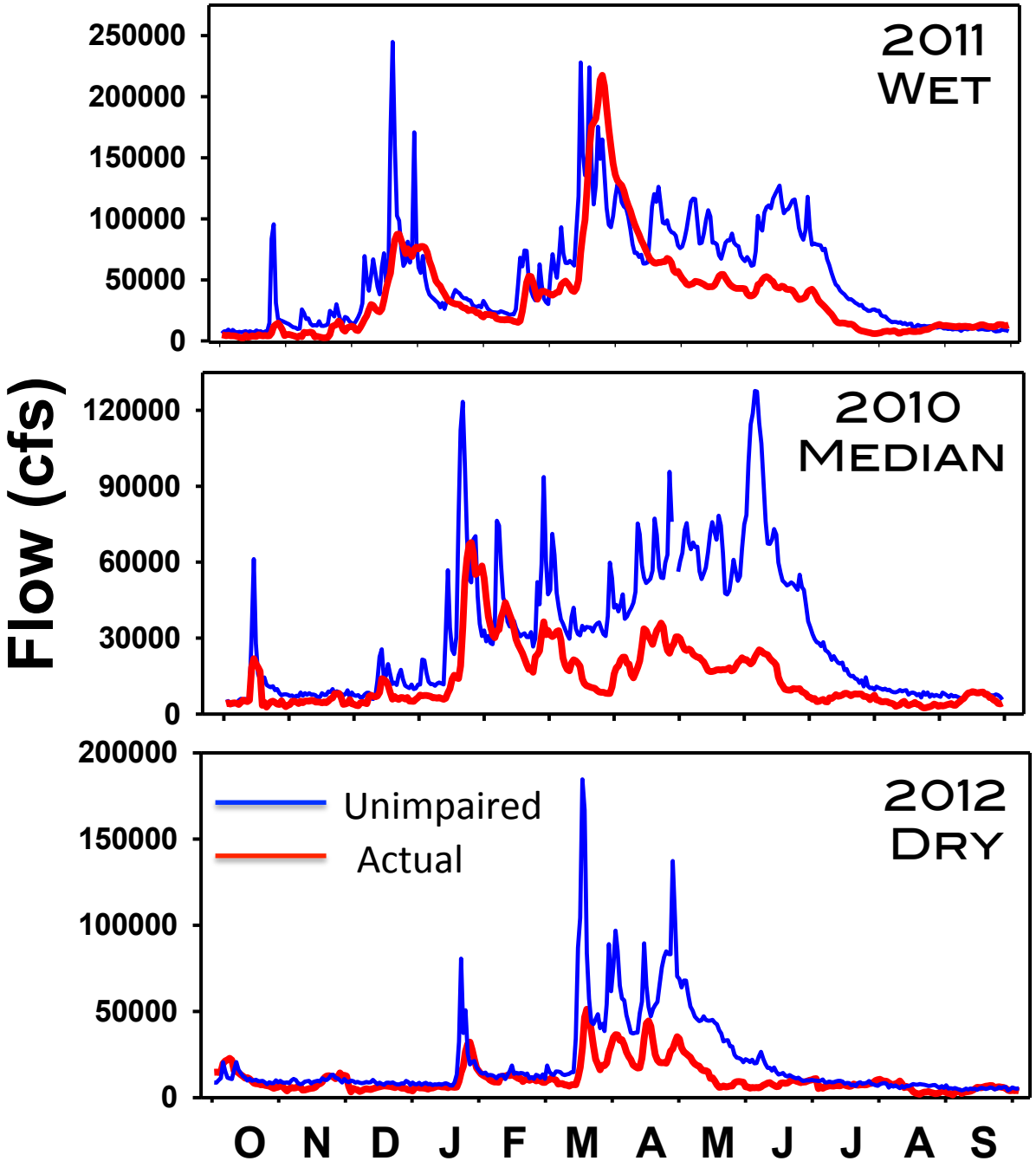
Trends in Delta Outflow and Population Dynamics of Bay-Delta Fish Species

Christina Swanson, Ph.D.
Director, Science Center
Natural Resources Defense Council

Jon Rosenfield, Ph.D.
Conservation Biologist
The Bay Institute



Wet

Annual: 58% of unimpaired

Spring: 59% of unimpaired

Median

Annual: 39% of unimpaired

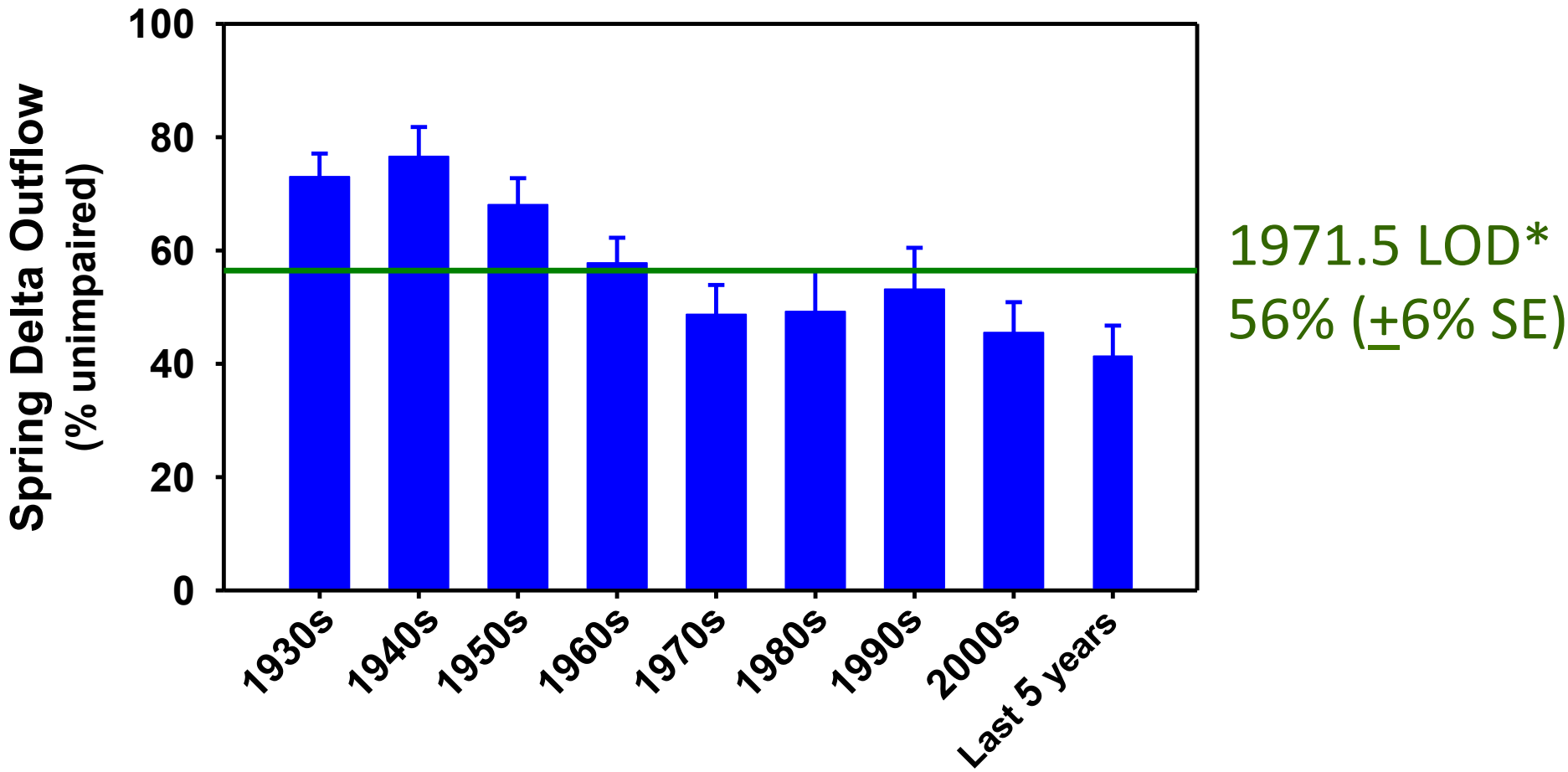
Spring: 34% of unimpaired

Dry

Annual: 50% of unimpaired

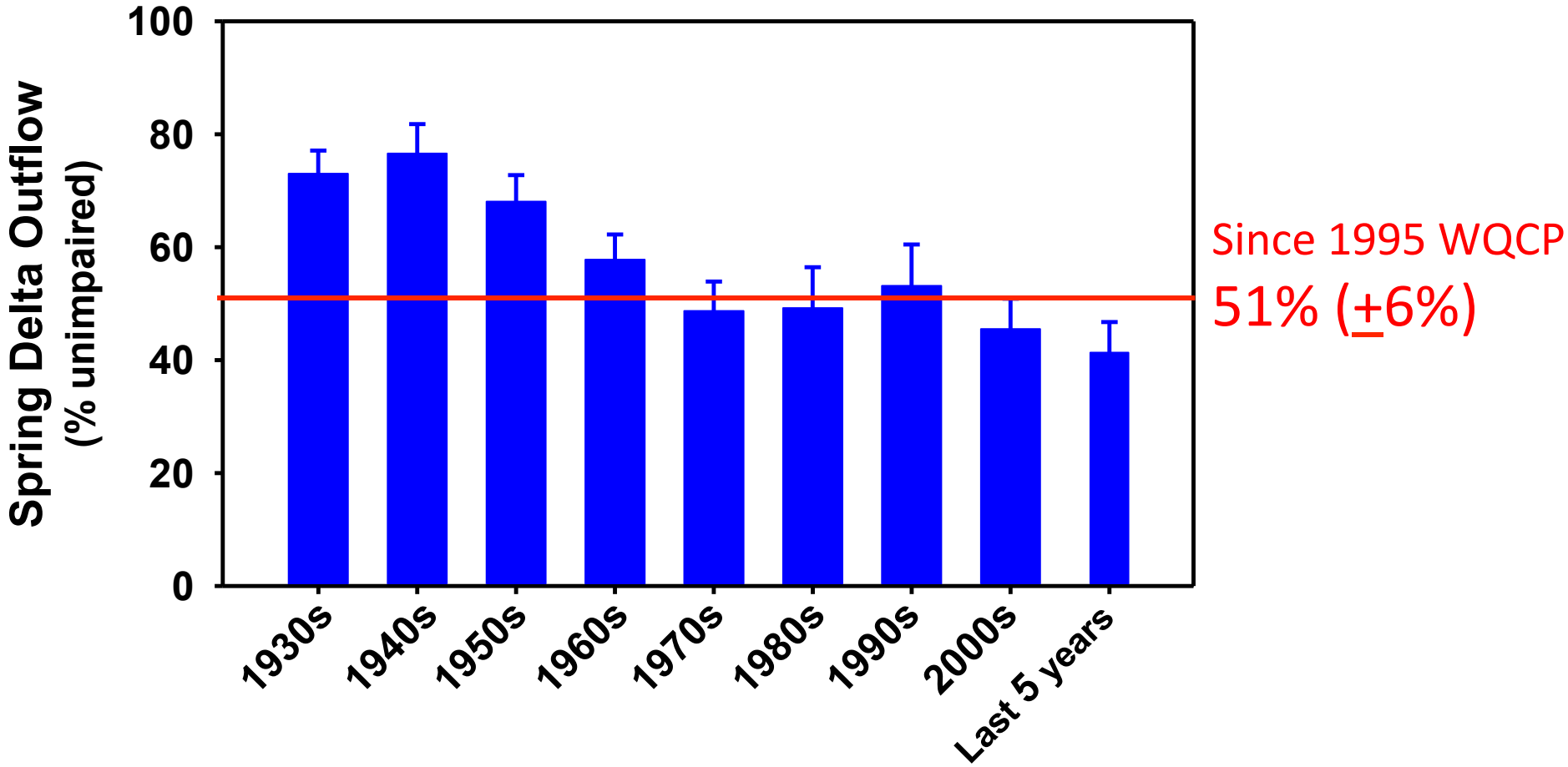
Spring: 43% of unimpaired

Spring Delta Outflow (% unimpaired) has declined

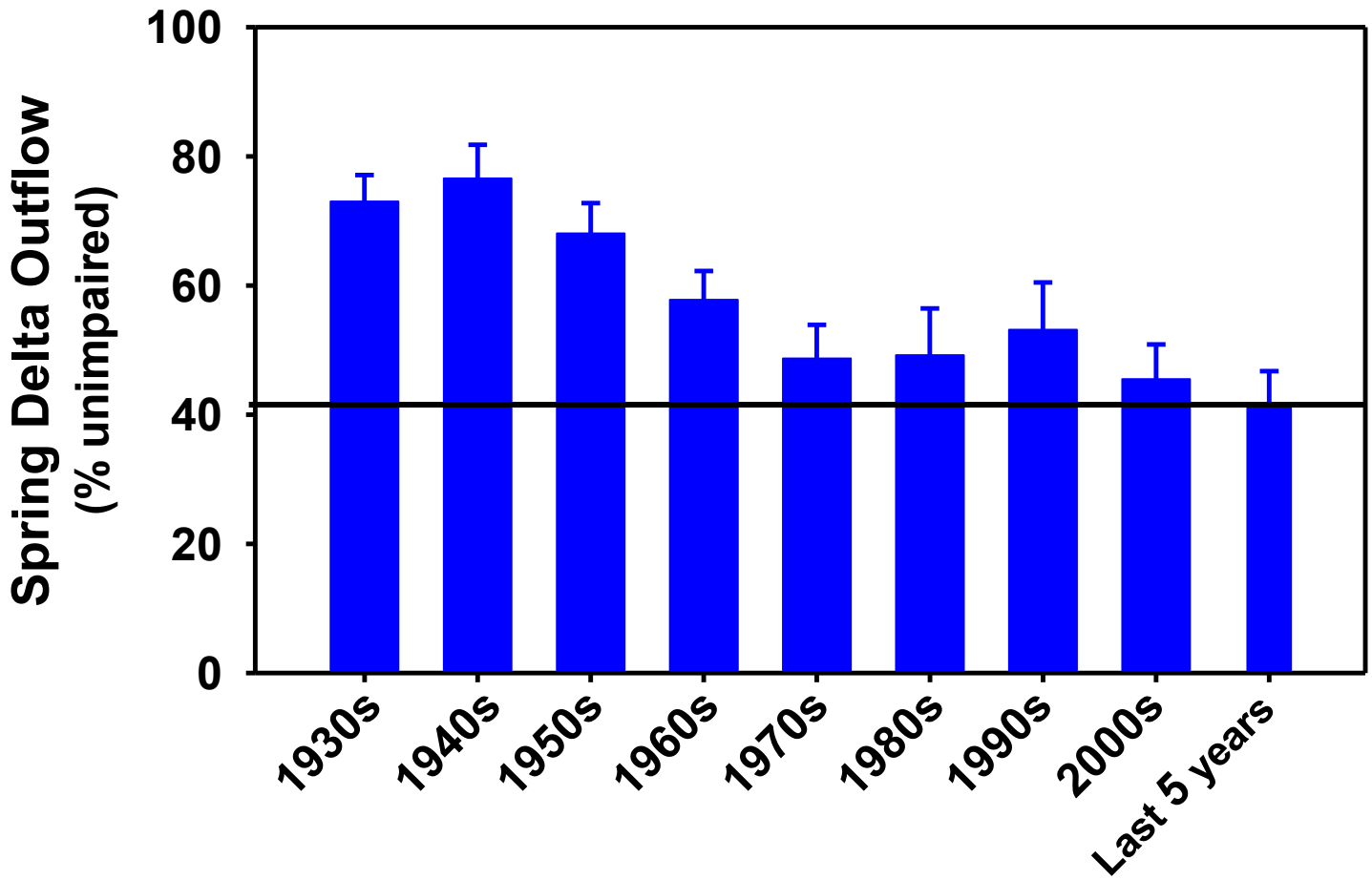


*LOD = Level of Development

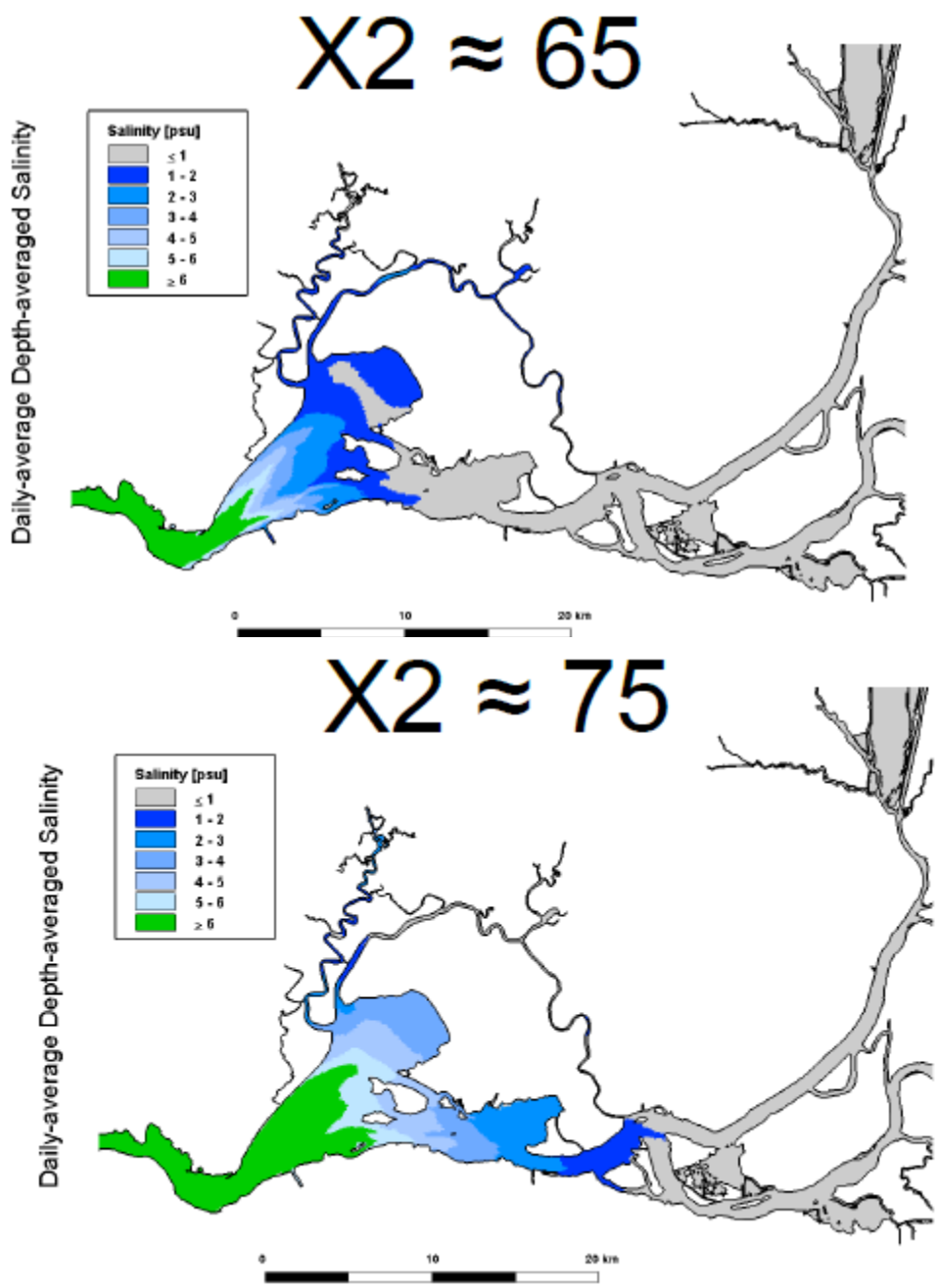
Spring Delta Outflow (% unimpaired) has declined



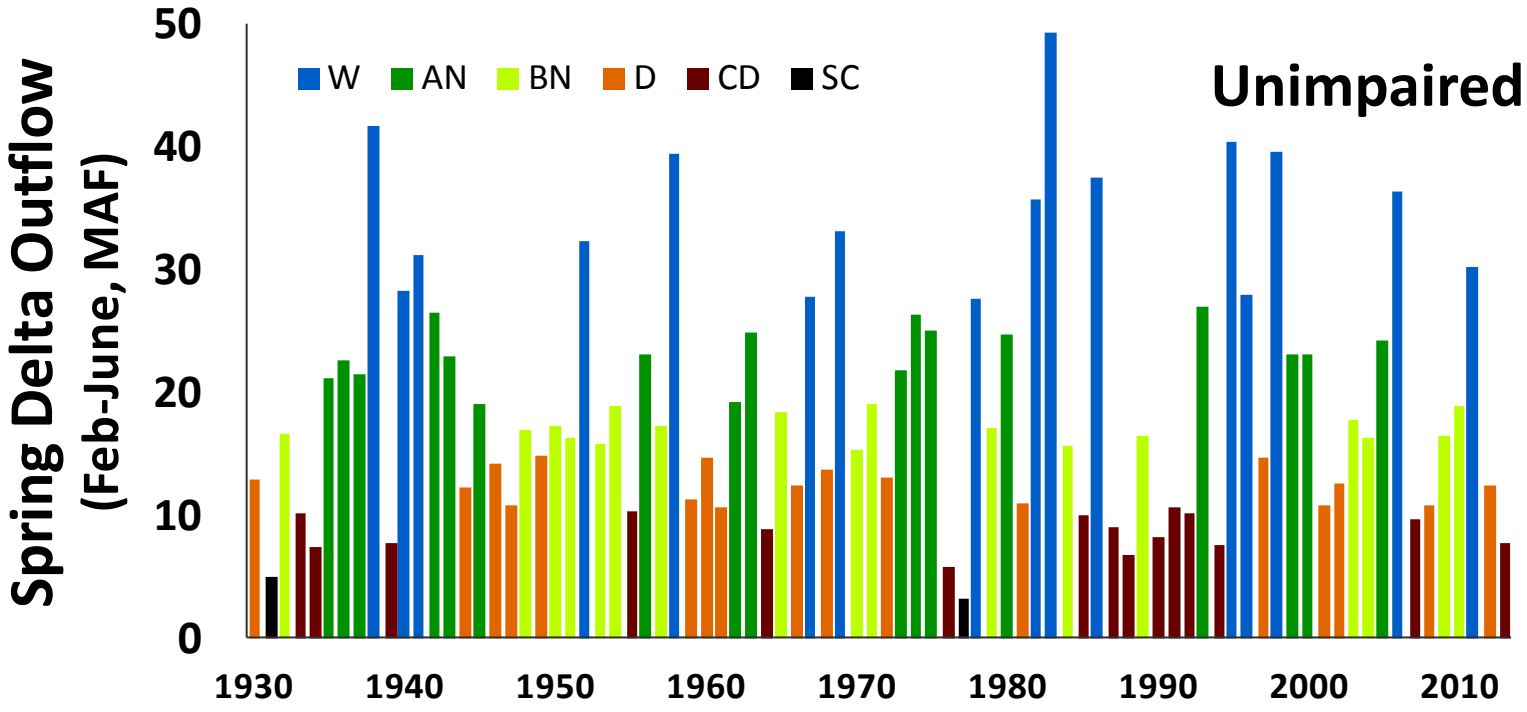
Spring Delta Outflow (% unimpaired) has declined

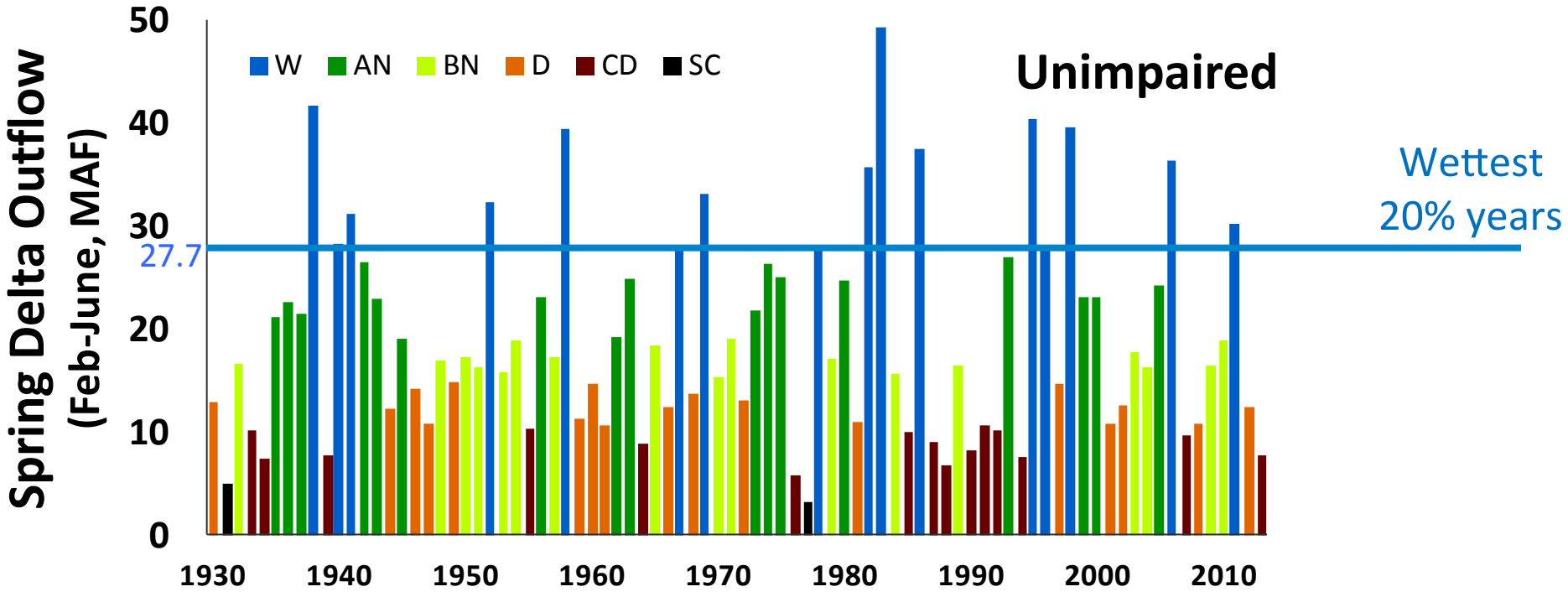


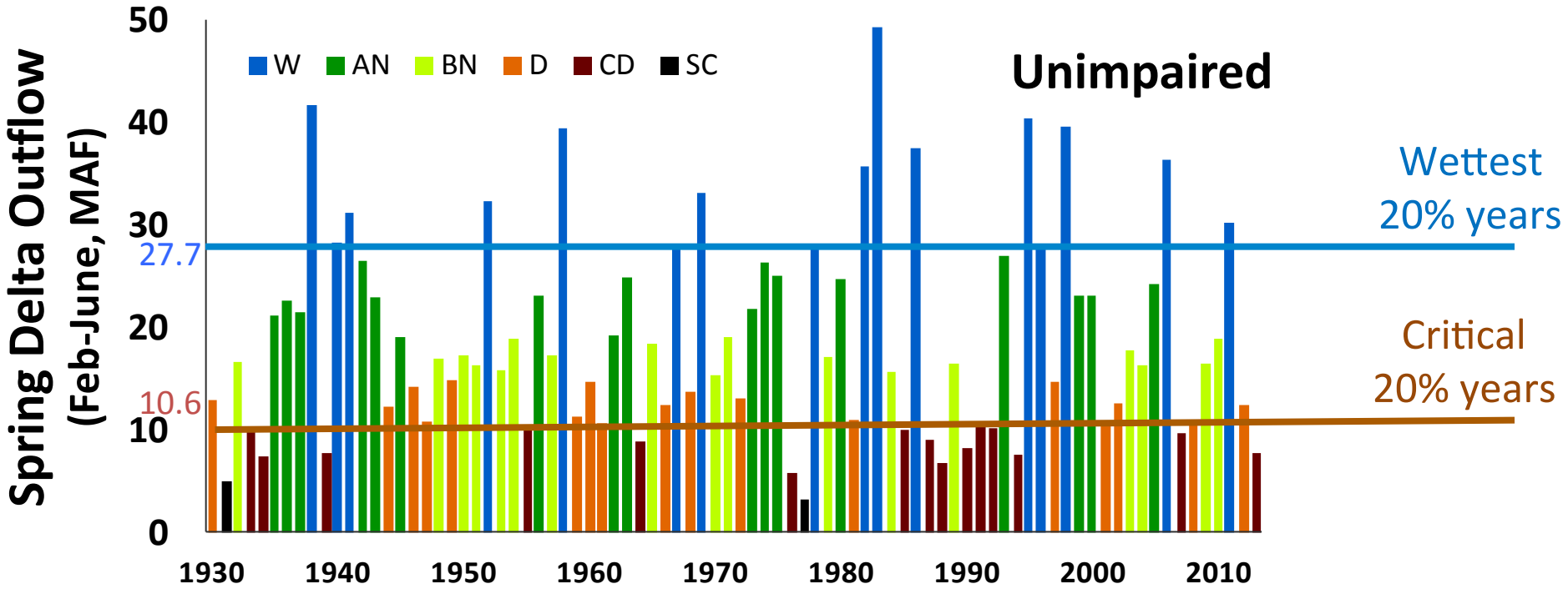
Last 5 years
41% (±5% SE)

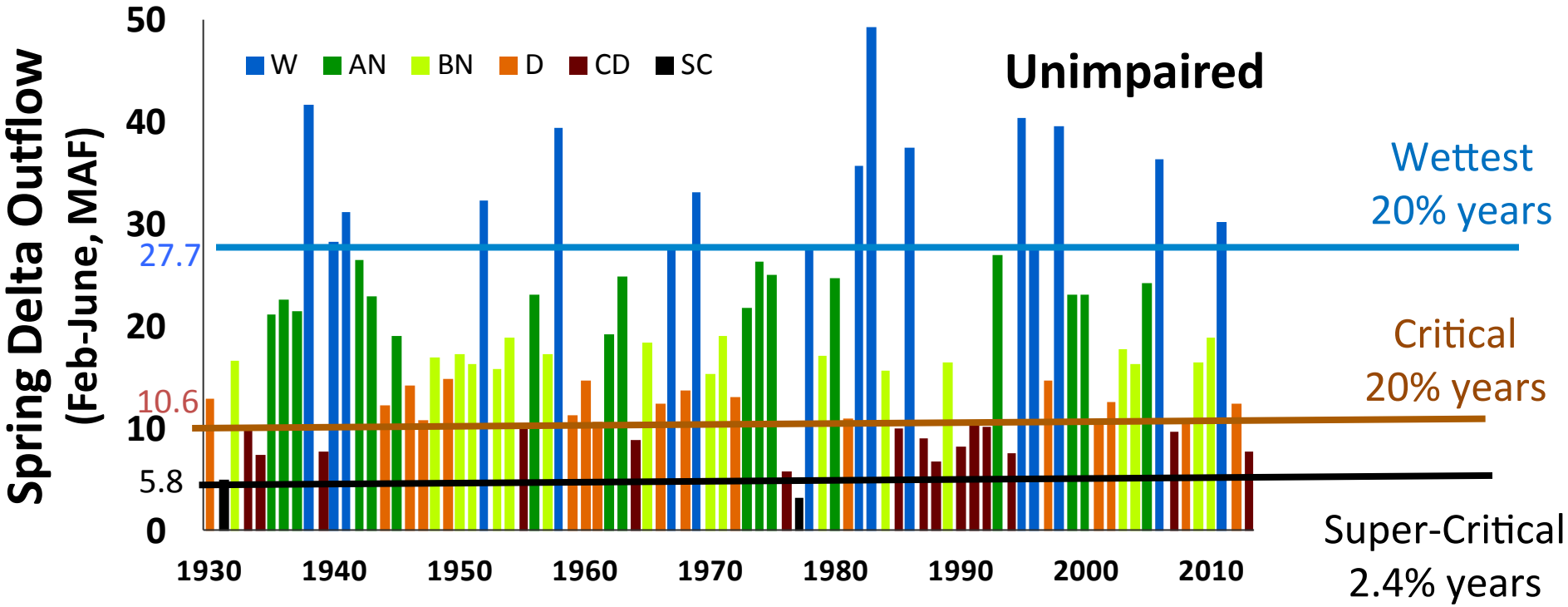


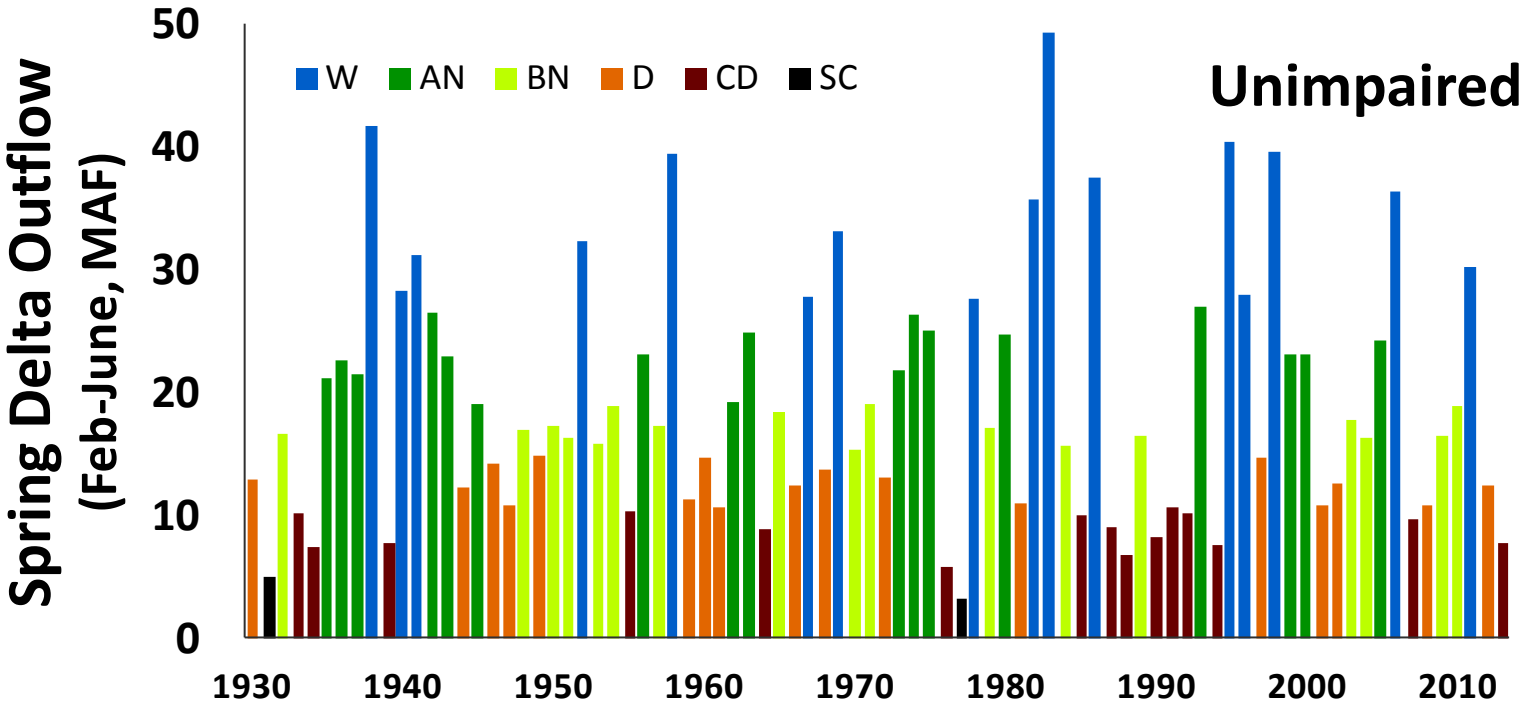
- Delta outflow creates and controls location of low-salinity habitat
- X2 used as indicator of outflow, often interchangeably

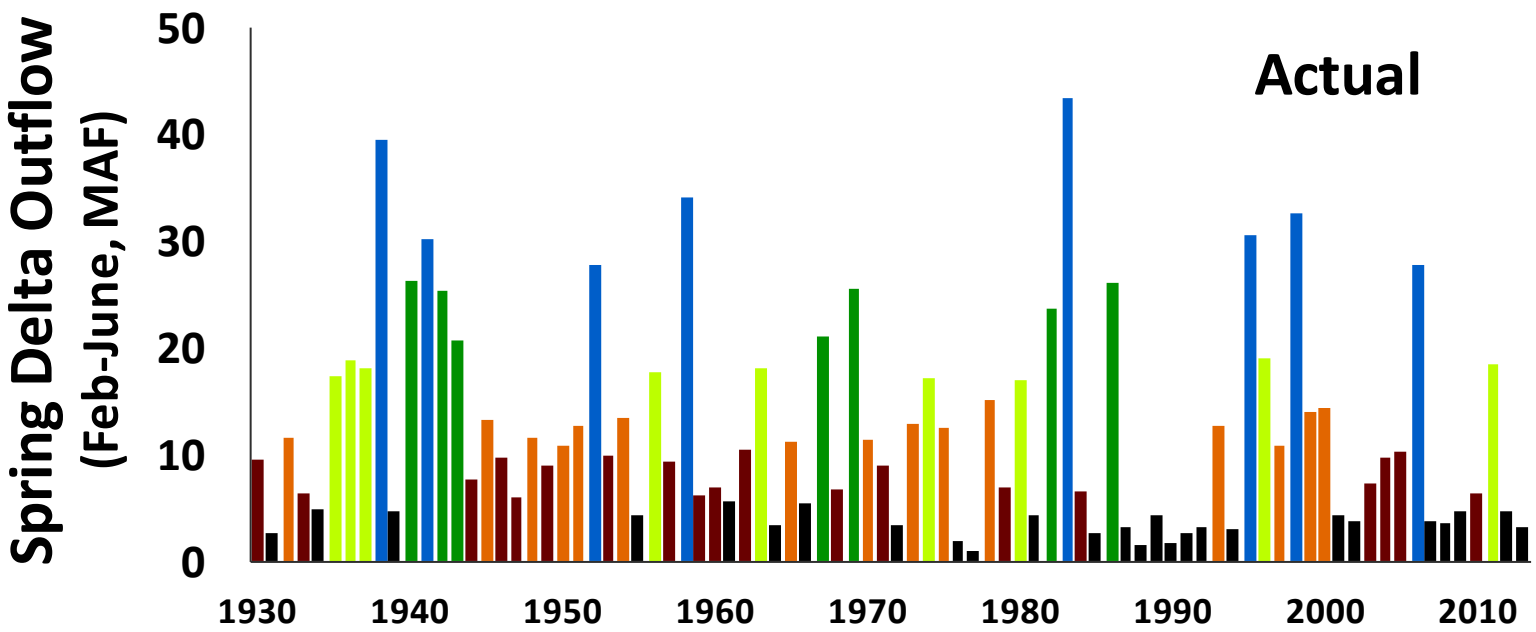

Spring Delta Outflow
(Feb-June, MAF)
50
40
30
20
10
0
W
AN
BN
D
CD
SC
Unimpaired
1930
1940
1950
1960
1970
1980
1990
2000
2010

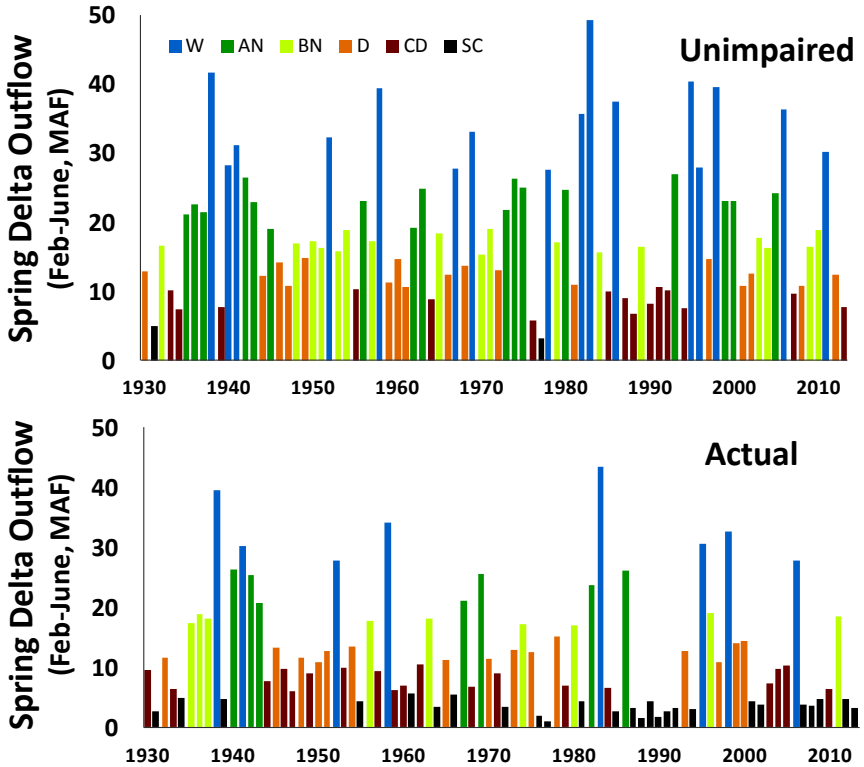

Spring Delta Outflow
(Feb-June, MAF)
50
40
30
20
10
0
27.7
W
AN
BN
D
CD
SC
Unimpaired
Wettest
20% years
1930
1940
1950
1960
1970
1980
1990
2000
2010


Spring Delta Outflow
(Feb-June, MAF)
50
40
30
20
10
0
27.7
10.6
W
AN
BN
D
CD
SC
Unimpaired
Wettest
20% years
Critical
20% years
1930
1940
1950
1960
1970
1980
1990
2000
2010


Spring Delta Outflow
(Feb-June, MAF)
50
40
30
20
10
0
27.7
10.6
5.8
W
AN
BN
D
CD
SC
Unimpaired
Wettest
20% years
Critical
20% years
Super-Critical
2.4% years
1930
1940
1950
1960
1970
1980
1990
2000
2010


Unimpaired
W
AN
BN
D
CD
SC
Spring Delta Outflow
(Feb-June, MAF)
0
10
20
30
40
50
1930
1940
1950
1960
1970
1980
1990
2000
2010


Actual
Spring Delta Outflow
(Feb-June, MAF)
0
10
20
30
40
50
1930
1940
1950
1960
1970
1980
1990
2000
2010

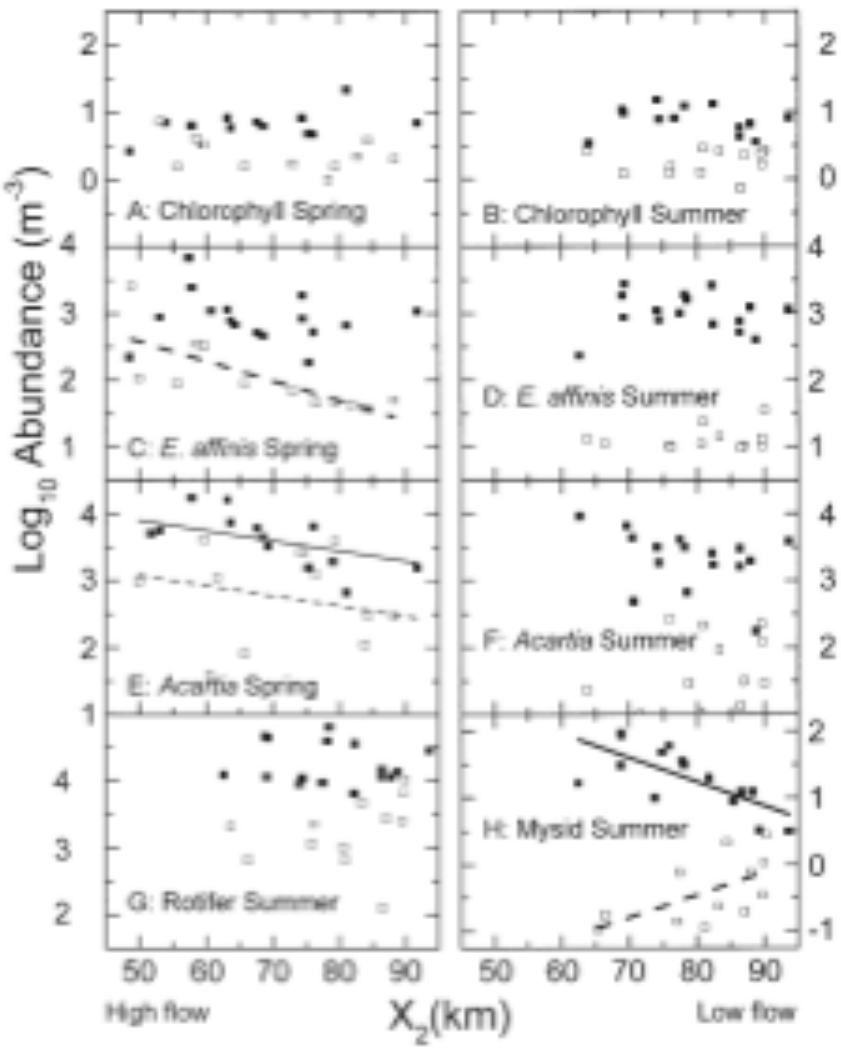


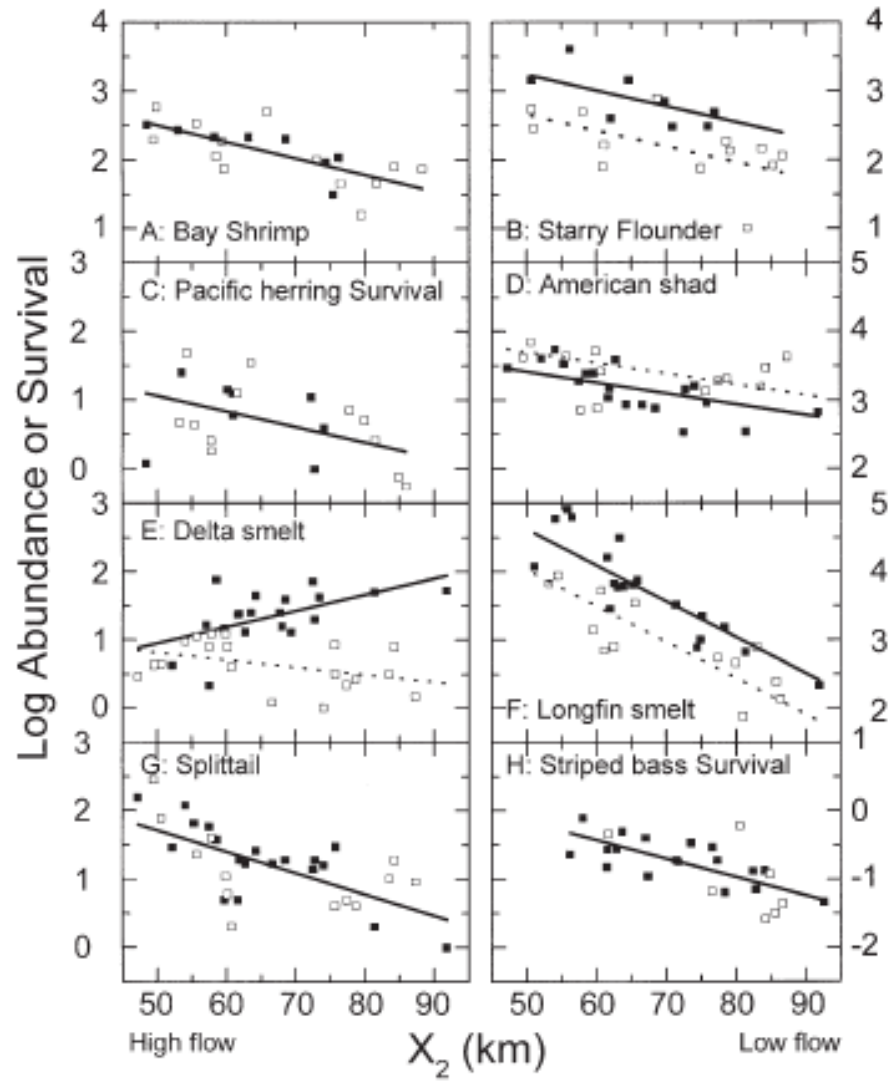
Chronic man-made drought

1967-2013			
	Wet	Critical (Includes Super-critical)	Super-critical
Unimpaired	11 (23%)	11 (23%)	1 (2%)
Actual	4 (9%)	27 (57%)	19 (40%)

Flow and Abundance Relationships

•Significant •Persistent •Large •Widespread

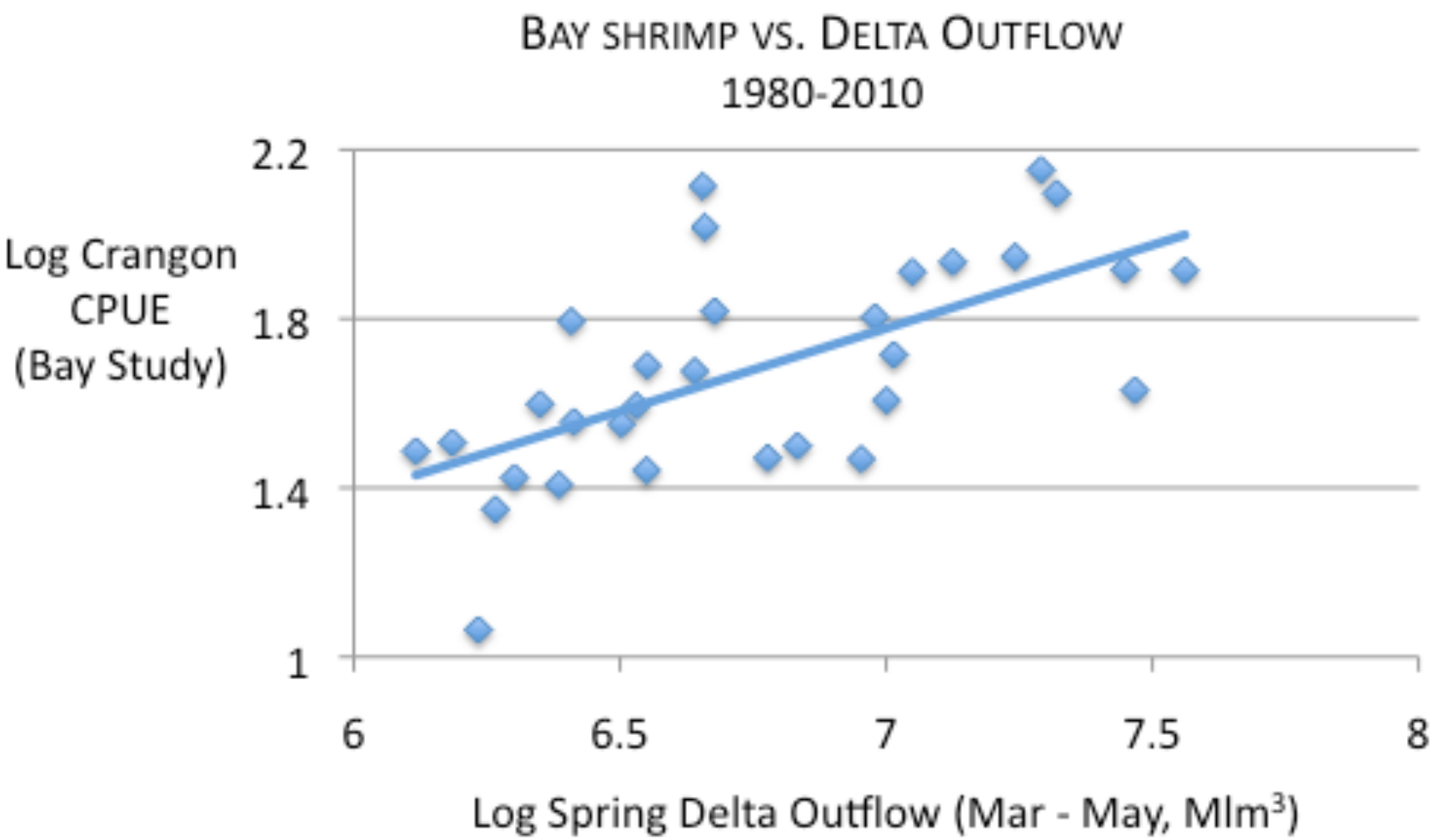




Copied from: Kimmerer (2002). Effects of freshwater flow on abundance of estuarine organisms…

Flow and Abundance Relationships

•Significant •Persistent •Large •Widespread



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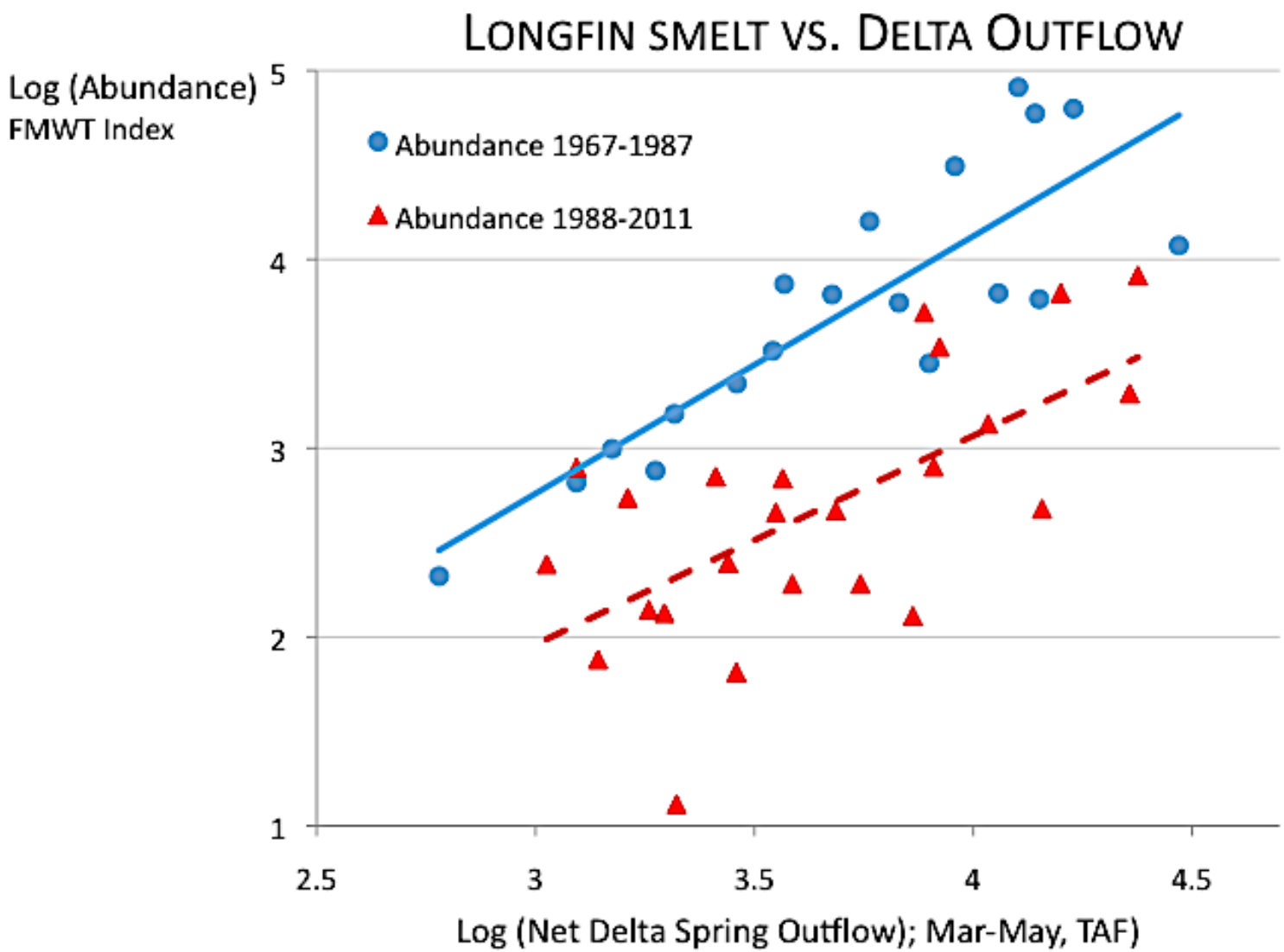
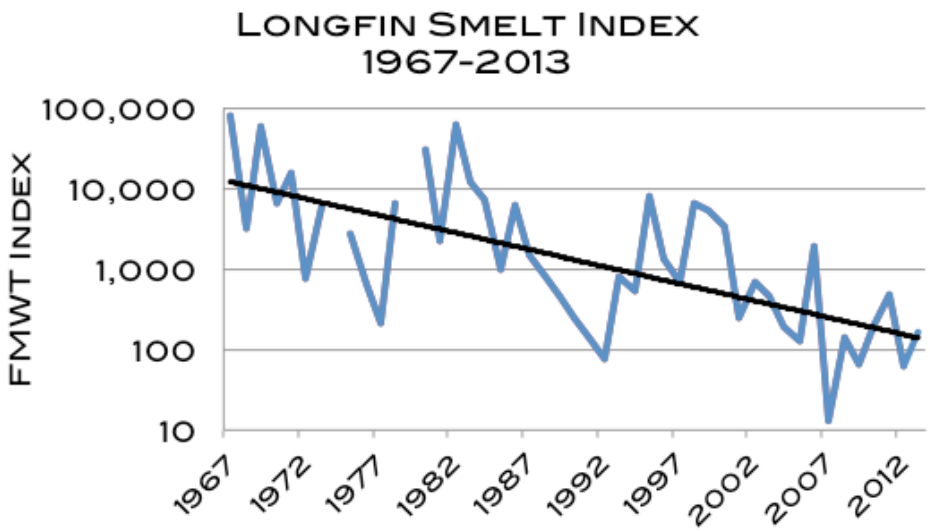
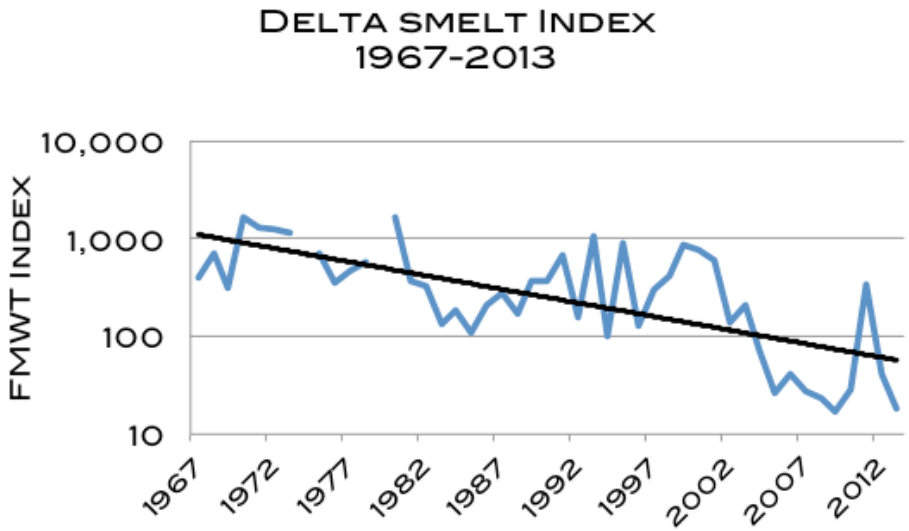


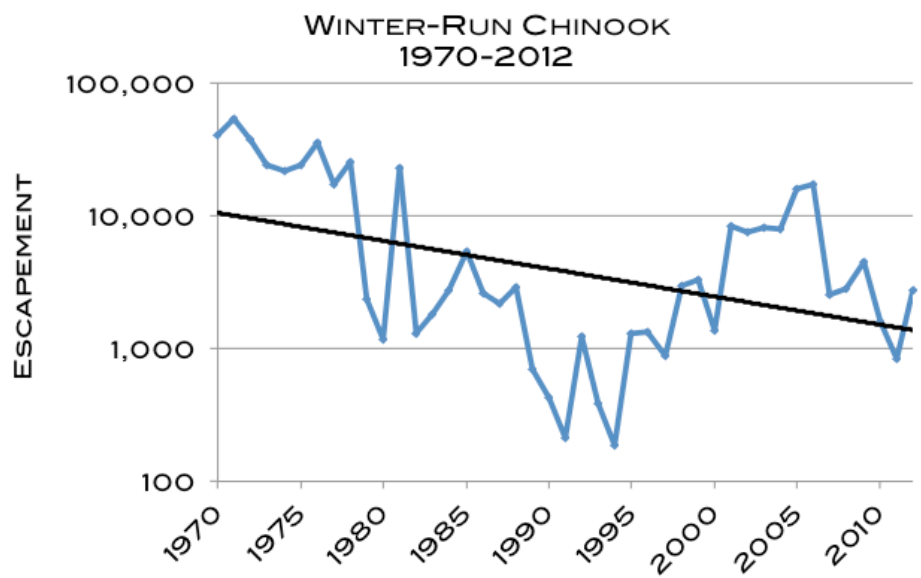
What do these species have in common?

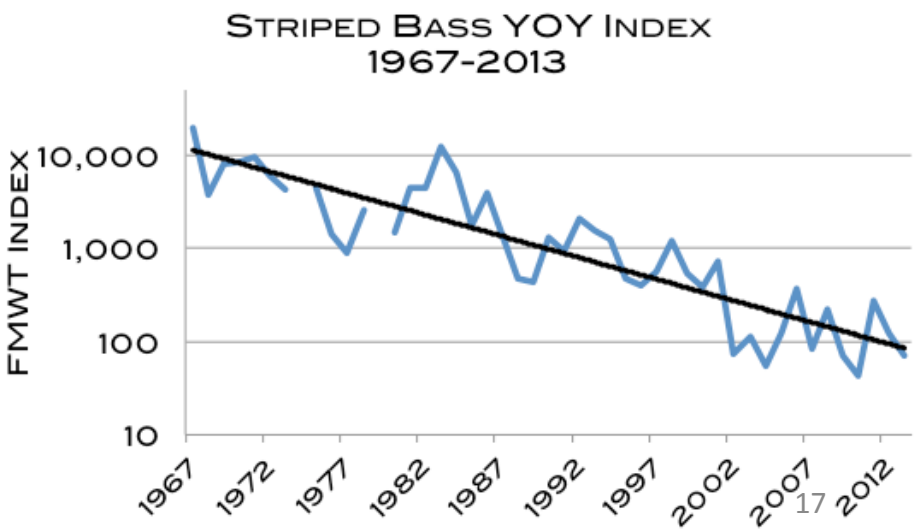
Species	Native?	Life span (years)	Resident/ Migratory?	Spawns Where?	Abundance correlated w/ Delta in-, thru-, or out-flow?
Chinook salmon	Yes	3-5	Anadromous	River	**Yes**
Striped bass	No	4-10	Anadromous	River	**Yes**
Green sturgeon	Yes	Decades	Anadromous	River	**Yes**
Delta smelt* (*Fall X_2)	Yes	1	Resident	Delta	**Yes**
Longfin smelt	Yes	1-3	Both	Delta/ Suisun	**Yes**
Starry flounder	Yes	7-8	Catadromous	Ocean	**Yes**
Sac. Splittail	Yes	5-7	Resident	Shallow FW	**Yes**
Am. Shad	No	5-7	Migratory	River	**Yes**
Bay shrimp	Yes	1.5-2.5	Catadromous	Ocean	**Yes**
Calanoid Copepods	Yes/No	<1	Resident	Varies	**Yes**

Decades of Steep Decline in Numerous Fisheries



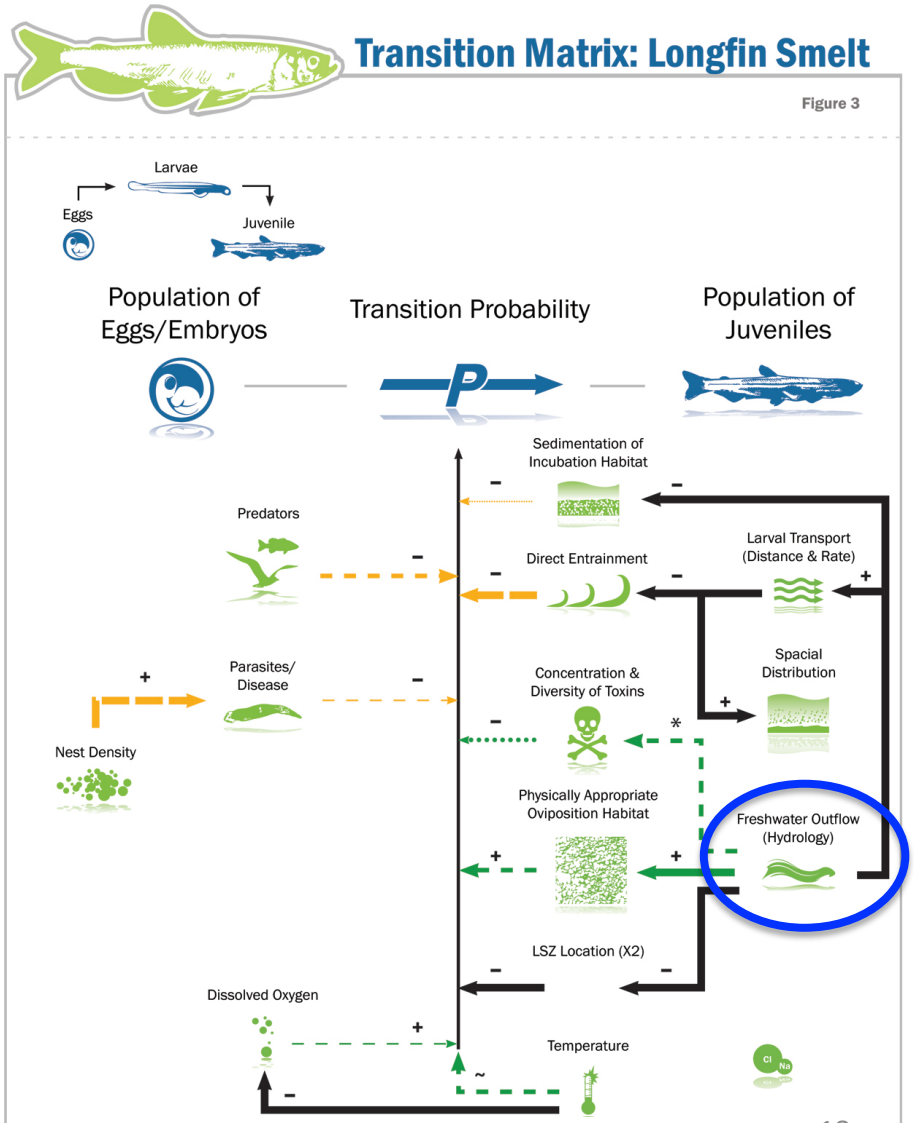




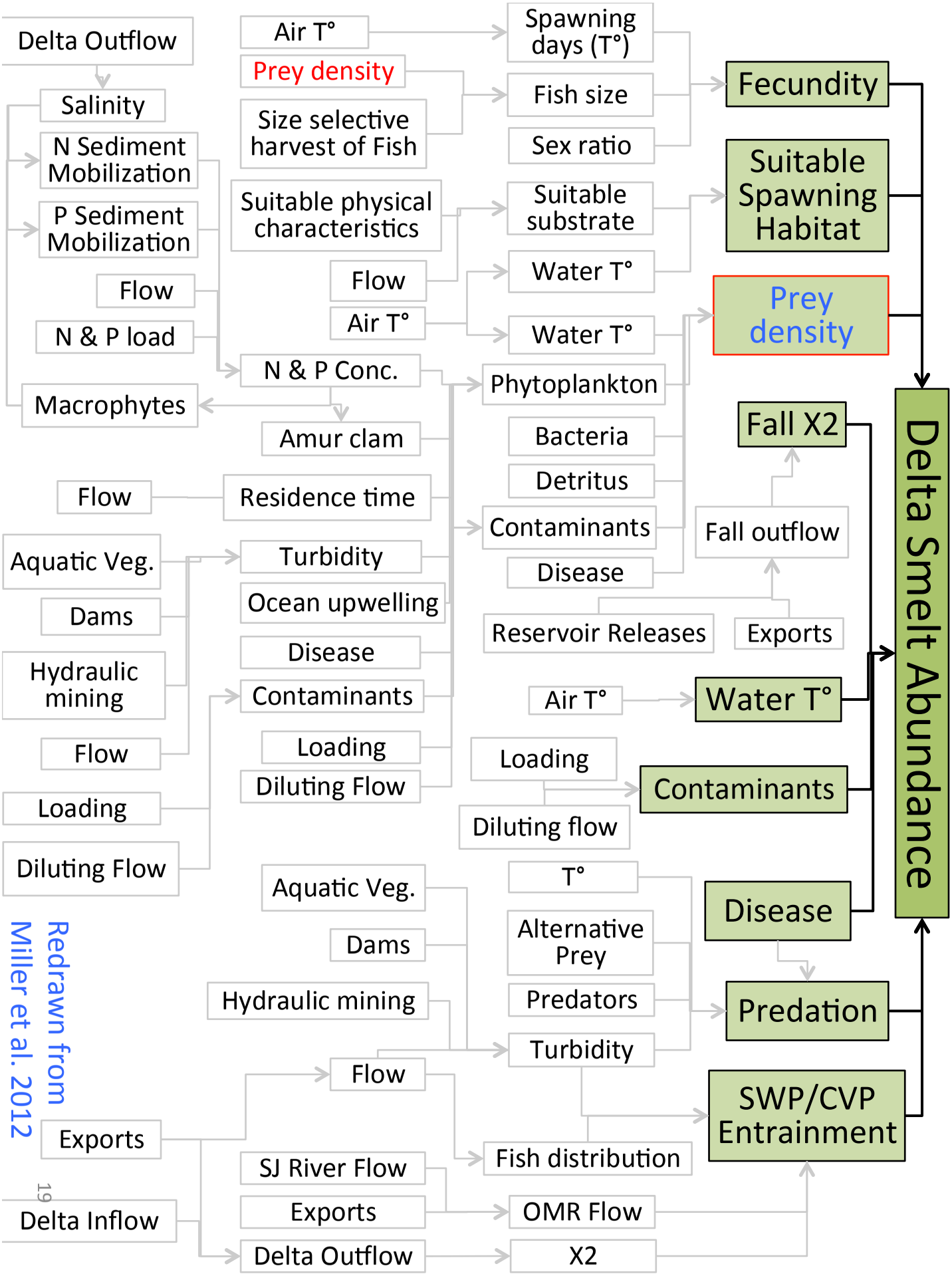


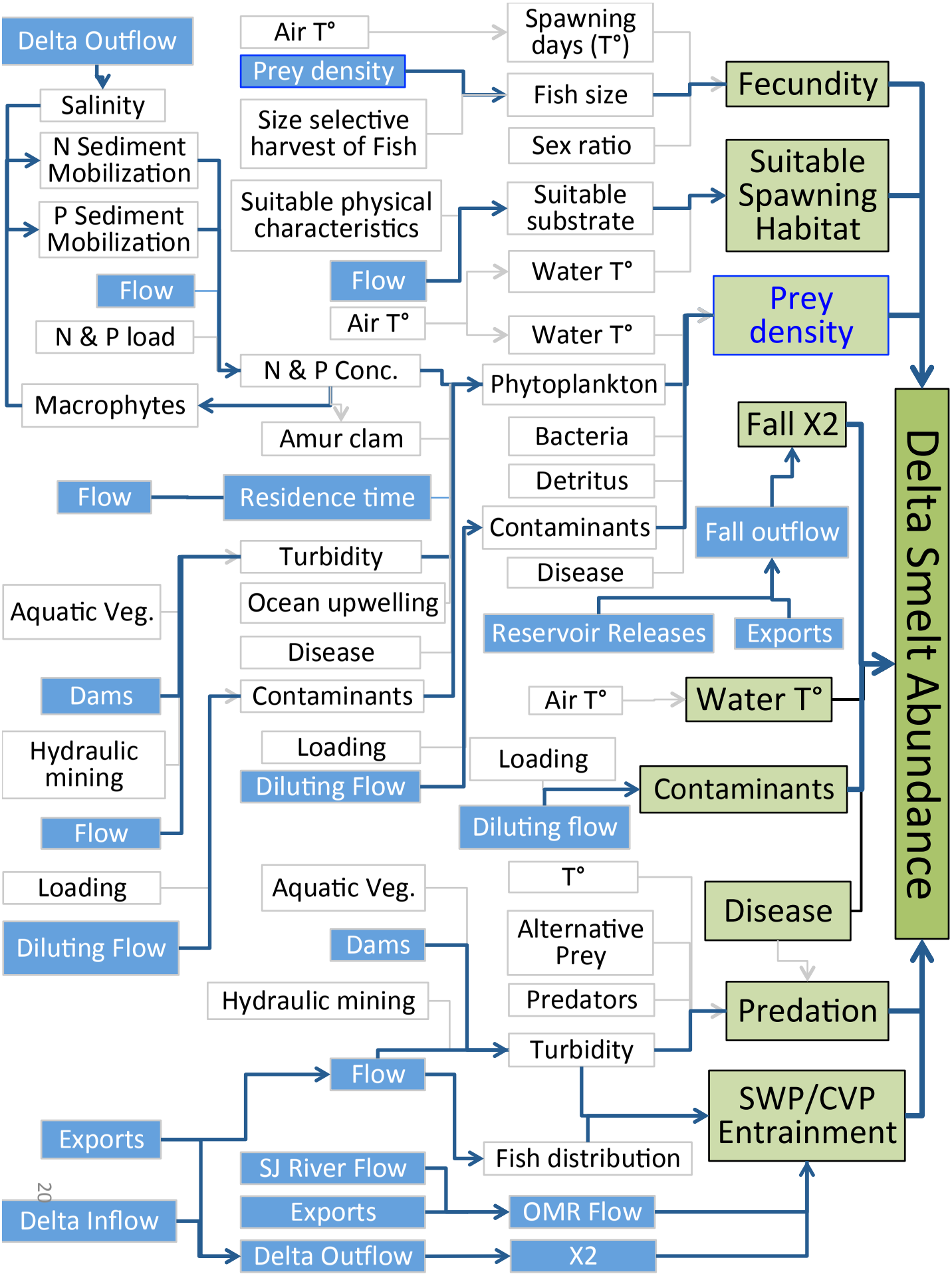
Reduced Flows Exacerbate Biological, Chemical, & Physical Stressors

- Reduced Delta Outflow
  - Altered Hydrodynamics and Transport/Retention
  - Exposure to Entrainment/ Predators
  - Impaired Water Quality
  - Reduced Food Web Productivity



Copied from DRERIP Conceptual Model 2010


Delta Outflow
Salinity
N Sediment Mobilization
P Sediment Mobilization
Flow
N & P load
Macrophytes
Air T°
Prey density
Size selective harvest of Fish
Suitable physical characteristics
Flow
Air T°
N & P Conc.
Amur clam
Flow
Residence time
Aquatic Veg.
Dams
Hydraulic mining
Flow
Loading
Diluting Flow
Turbidity
Ocean upwelling
Disease
Contaminants
Loading
Diluting Flow
Aquatic Veg.
Dams
Hydraulic mining
Flow
Exports
Delta Inflow
SJ River Flow
Exports
Delta Outflow
Spawning days (T°)
Fish size
Sex ratio
Suitable substrate
Water T°
Water T°
Phytoplankton
Bacteria
Detritus
Contaminants
Disease
Reservoir Releases
Exports
Air T°
Loading
Diluting flow
T°
Alternative Prey
Predators
Turbidity
Fish distribution
OMR Flow
X2
Fecundity
Suitable Spawning Habitat
Prey density
Fall X2
Fall outflow
Water T°
Contaminants
Disease
Predation
SWP/CVP Entrainment
Delta Smelt Abundance
Redrawn from Miller et al. 2012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Predation
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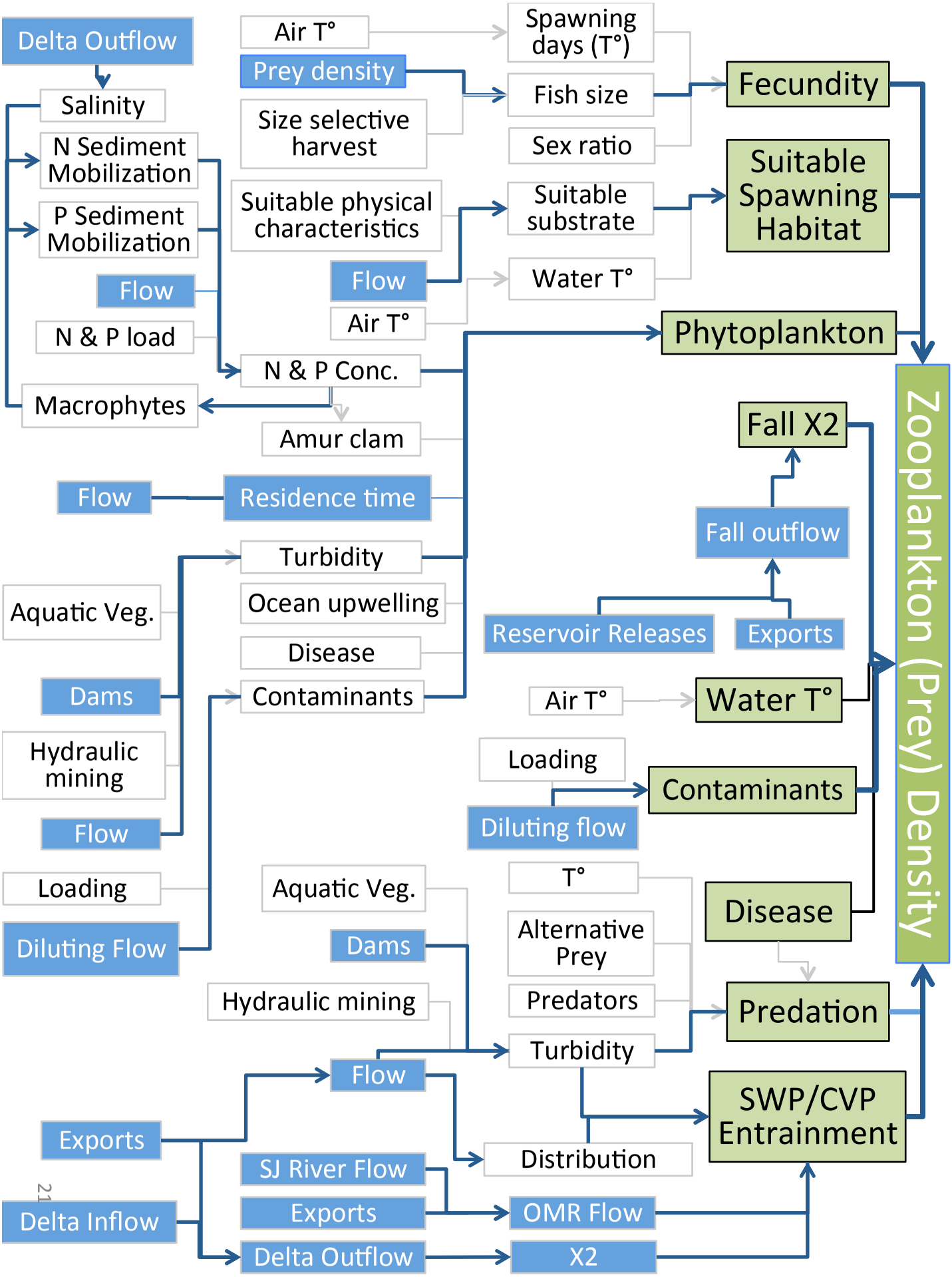
Delta Smelt Abundance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Salinity
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Macrophytes
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Water T°
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Suitable Spawning Habitat
Phytoplankton
Zooplankton (Prey) Density
Fall X2
Fall outflow
Reservoir Releases
Exports
Flow
Residence time
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Contaminants
Aquatic Veg.
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Water T°
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Diluting flow
Aquatic Veg.
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Alternative Prey
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Exports
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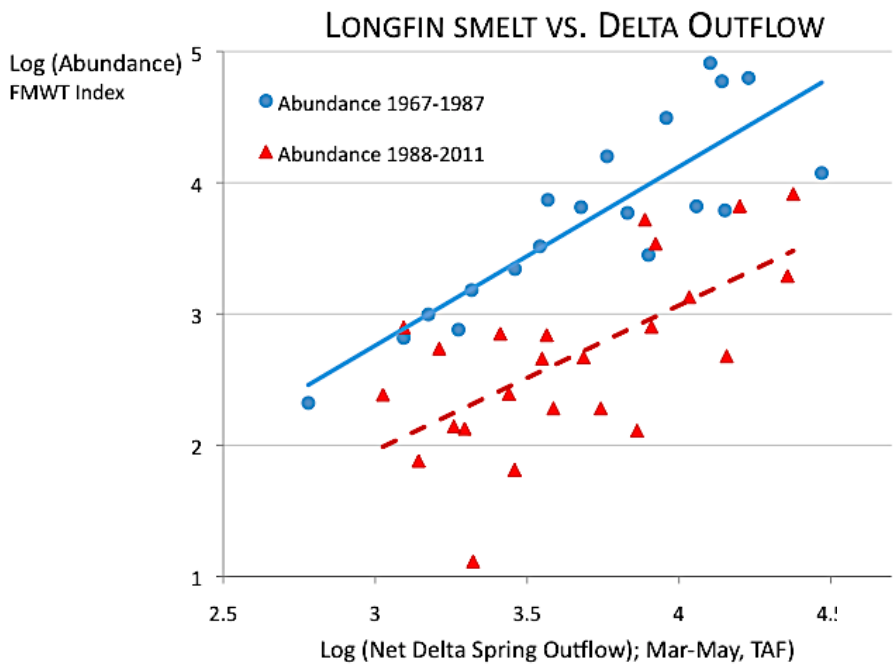
SJ River Flow
Exports
OMR Flow
Delta Inflow
Delta Outflow
X2

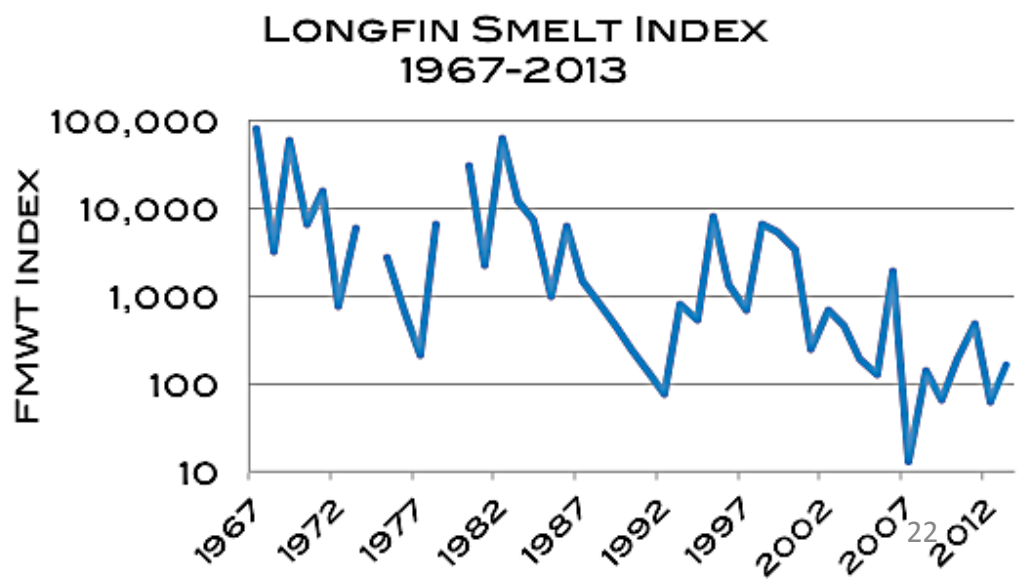
Flows and Population Response

Case Study: Longfin Smelt

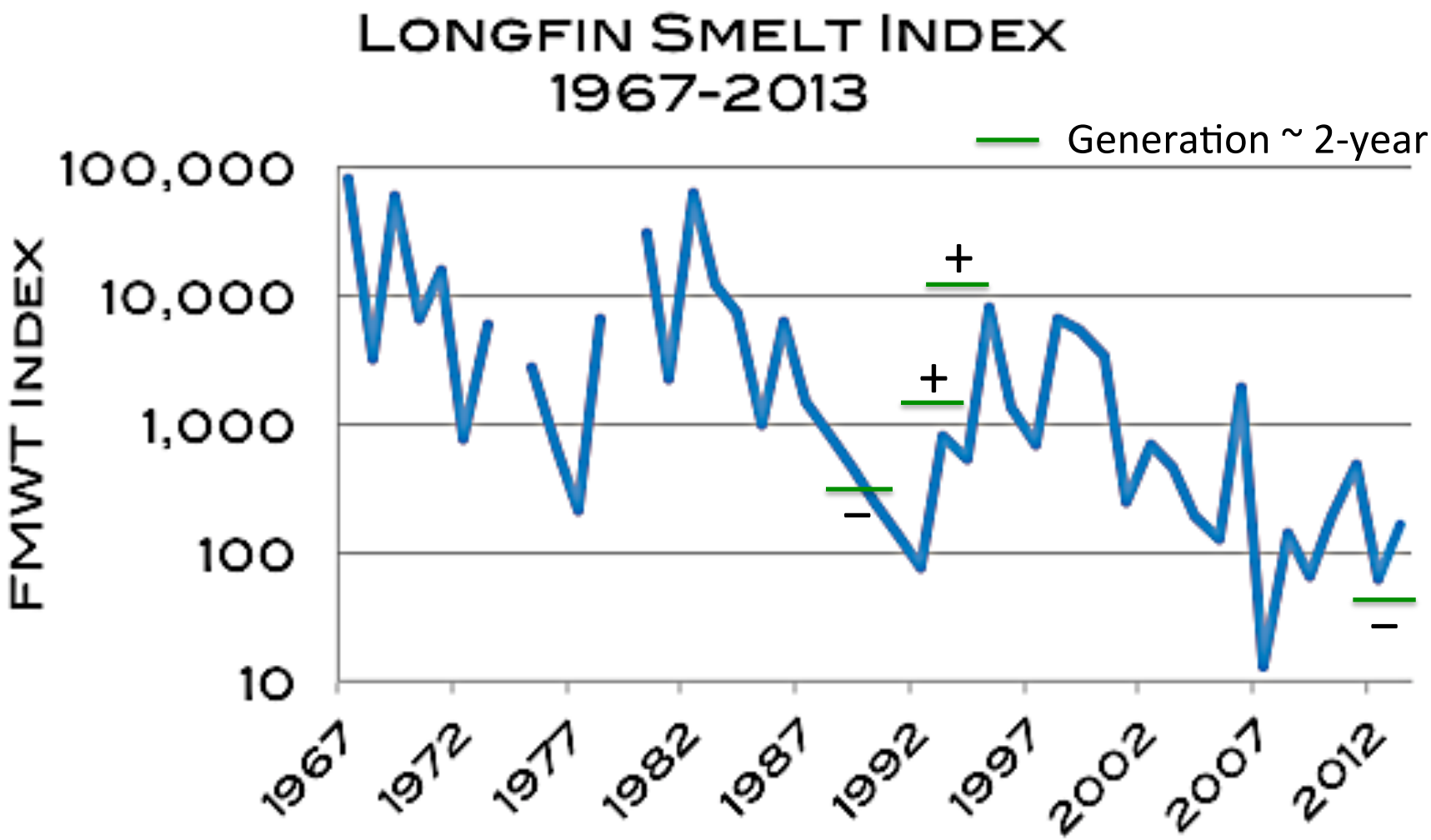


Abundance and Flow
Very strong correlation

Population Growth
How much flow is needed?
For how long?
How often?



Focus on Inter-generation Population Change



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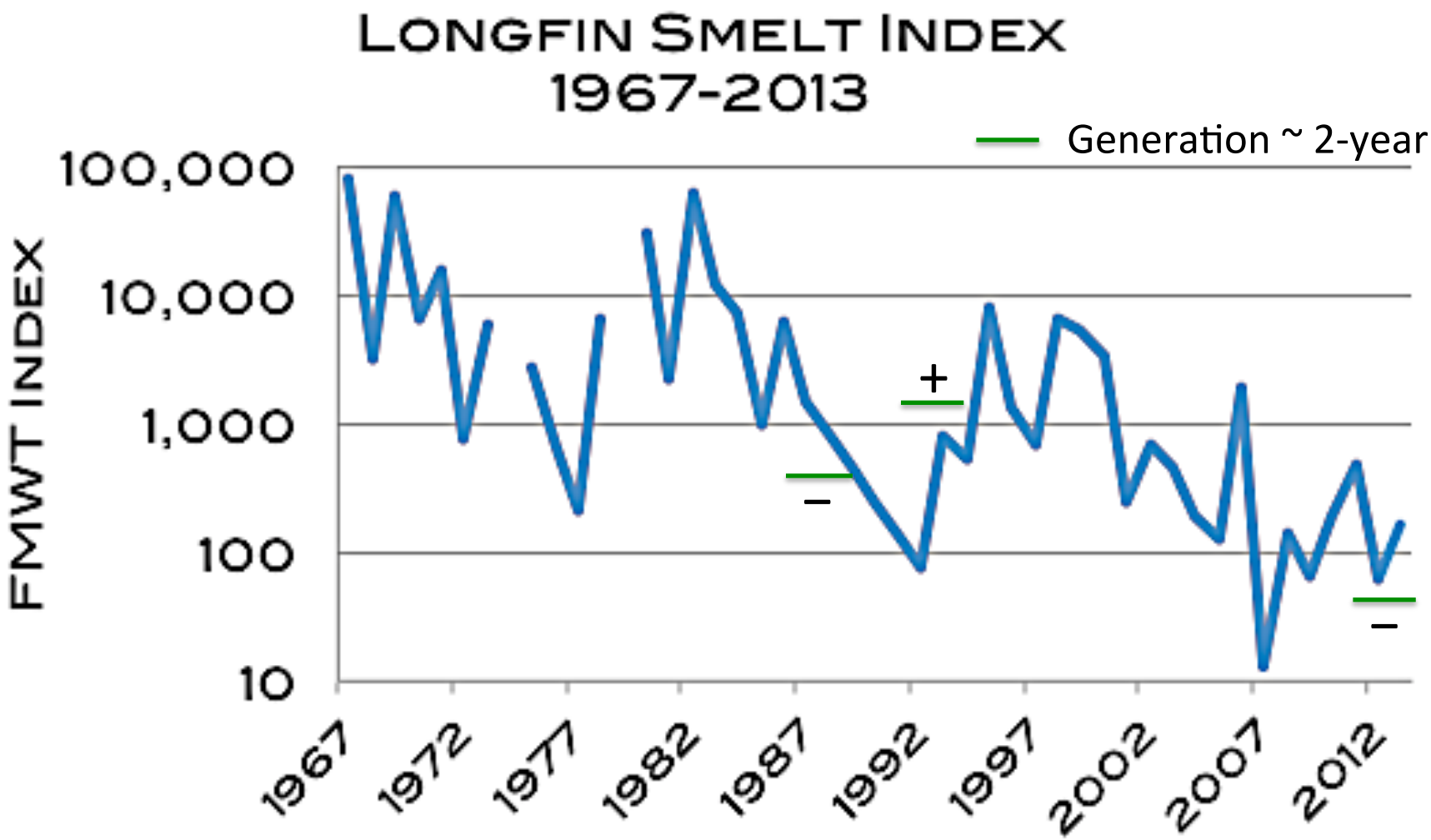
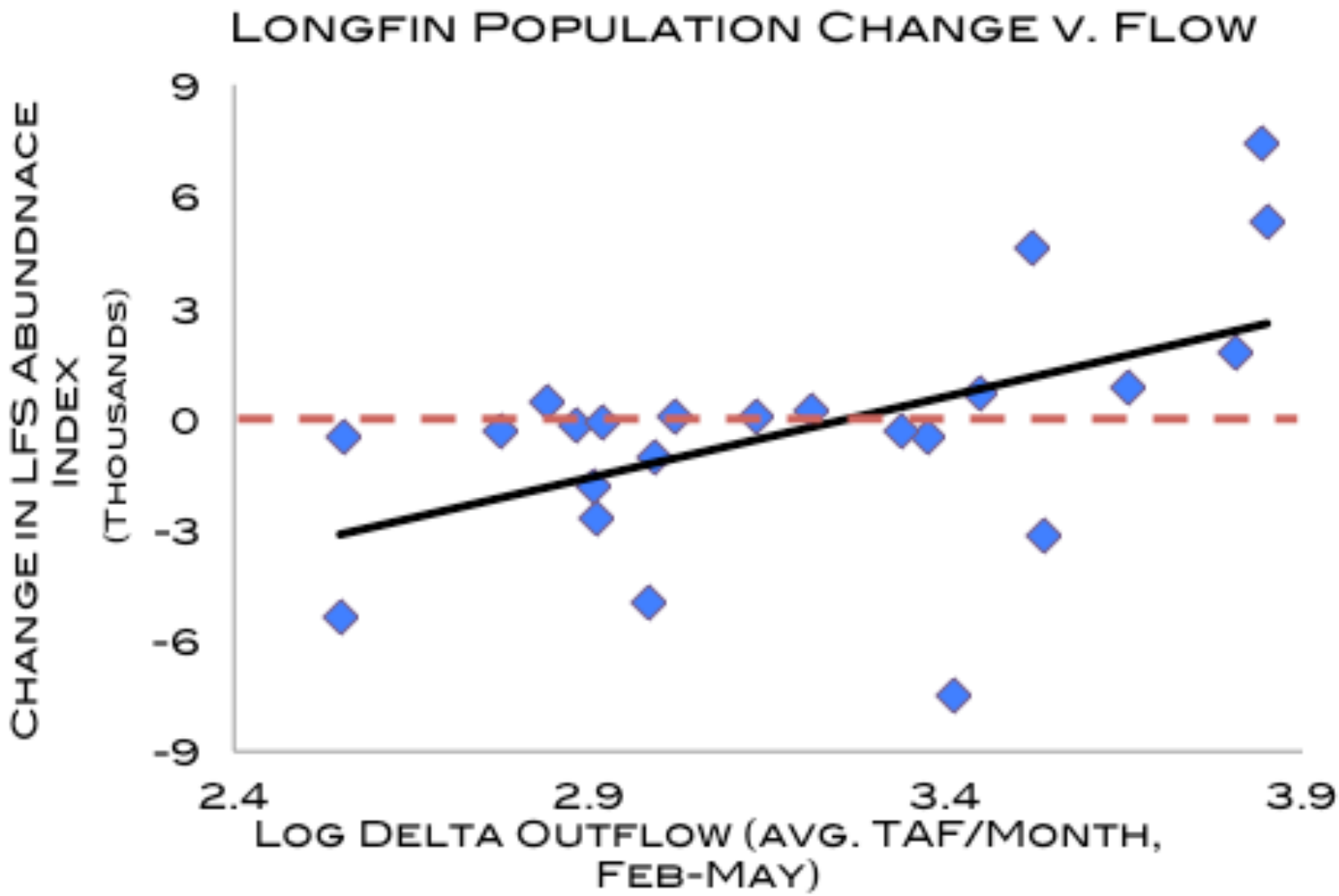


LFS Index_{t-2} & $\text{Outflow}_{\text{Feb-May}}$ → 75% of Variation in LFS Index

*After accounting for these 2 variables, residuals still show a declining time trend.
Flow & previous population do not explain **all** of the decline in the LFS population

Change in LFS Abundance Index v. Delta Outflow 1988-2010



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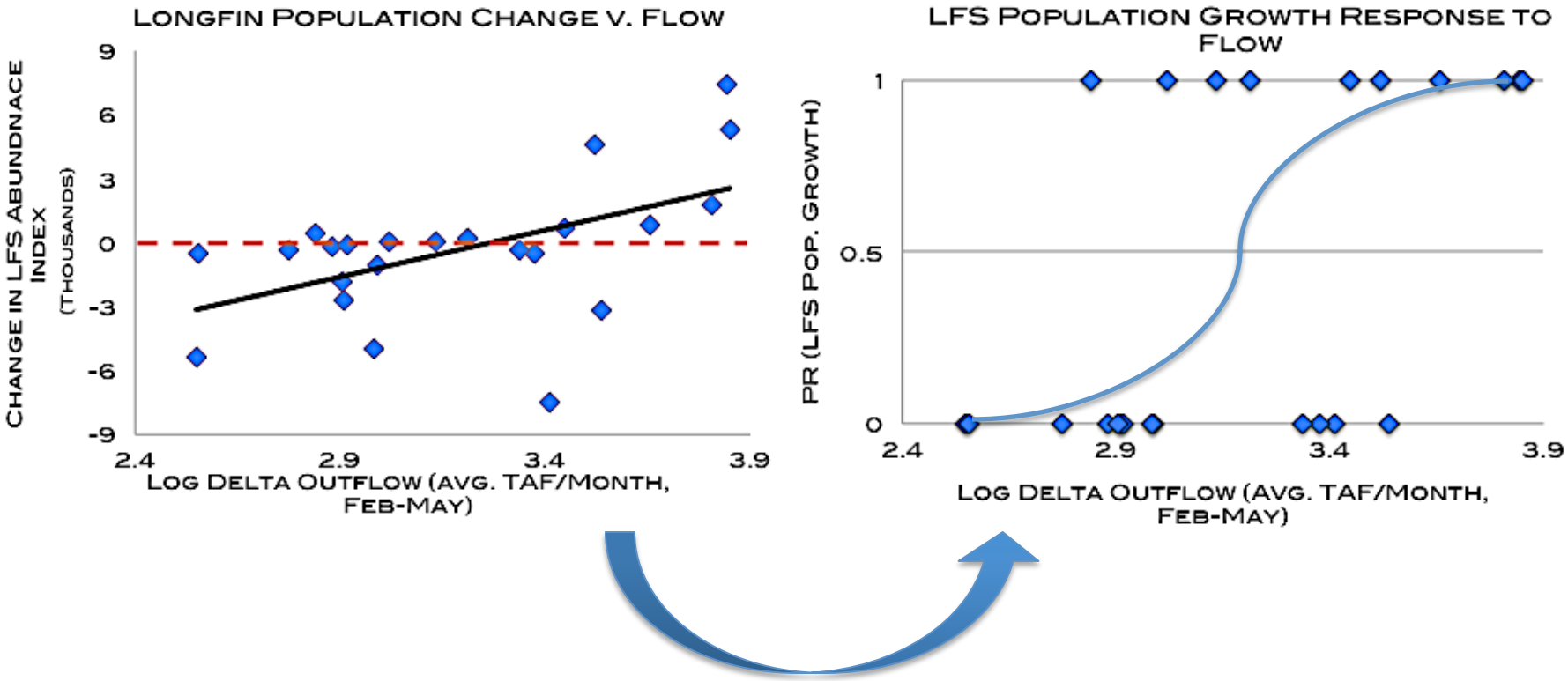
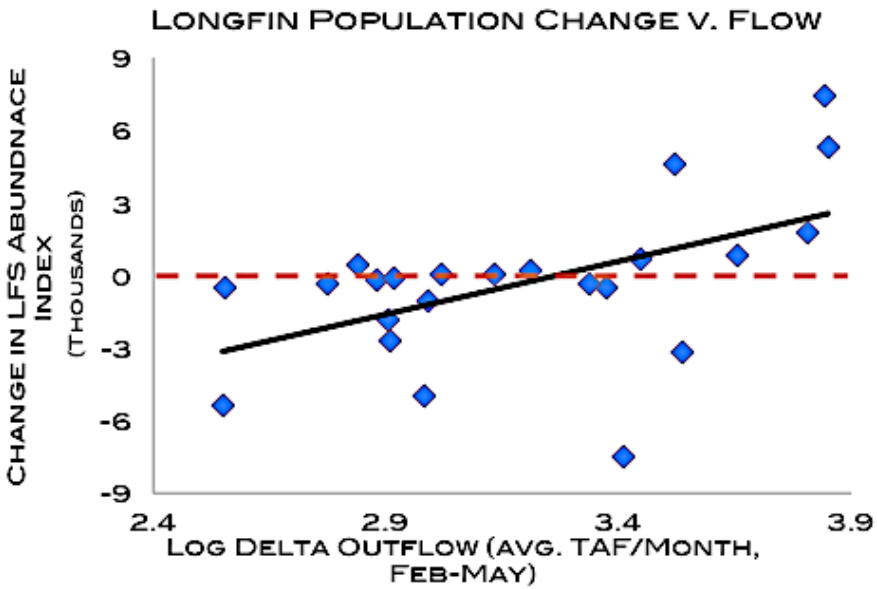
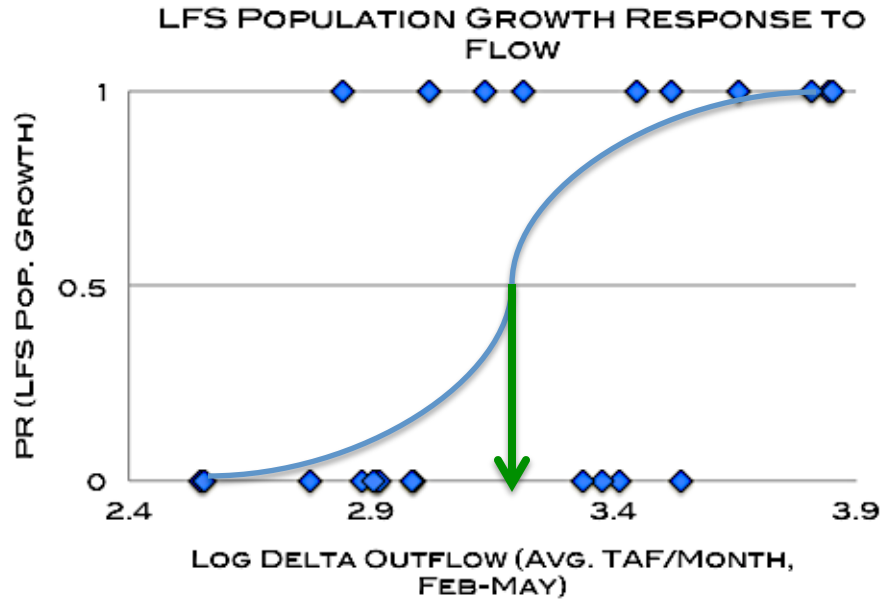


Redrawn from TBI (2010) – Exh 2.

Change in LFS Abundance Index v. Delta Outflow 1988-2010





Results can be interpreted to suggest a threshold flow, above which LFS population growth is likely

Timing, Magnitude & **Duration** of Delta Outflows that Support LFS Population Growth

Timing: CDFW (2010) identifies Feb-May as critical flow period for LFS productivity

Magnitude and Duration of Delta Outflow and LFS Population Growth			
Feb-May Avg Outflow	Positive Cohort Replacement	Negative Cohort Replacement	Total
HIGH >35 Kcfs for 3+ months	10 (83%)	2	12
MEDIUM <35 Kcfs for 2 months >35 Kcfs for 2 months	2 (29%)	5	7
LOW <35 Kcfs for 3+ months	5 (23%)	17	22

Frequency of Delta Outflows that Support LFS Population Growth

Positive Cohort Replacement in ~41% of years

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*Residuals from this equation reveal a gradual but significant decline with time (i.e. flow and previous population do not explain all of the decline in the LFS population)

Frequency of Delta Outflows that Support LFS Population Growth

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Actual outflows of this magnitude have occurred ~29% of years 1967-2013

Frequency of Delta Outflows that Support LFS Population Growth

Flows of this magnitude will occur in ~50% of years if Actual Outflows = ~70% Unimpaired Outflow

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Actual outflows of this magnitude have occurred ~29% of years 1967-2013

Delta Outflows: Measurement and Management

Metrics

- Timing (season)
- Magnitude (flow level)
- Frequency (% of years with favorable conditions)
- Duration (days, weeks, months)

Management

- % of unimpaired as a _X_day running average

Summary

Delta Outflows are Highly Altered

- Current management produces chronic drought conditions, 40% of years "super-critically dry"

Outflow is Key Physical and Ecological Driver

- Significant, persistent and large effects on abundance
- Affects other variables and stressors
- Low outflow a driver for population declines

Substantial Improvement in Outflow Required

- 1995 WQCP did not improve outflows

New Objectives Should Include:

- Metrics: Timing, Magnitude, Duration, and Frequency
- Management: % Unimpaired as a _X_ day running average