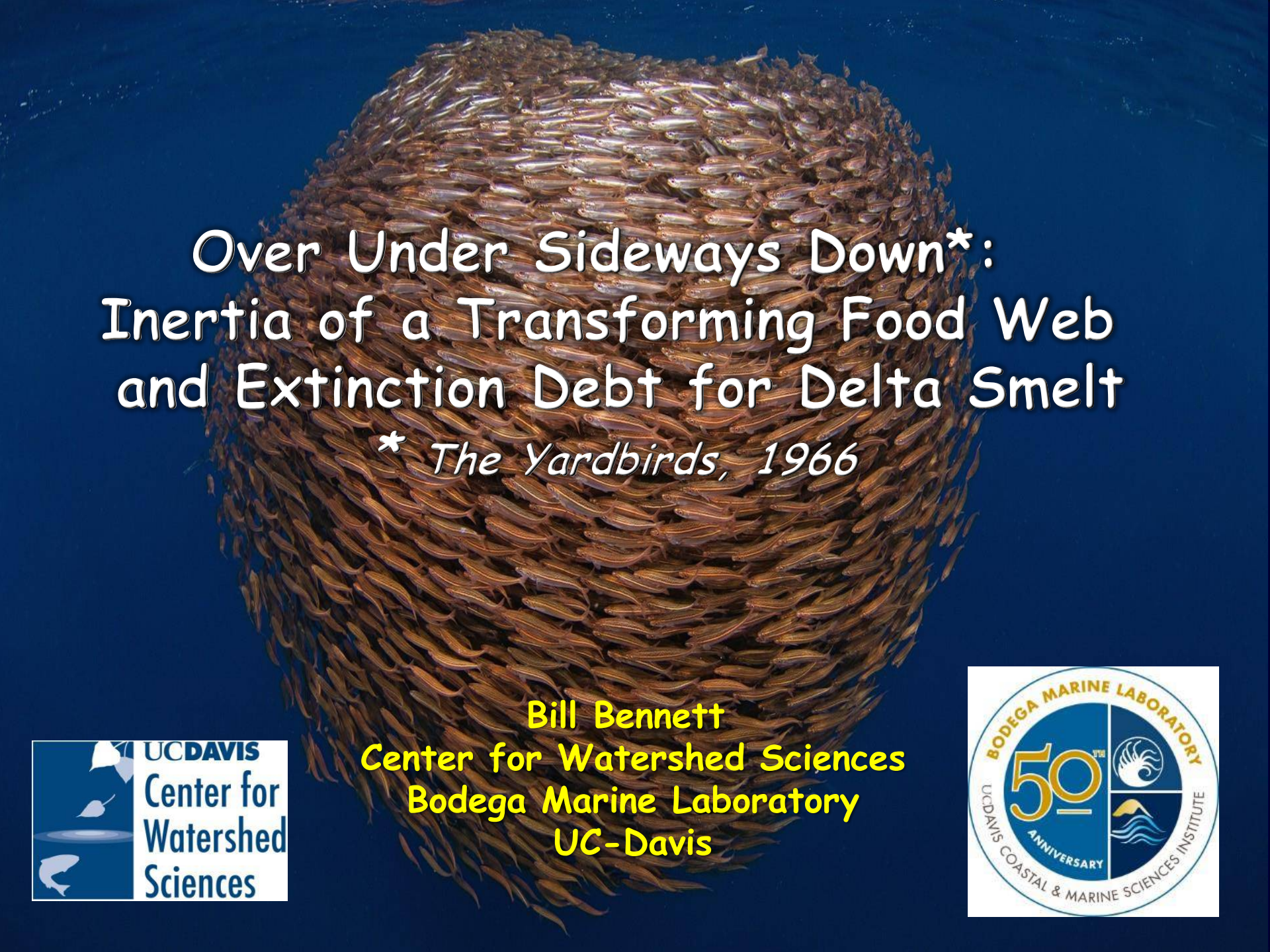


Over Under Sideways Down*: Inertia of a Transforming Food Web and Extinction Debt for Delta Smelt

* *The Yardbirds, 1966*

Bill Bennett
Center for Watershed Sciences
Bodega Marine Laboratory
UC-Davis

Conceptual Model: Aquatic Food Web

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE VOLUME 13, ISSUE 3, ARTICLE 5

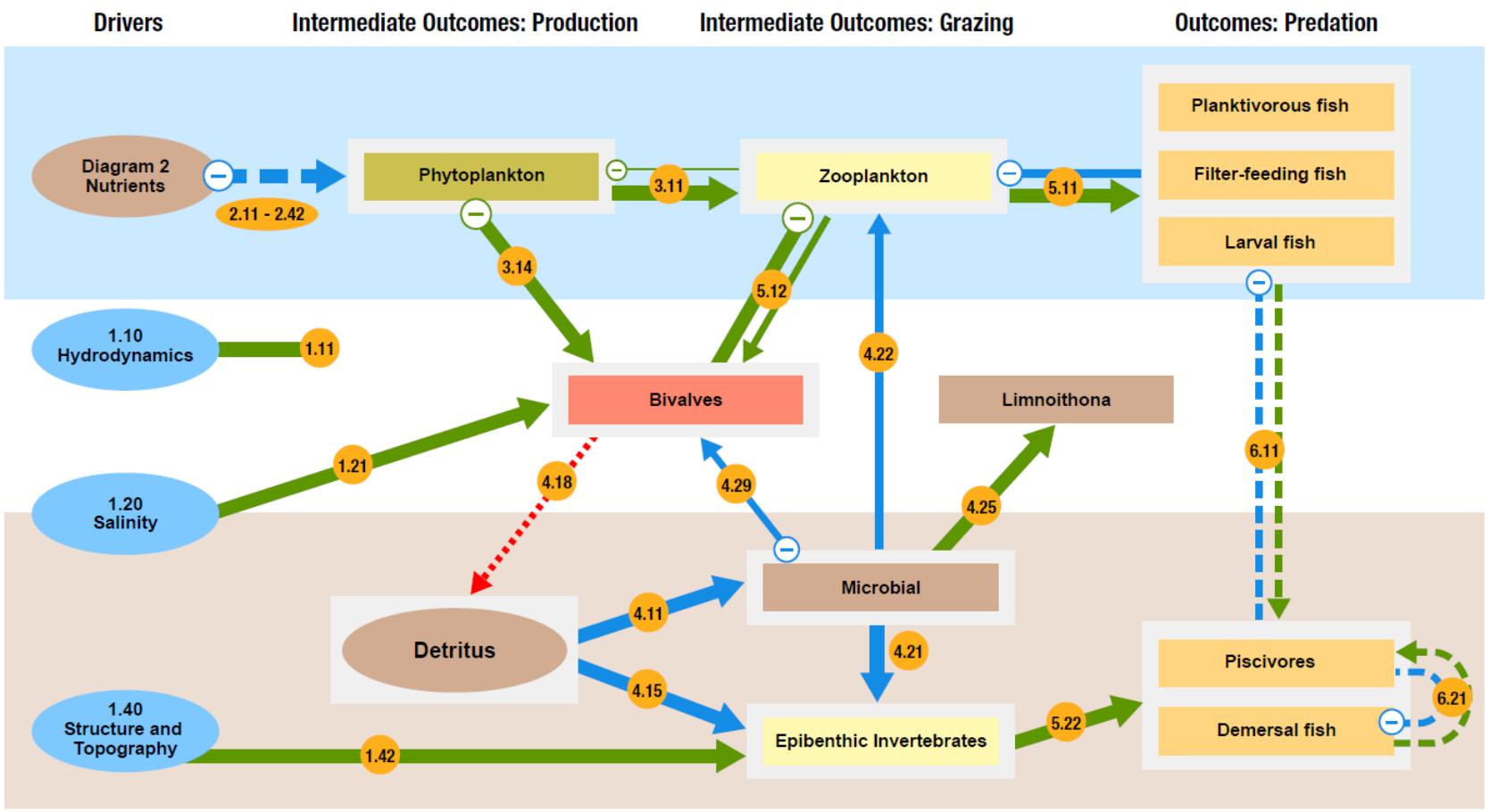


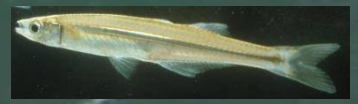
Diagram 7 Conceptual model of key drivers and linkages

Food Web & Extinction?

- Alien food web rapidly transforming native food web.
- A little Theory…Habitat loss, Hysteresis, and Extinction Debt
- Evidence?
- Is Extinction Inevitable?





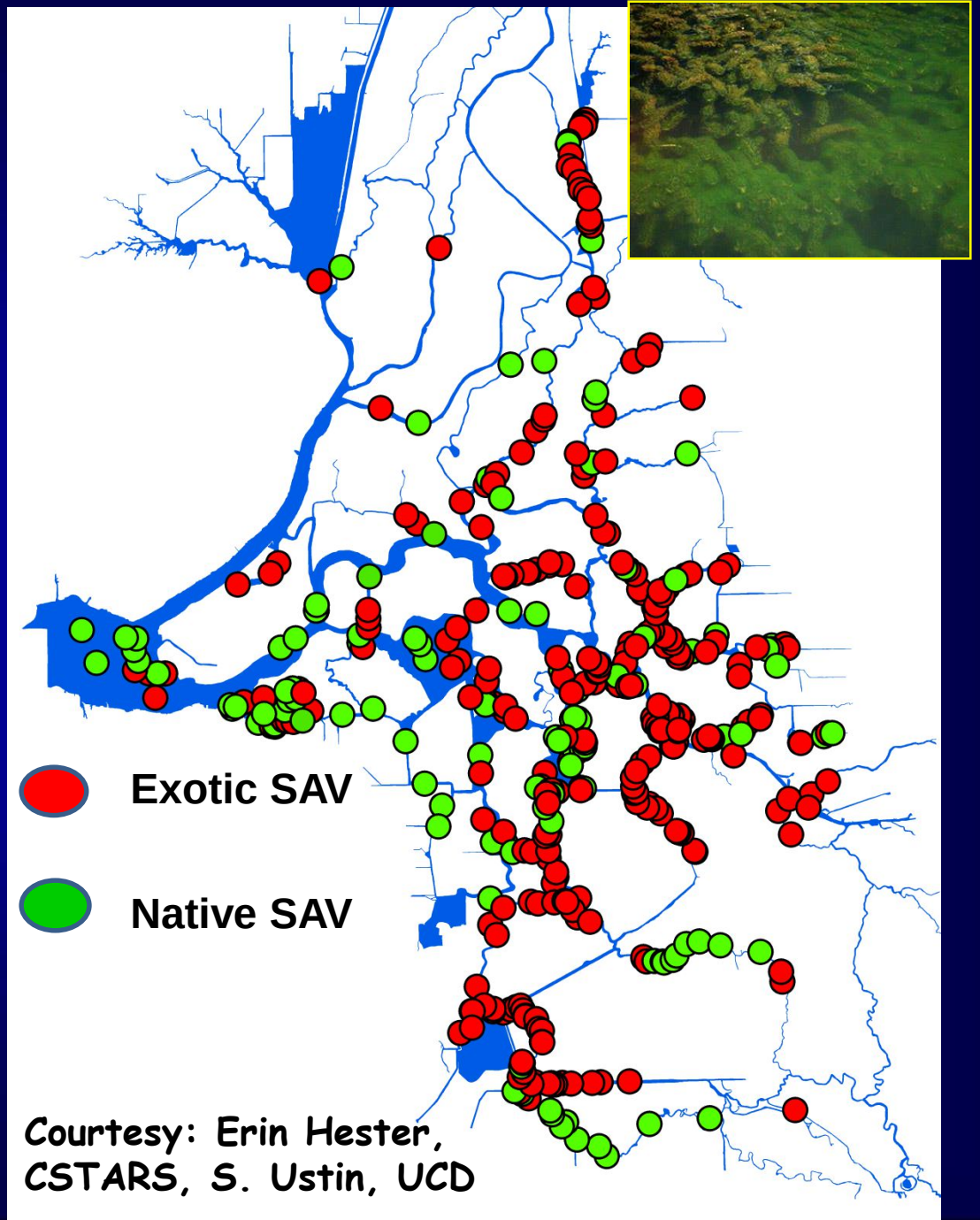


Can "Flow" Alone Reverse the Regime?

Hysteresis – Much harder to push system back!

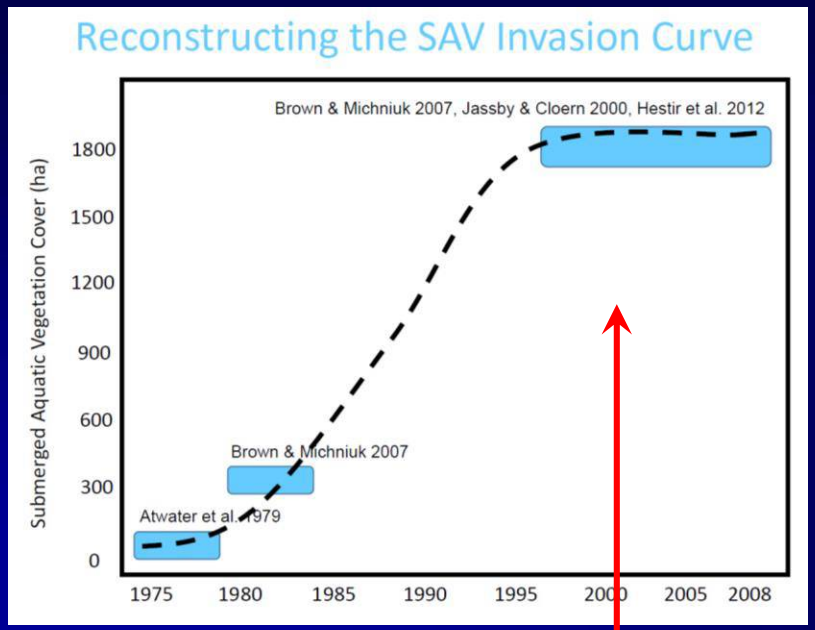
Distribution of SAV June 2008

- Boat samples with GPS referencing.
- Exotic SAV primarily Brazilian waterweed.



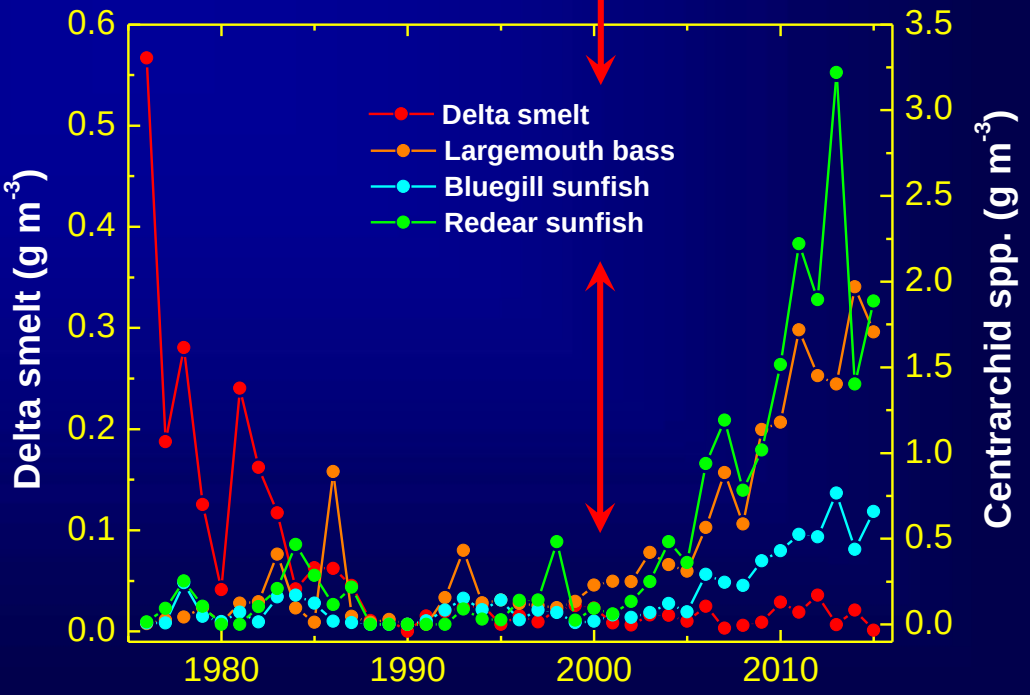
Inertia of Food Web Transformation

Egeria expansion:
(Graph, S. Ustin 2016)

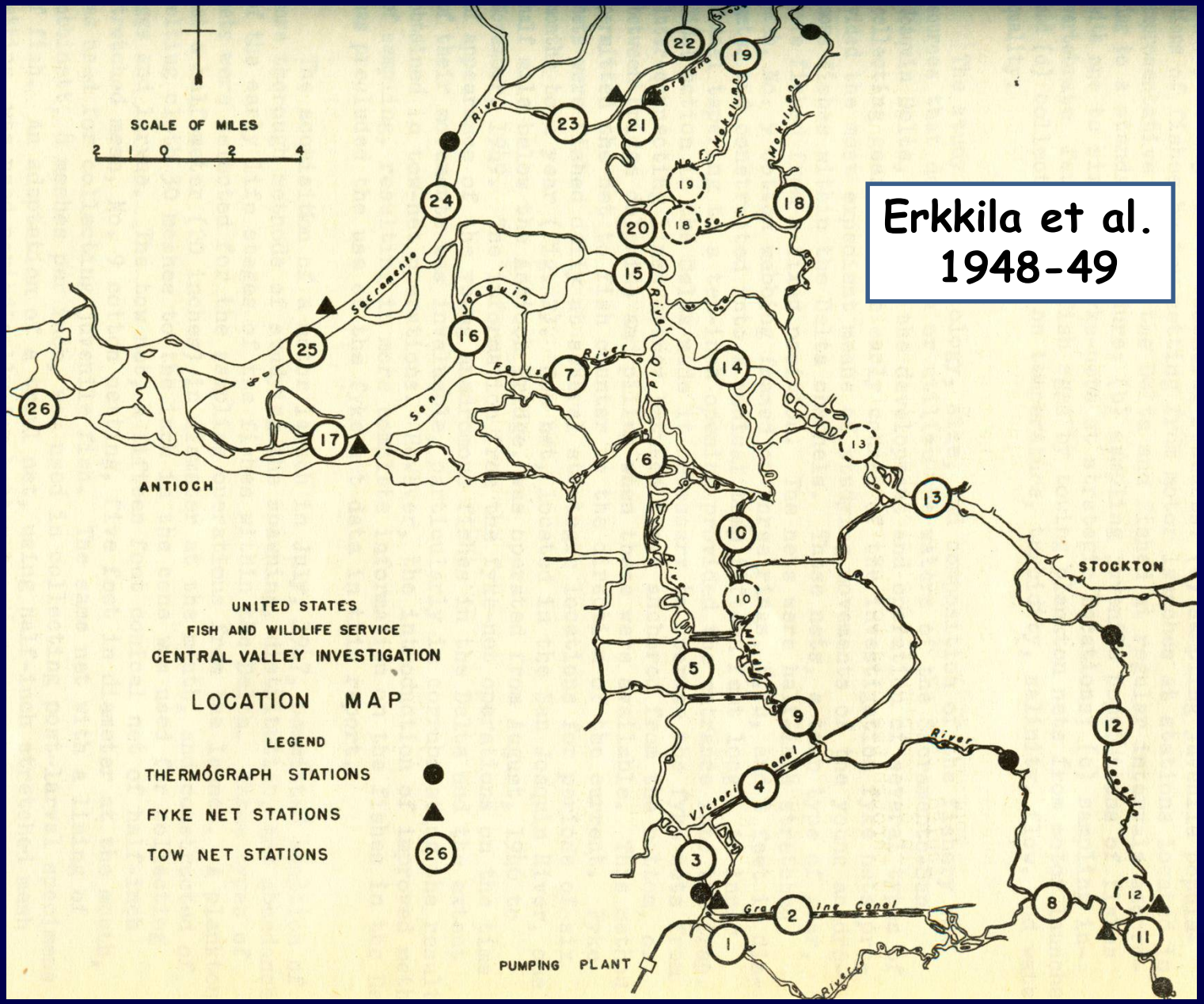


Centrarchid expansion:
(Data, USFWS Beach seines)

Alien fishes: range expansion lags *Egeria* by ~ 10yrs.

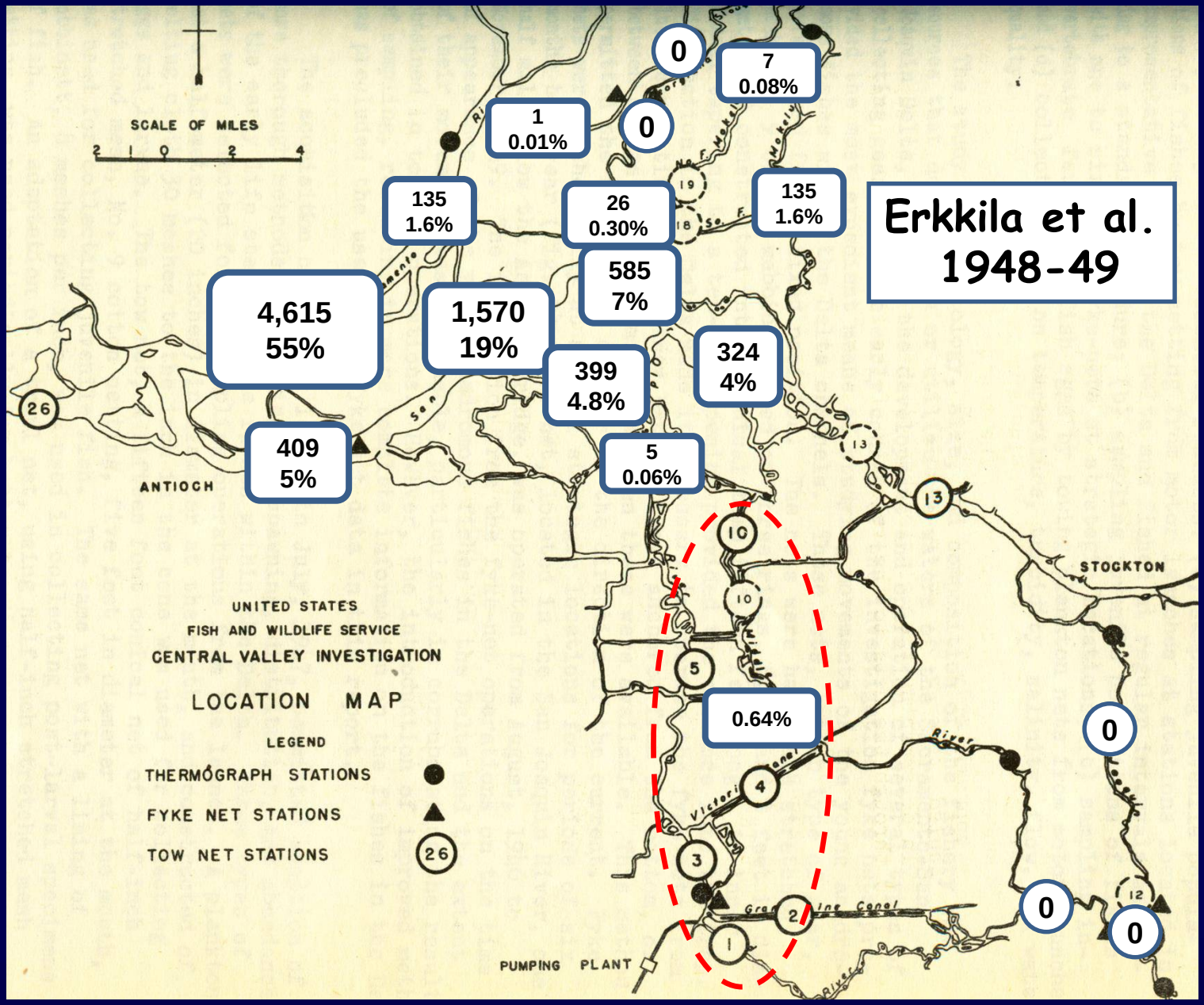


Historical Habitat Use



Erkkila et al.
1948-49

Historical Habitat Use



Historical Habitat Use

L. Radtke, 1966

Sampling 1963-64

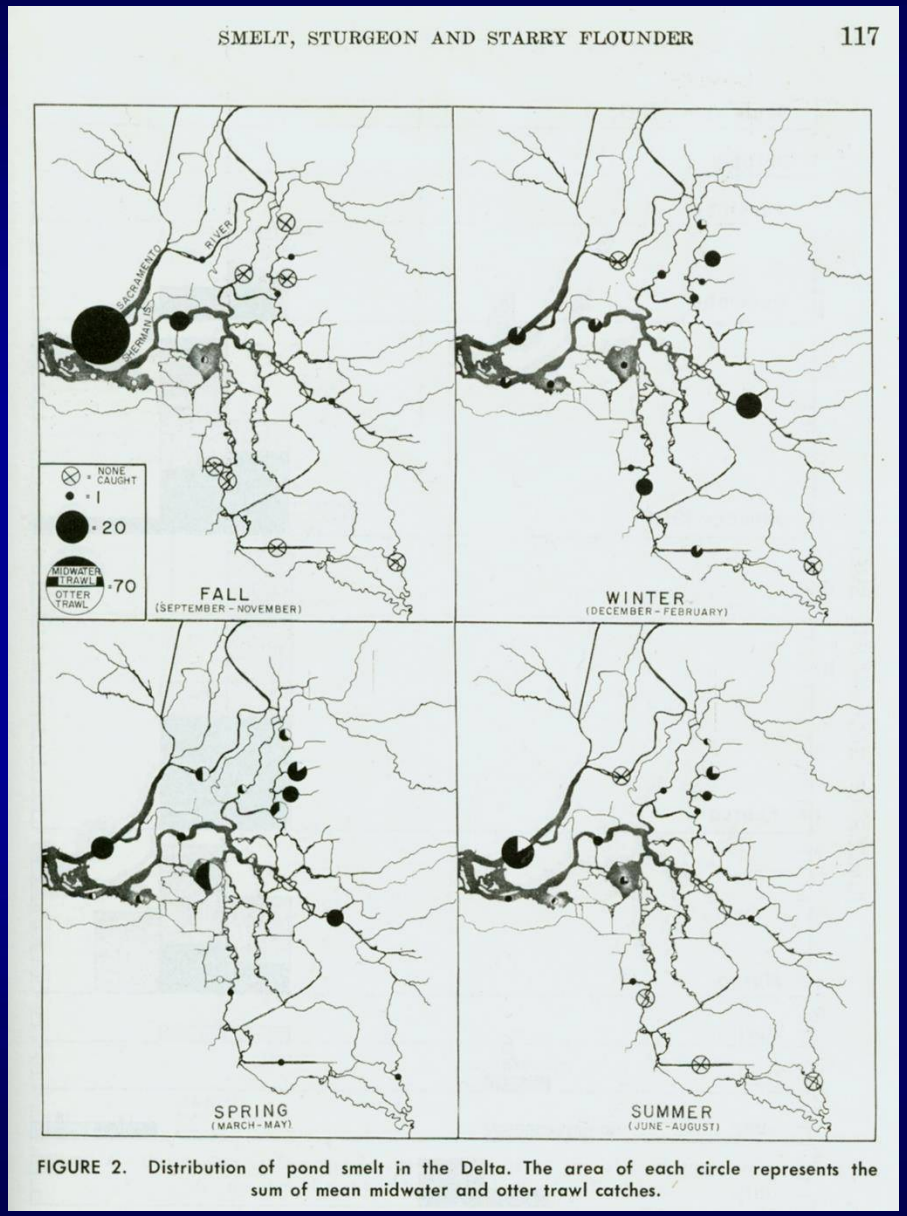
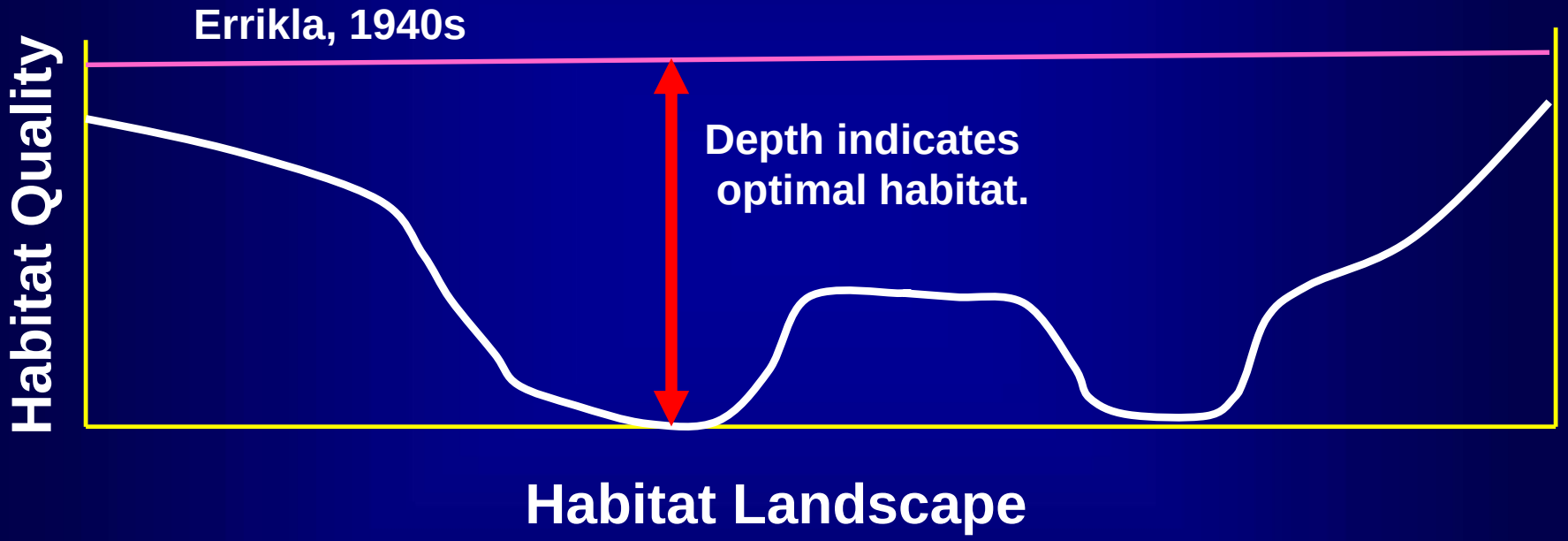


FIGURE 2. Distribution of pond smelt in the Delta. The area of each circle represents the sum of mean midwater and otter trawl catches.

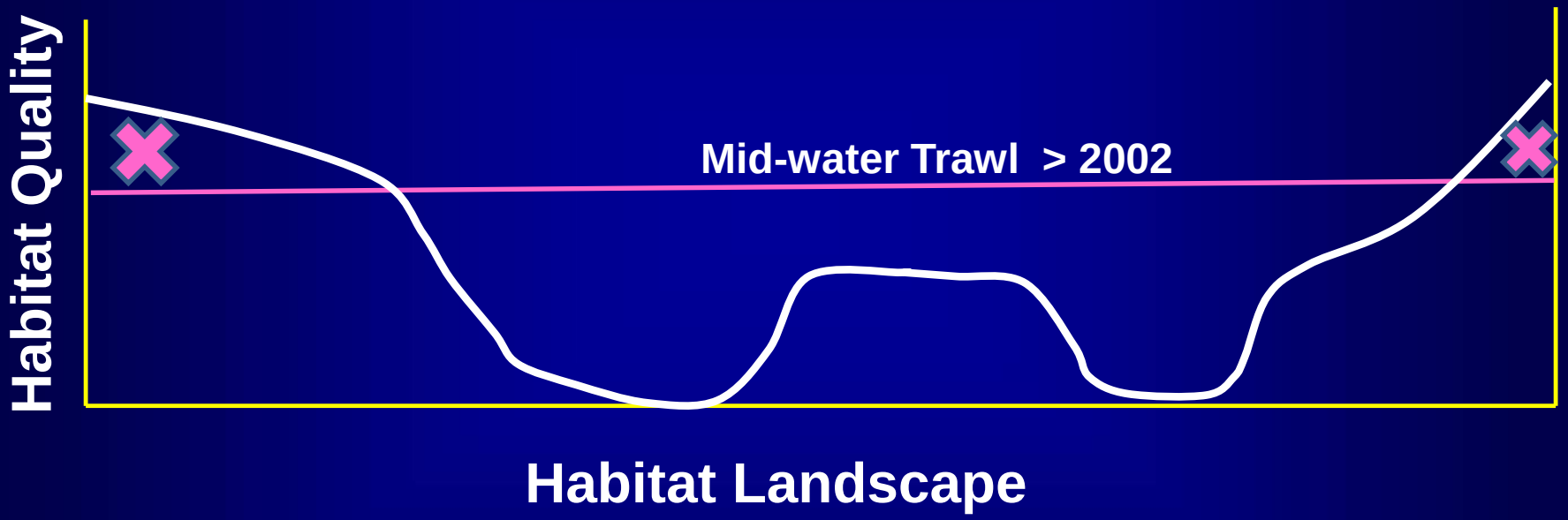
Historical Habitat Use

MacCall's (1990) Basin Model: Sardines -Individuals fill-up habitat of highest quality 1st, and then spill-over.



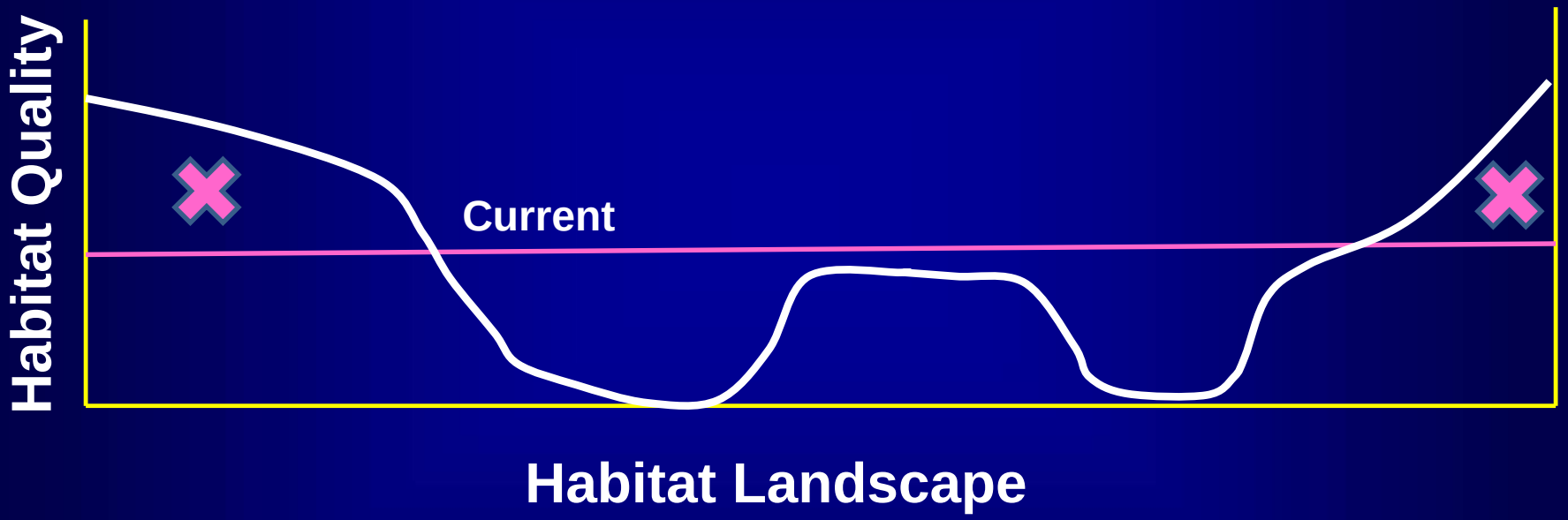
Historical Habitat Use

MacCall's (1990) Basin Model:



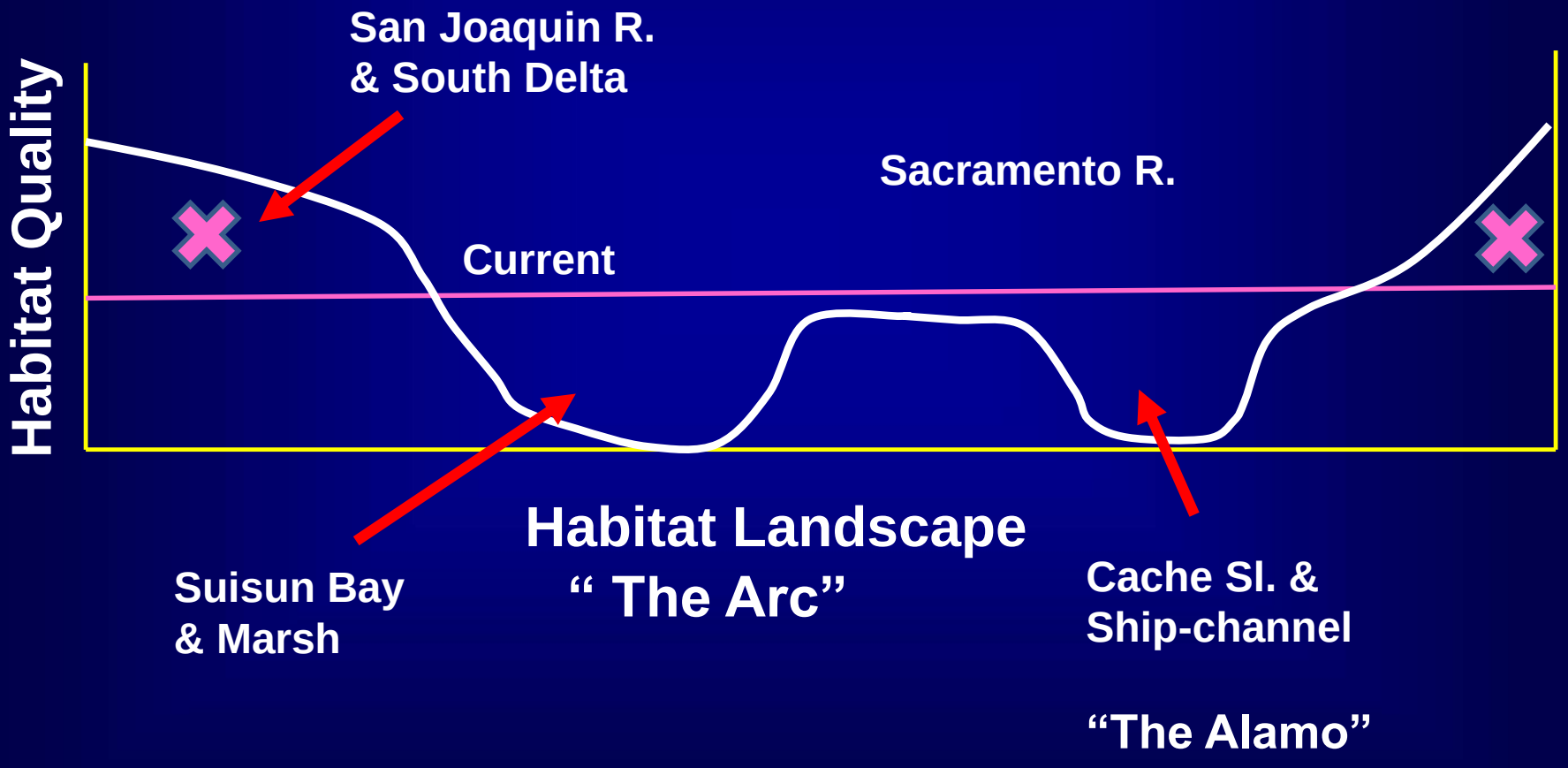
Historical Habitat Use

MacCall's (1990) Basin Model:



Historical Habitat Use

MacCall's (1990) Basin Model:



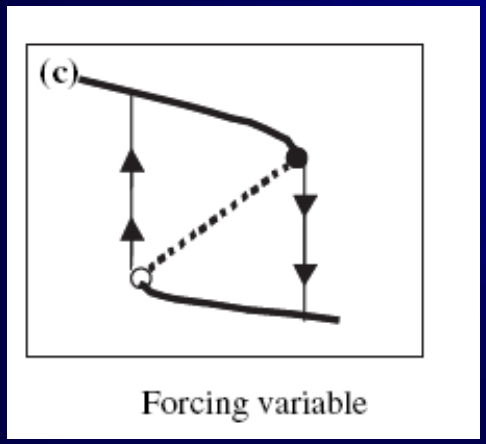
Food Web & Extinction?

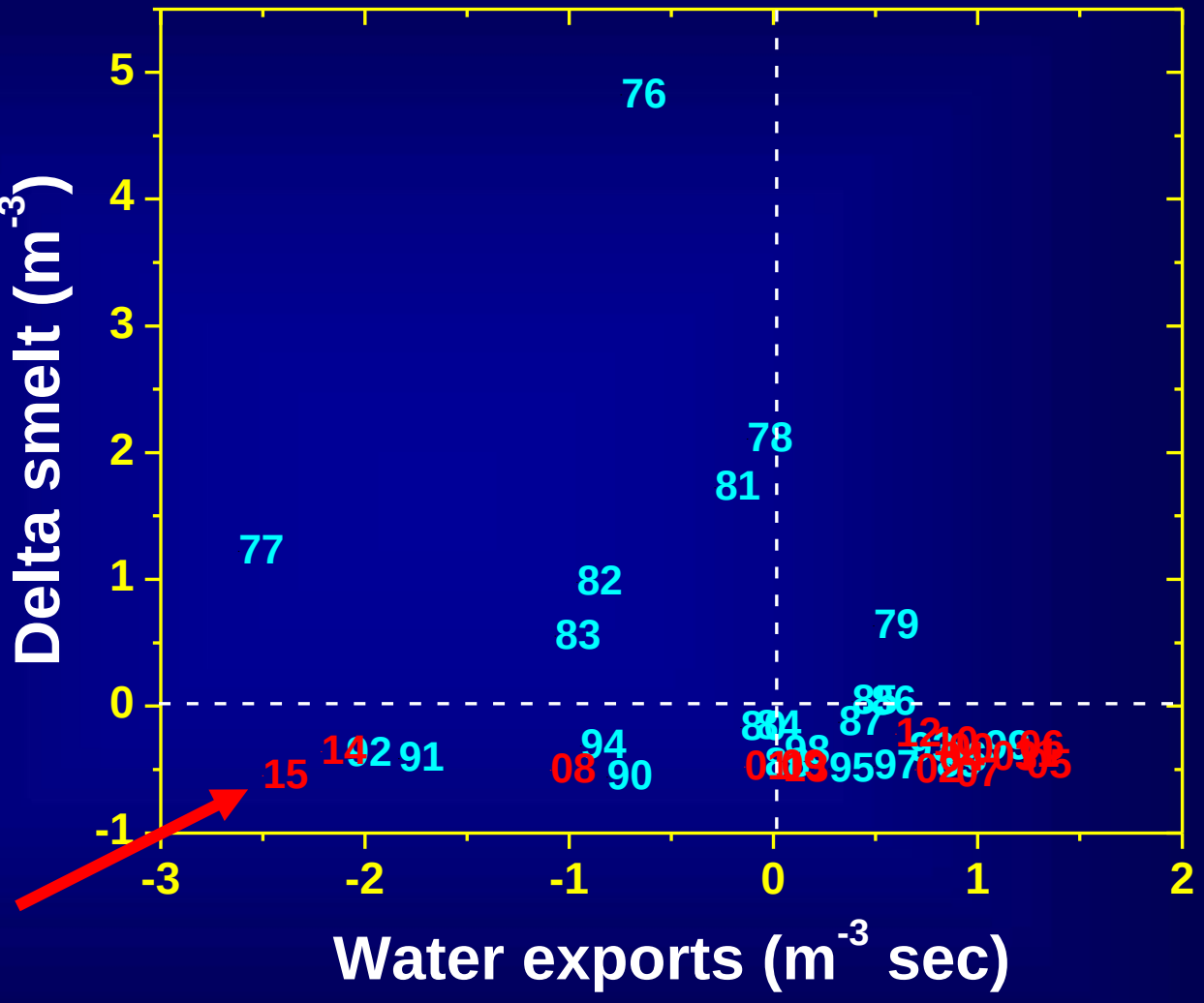
Extinction Debt ?

- Habitat loss most important cause of extinction.
- Most apparent for small-bodies species faced with fragmented habitat.
- Extinction Debt. Habitat has declined faster than ability to adapt. "You're dead, but you don't know that!" An extension of metapopulation theory (Levins 1970, Tilman 1994).

Dynamic Regime Shift

Hysteresis reflects Extinction Debt

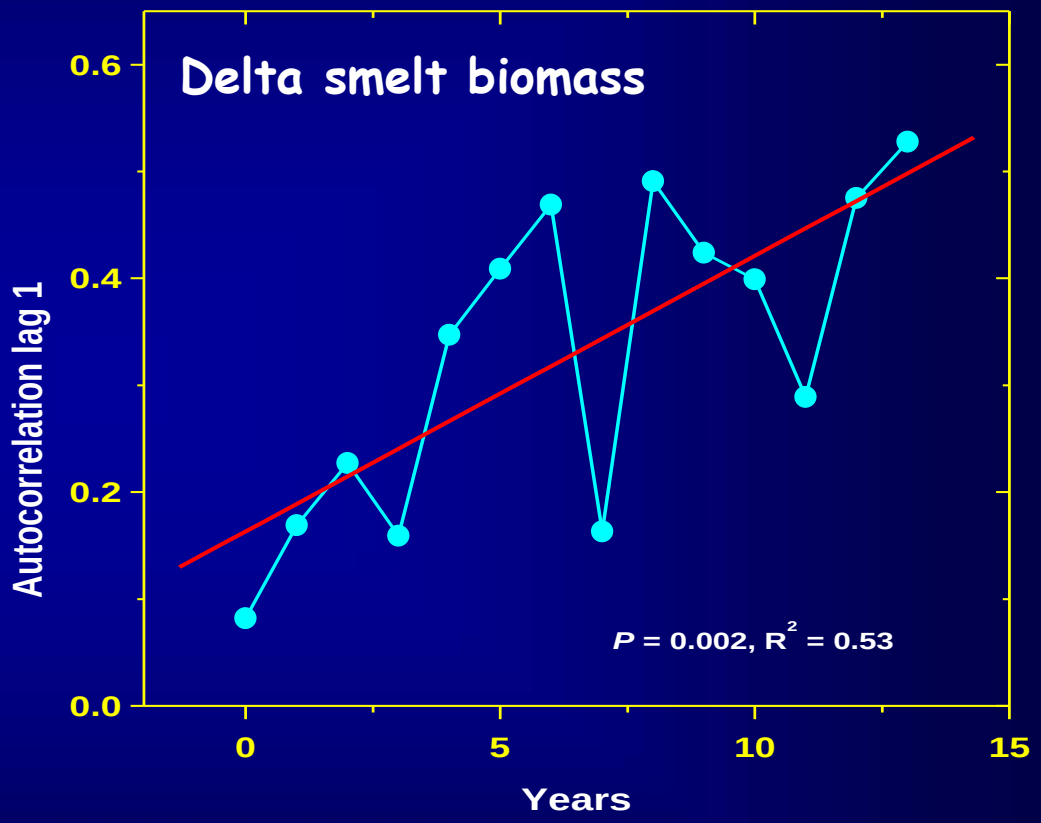




System Behavior Indicates Regime Shift

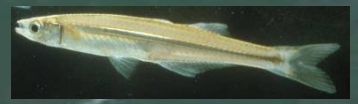
- Evidence for system dynamics slowing-down in years < 2001.
- Points = autocorrelation coefficients at lag 1, for years before 2001.

Method: Dakos et al. 2008 Proc. Nat. Acad. Sci.









Is Extinction Inevitable?

a. Delta region has fundamentally changed – since about 2000, it has undergoing a rapid transition to a new dynamic regime characterized by an alien food web.

b. Delta smelt disappearing, but historic optimal habitat hasn't changed much; i.e., densities way down but optimal habitats still have highest densities.

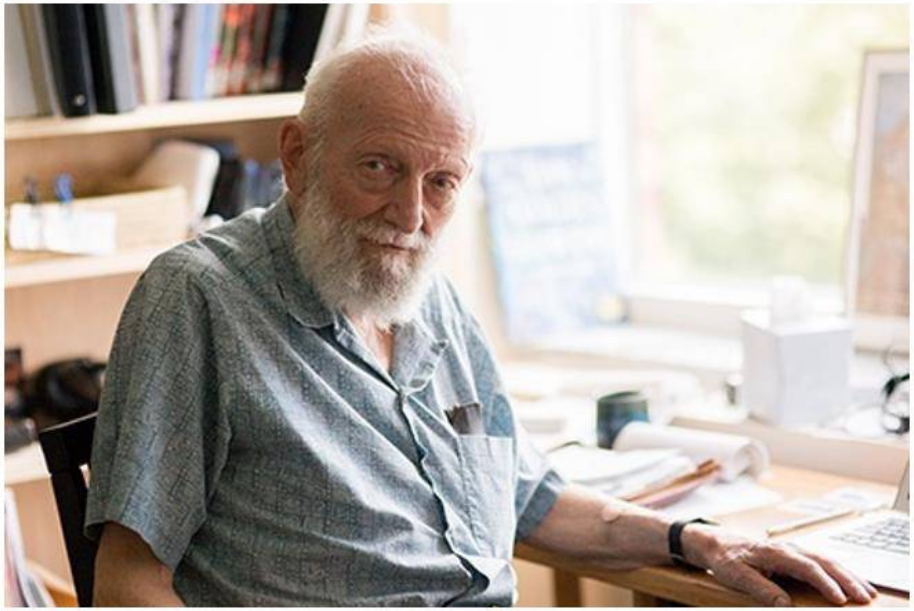
c. Hysteresis associated with regime shift also reflects Extinction Debt.

d. Extinction is inevitable -UNLESS fundamental change occurs to halt the inertia of the alien food web.

Richard Levins, 1930-2016

by Greg Mayer

Richard 'Dick' Levins, the John Rock Professor of Population Sciences at the Harvard School of Public Health, died on January 19 of this year. He was one of the most influential population biologists of the 20th century, and a close colleague and associate of Dick Lewontin, Jerry's doctoral advisor.



Richard Levins, 1930-2016

Levins was an early and active participant in the group of biologists that, in the early 1960s, worked to unite ecology, evolutionary biology, and genetics into a unified and theoretically-rich science of the biology of populations. Included among this group was Dick Lewontin, Larry Slobodkin, E.O. Wilson, and, perhaps most saliently for Levins, Robert MacArthur.