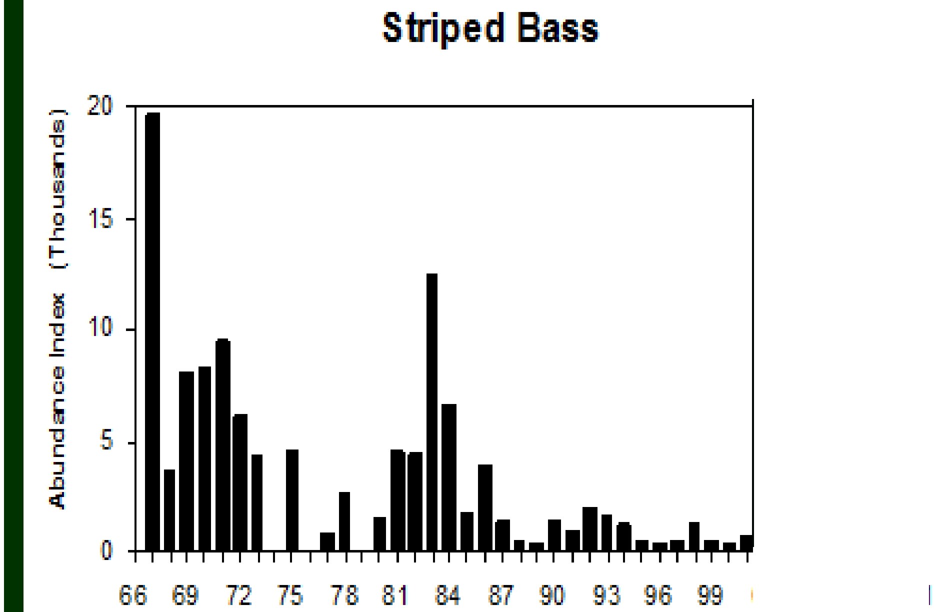
Delta smelt

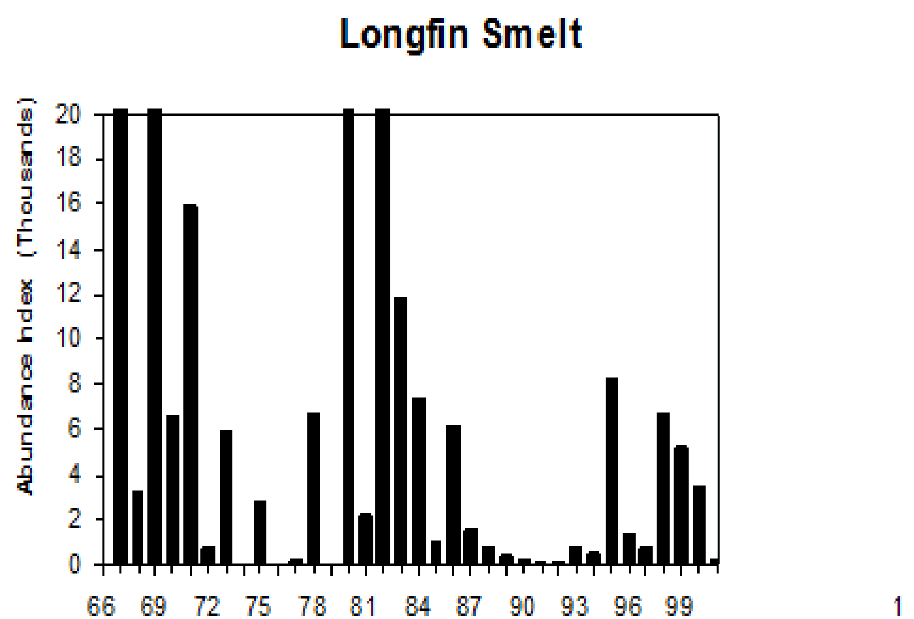
Longfin smelt

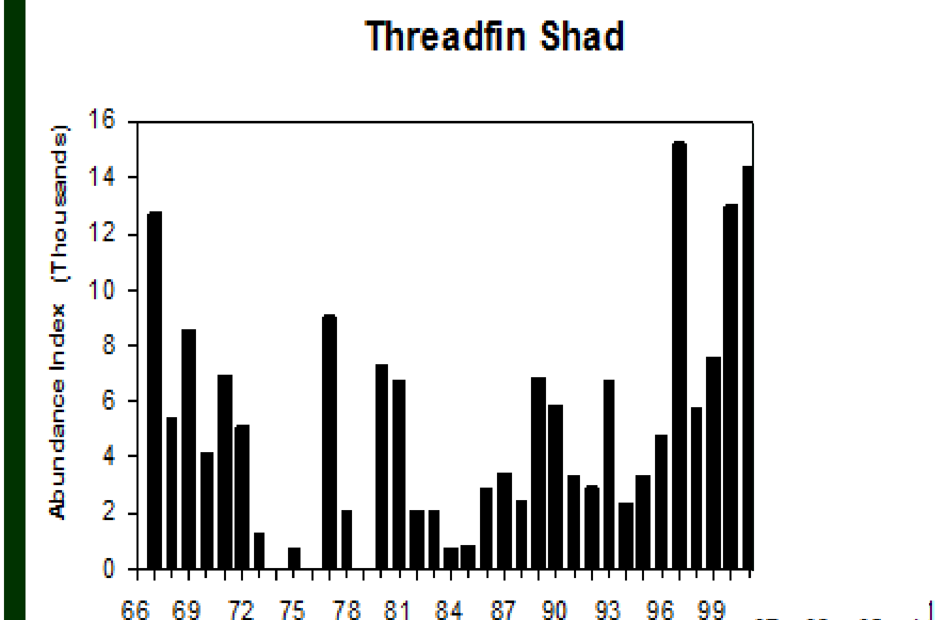
Threadfin shad

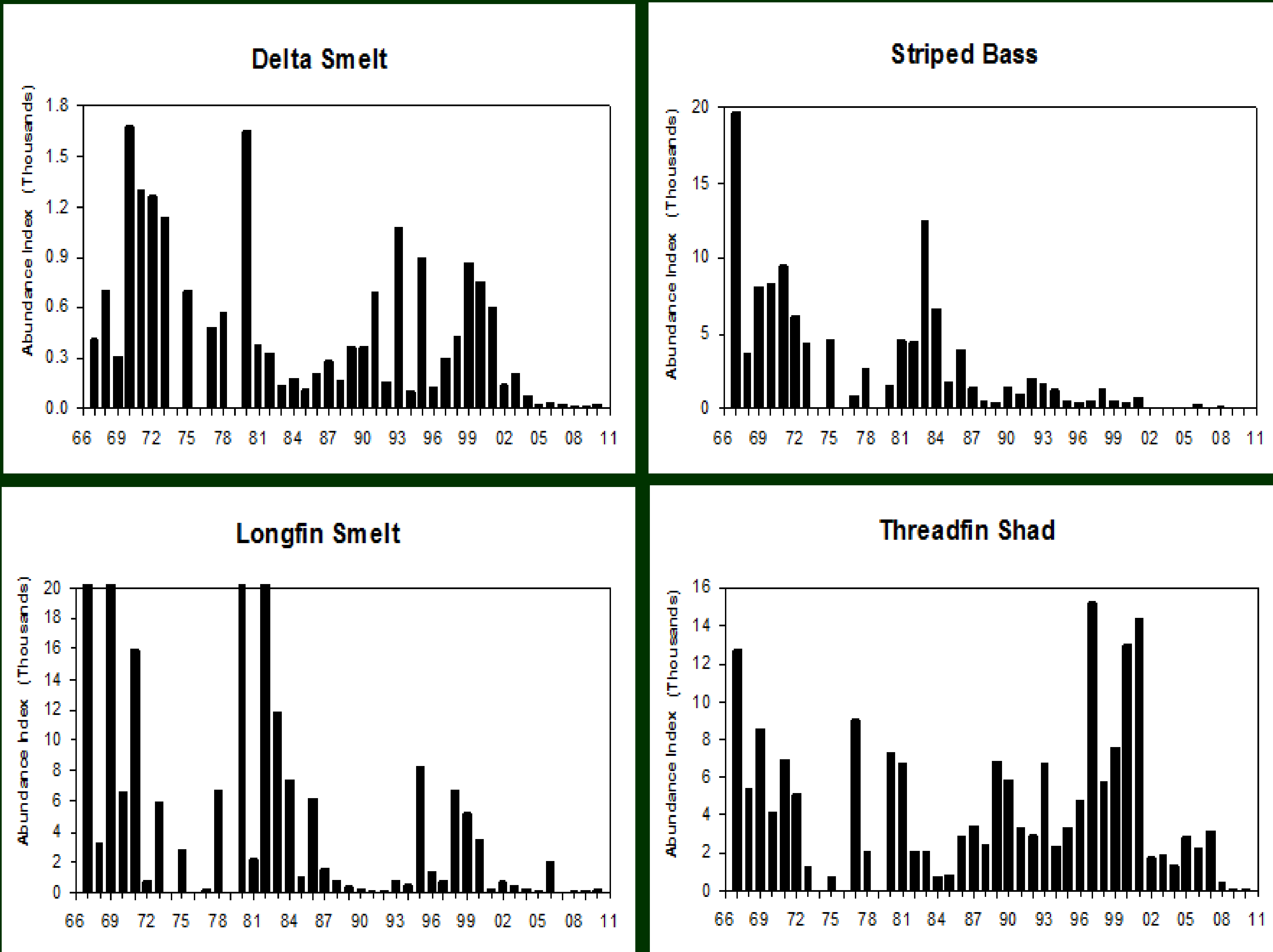
Striped bass


Delta Smelt
Abundance Index (Thousands)
1.8
1.5
1.2
0.9
0.6
0.3
0.0
66 69 72 75 78 81 84 87 90 93 96 99 0

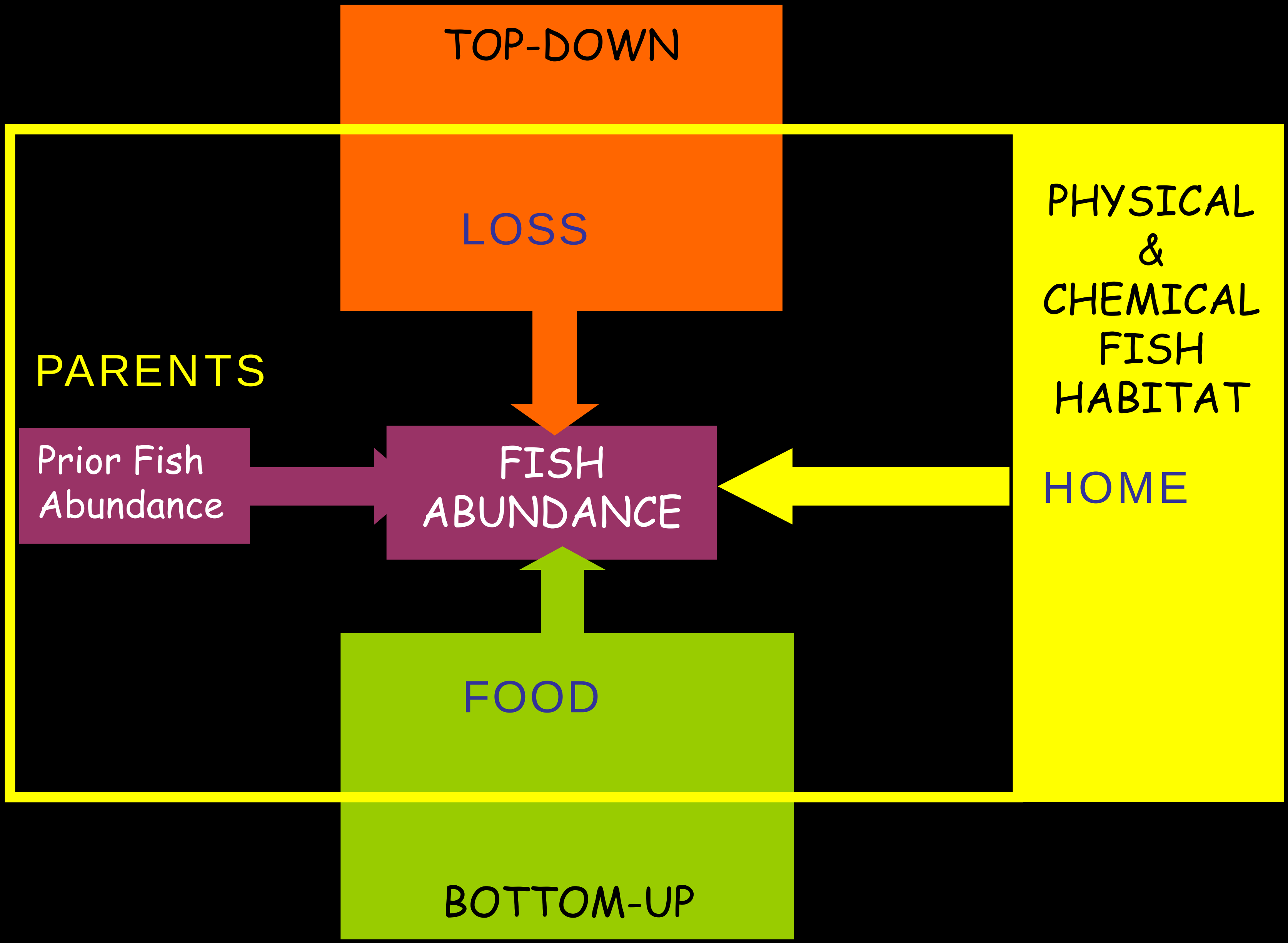

Striped Bass
Abundance Index (Thousands)
20
15
10
5
0
66 69 72 75 78 81 84 87 90 93 96 99


Longfin Smelt
Abundance Index (Thousands)
20
18
16
14
12
10
8
6
4
2
0
66 69 72 75 78 81 84 87 90 93 96 99


Threadfin Shad
Abundance Index (Thousands)
16
14
12
10
8
6
4
2
0
66 69 72 75 78 81 84 87 90 93 96 99

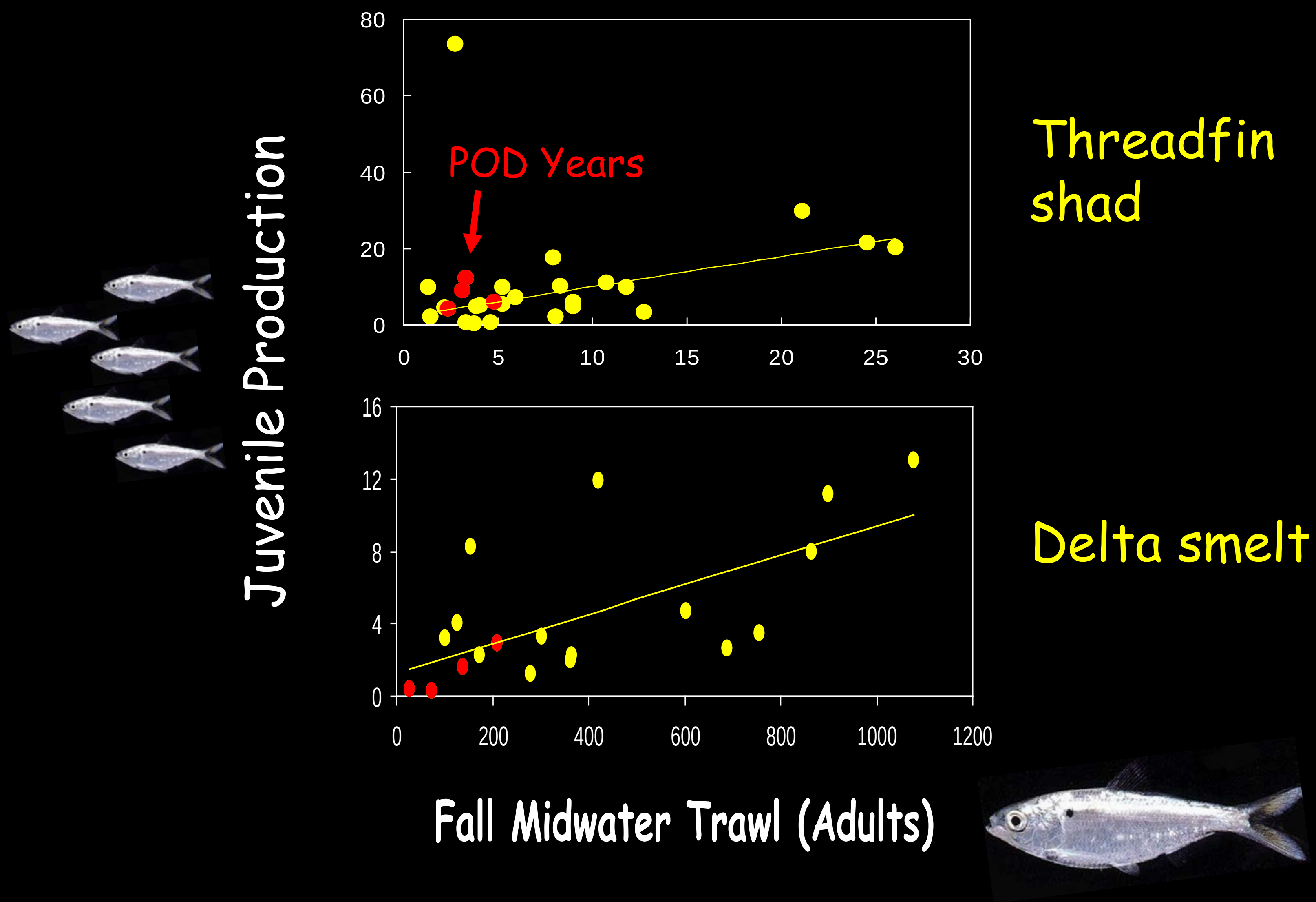


Delta Smelt
Abundance Index (Thousands)
1.8
1.5
1.2
0.9
0.6
0.3
0.0
66 69 72 75 78 81 84 87 90 93 96 99 02 05 08 11
Striped Bass
Abundance Index (Thousands)
20
15
10
5
0
66 69 72 75 78 81 84 87 90 93 96 99 02 05 08 11
Longfin Smelt
Abundance Index (Thousands)
20 18 16 14 12 10 8 6 4 2 0
66 69 72 75 78 81 84 87 90 93 96 99 02 05 08 11
Threadfin Shad
Abundance Index (Thousands)
16 14 12 10 8 6 4 2 0
66 69 72 75 78 81 84 87 90 93 96 99 02 05 08 11

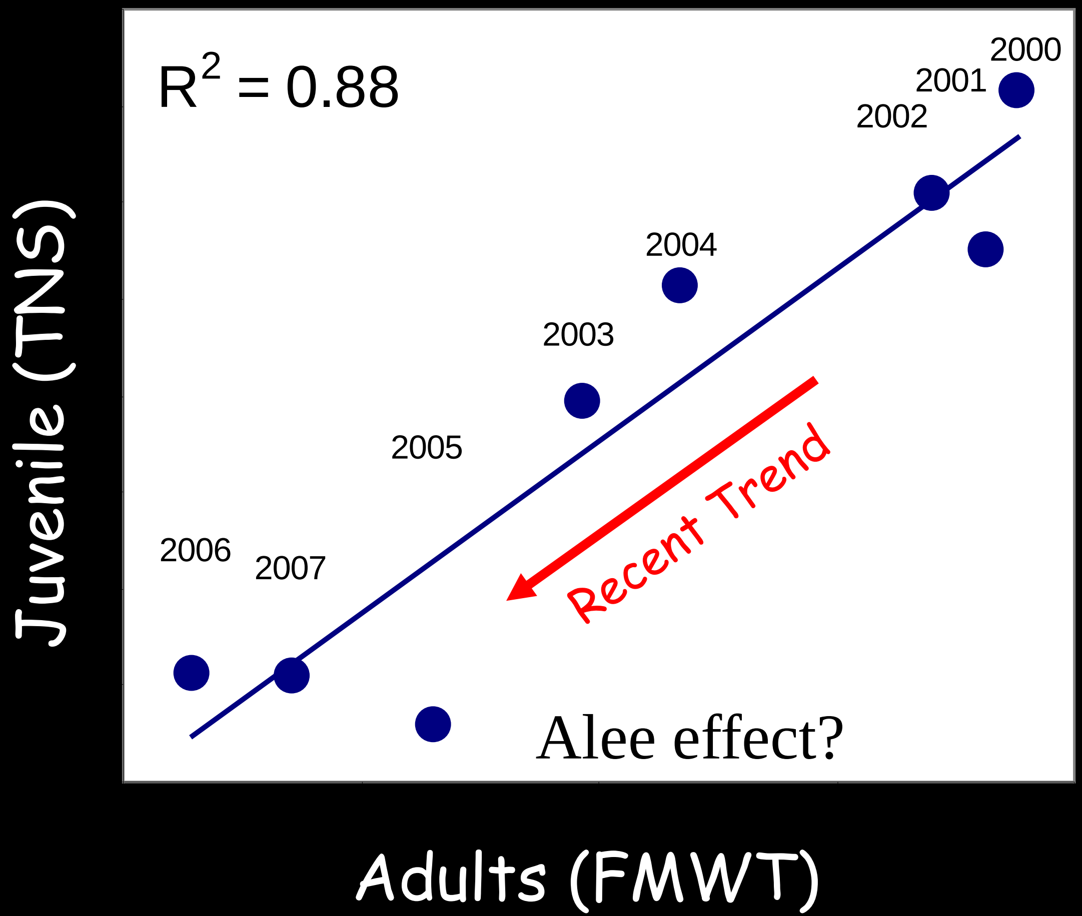

TOP-DOWN
LOSS
PARENTS
Prior Fish Abundance
FISH ABUNDANCE
PHYSICAL & CHEMICAL FISH HABITAT
HOME
FOOD
BOTTOM-UP

Prior Abundance → PRESENT ABUNDANCE

Stock - Recruitment Effects



Have Delta Smelt Dropped Below Critical Population Levels?



Source: Anke Mueller-Solger (DWR)

PHYSICAL
&
CHEMICAL
FISH
HABITAT

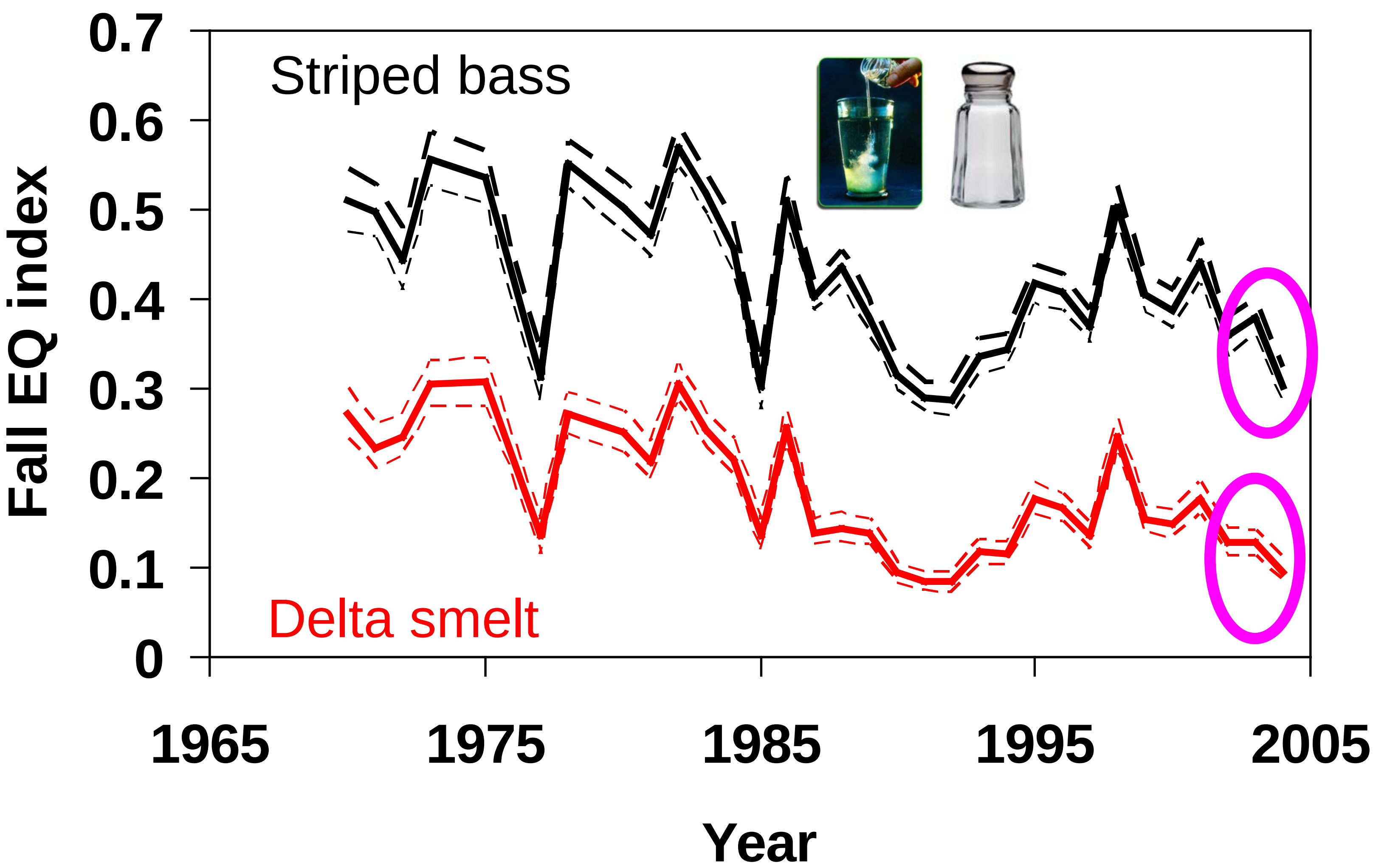
FISH
ABUNDANCE

PHYSICAL & CHEMICAL FISH HABITAT

FISH ABUNDANCE

- *Temperature*
- *Turbidity*
- *Salinity*
- *Nutrients*
- *Contaminants*
- *Disease*
- *Toxic algae*

Fall "habitat quality" deteriorated

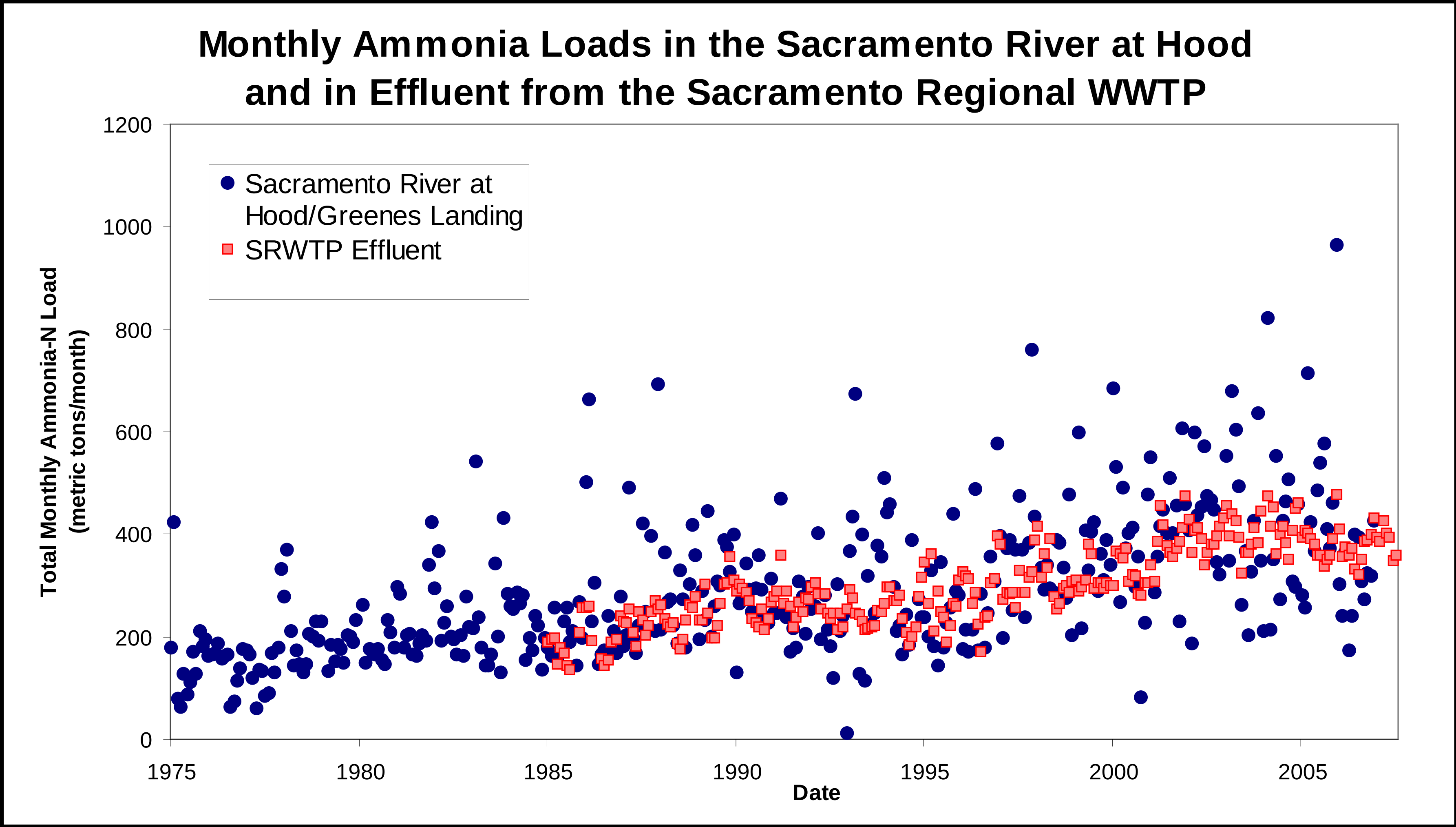


Source: Feyrer et al. (CJFAS 2007)

Other habitat stressors

- Bioassays showed little effect (<5 %) in 2005 or 2006.
- <15% adult delta smelt impaired
- 100 % of young striped bass show multiple infections

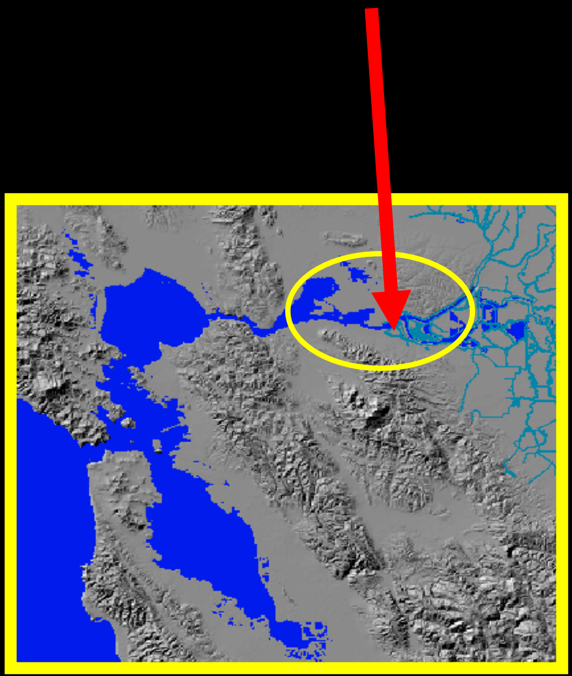
Source: Inge Werner, Swee Teh, and Dave Ostrach (UCD)



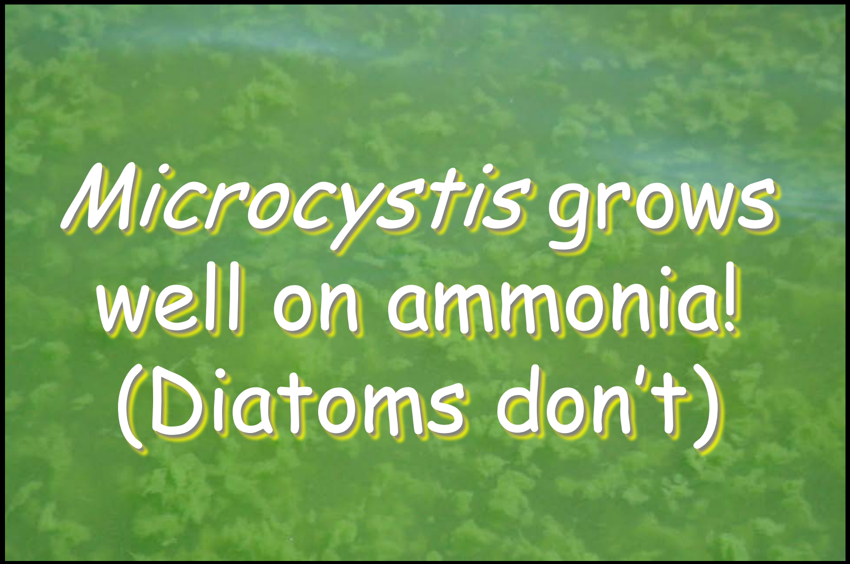
Sources: A. Mueller-Solger, DWR; A. Jassby, in press SFEWS

Widespread blooms of the toxic alga *Microcystis* in 2007

August Levels: 1.3 million cells/mL



Core Habitat of Delta Smelt



Source: Peggy Lehman (DWR)

TOP-DOWN

Water Diversions

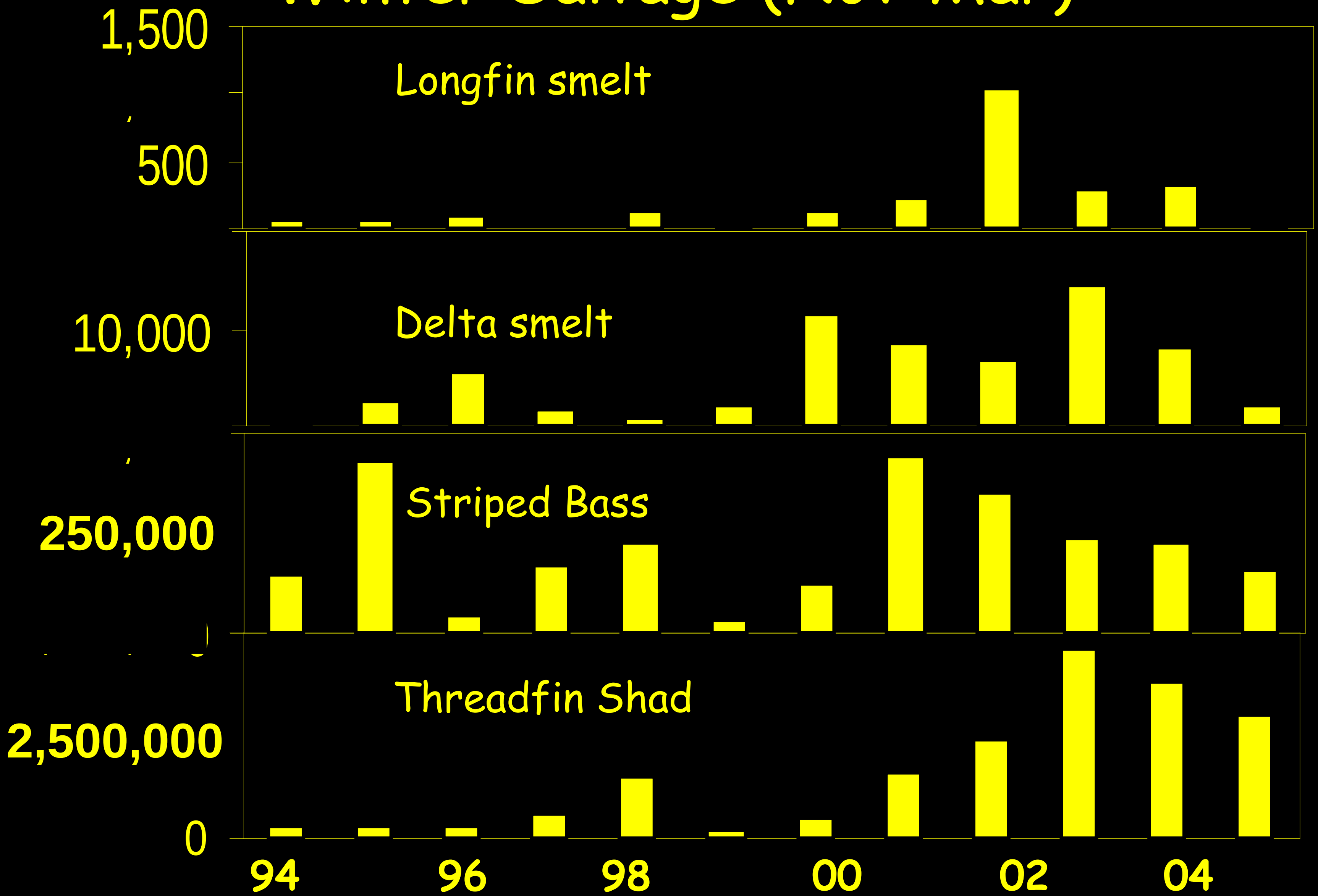
Predation

FISH ABUNDANCE

Water Project Losses

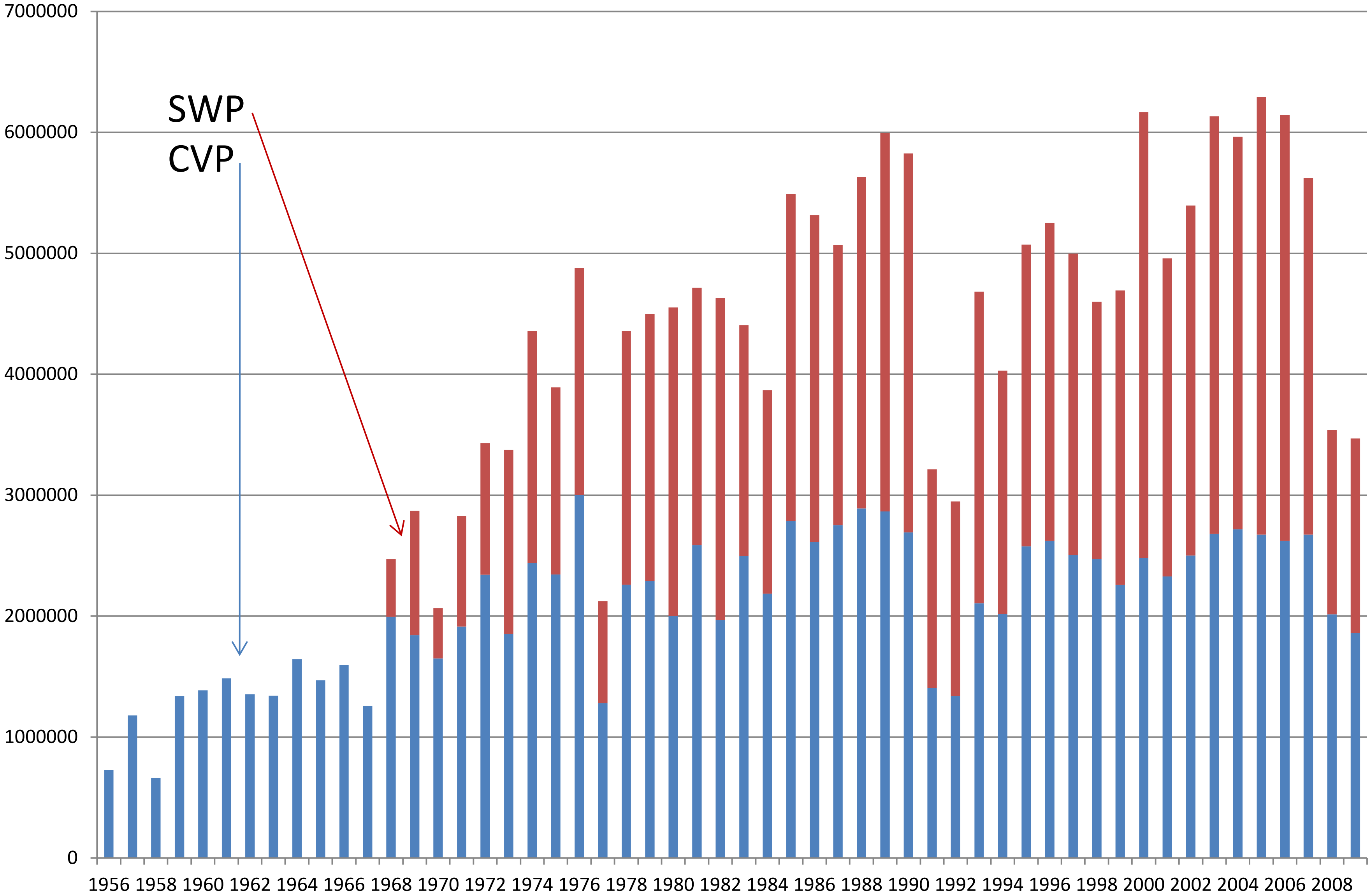
Fish Facilities Provide Data on Numbers "Salvaged"

Winter Salvage (Nov-Mar)

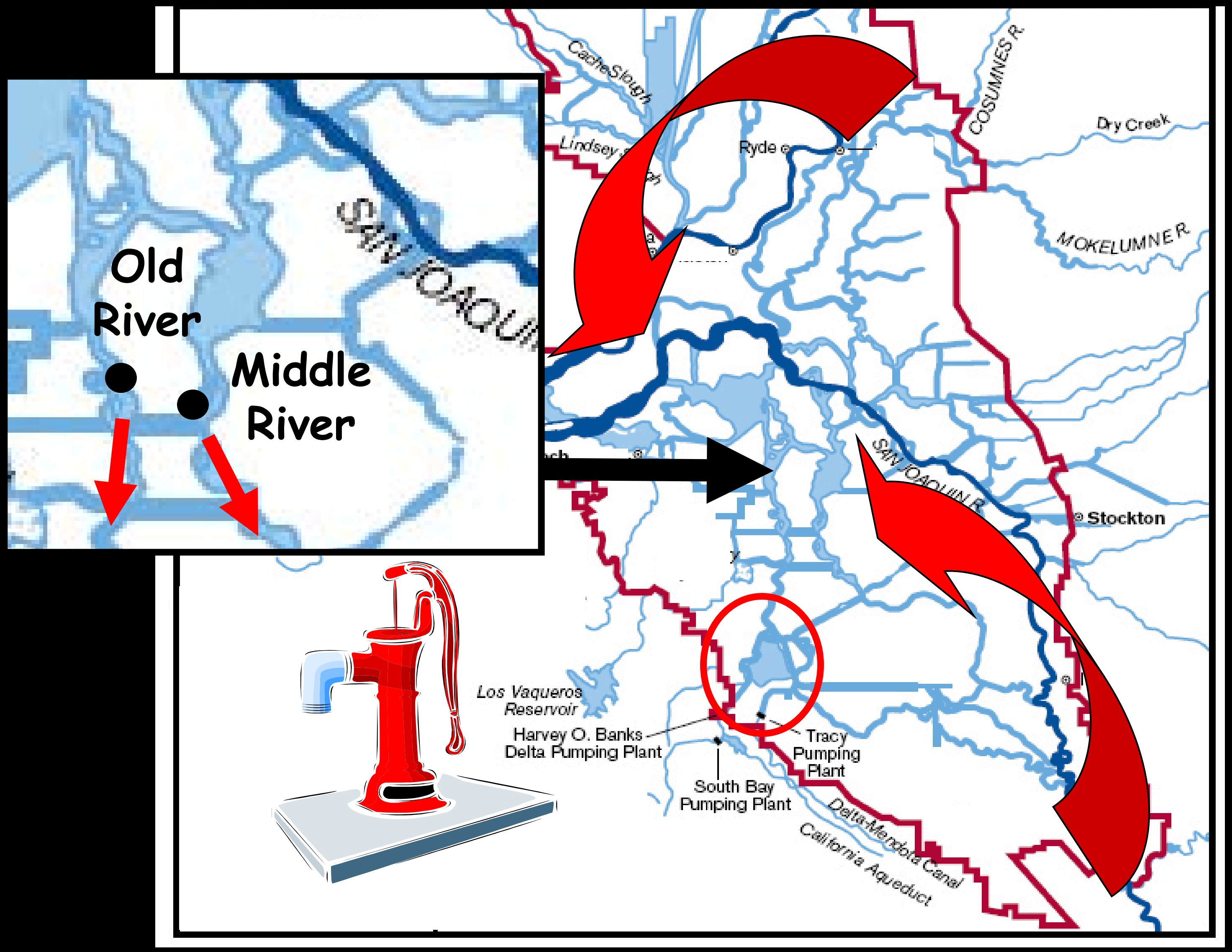


Exports in acre-feet

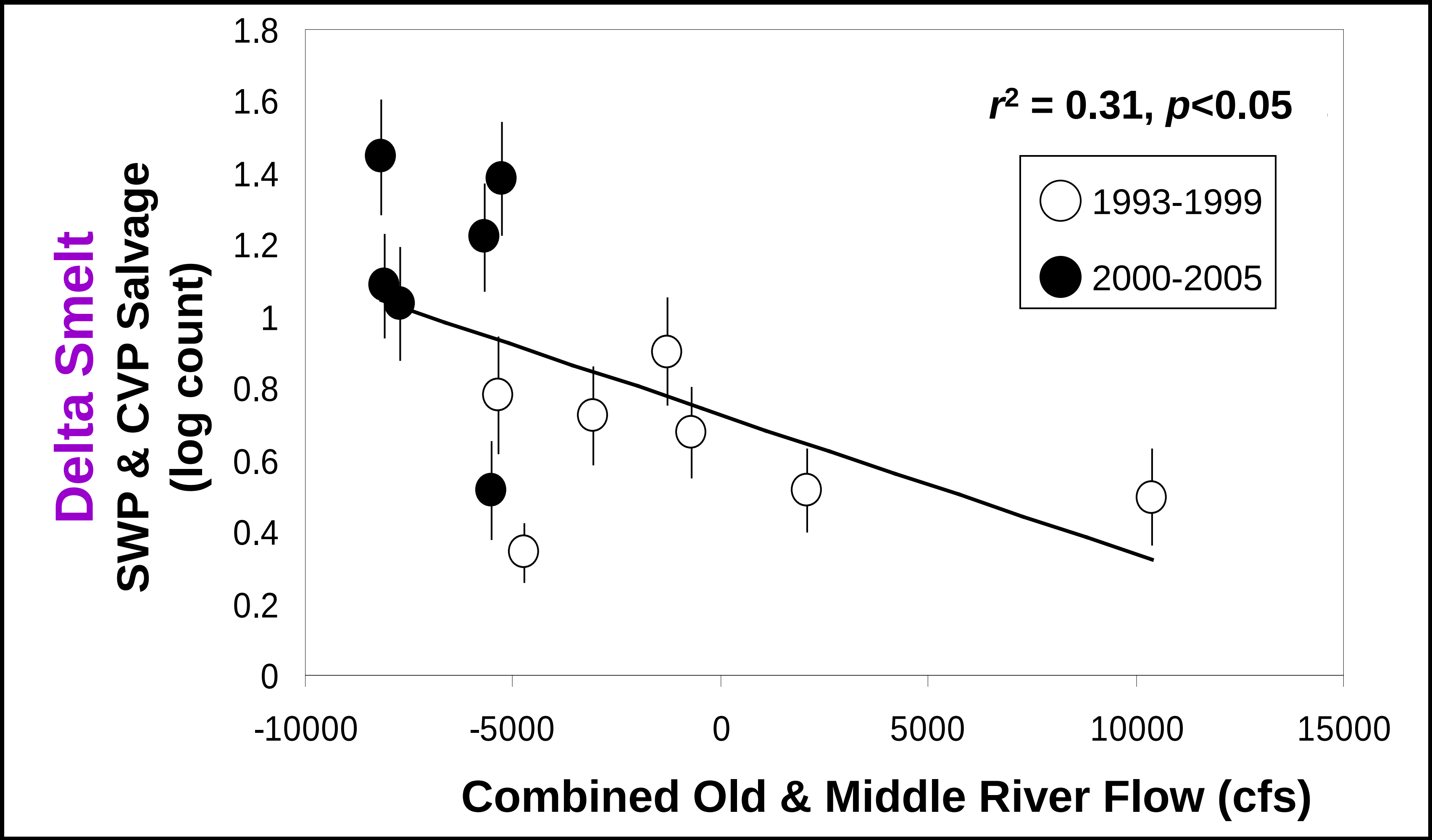
1 acre-foot =325,851 gallons =1233 kiloliters



OMR = Old and Middle River flows

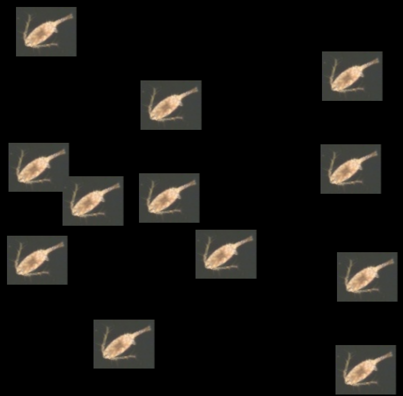


Negative Old & Middle River Flows Apparently Increase Adult Delta Smelt Entrainment



Mean Values for December-March 1993-2005

Source: Source Lenny Grimaldo (In Review)



FISH ABUNDANCE

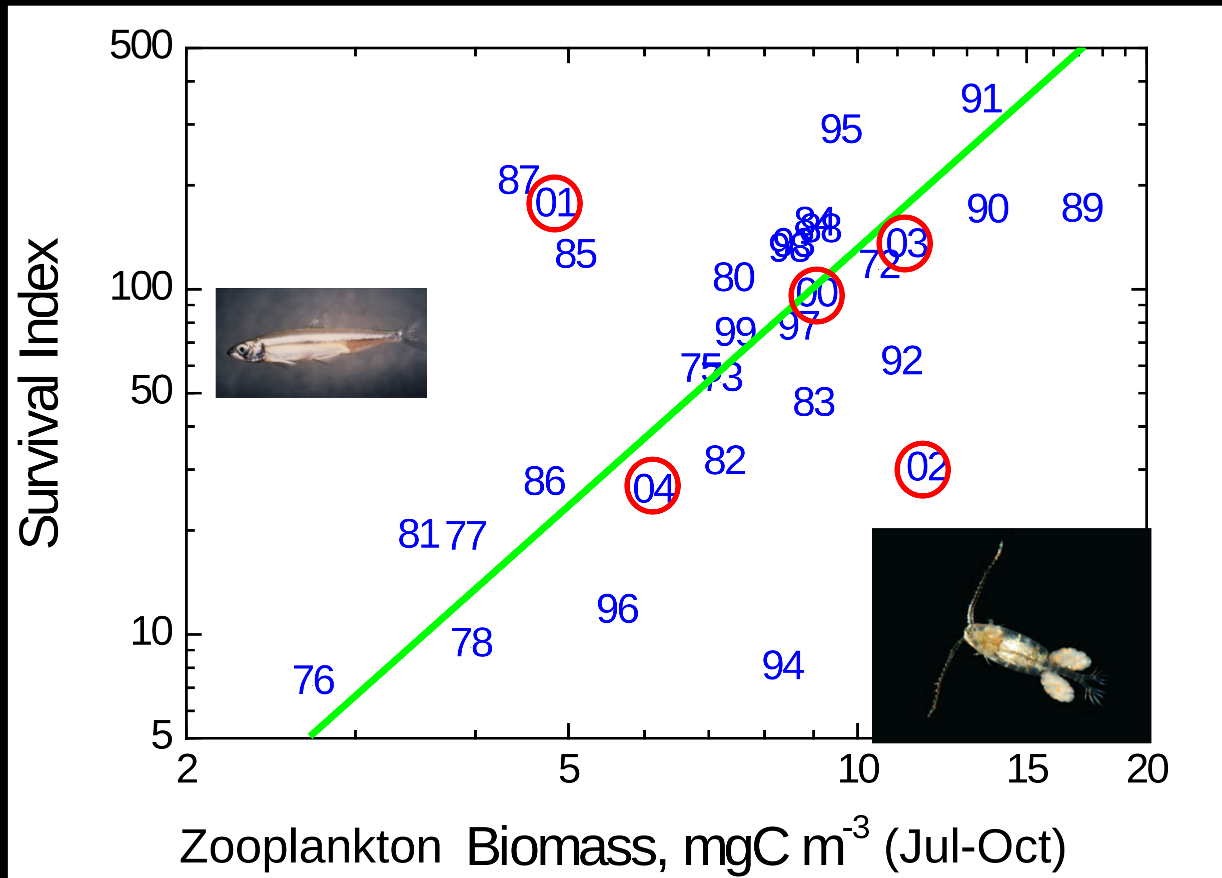
Food availability

Food quality

BOTTOM-UP

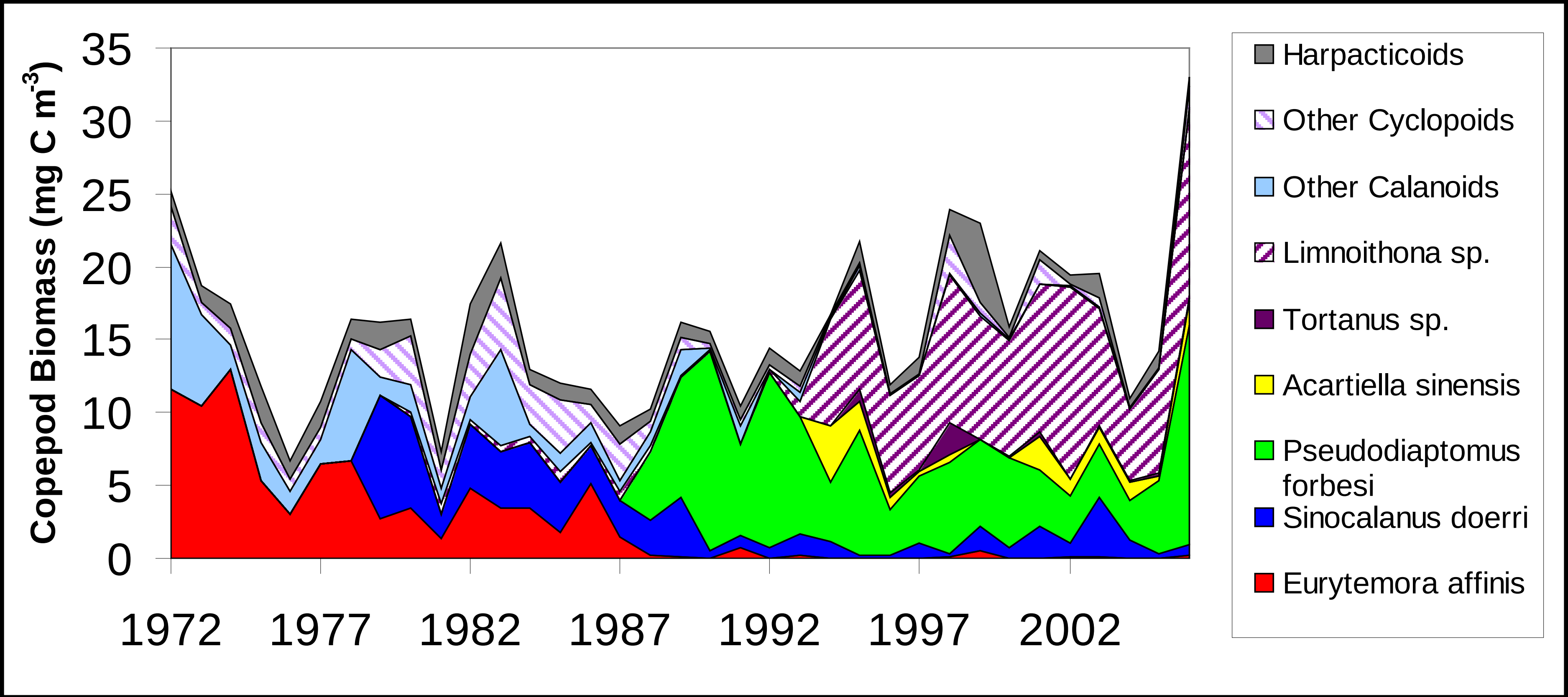
Food Affects Summer Smelt Survival

But Recent Levels Were Not Remarkable



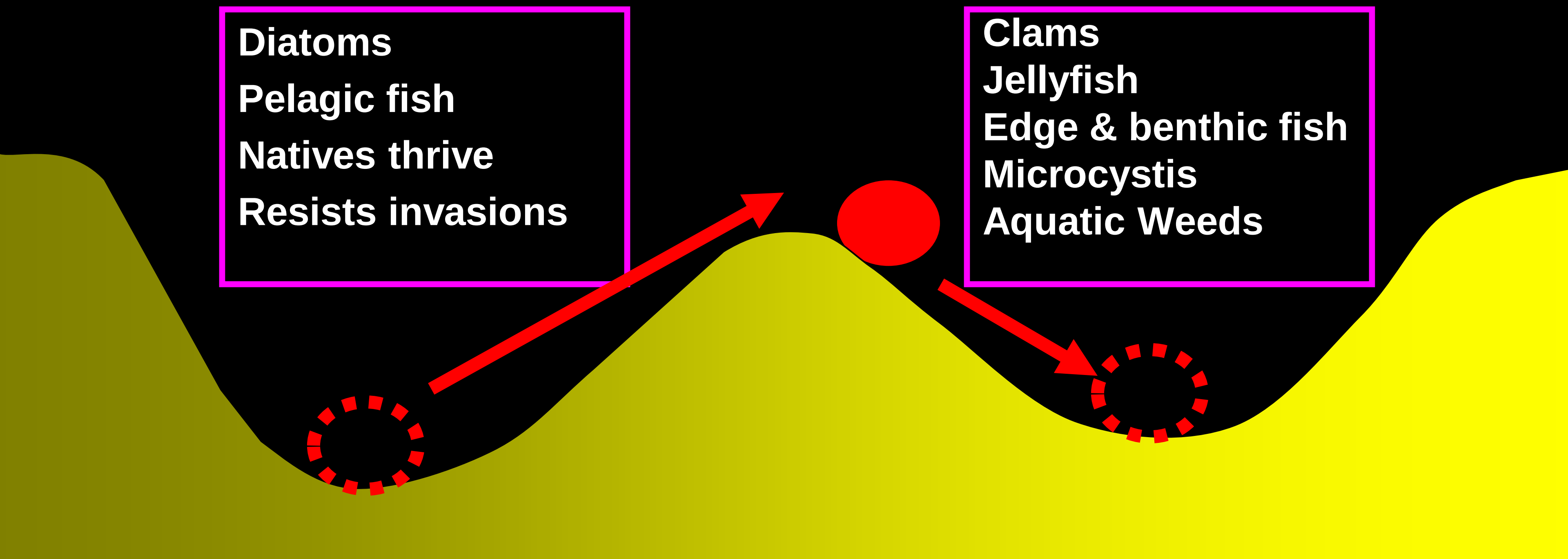
Source: Wim Kimmerer

No Major Change in Zooplankton Biomass, But Big Change In Species



Source: Anke Mueller-Solger (DWR); IEP (2007)

Little	Ammonia	Lots
Low	Contaminants	High
Highly variable	Flow	Low and Constant
Low	"Harvest"	High
Lots	Phosphorus	Limited
Cool	Temperature	Warm
High	Turbidity	Low



Little	Ammonia	Lots
Low	Contaminants	High
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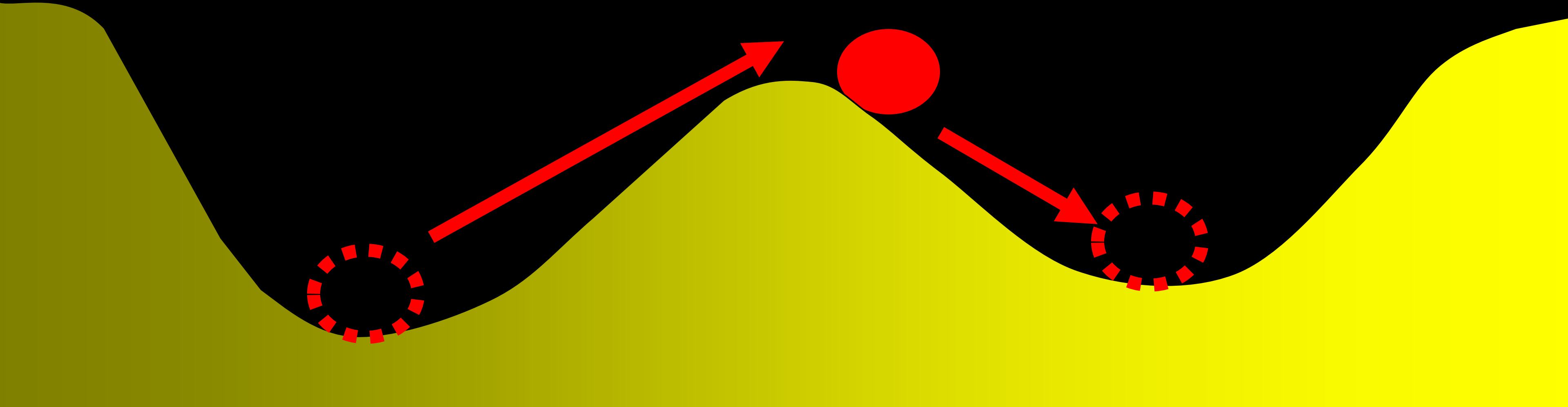
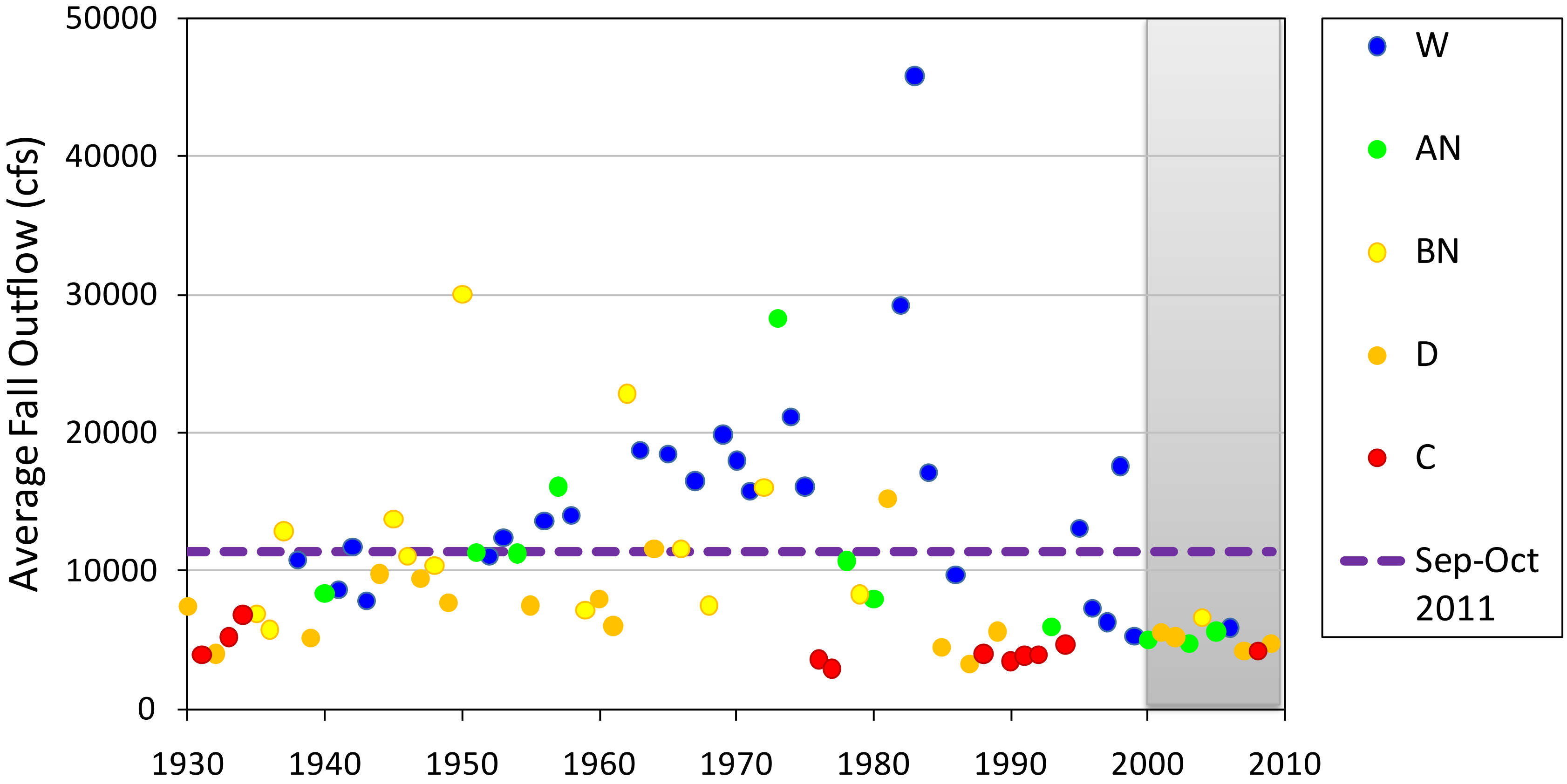
Low	“Harvest”	High
Lots	Phosphorus	Limited
Cool	Temperature	Warm
High	Turbidity	Low

CLIMATE CHANGE
Directions

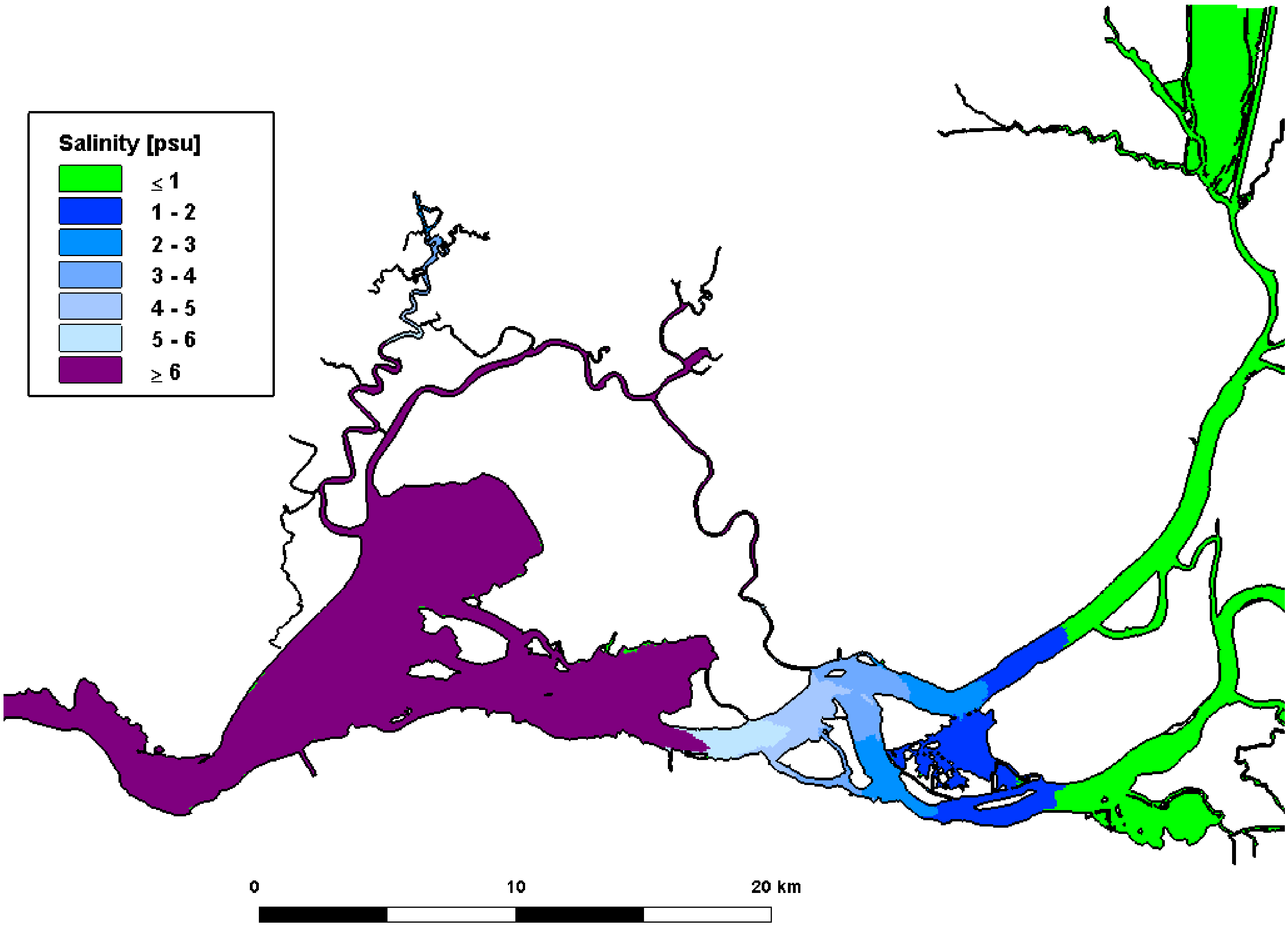


FLaSH

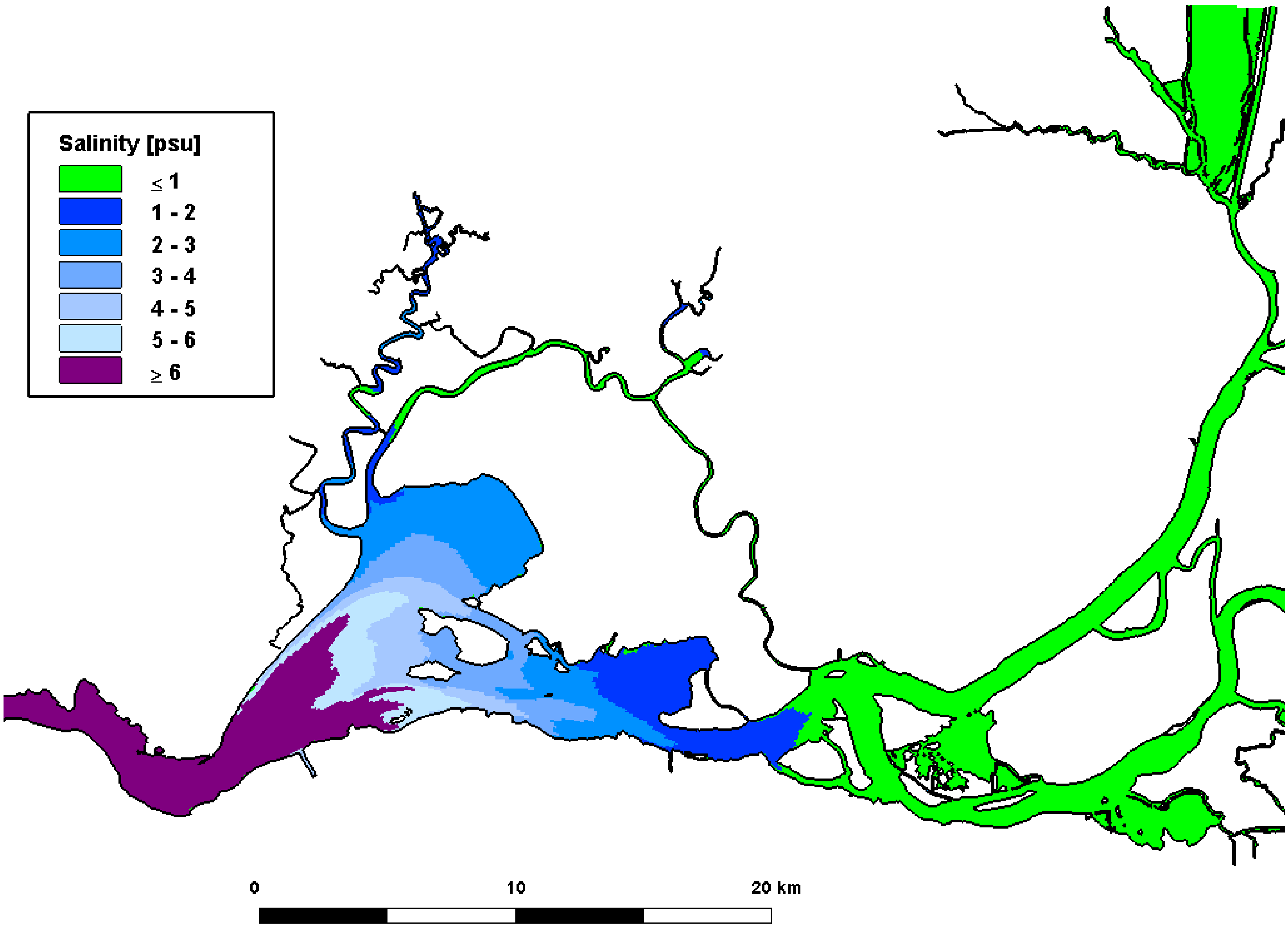


Average Fall Outflow (cfs)
50000
40000
30000
20000
10000
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
W
AN
BN
D
C
Sep-Oct 2011

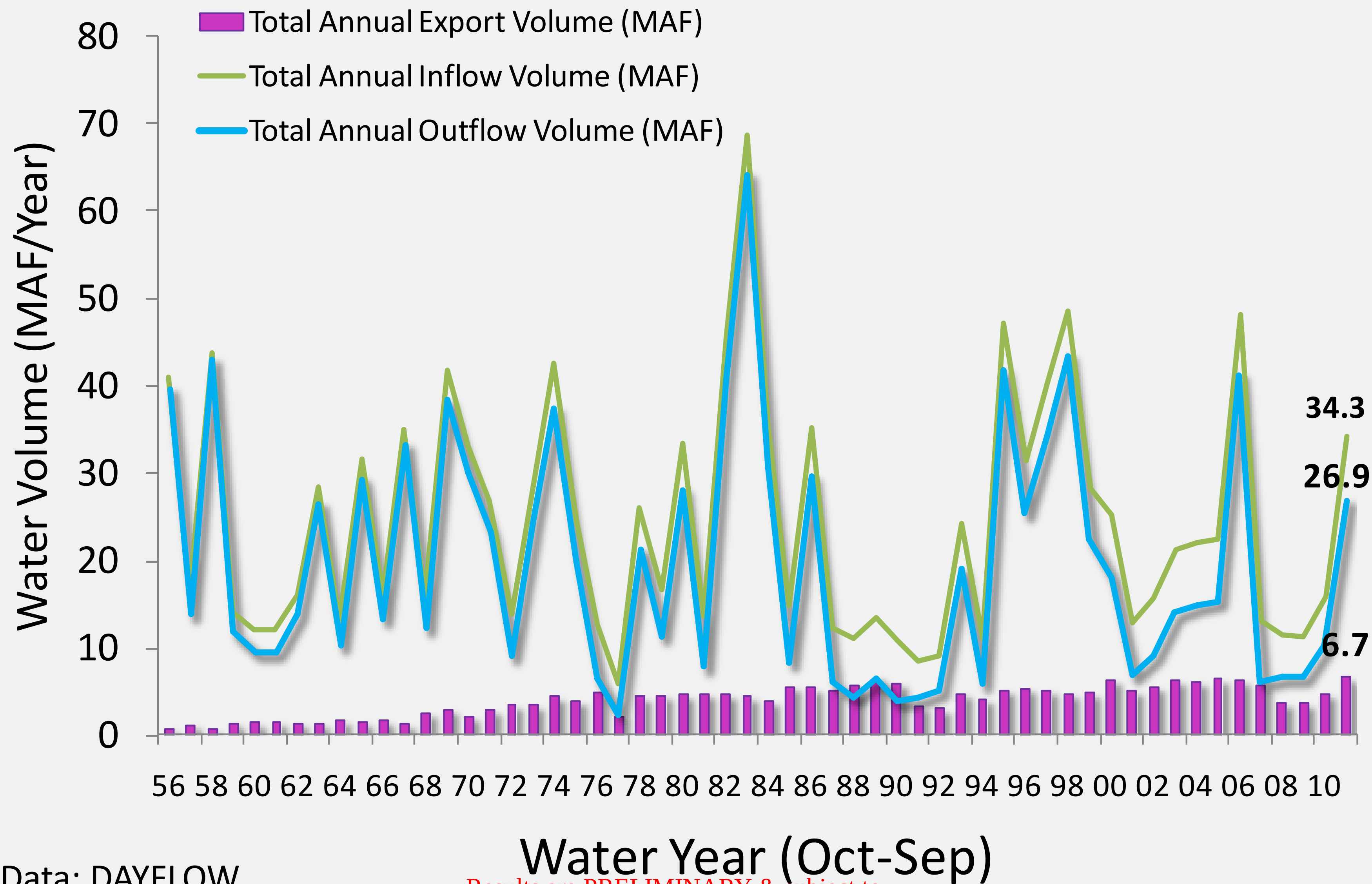
Daily-Average Depth-Averaged Salinity



Daily-Average Depth-Averaged Salinity



2011 Had High In- & Outflows and Record High Exports

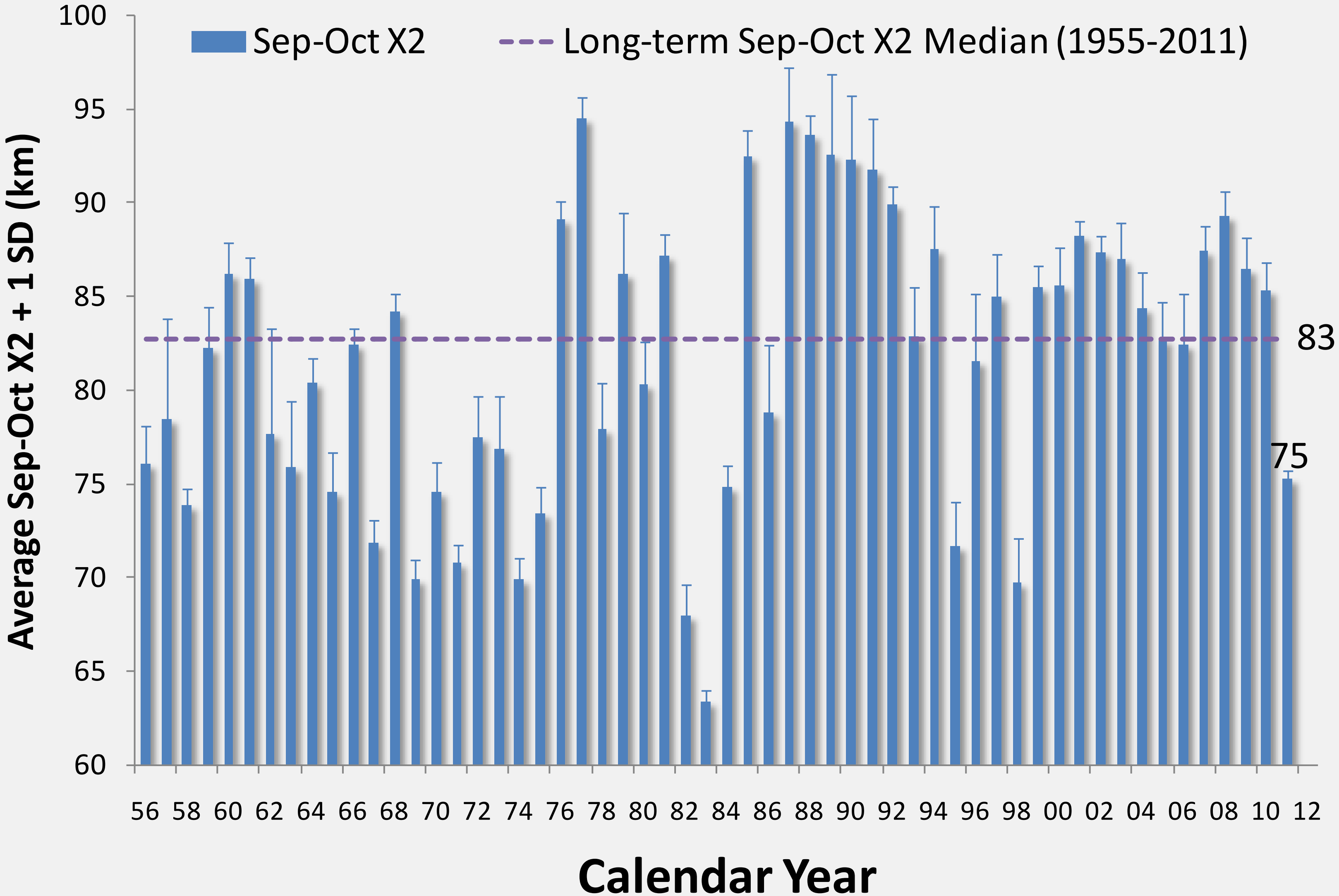


Data: DAYFLOW

Results are PRELIMINARY & subject to change!

… And a Westward Low Salinity Zone in the Fall.

(September-October)



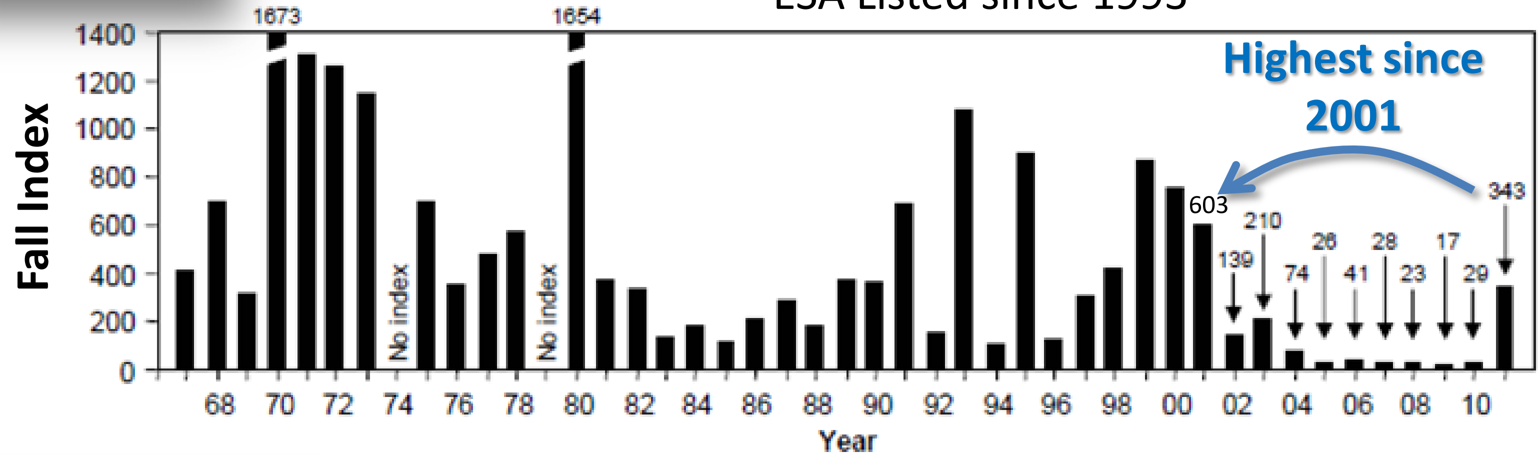
Data: DAYFLOW

Results are PRELIMINARY & subject to change!

Some Fish Abundance Indices Improved in 2011

Delta Smelt

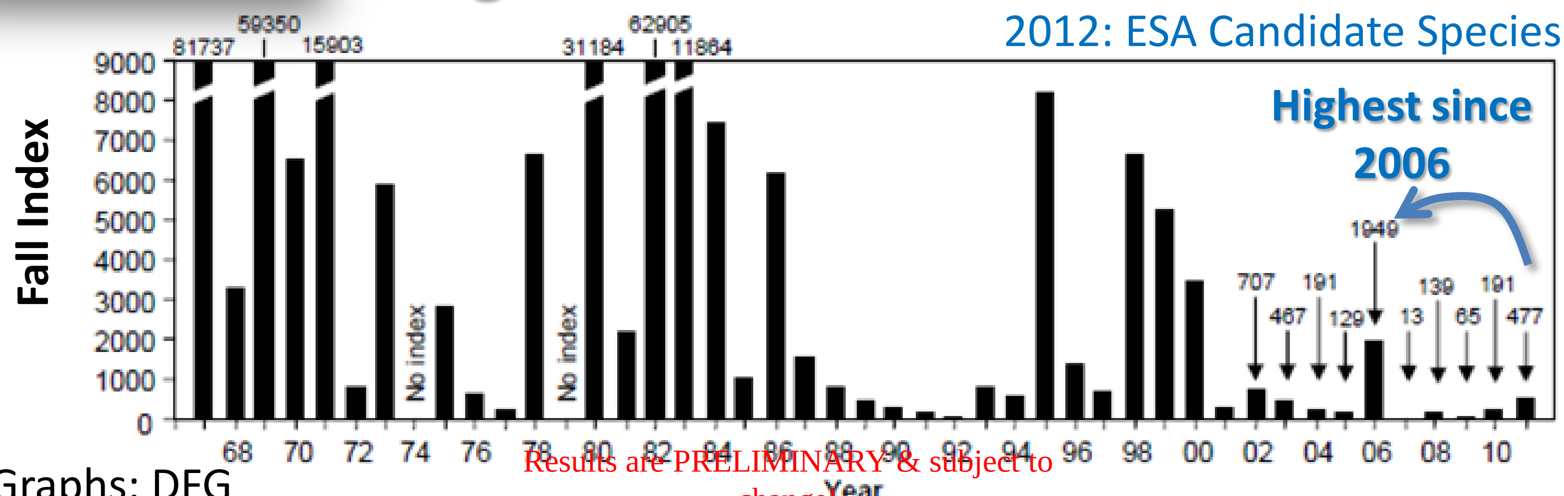
ESA Listed since 1993



Longfin Smelt

CESA Listed since 2009

2012: ESA Candidate Species

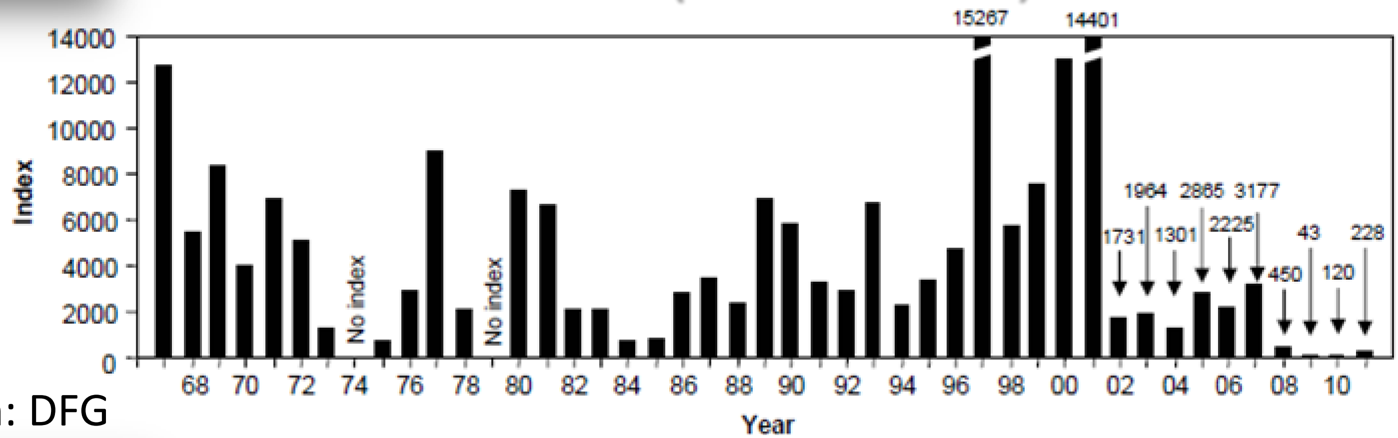


Results are PRELIMINARY & subject to change!

Graphs: DFG

Some fish indices did not improve in 2011

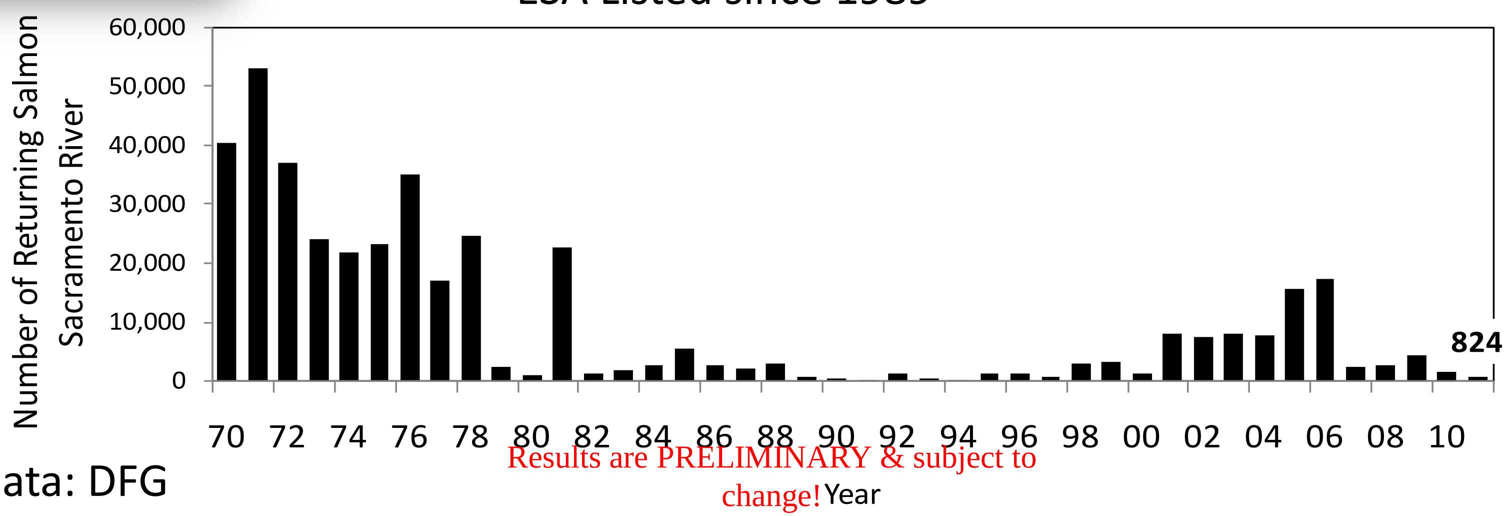
Threadfin Shad (non-native)



Graph: DFG

Winter Run Chinook Salmon

ESA Listed since 1989

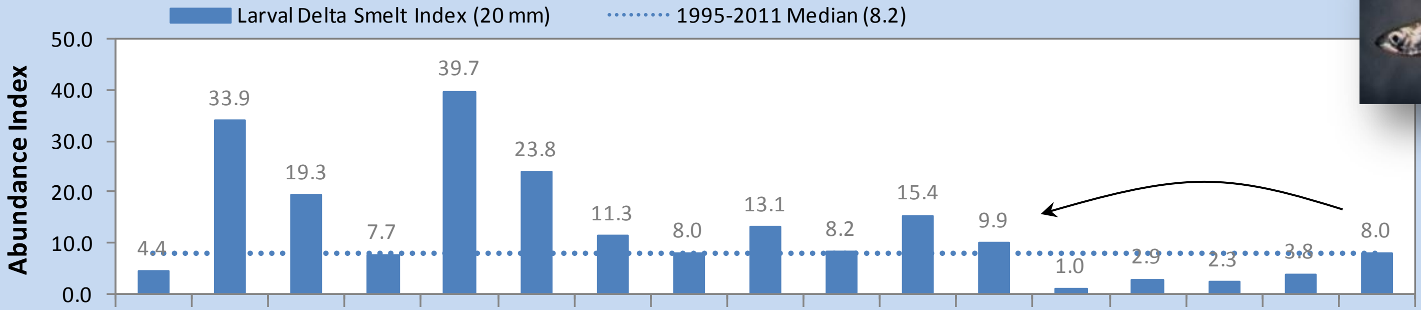


Data: DFG

Delta smelt indices increased throughout 2011

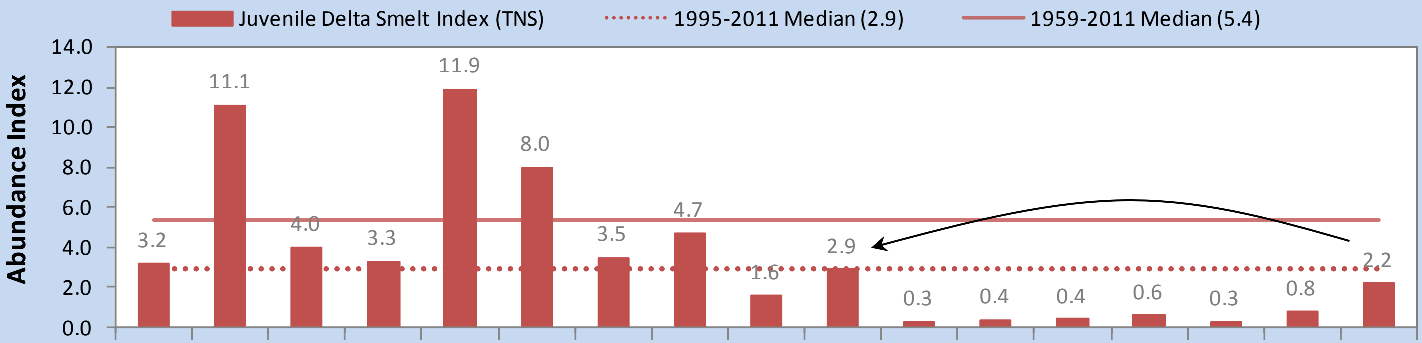
Results are PRELIMINARY & subject to change!

Spring: Larval Delta Smelt Index (20 mm)



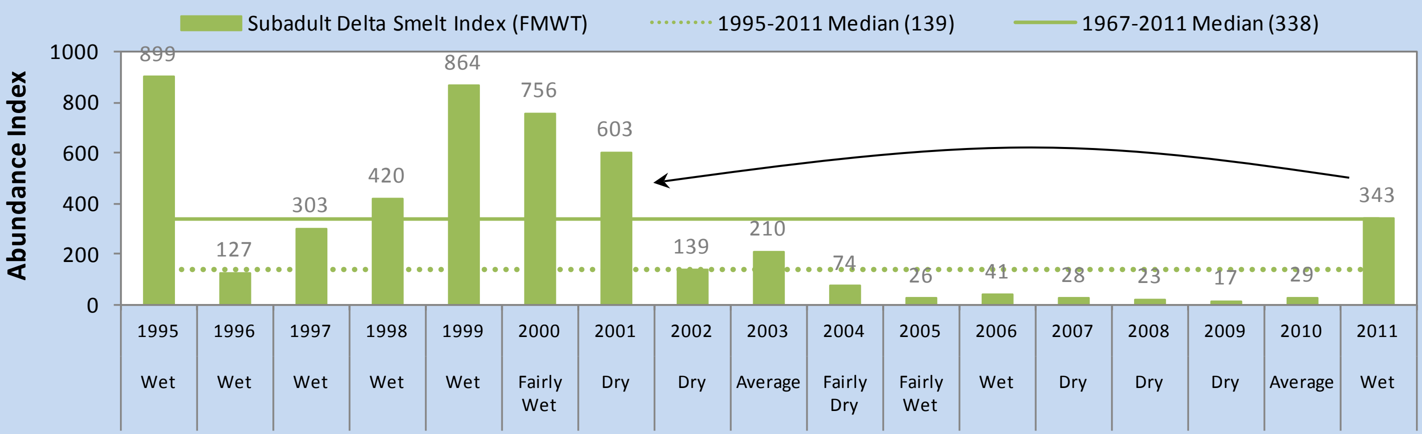
Spring: Highest since 2006

Summer: Juvenile Delta Smelt Index (TNS)



Summer: Highest since 2004

Fall: Subadult Delta Smelt Index (FMWT)



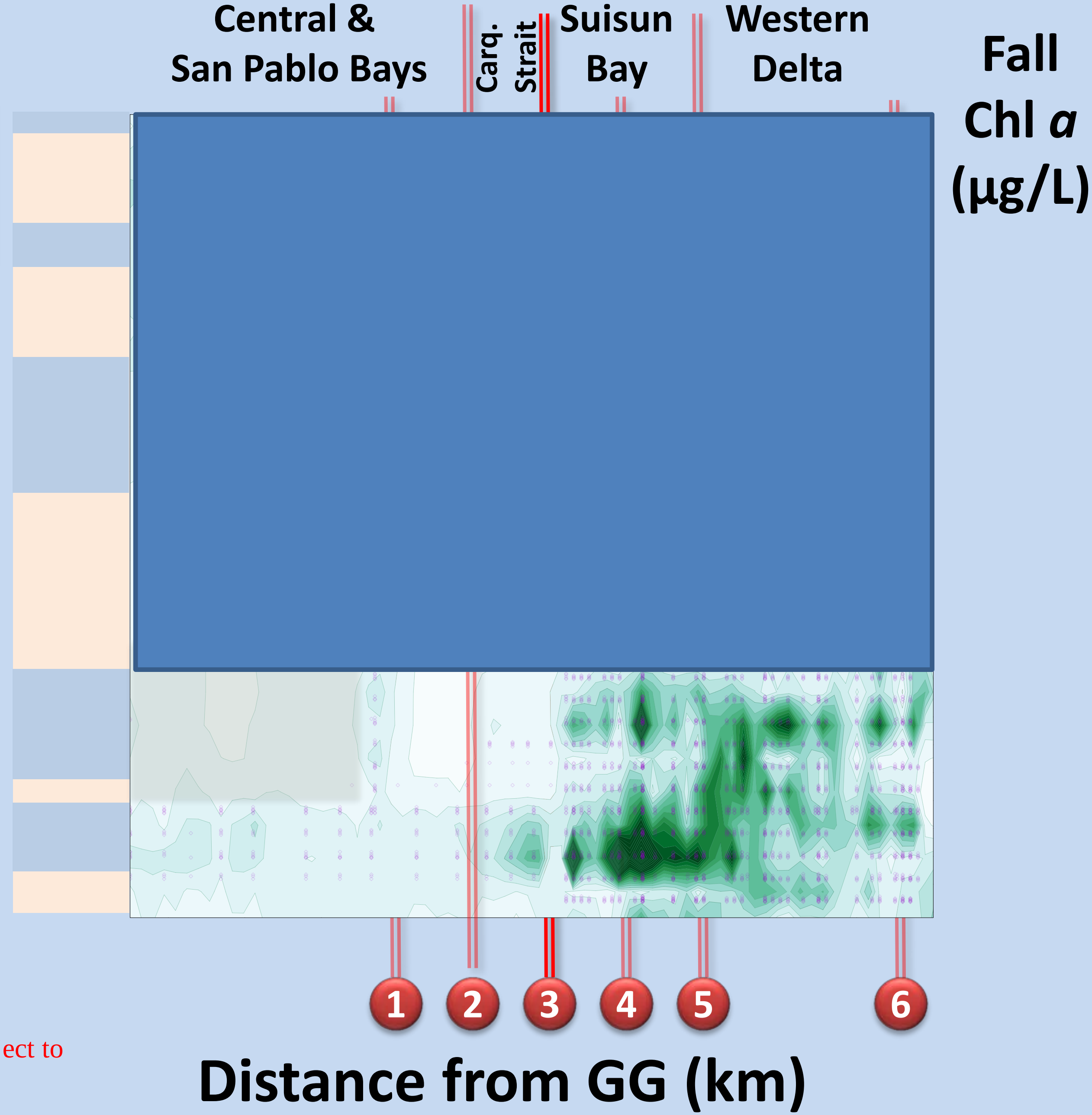
Fall: Highest since 2001

Was the fall 2011 phytoplankton bloom unusual?

Golden Gate **Rio Vista**

Data: EMP, USGS-Polaris, DFG “NZ”, Graph: A. Mueller-Solger, DSC

Date



Fall Blooms common in Suisun/West Delta before 1987

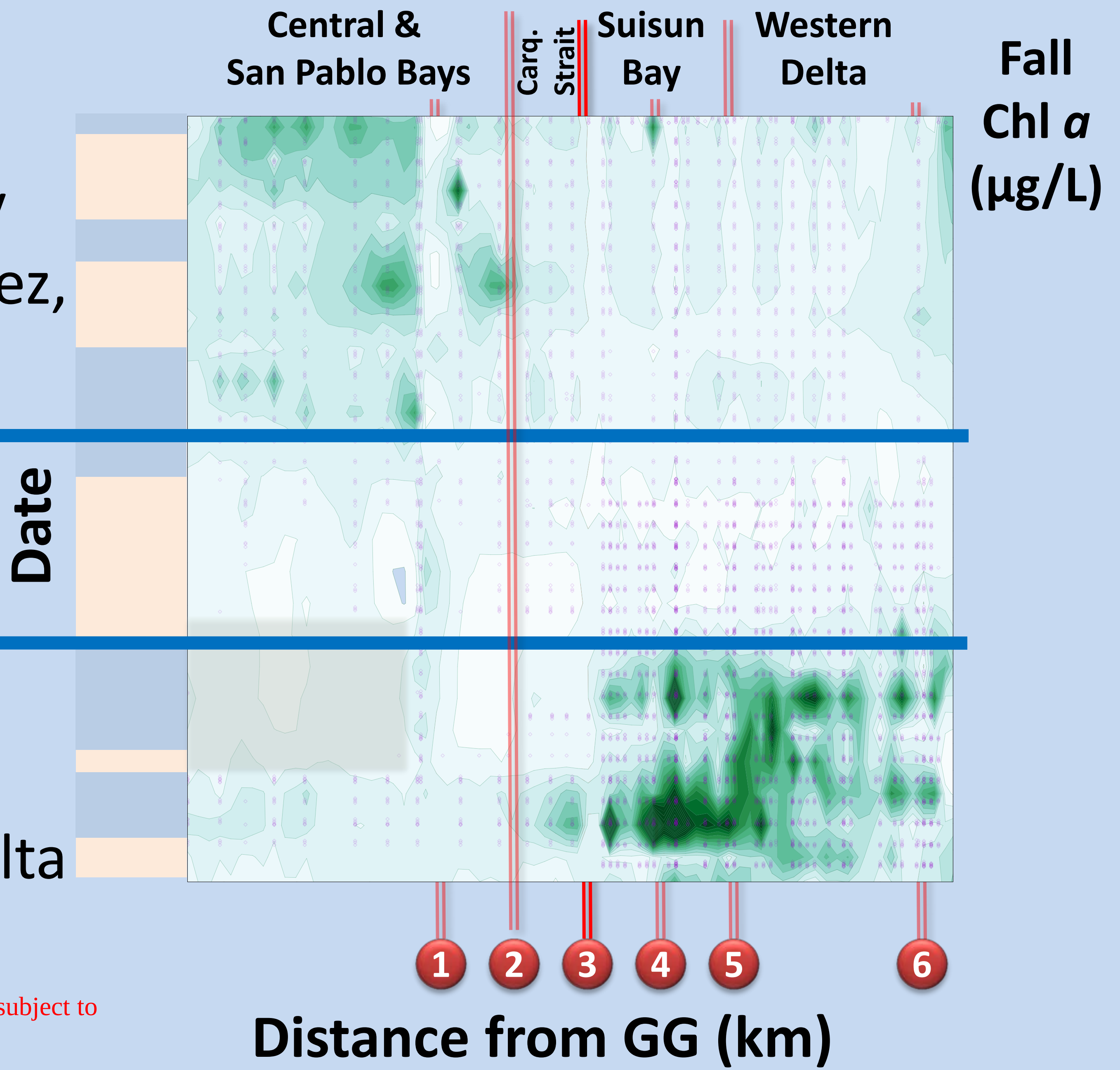
Results are PRELIMINARY & subject to change!

Was the fall 2011 phytoplankton bloom unusual?

Fall blooms only west of Carquinez, **except 2011**

“Depression”

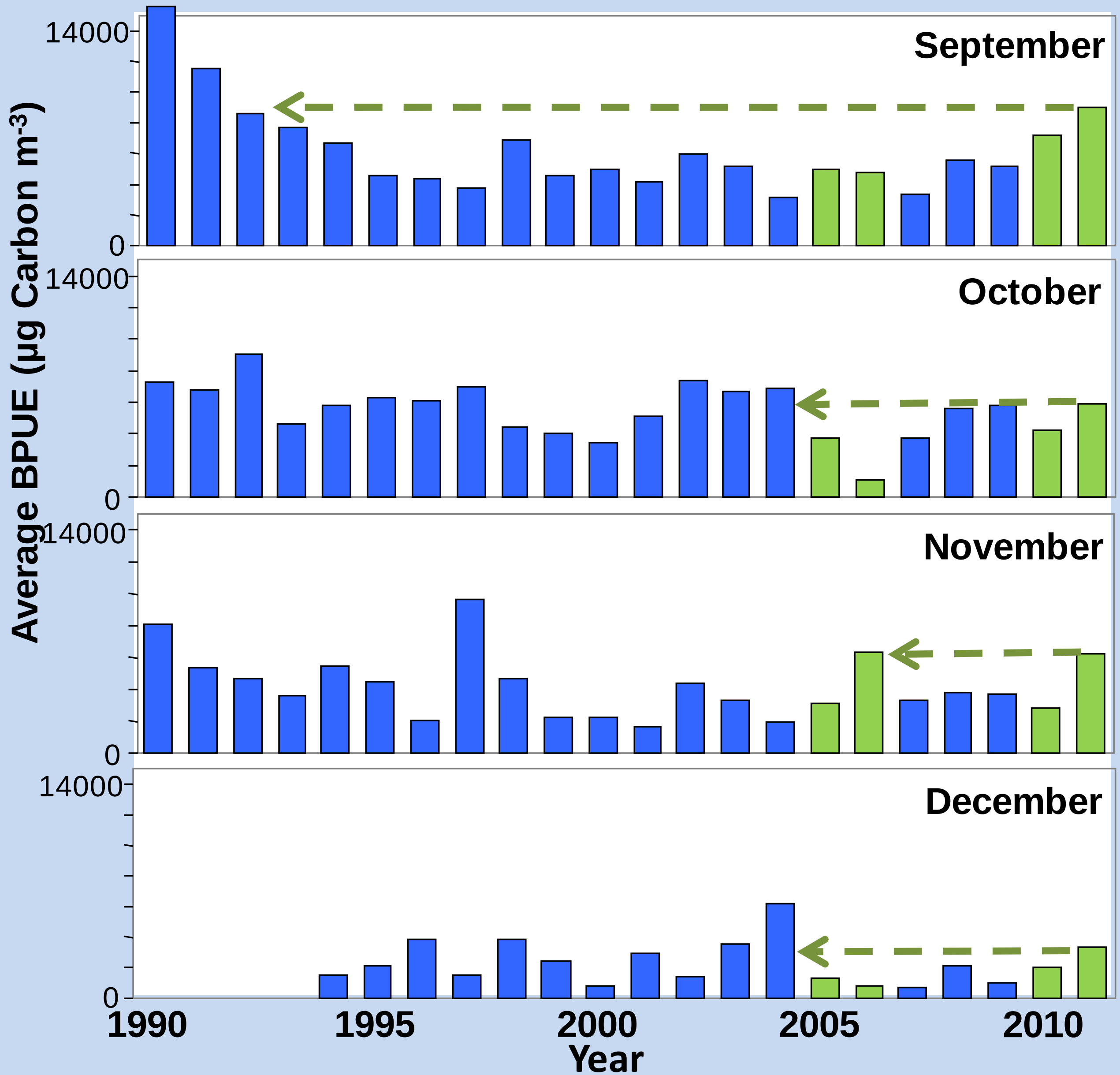
Fall Blooms common in Suisun/West Delta before 1987



Results are PRELIMINARY & subject to change!

Zooplankton Biomass (2)

High total zooplankton biomass in LSZ in fall 2011

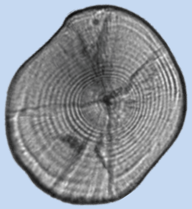


Data: IEP EMP

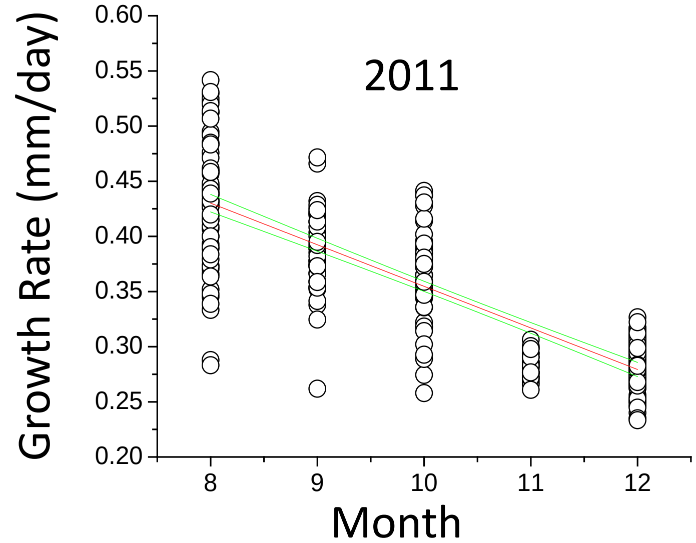
Graph: A. Hennessy, DFG

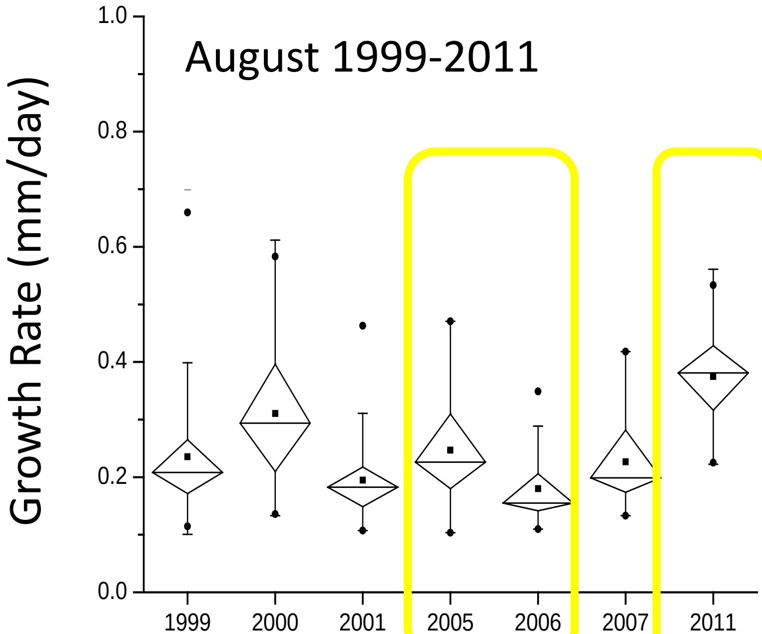
Results are PRELIMINARY
&
subject to change!

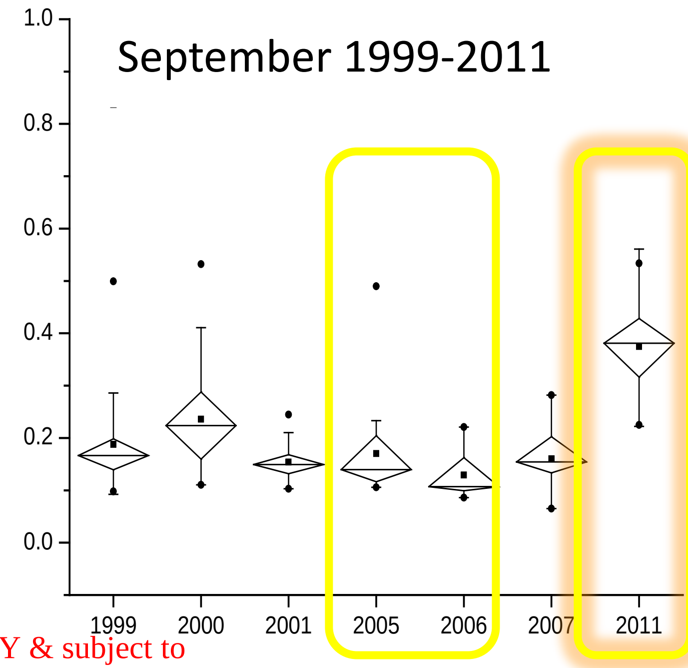
Delta smelt grew well in 2011



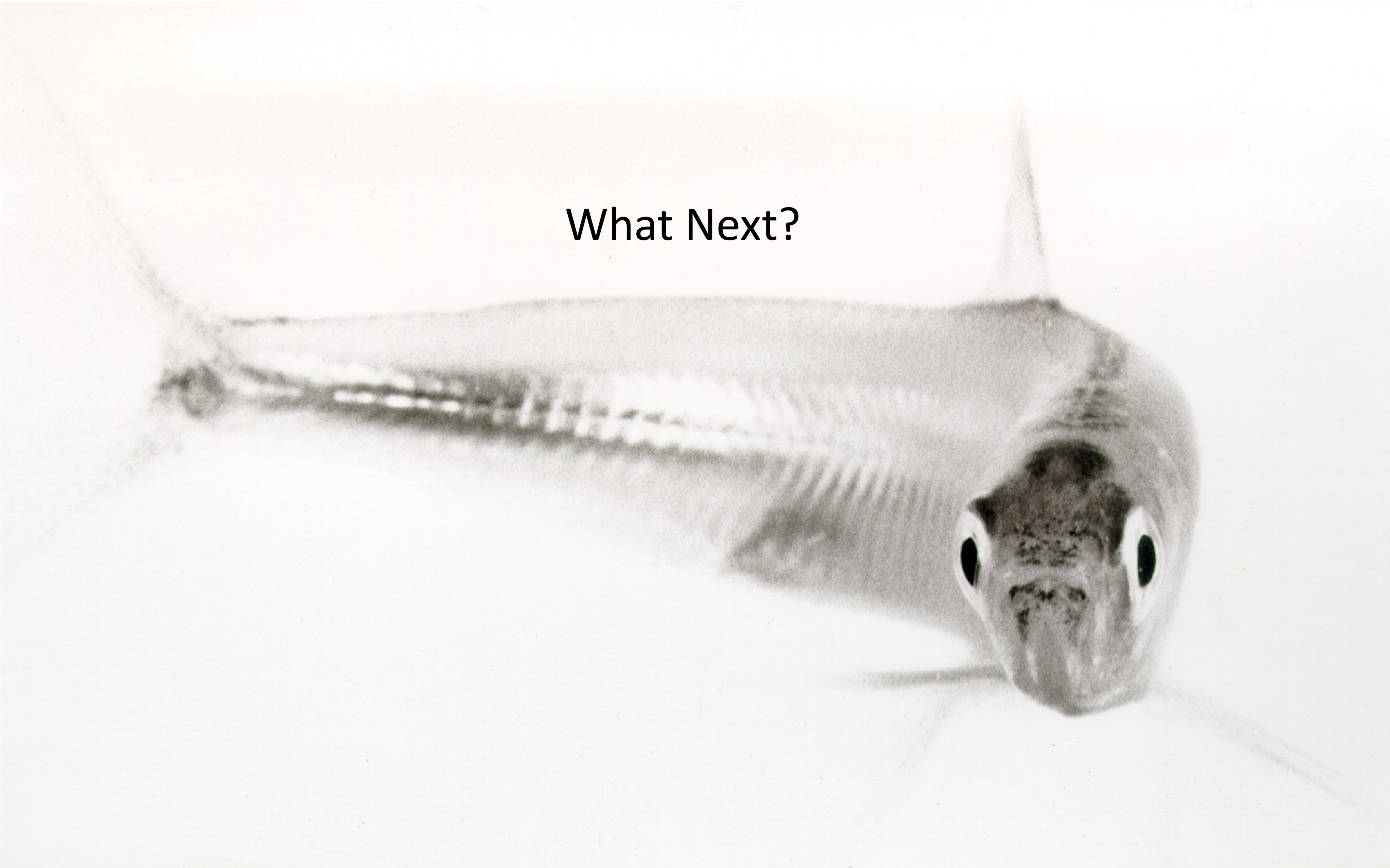
Data and Graphs:
J. Hobbs, UC Davis



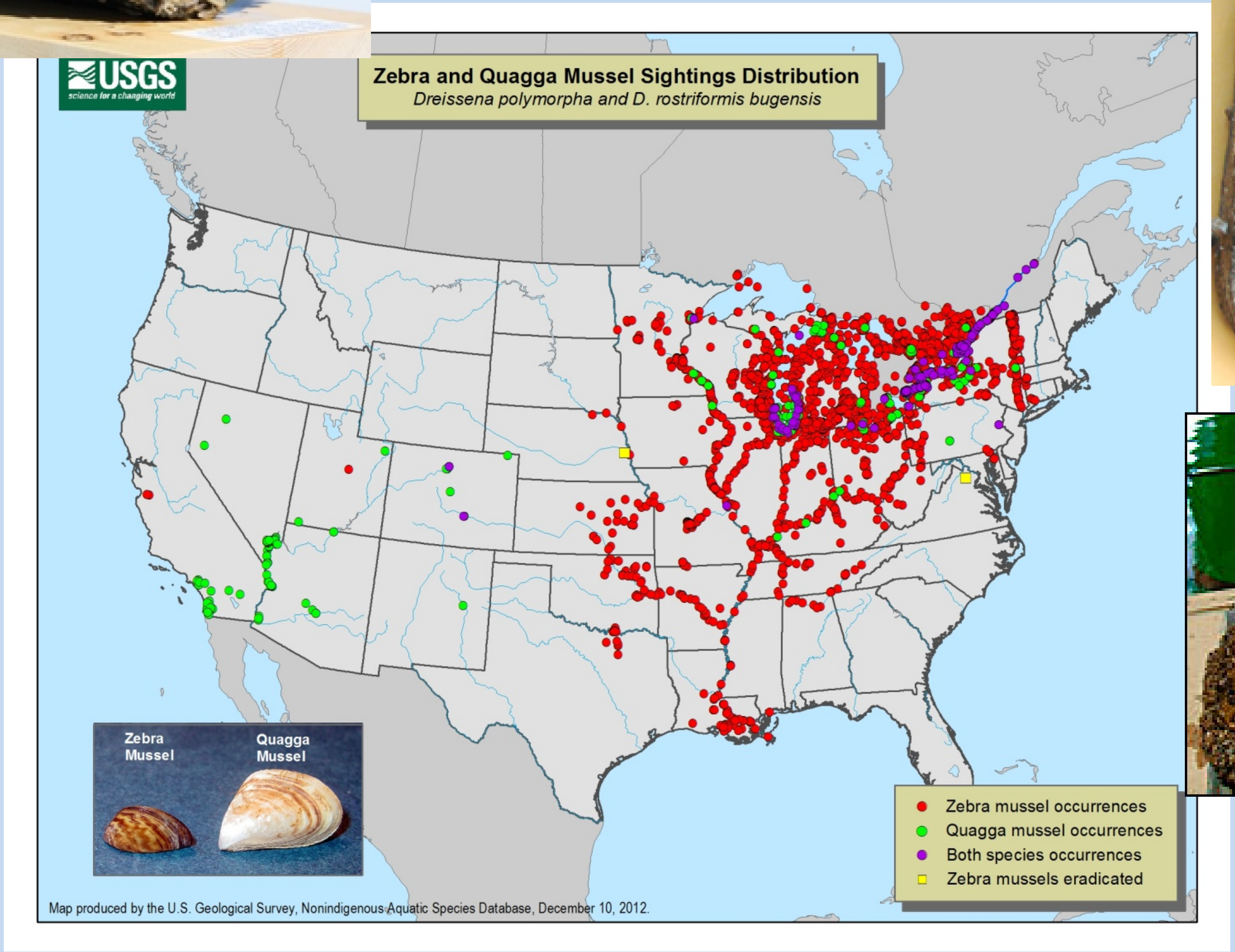




Results are PRELIMINARY & subject to change!

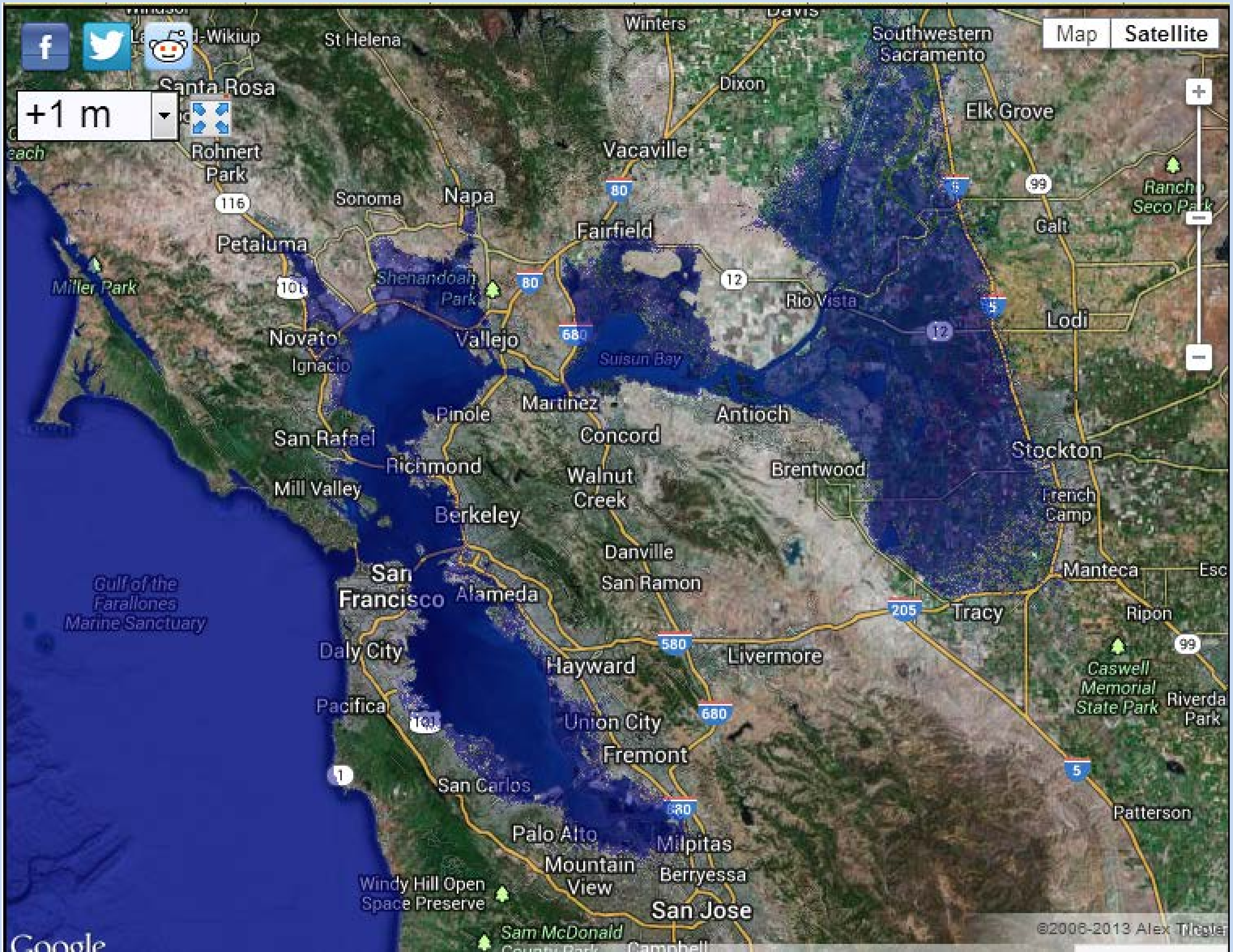

What Next?

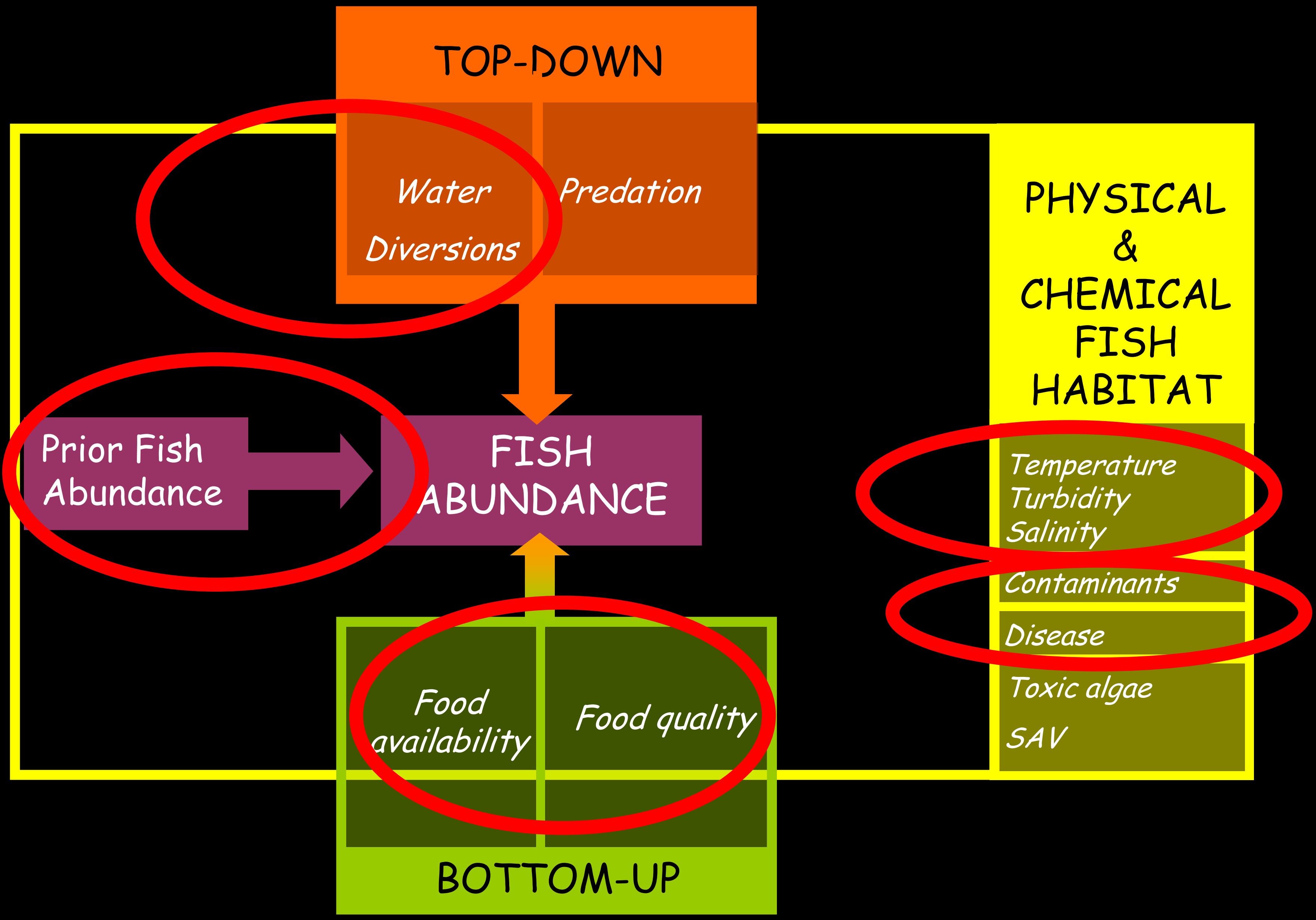
Today?


USGS
science for a changing world
Zebra and Quagga Mussel Sightings Distribution
Dreissena polymorpha and D. rostriformis bugensis
Zebra Mussel
Quagga Mussel
Zebra mussel occurrences
Quagga mussel occurrences
Both species occurrences
Zebra mussels eradicated
Map produced by the U.S. Geological Survey, Nonindigenous Aquatic Species Database, December 10, 2012.

Earthquake or flood
64% chance in 50 years

1 M sea level rise (2100?)

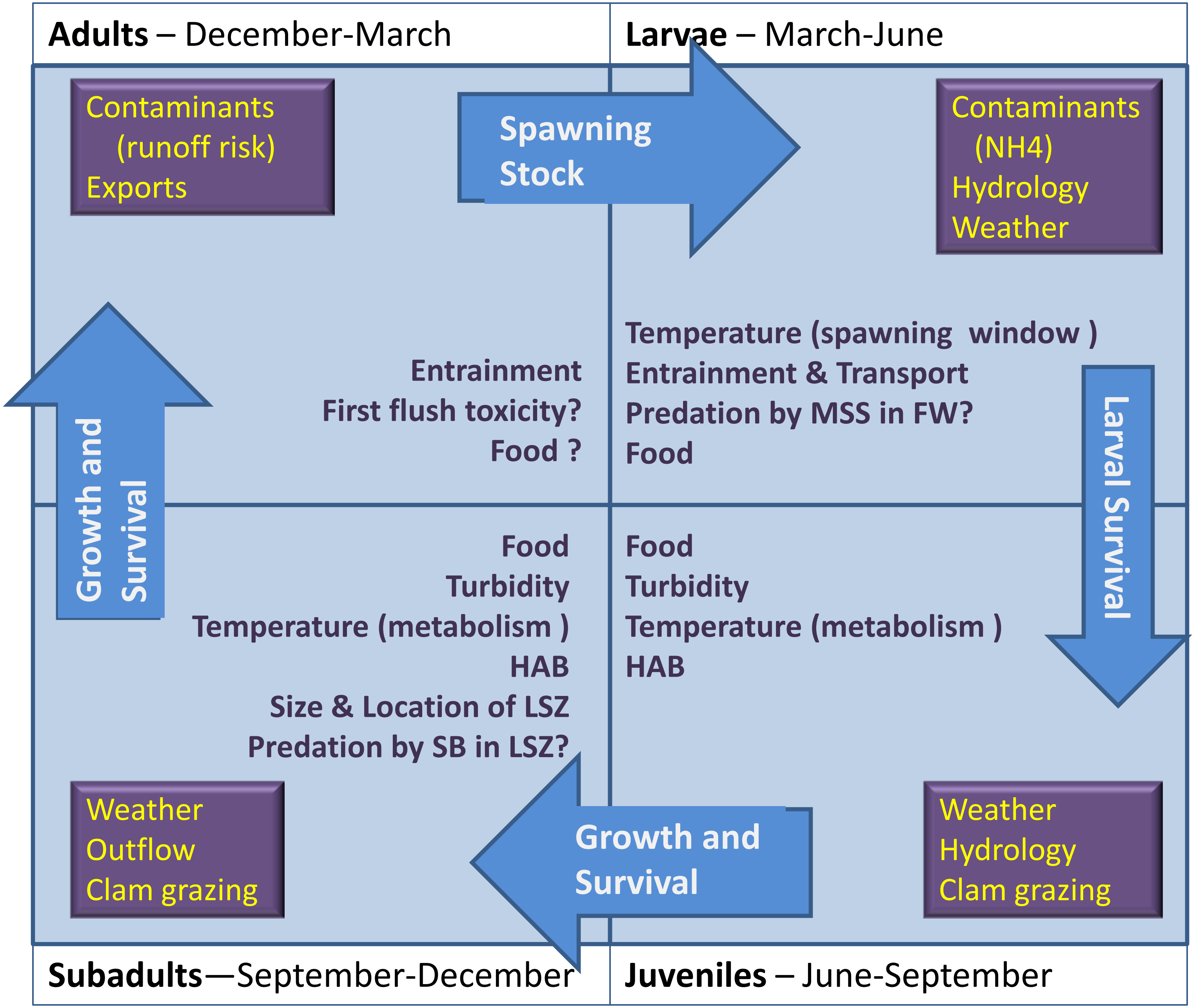



TOP-DOWN
Water Diversions
Predation
Prior Fish Abundance
FISH ABUNDANCE
PHYSICAL & CHEMICAL FISH HABITAT
Temperature
Turbidity
Salinity
Contaminants
Disease
Toxic algae
SAV
Food availability
Food quality
BOTTOM-UP

BIG Disclaimer:

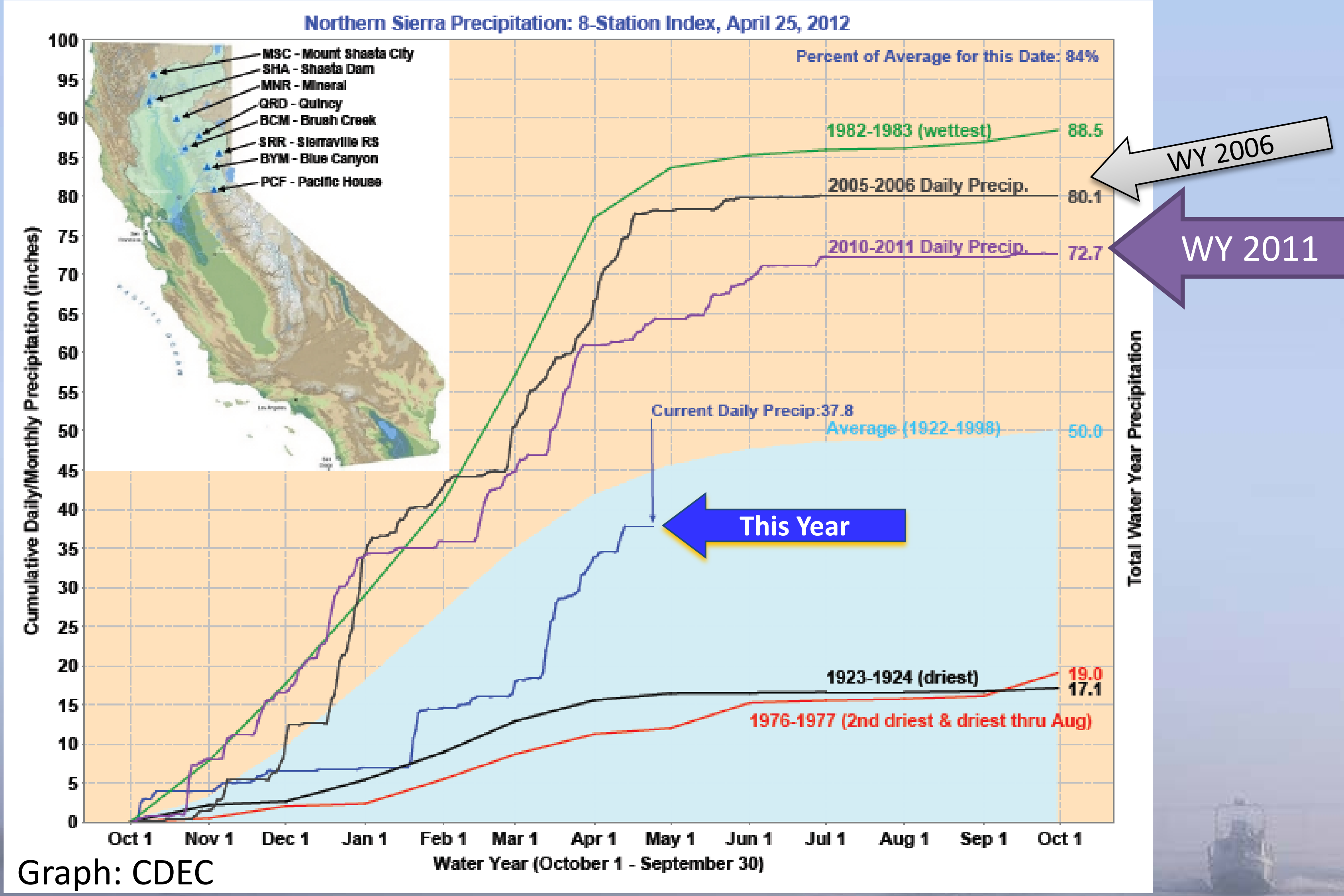
Many graphs and data and their interpretation in this presentation are PRELIMINARY and subject to change!!!

Many thanks to everyone who provided data and graphs – all errors in display and interpretation are mine, not theirs.



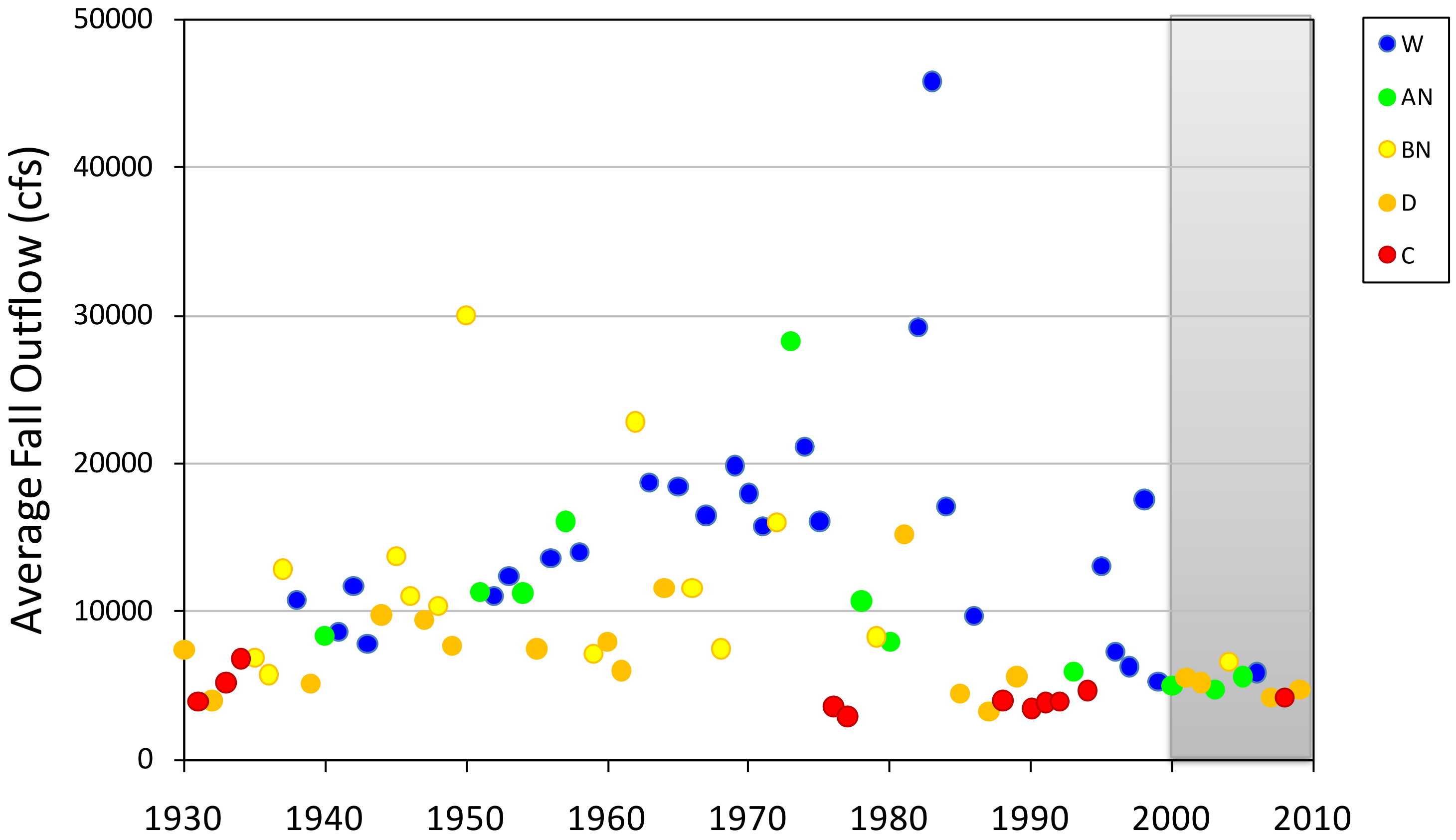
Adults – December-March
Larvae – March-June
Contaminants (runoff risk)
Exports
Spawning Stock
Contaminants (NH4)
Hydrology
Weather
Entrainment
First flush toxicity?
Food ?
Temperature (spawning window)
Entrainment & Transport
Predation by MSS in FW?
Food
Growth and Survival
Larval Survival
Food
Turbidity
Temperature (metabolism)
HAB
Size & Location of LSZ
Predation by SB in LSZ?
Food
Turbidity
Temperature (metabolism)
HAB
Weather
Outflow
Clam grazing
Growth and Survival
Weather
Hydrology
Clam grazing
Subadults—September-December
Juveniles – June-September

2011 Was Very Wet



Graph: CDEC

Results are PRELIMINARY & subject to change!



Average Fall Outflow (cfs)
50000
40000
30000
20000
10000
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
W
AN
BN
D
C

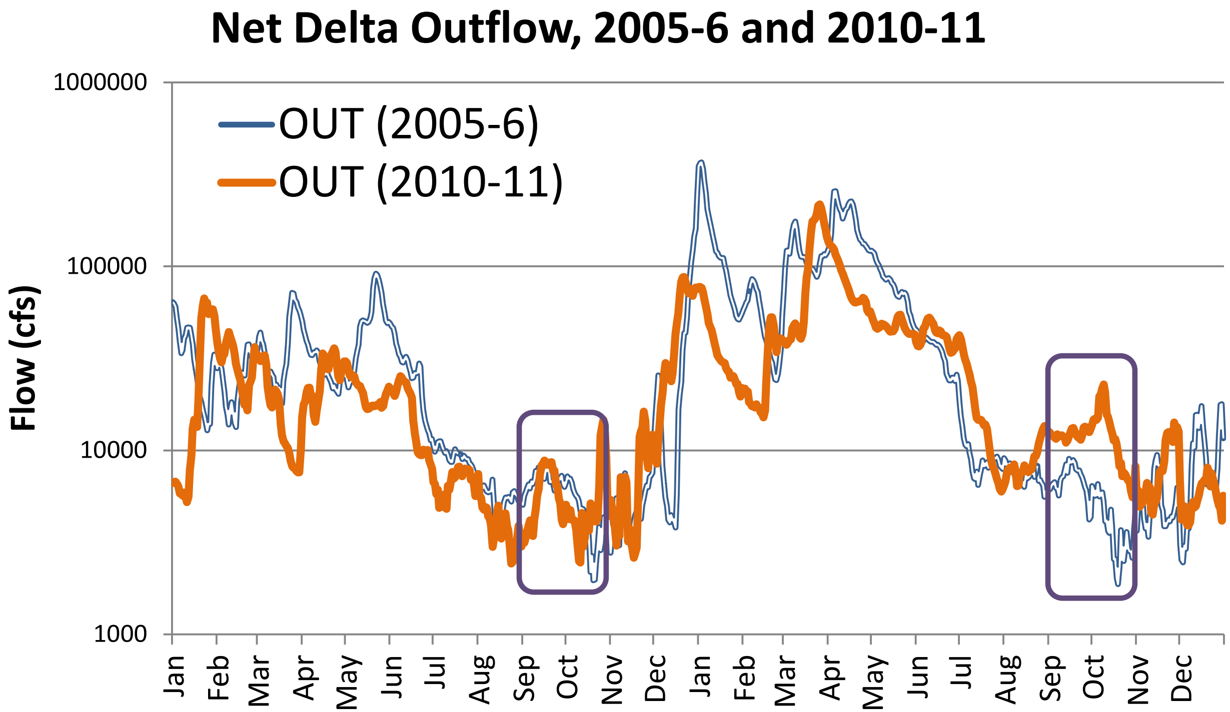
Causes of Changes in Fall Turbidity

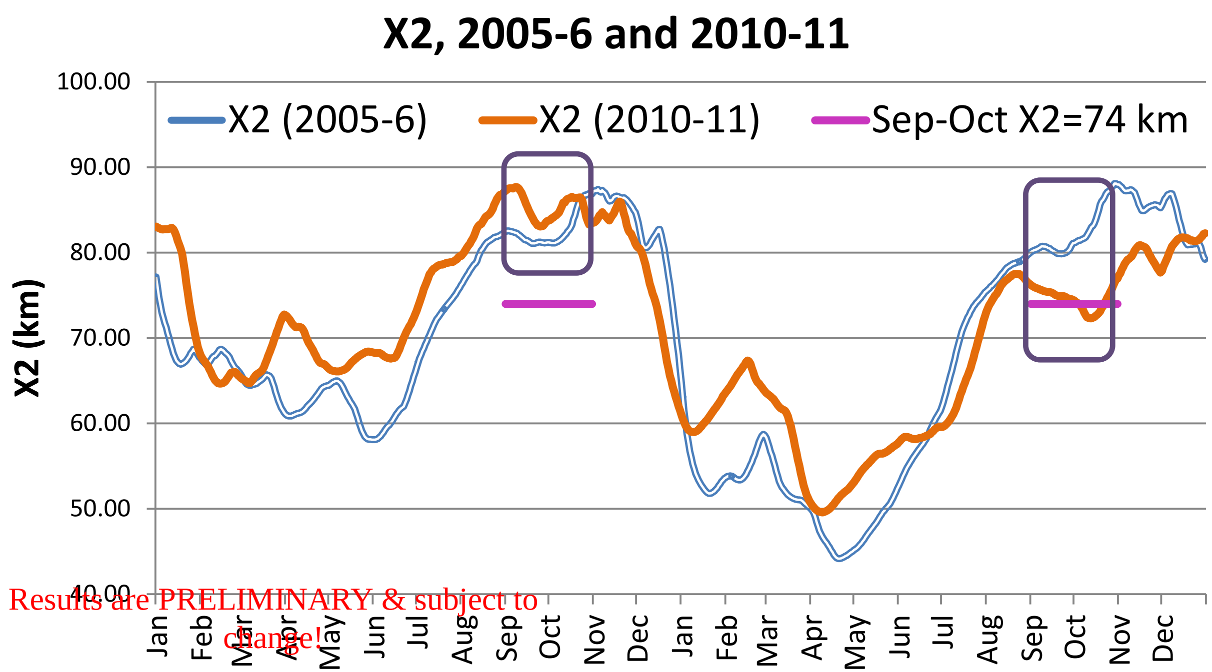
Reduced Sediment Inputs

Continued Spread by Egeria

Source: Erin Hestir (UCD), Dave Schoellhamer (USGS)

Outflow & X2





Results are PRELIMINARY & subject to change!

Data: DAYFLOW
Graphs: A. Mueller-Solger

Causes of Changes in Fall Salinity

Suisun Marsh Salinity Control Gates

Delta Cross Channel

E/I Ratios

Source: Marianne Guerin (CCWD), Dave Fullerton (MWD), Wim Kimmerer (SFSU), Chris Enright (DWR)

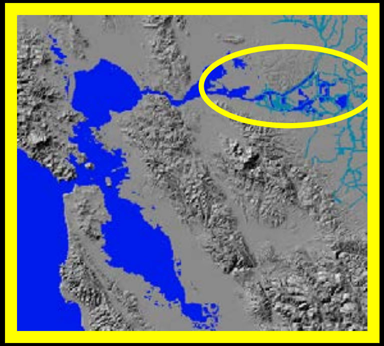

Roe Island
Chipps Island
Collinsville

Mean number of Days with X2 west of Chipps Island (Feb-Jun)

	Critical	Dry	Below Normal	Above Normal	Wet
1930-39	108	133	150		150
1940-49		131	148	151	150
1950-59		129	126	145	150
1960-75		96	99	131	145
1976-90	7	45	117	147	129

POD & Nutrients
Example: Ammonia pollution

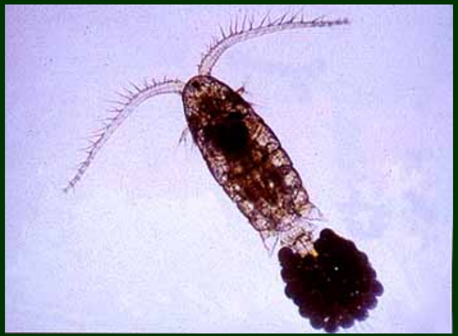
Sewage Treatment Plants

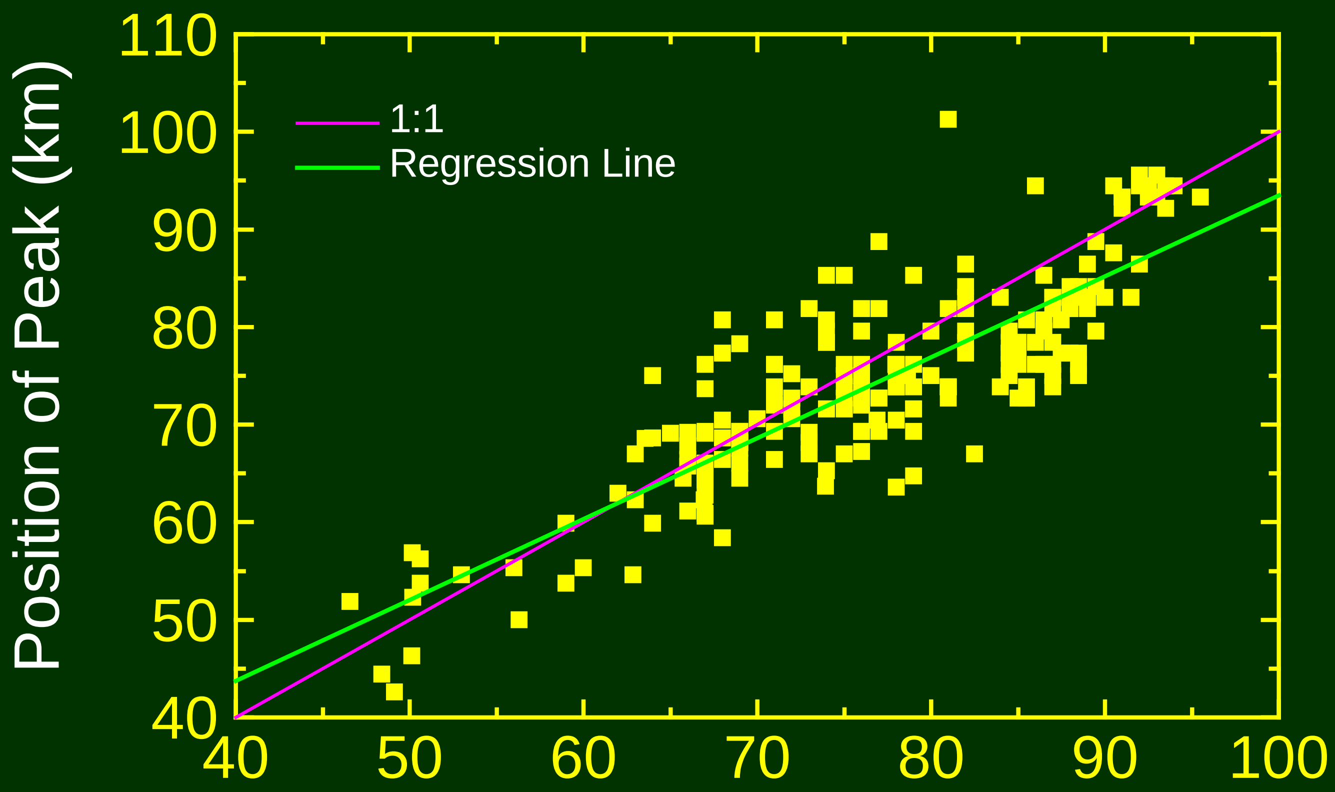


Increasing Ammonia levels in Delta and Suisun Bay

Potential Ecosystem Effects

Pelagic organisms follow salinity:
The copepod *Eurytemora affinis*



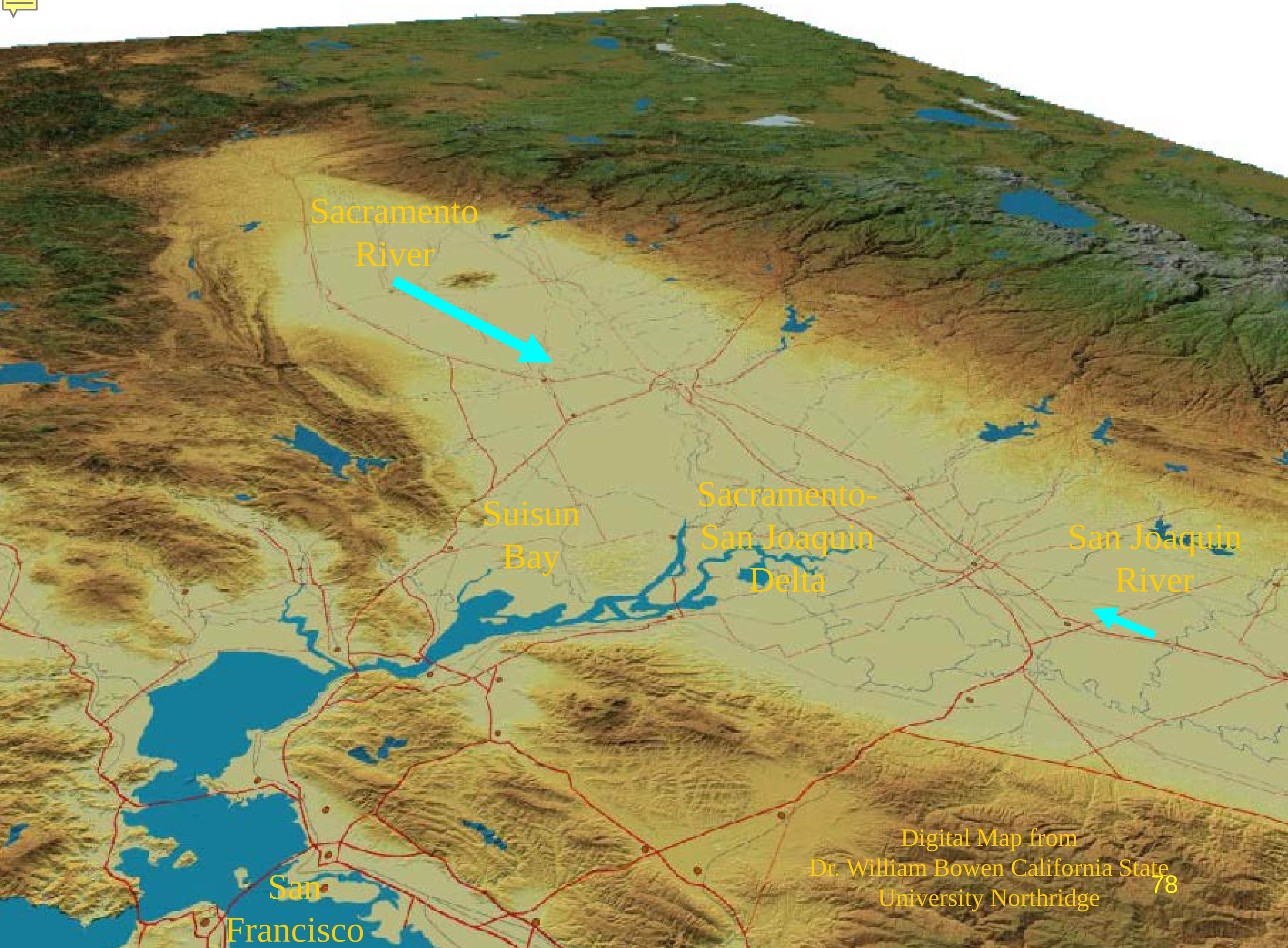


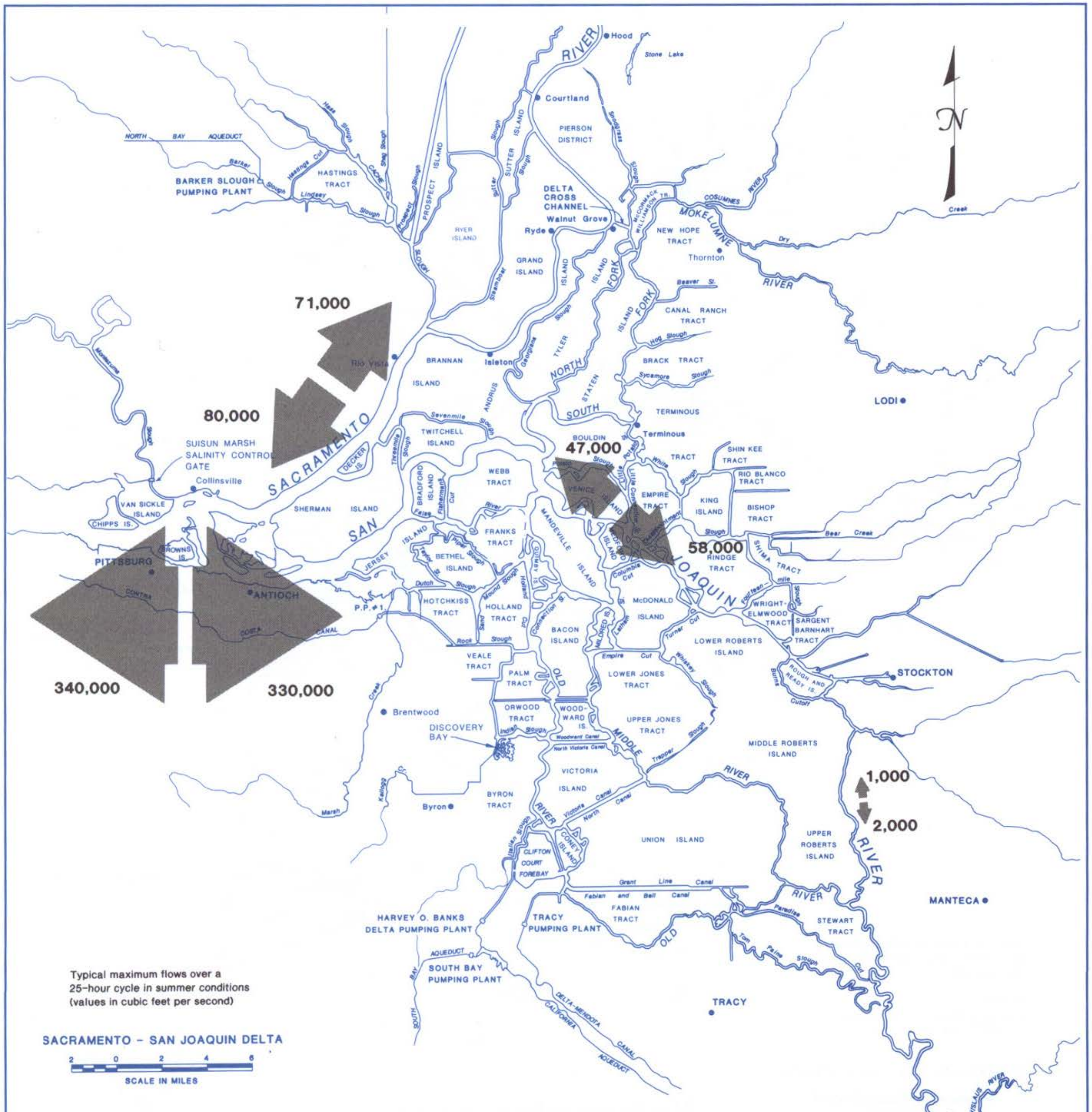
Location of 2 ppt

Kimmerer 1998

Unionized ammonia is toxic to fish

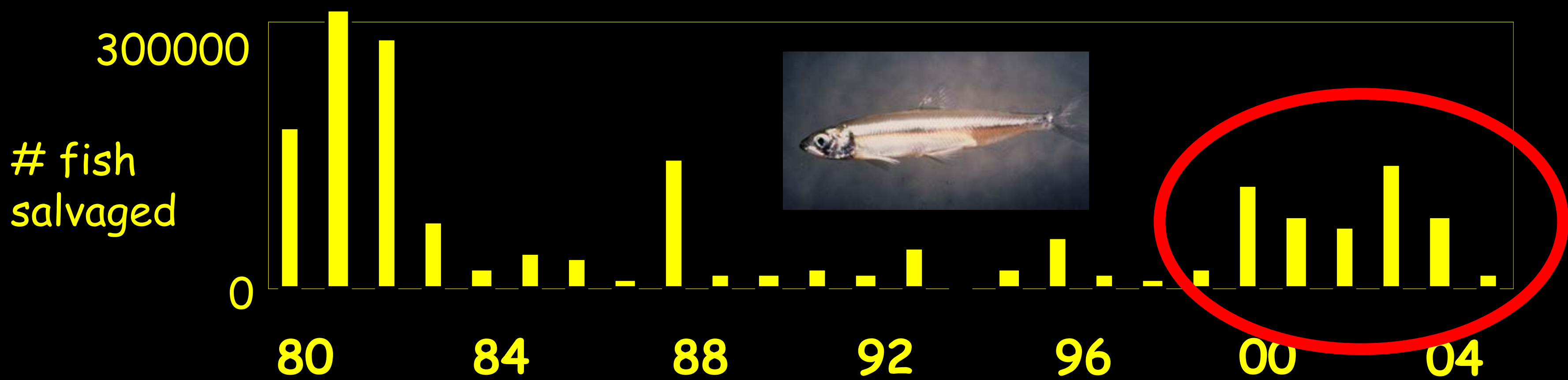
- Salmonids and smelt are particularly sensitive
    - But levels generally not high enough
- Invertebrates can be affected at observed concentrations and some impacts demonstrated
- Occasional Diatom inhibition, but light usual limiter
- Phytoplankton species compositions very likely changed


Sacramento
River
Suisun
Bay
Sacramento-
San Joaquin
Delta
San Joaquin
River
San
Francisco
Digital Map from
Dr. William Bowen California State
University Northridge



Delta Tidal Flows

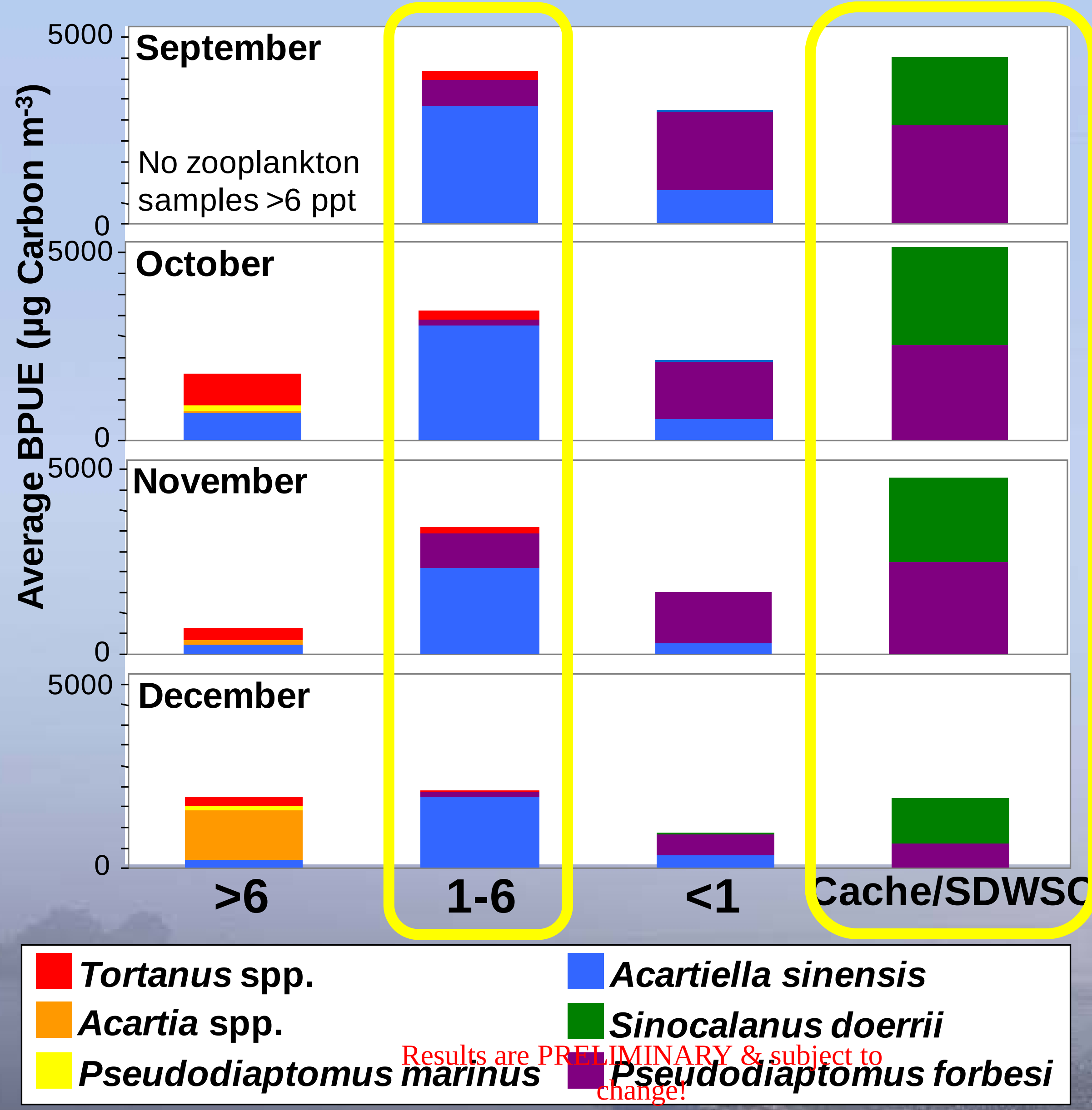
Evidence of Increased Entrainment of Adult Delta Smelt During Winter



Source: IEP (2005), Grimaldo (In prep)

Zooplankton Biomass (1)

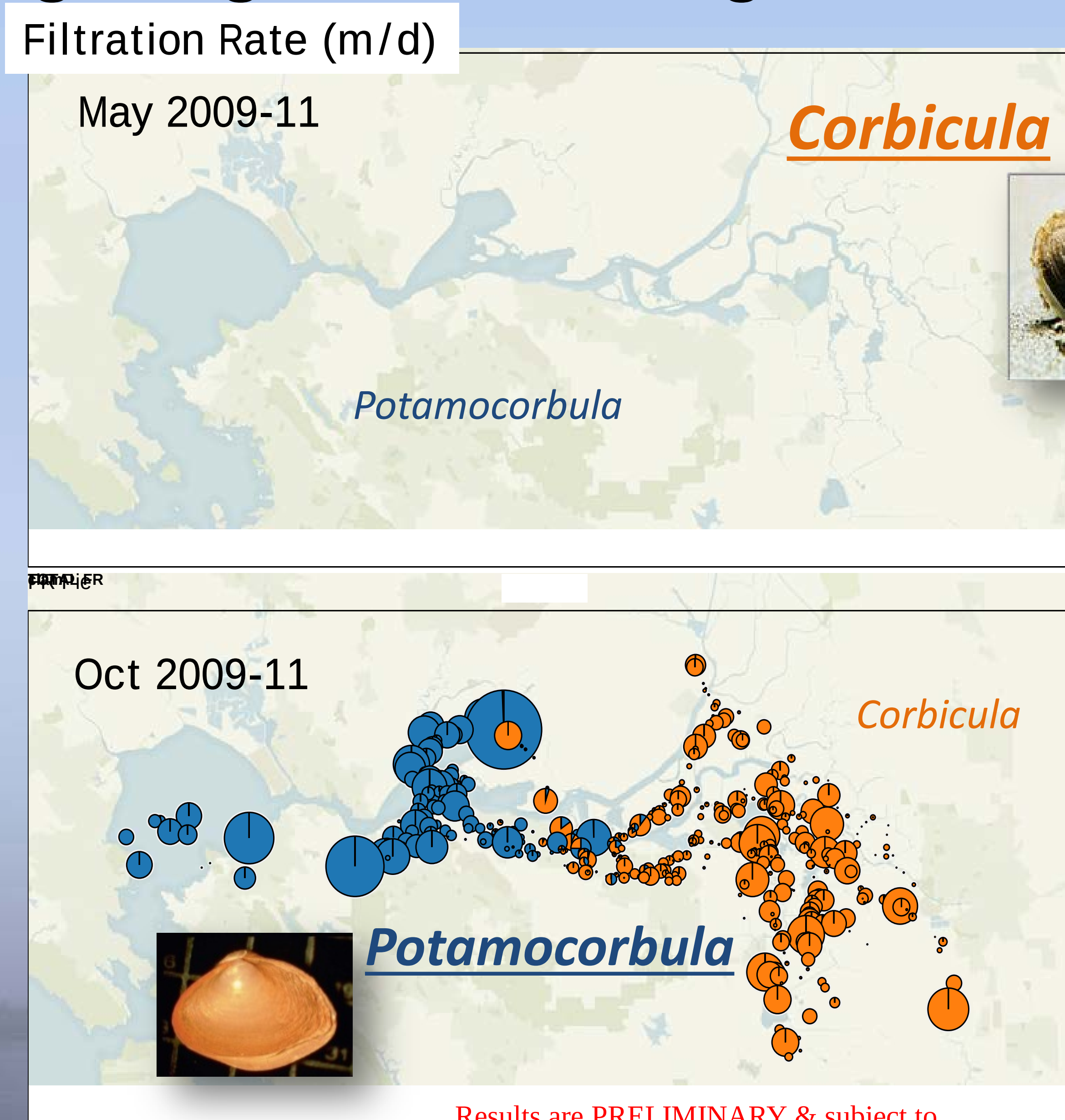
High adult calanoid copepod biomass in LSZ & Cache/DWSC in fall 2011

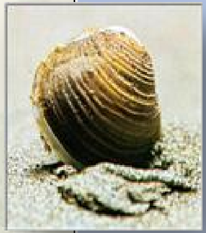


Data: FMWT

Graph: A. Hennessy, DFG

Clam grazing in the LSZ is higher in fall than in spring

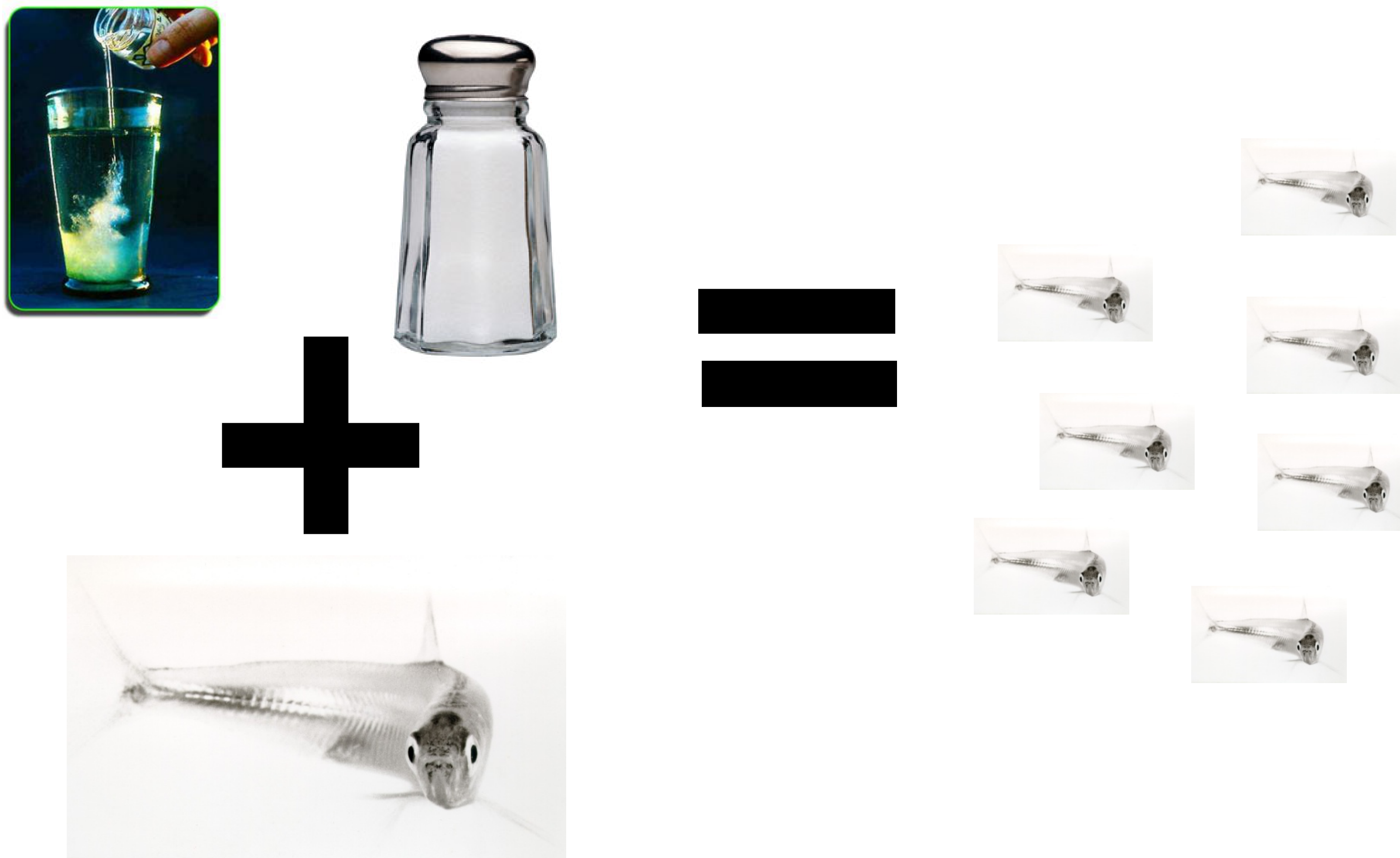




Data: IEP EMP “GRTS” & Jan Thompson, USGS; Graphs: Jan Thompson, USGS

Results are PRELIMINARY & subject to change!

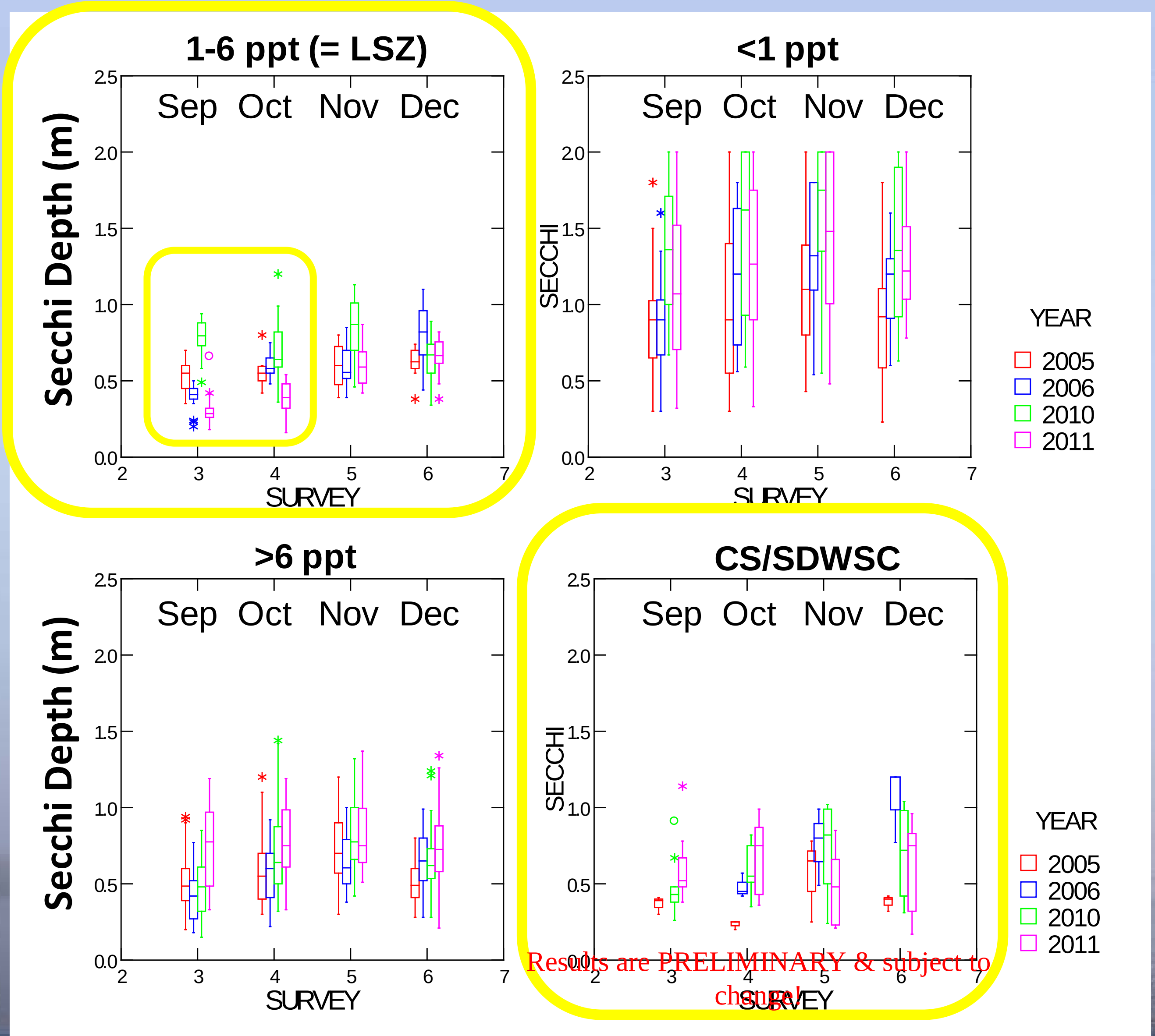
Fall "habitat quality" matters to the delta smelt population



Fall EQ + Fall Abundance predicts juvenile production

Turbidity (1)

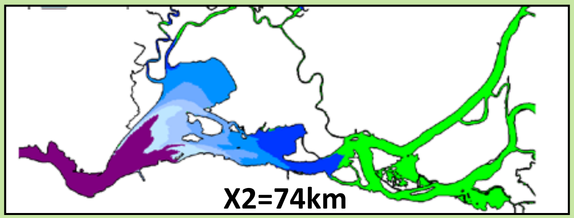
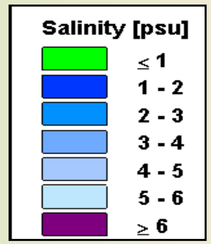
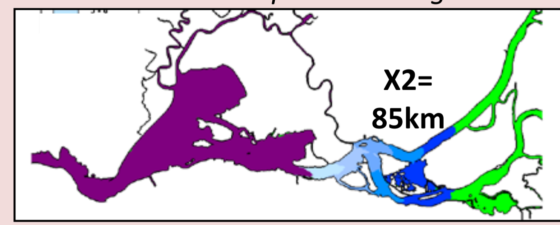
Monthly Secchi depths lowest in the LSZ and CS/SDWSC (= most turbid).
In LSZ, lowest Secchi depths in Sep & Oct 2011.

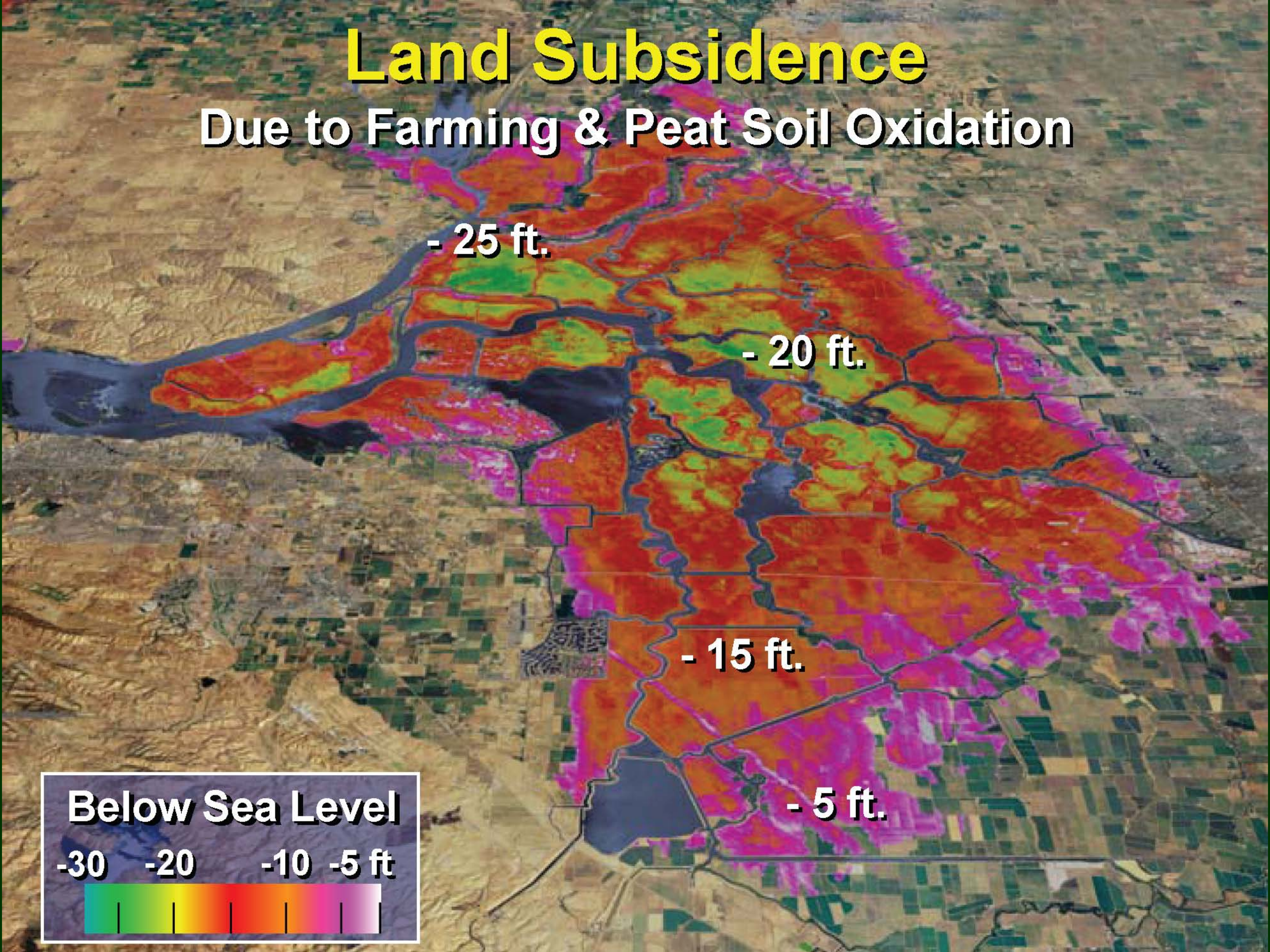


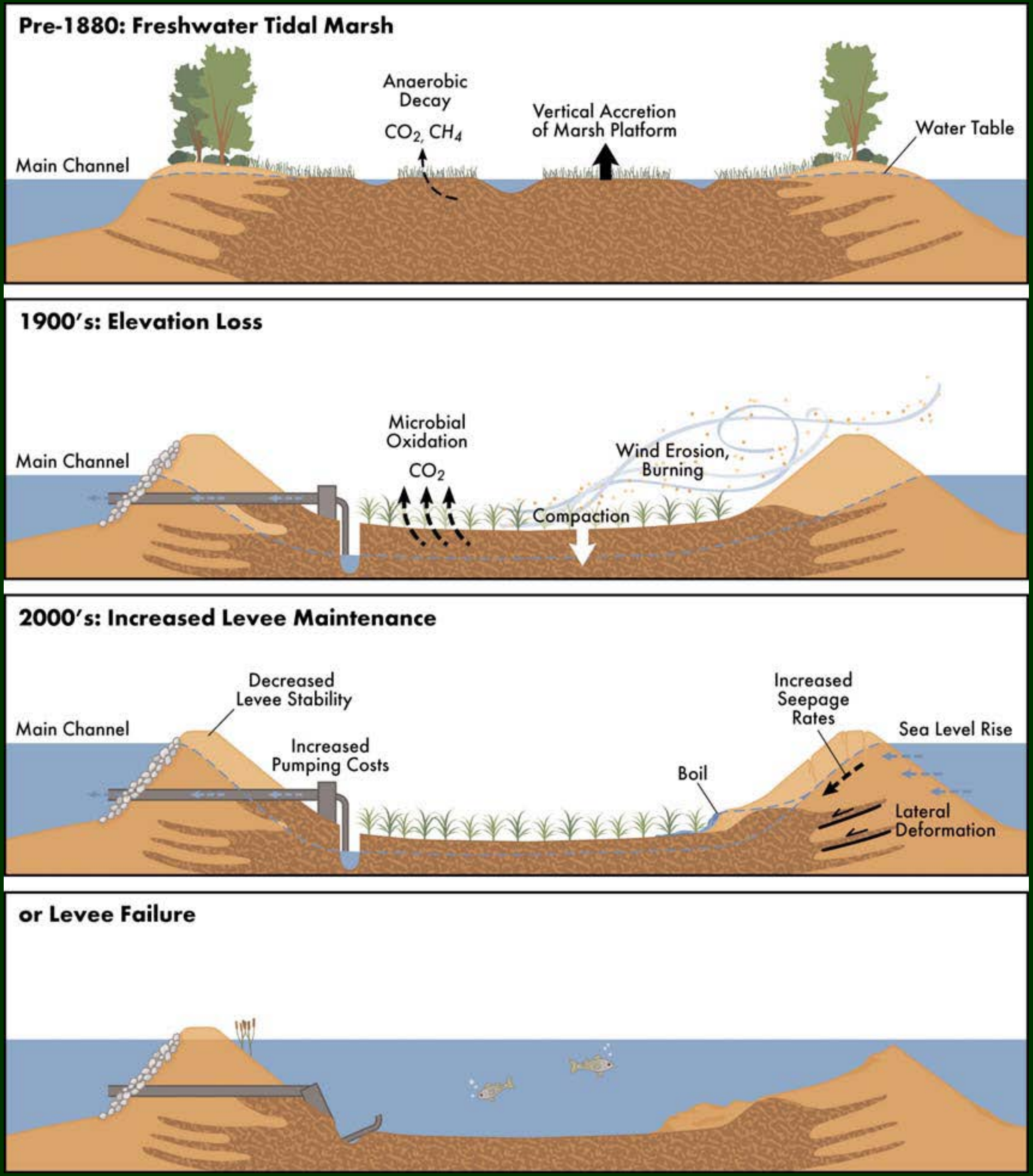
Data: IEP FMWT
Graphs:
S. Slater, DFG

1994 X2 requirements

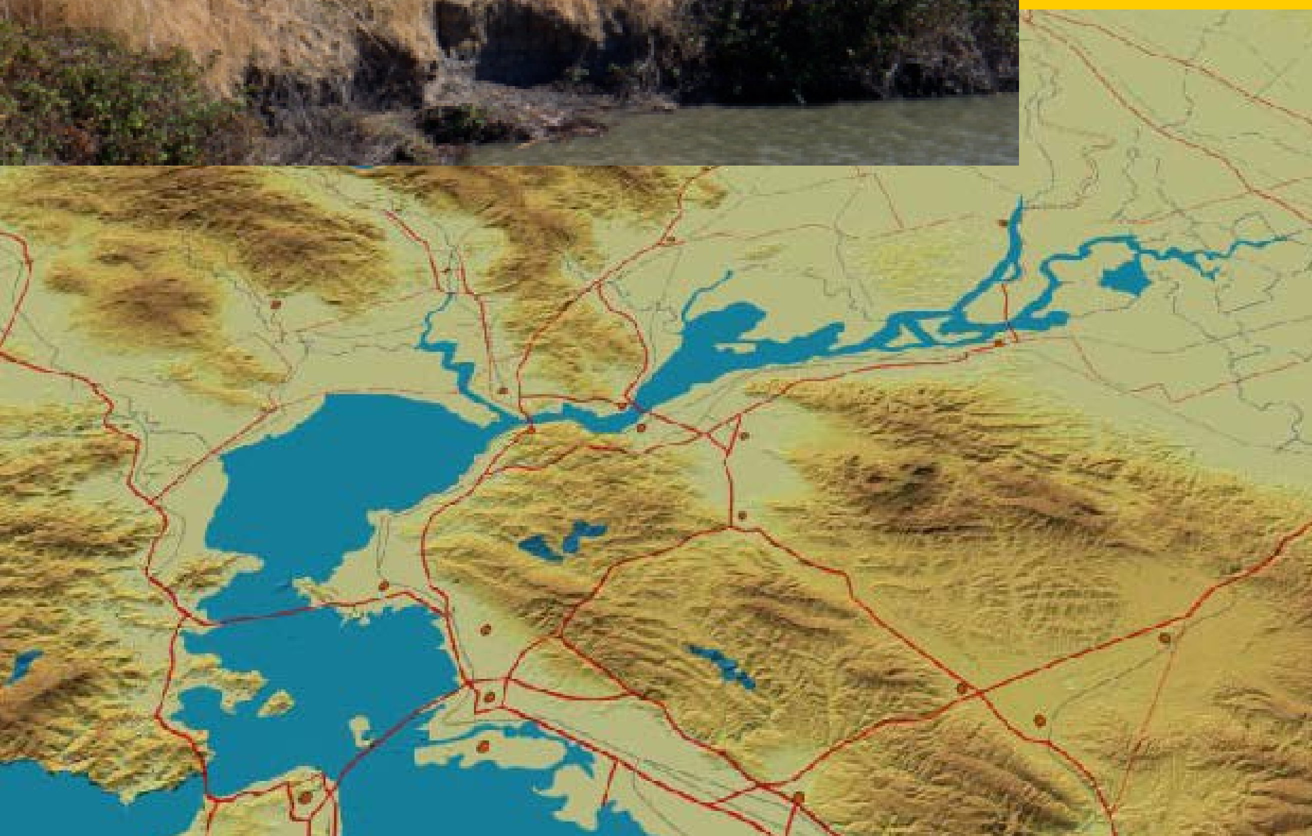
- Inflow on 8 Rivers in previous month, Feb- Jun
- Sets number of days for X2 west of each location,
  - More westward days when wet
  - Less in later months

Suisun Region	Stationary Abiotic Habitat Components	River Confluence
Higher	Bathymetric Complexity	*Lower*
Higher	Erodible Sediment Supply	*Lower*
Many in South, Fewer in North	Contaminant Sources	*Many*
Fewer	Entrainment Sites	*More*
Variable Fall Outflow Regime	**Dynamic Abiotic Habitat Components**	***Static Fall Outflow Regime***
Higher After Wet Springs	Net Total Delta Fall Outflow	*Always Low*
Higher After Wet Springs	San Joaquin River Contribution to Fall Outflow	*Always Low*
After Wet Springs, Broad Fall LSZ Overlaps Suisun Region 	Location and Extent of the Fall LSZ (1-6 psu) 	*Narrow Fall LSZ In River Channels, Never Overlaps Suisun Region* 
Higher After Wet Springs	Hydrodynamic Complexity in the Fall LSZ	*Always Lower*
Higher After Wet Springs	Wind speed in the Fall LSZ	*Always Lower*
More Variable, Higher After Wet Springs	Turbidity in the Fall LSZ	*Always Less Variable, Lower*
More Variable, Maybe Lower After Wet Springs	Contaminant Concentrations in the Fall LSZ	*Less Variable, Maybe Higher*
LSZ Overlaps Suisun Region	**Dynamic Biotic Habitat Components**	***LSZ Overlaps River Confluence***
Higher	Food Availability and Quality	*Lower*
Variable	Predator Abundance	*Higher*
LSZ Overlaps Suisun Region	**Delta Smelt Responses**	***LSZ Overlaps River Confluence***
Broad, Westward	Distribution	*Constricted, Eastward*
Higher	Growth, Survival, Fecundity	*Lower*
Better	Health and Condition	*Worse*
May be Higher	Recruitment in the next Spring	*Lower*


Land Subsidence
Due to Farming & Peat Soil Oxidation
- 25 ft.
- 20 ft.
- 15 ft.
- 5 ft.
Below Sea Level
-30 -20 -10 -5 ft

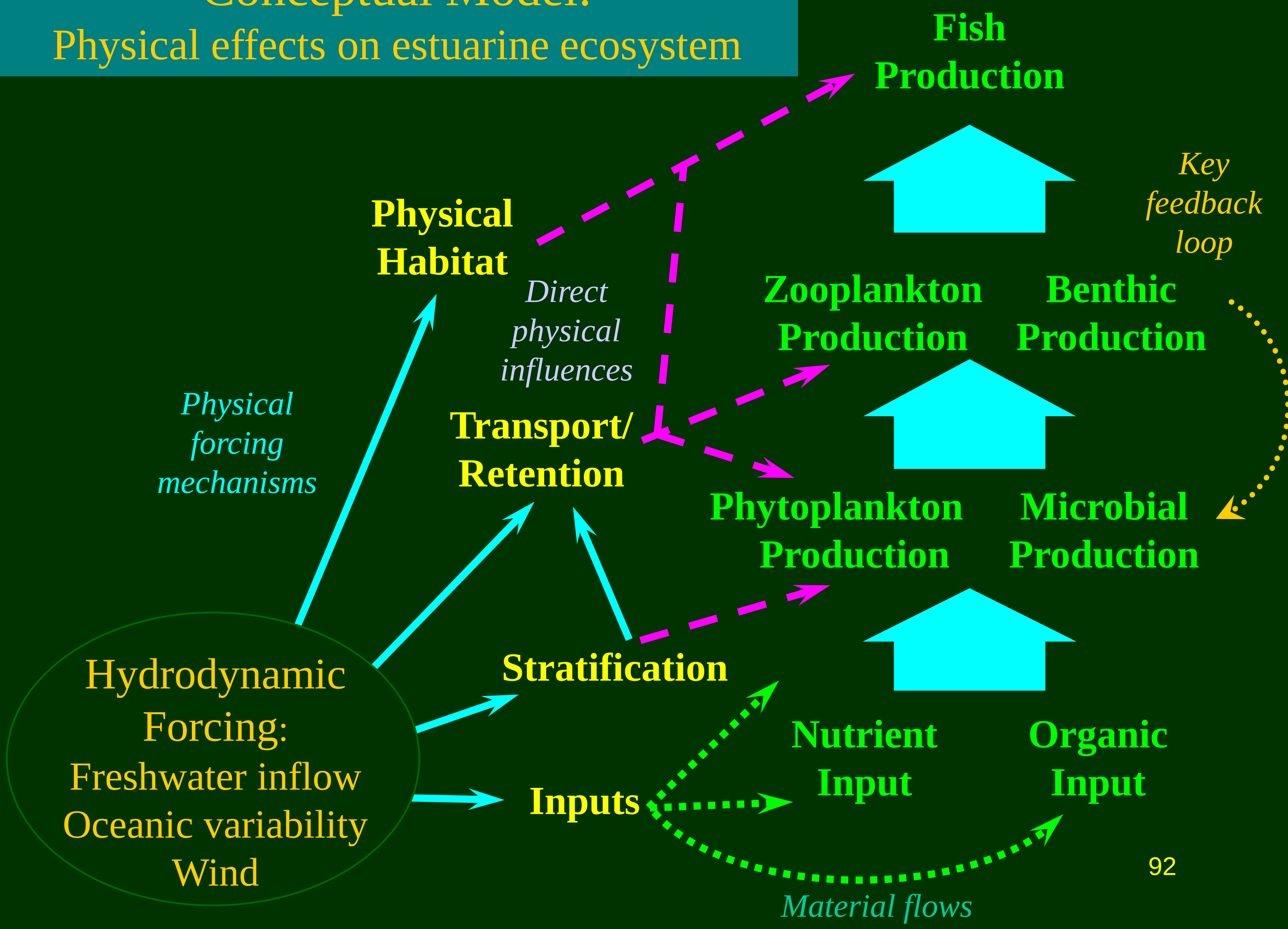

Pre-1880: Freshwater Tidal Marsh
Anaerobic Decay
CO_2, CH_4
Vertical Accretion of Marsh Platform
Water Table
Main Channel
1900's: Elevation Loss
Microbial Oxidation
CO_2
Wind Erosion, Burning
Main Channel
Compaction
2000's: Increased Levee Maintenance
Decreased Levee Stability
Increased Seepage Rates
Main Channel
Sea Level Rise
Increased Pumping Costs
Boil
Lateral Deformation
or Levee Failure

Flows are important but so is geometry




SACRAMENTO
Davisville
Batavia
Elk Grove
NAPA
FAIRFEILD
Suisun
Rio Vista
Vallejo
SAN PABLO BAY
SUISUN BAY
Benicia
Newport
MARTINEZ
SAN RAFAEL
Mokelumne
STOCKTON
Lathrop
Nortonville
MT. DIABLO BASE LINE
MT. DIABLO MERIDIAN
MONTE DIABLO
OAKLAND
SAN FRANCISCO
BAY OF SAN FRANCISCO
CONTRA COSTA
ALAMEDA
SAN JOAQUIN
COSUMNES
MOKELUMNE
CALAVERAS
STANISLAUS
MODESTO
Empire City
San Joaquin City
REDWOOD

Conceptual Model:
Physical effects on estuarine ecosystem



VAMP

Vernalis Adaptive Management Program

VAMP

- 12 year study on delta survival of San Joaquin salmon; 5 years done
- 5 experimental flow/export combinations
- Midwater trawl, Kodiak trawl and adult ocean captures supply data


Head of Old River Barrier

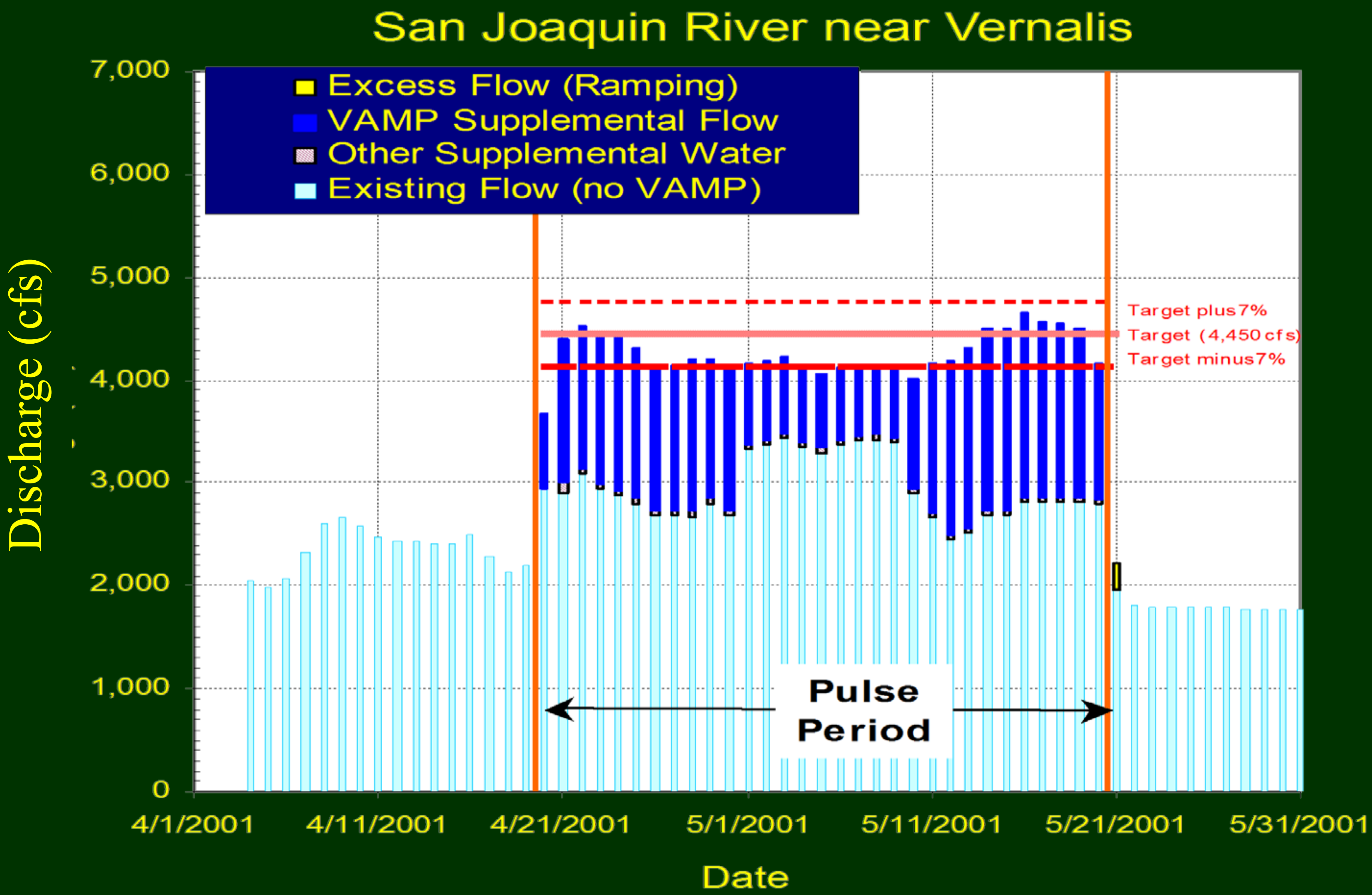
VAMP Target conditions

Flow at Vernalis (cfs)

Exports (cfs)

	3200	4450	5700	7000
1500	A	B		C
2250			D	
3200				E

Actual VAMP flows



VAMP Conditions (so far)

Flow at Vernalis

Exports

	3200	4450	5700	7000
1500	2002 2003 2004	2001		C
2250			2000	
3200				E

Management Implications

- Actual adaptive management
- Protective of salmon and estuarine species
- Short-term support
- Long-term implications