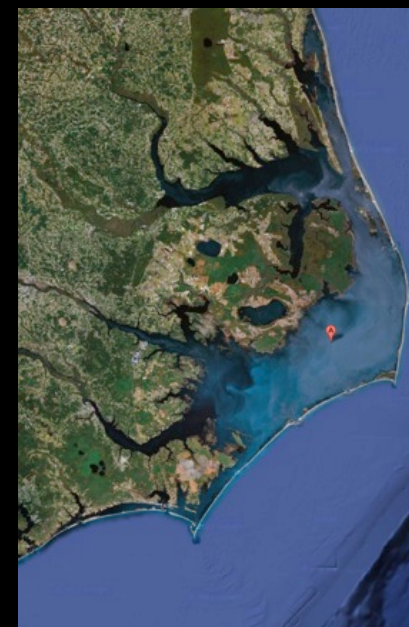
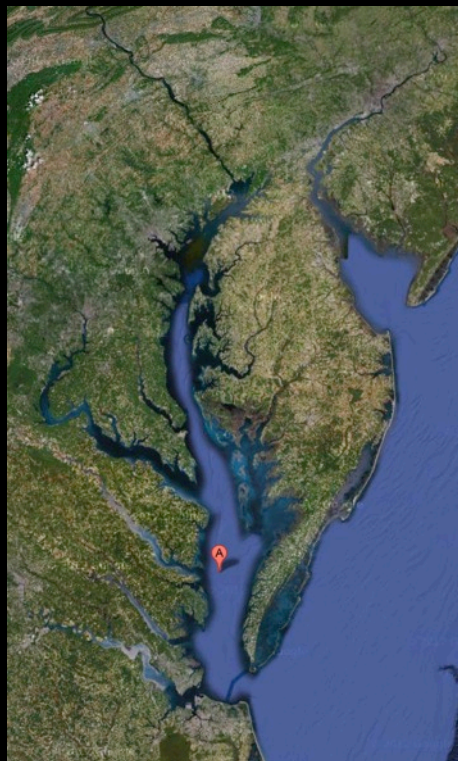


# Lessons From Sustained Observations in Estuaries



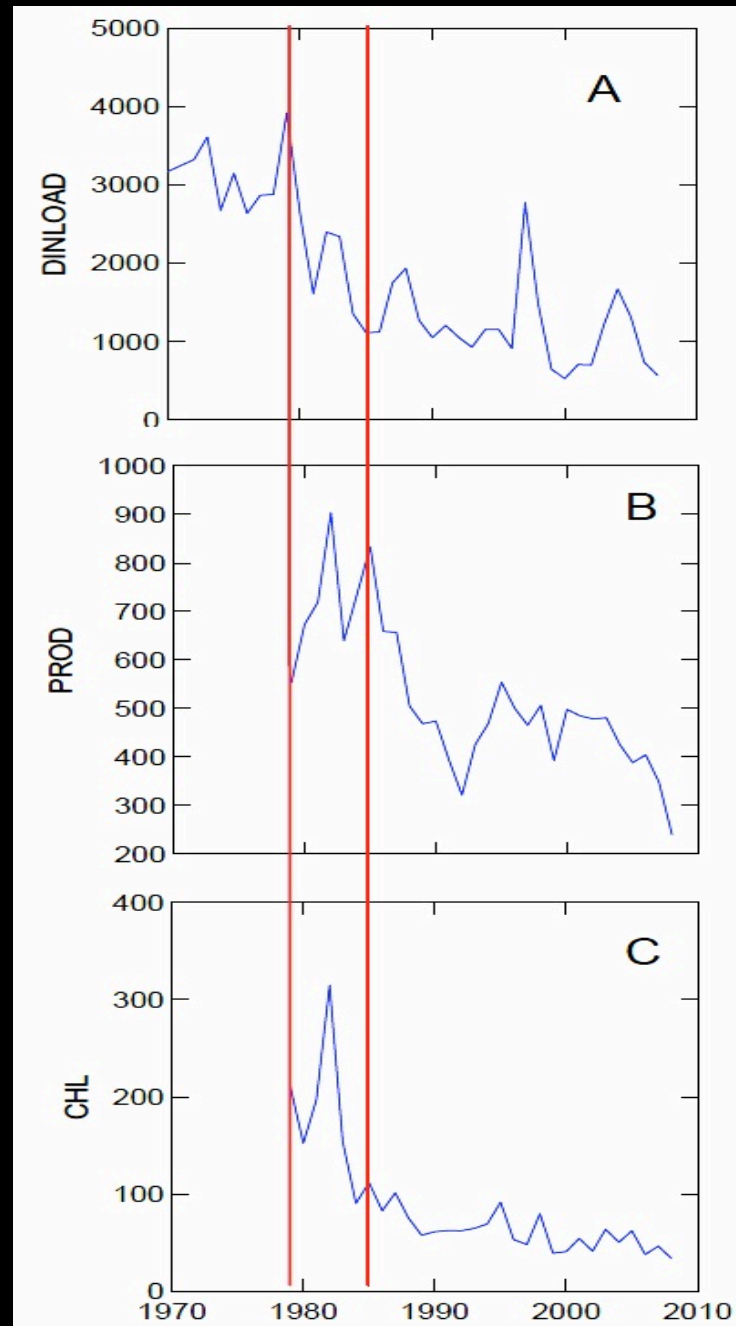
Jim Cloern, USGS, Menlo Park CA



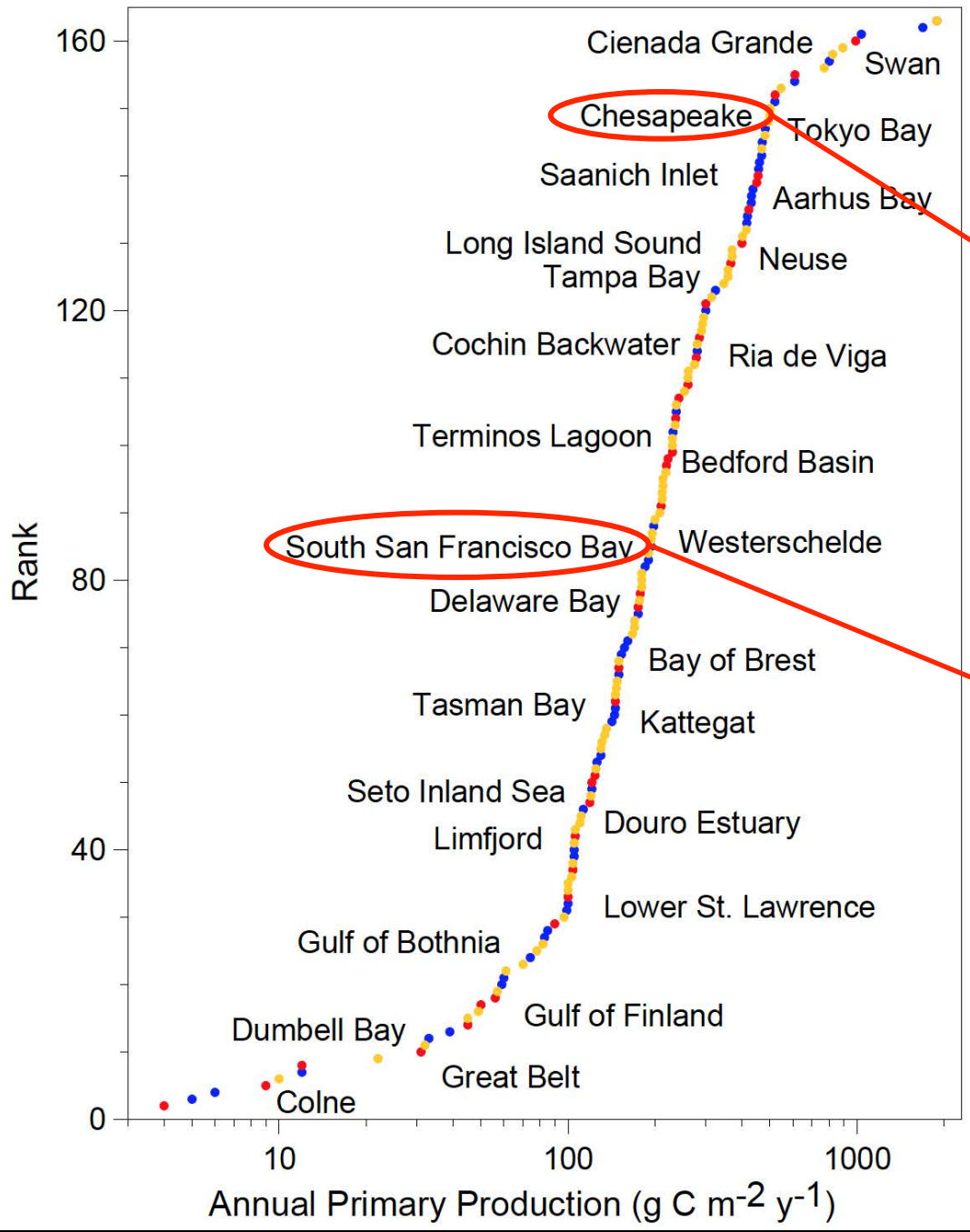
# 1: Responses to Nutrient Reductions



Tampa Bay



## 2: Variable Sensitivity Across Estuaries

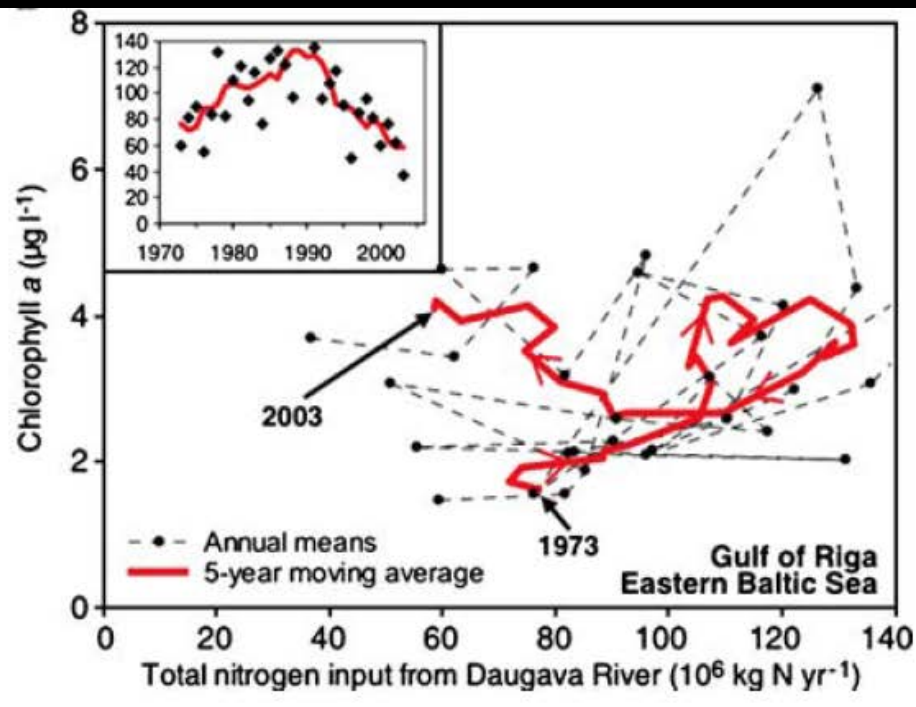
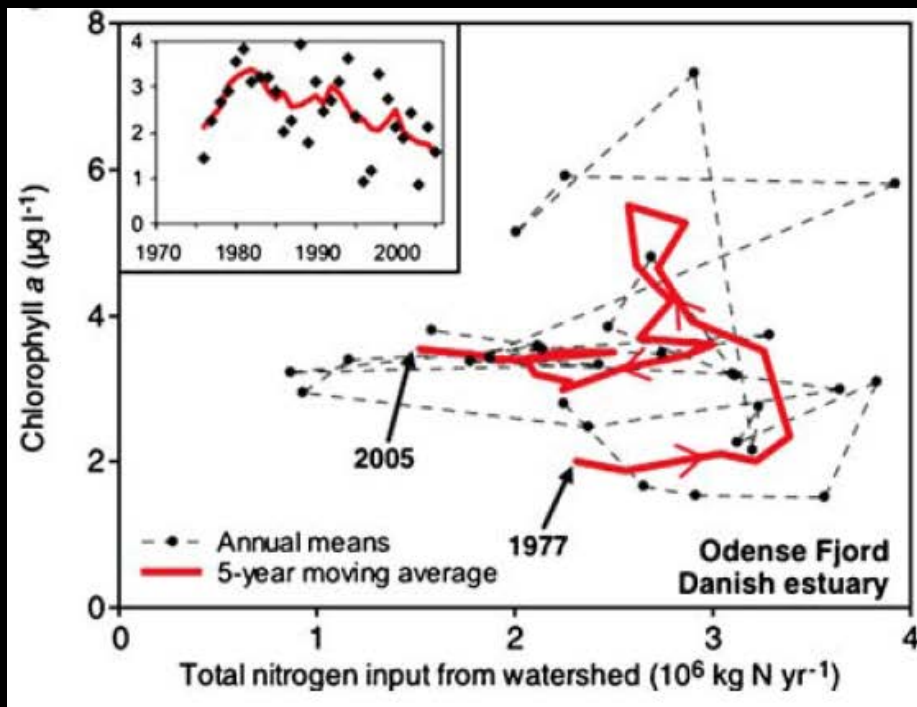


450-500  
hypertrophic; 141/163

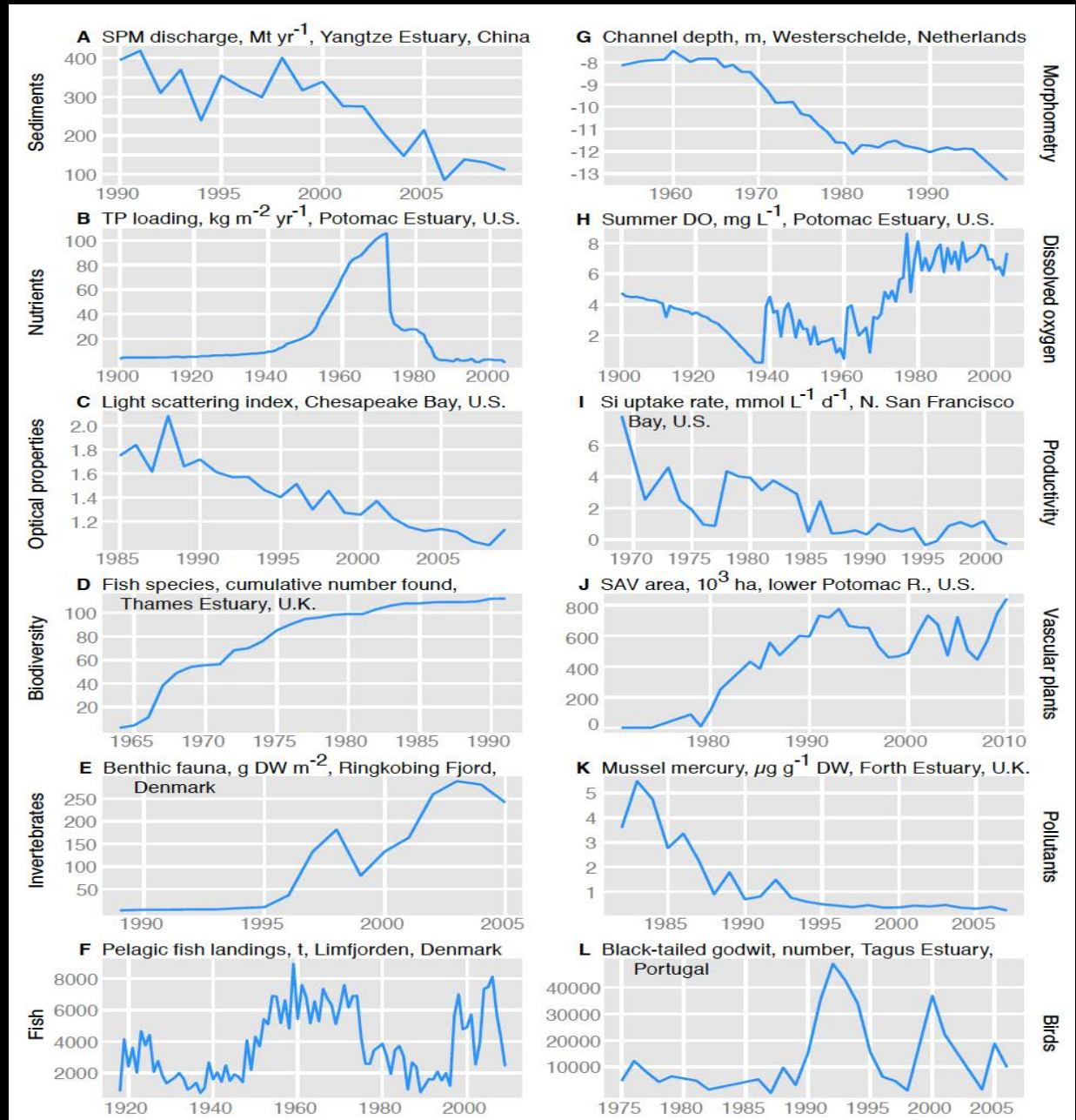
185  
mesotrophic



### 3: Disappointing/Unexpected Responses to Nutrient Reductions



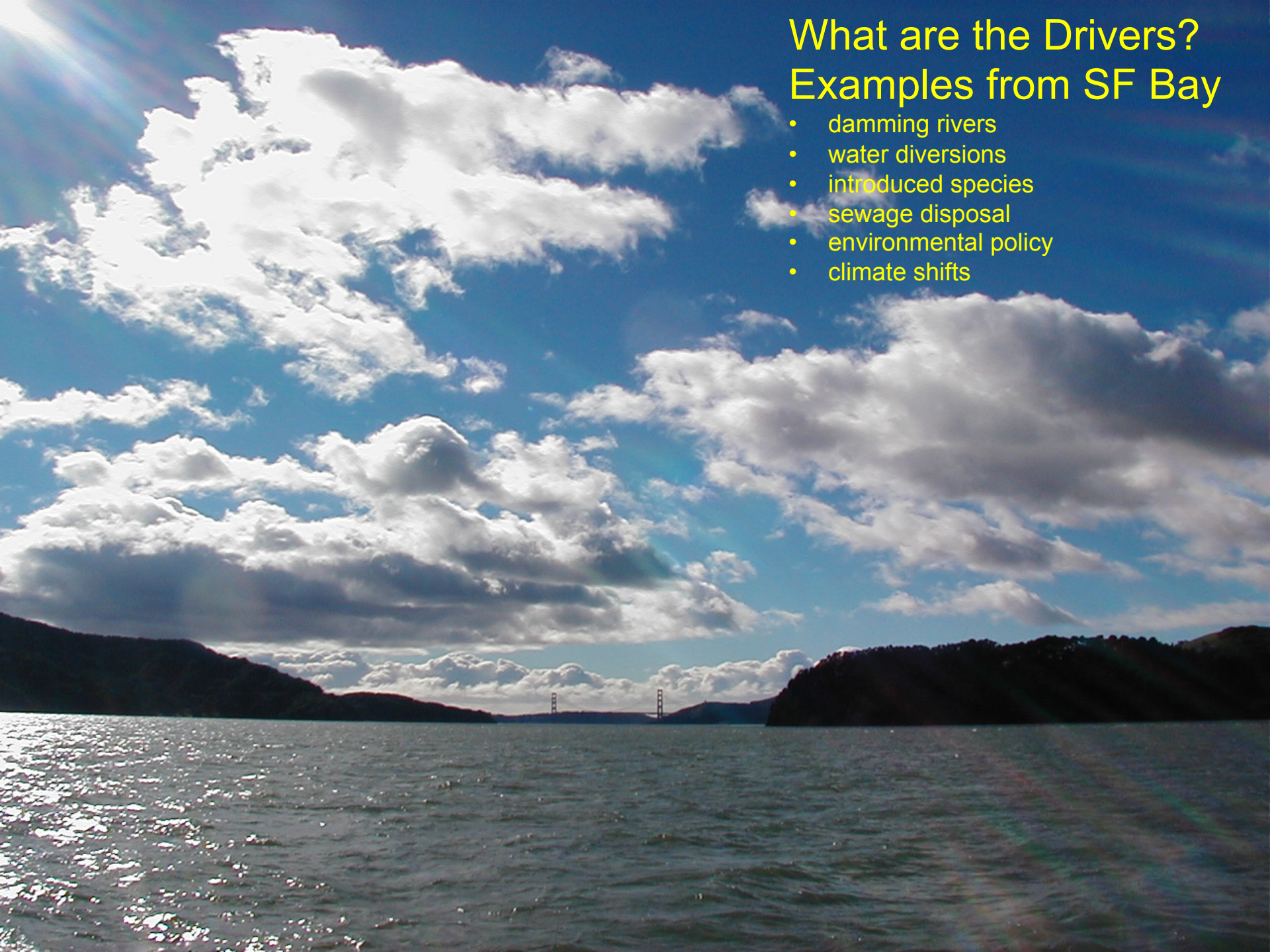
# 4: Things Change



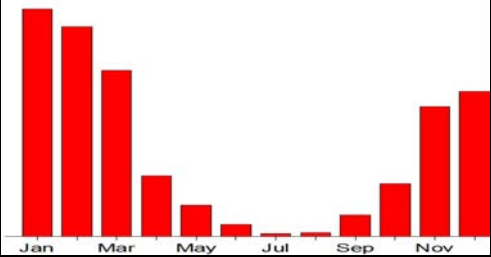
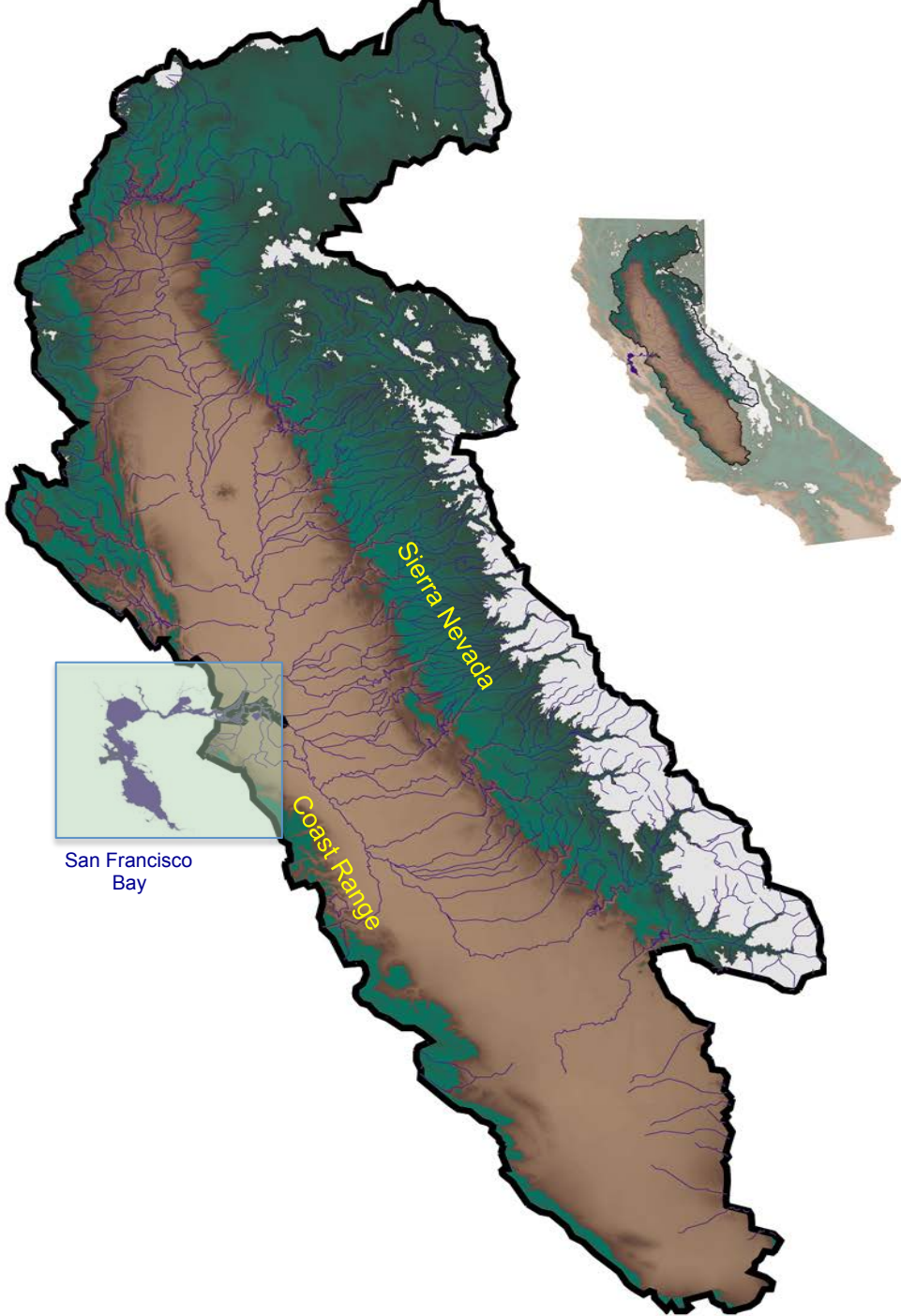


# What are the Drivers? Examples from SF Bay

- damming rivers
- water diversions
- introduced species
- sewage disposal
- environmental policy
- climate shifts



# San Francisco Bay is an Estuary







San Pablo

Suisun Bay

Sacramento

San Joaquin

Delta

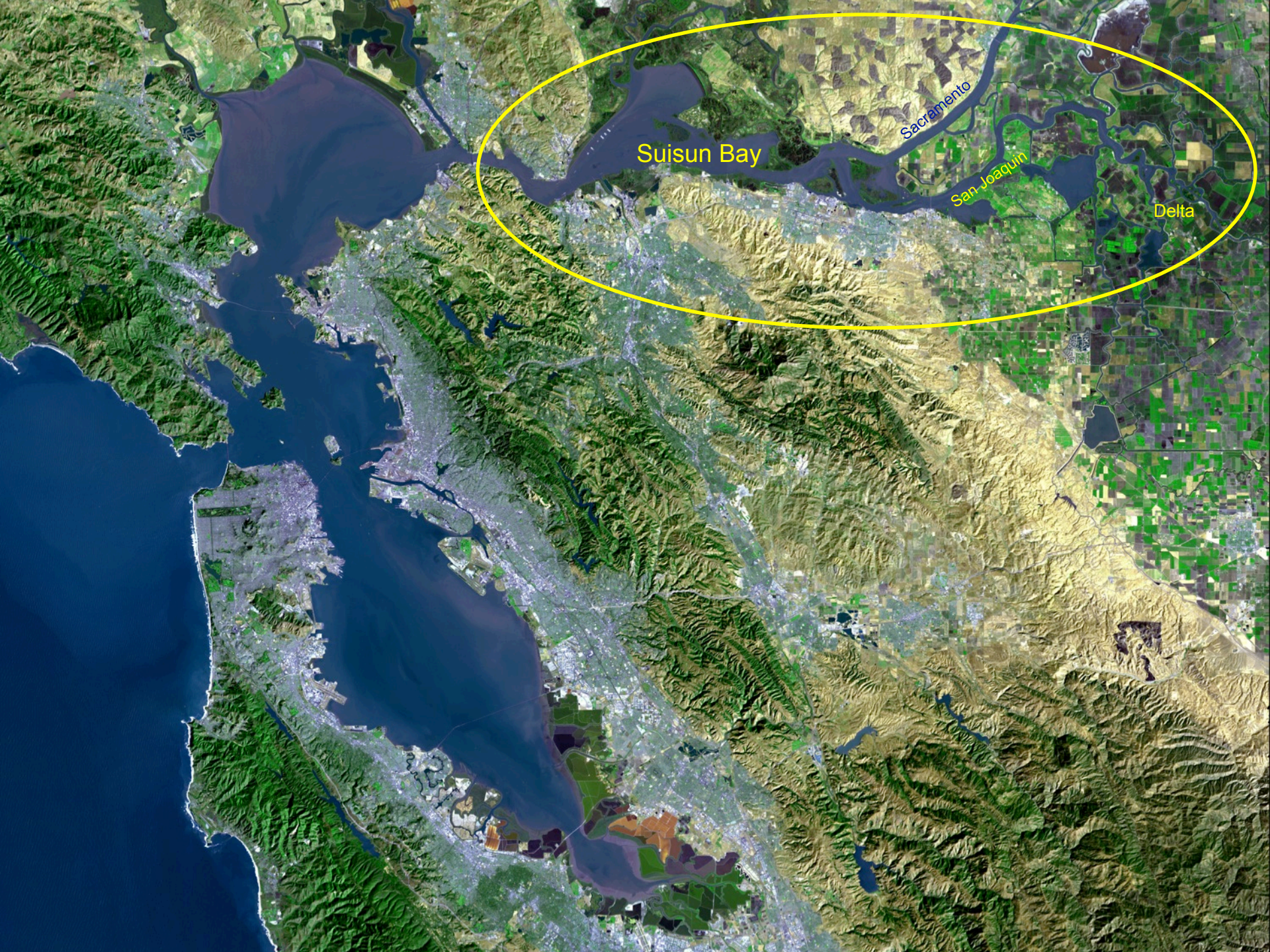
Golden Gate

San Francisco

Pacific Ocean

South Bay





Suisun Bay

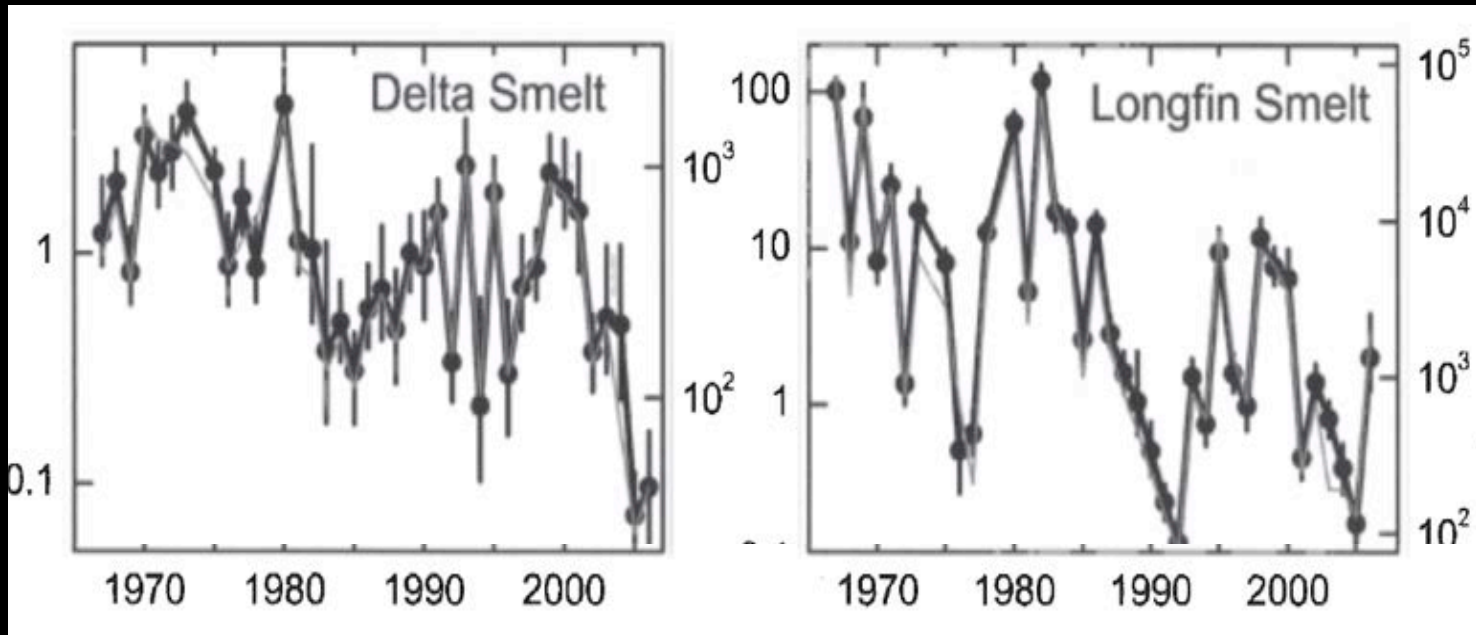
Sacramento

San Joaquin

Delta

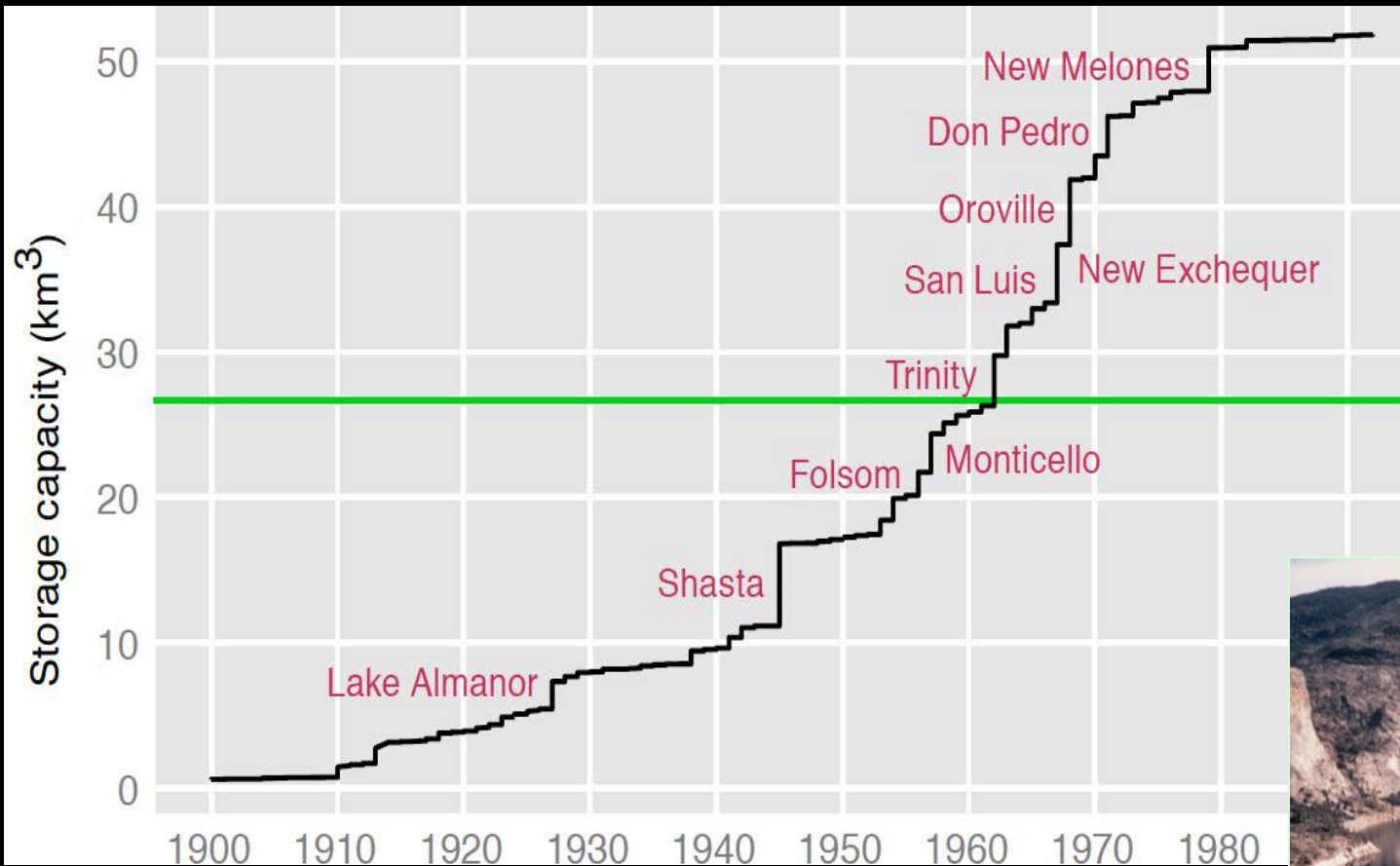


# Priority Management Issue: Endangered Native Fishes

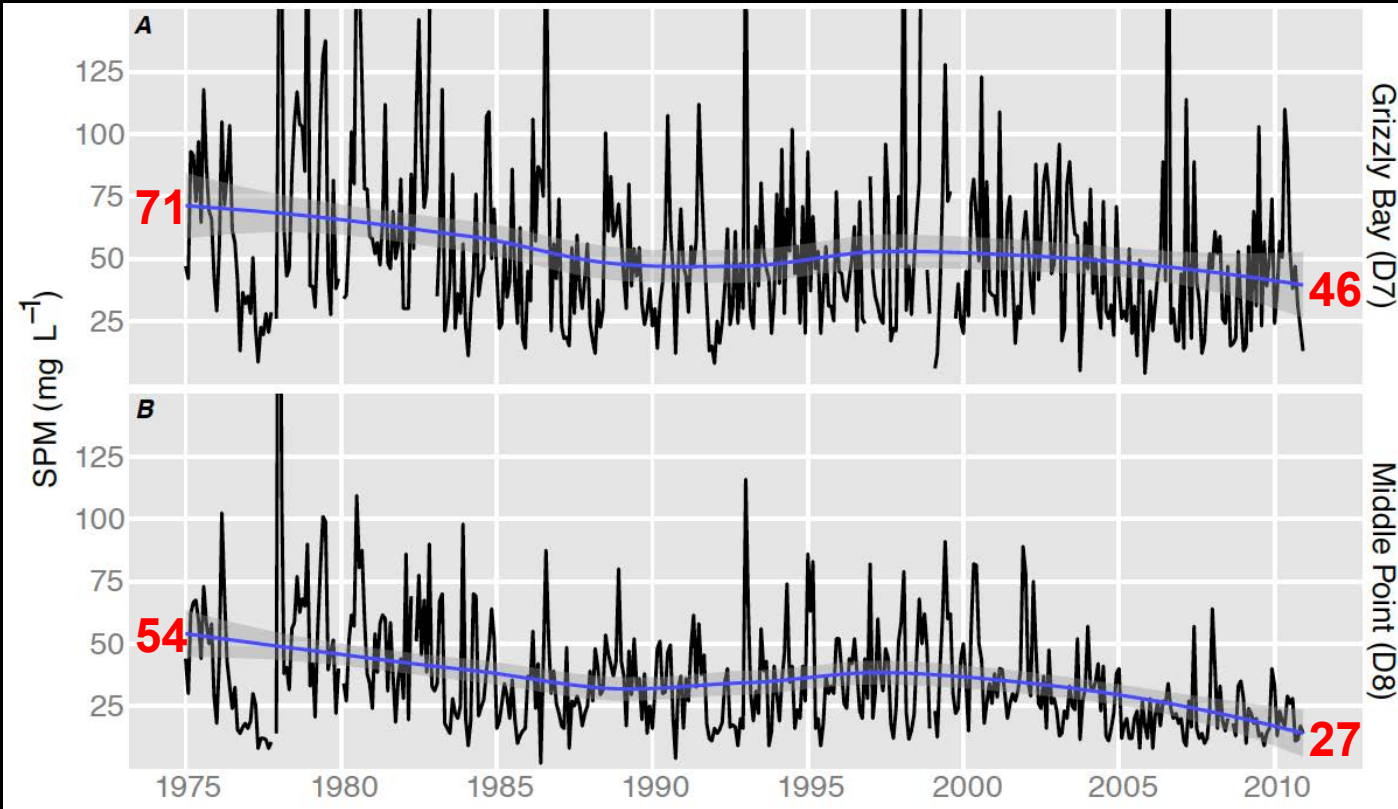
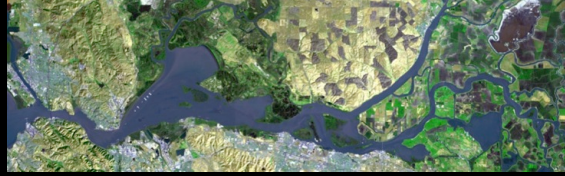




# DRIVER #1: damming rivers



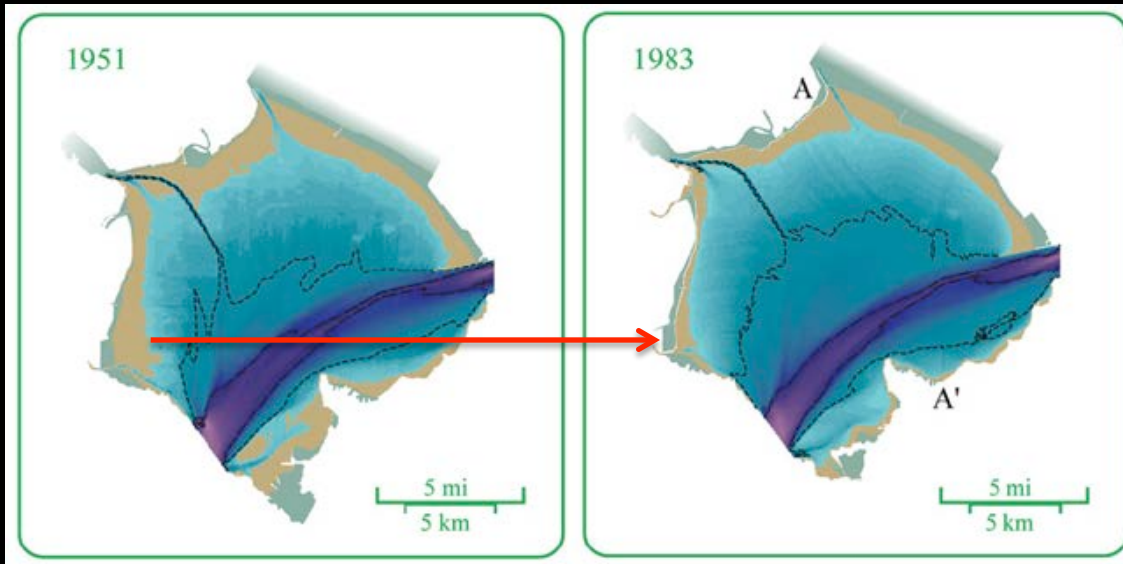
RESPONSE: reduced sediment supply and sediment concentrations





# IMPLICATIONS:

increasing transparency



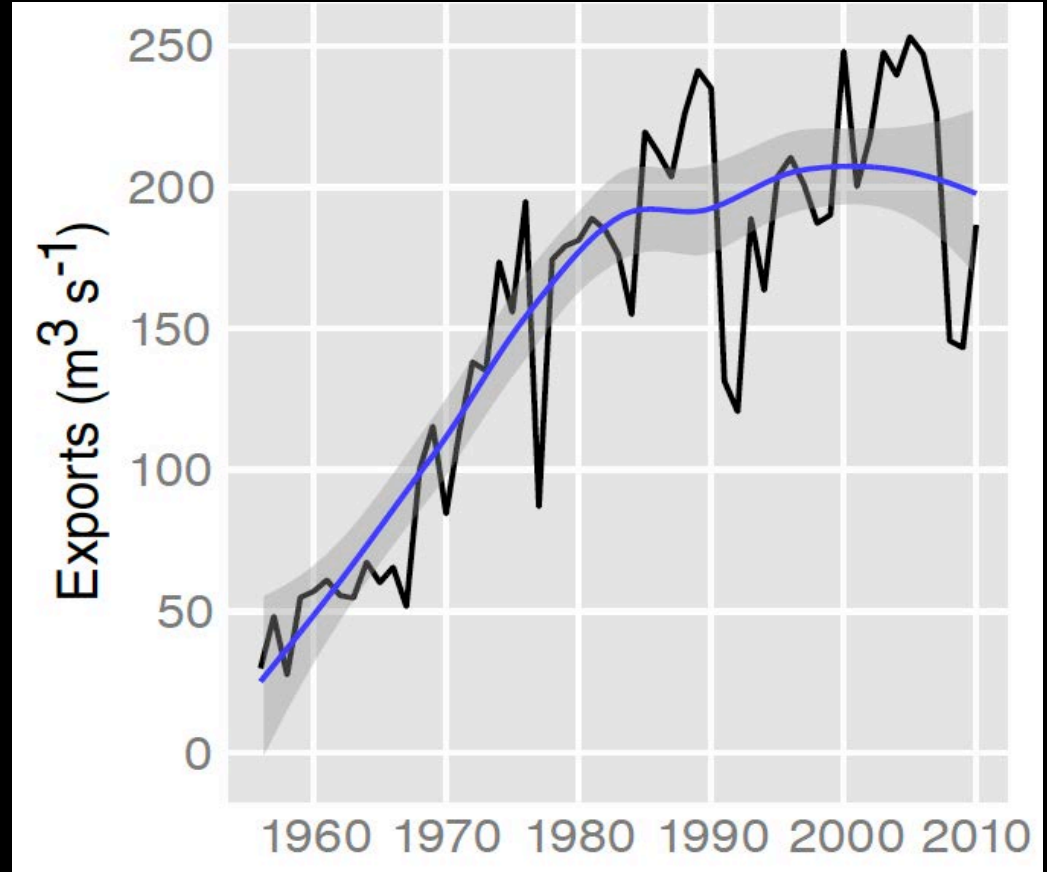
loss of mudflats

sustainability of tidal marshes ?

OM (mm/yr)	SSC (mg/L)	SLR = 0.52 m/century					SLR = 1.65 m/century				
		Year					Year				
		20	40	60	80	100	20	40	60	80	100
1	25	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	25	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	25	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
1	50	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	50	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	50	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
1	100	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	100	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	100	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
1	150	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	150	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	150	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
1	200	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	200	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	200	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
1	250	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	250	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	250	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
1	300	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
2	300	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
3	300	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green

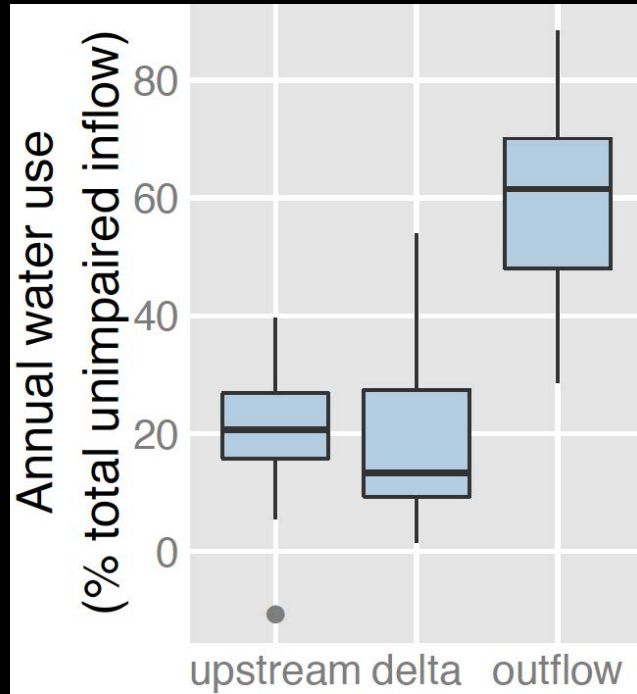
Evaluating Tidal Marsh Sustainability in the Face of Sea-Level Rise: A Hybrid Modeling Approach Applied to San Francisco Bay  
 Diana Stralburg<sup>1,2</sup>, Matthew Brennan<sup>1</sup>, John C. Callaway<sup>1</sup>, Julian K. Wood<sup>1</sup>, Lisa M. Schib<sup>1</sup>, Dennis Jansons<sup>1</sup>, Maggie Kelly<sup>1</sup>, S. Thomas Parker<sup>1</sup>, Stephen Crooks<sup>1</sup>

## DRIVER #2: water consumption and diversions

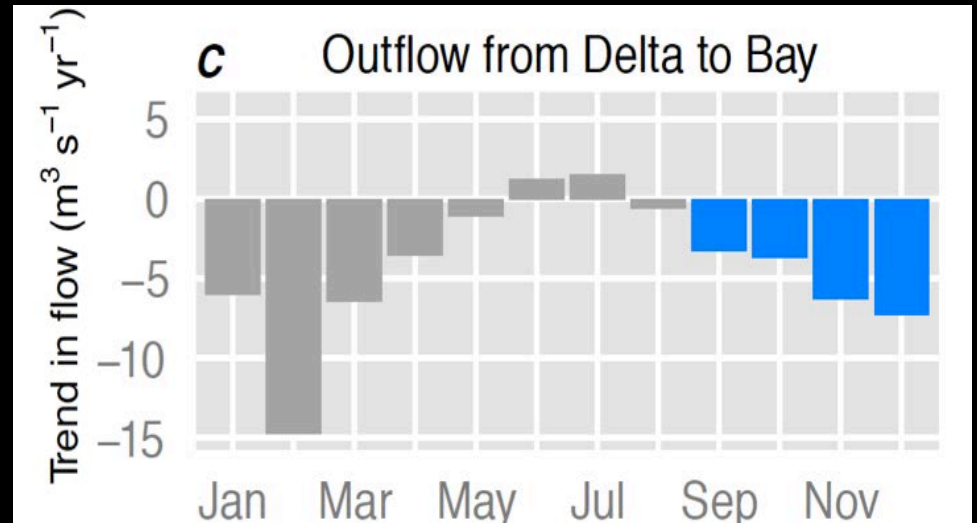




# RESPONSE:



39% reduction in freshwater inflow

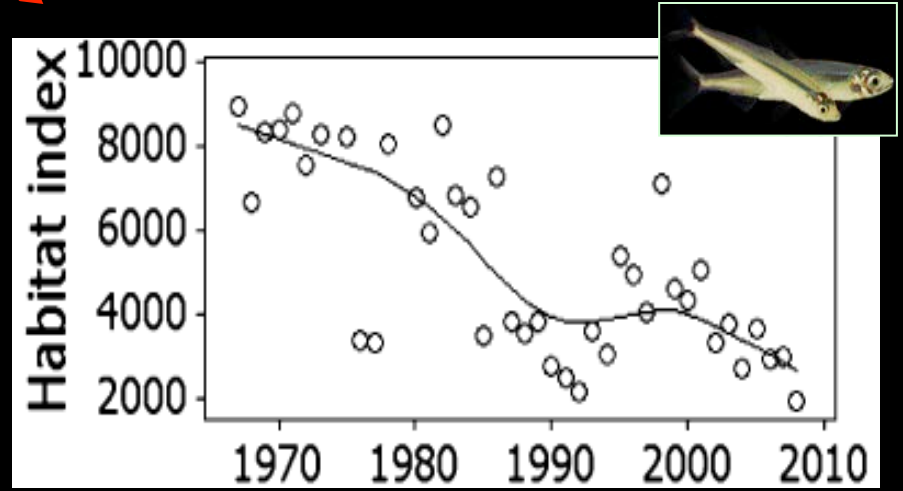
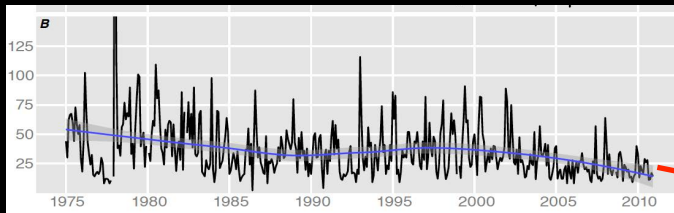


altered hydrograph

# IMPLICATIONS:

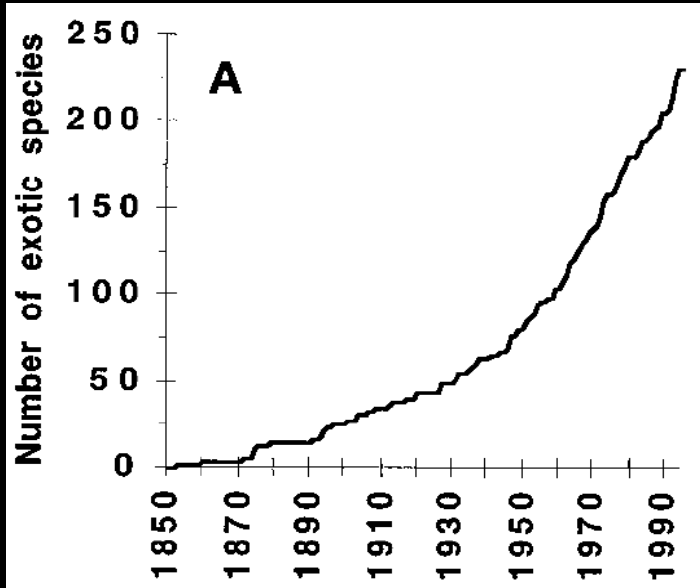


*New Flow Standard*





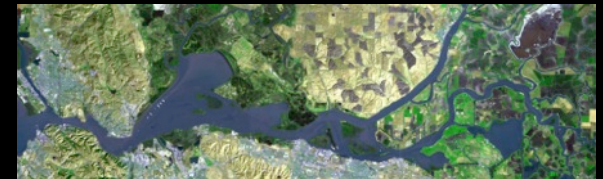
## DRIVER #3: introduced species



*"San Francisco Bay and Delta ecosystem may be the most invaded estuary in the world"*

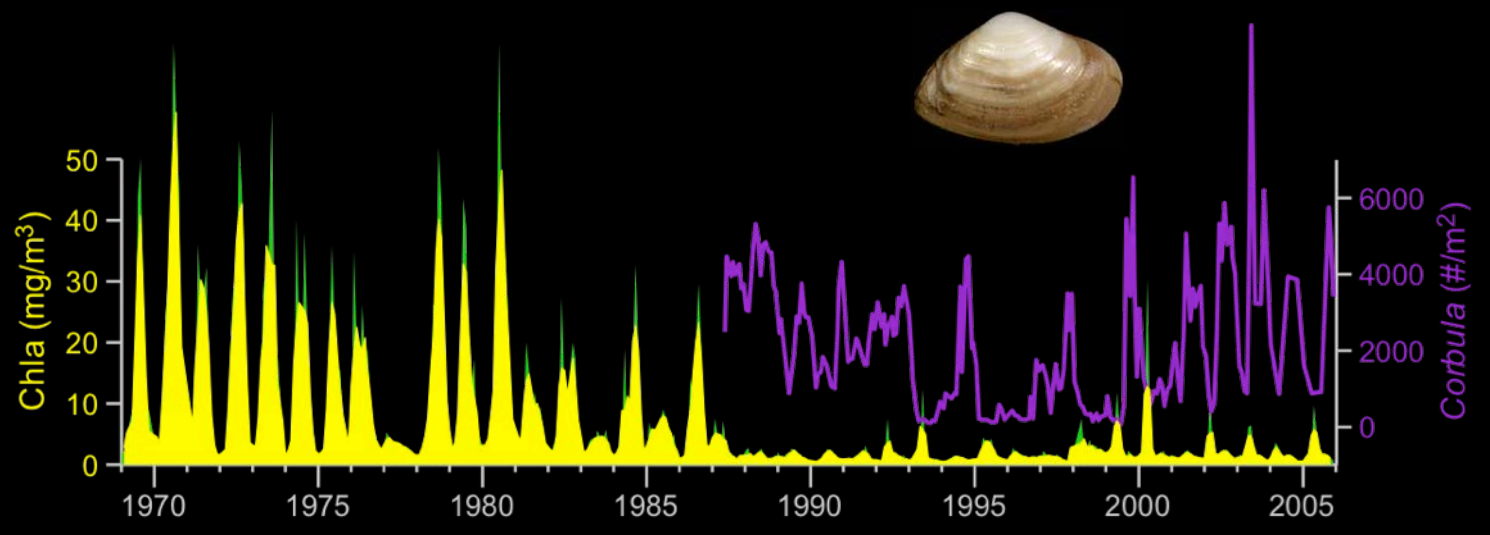
### Accelerating Invasion Rate in a Highly Invaded Estuary

Andrew N. Cohen\* and James T. Carlton



*Corbula amurensis*

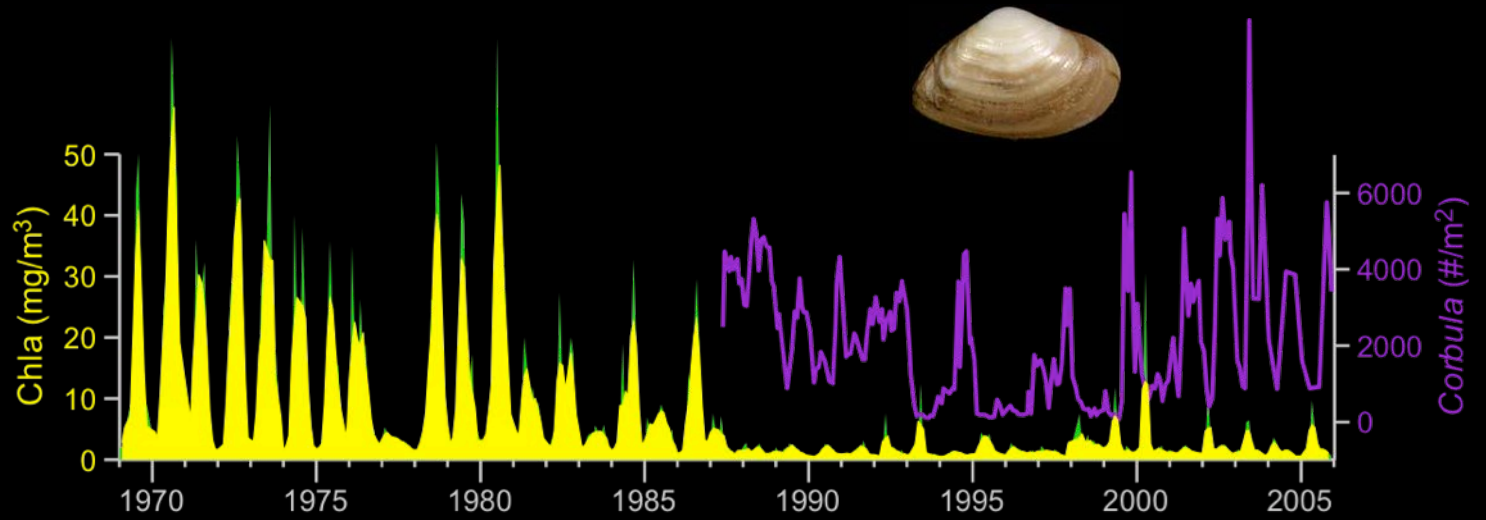
# RESPONSE:



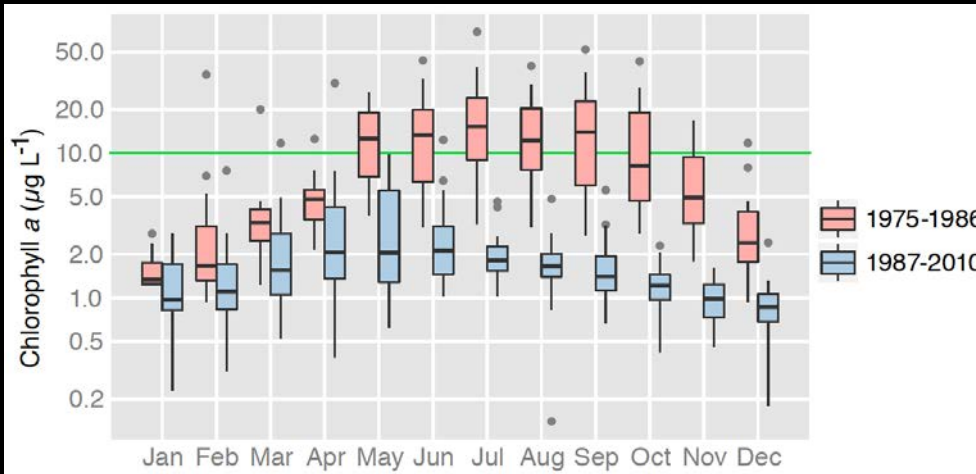
5-fold reduction of phytoplankton biomass and production



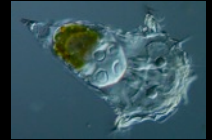
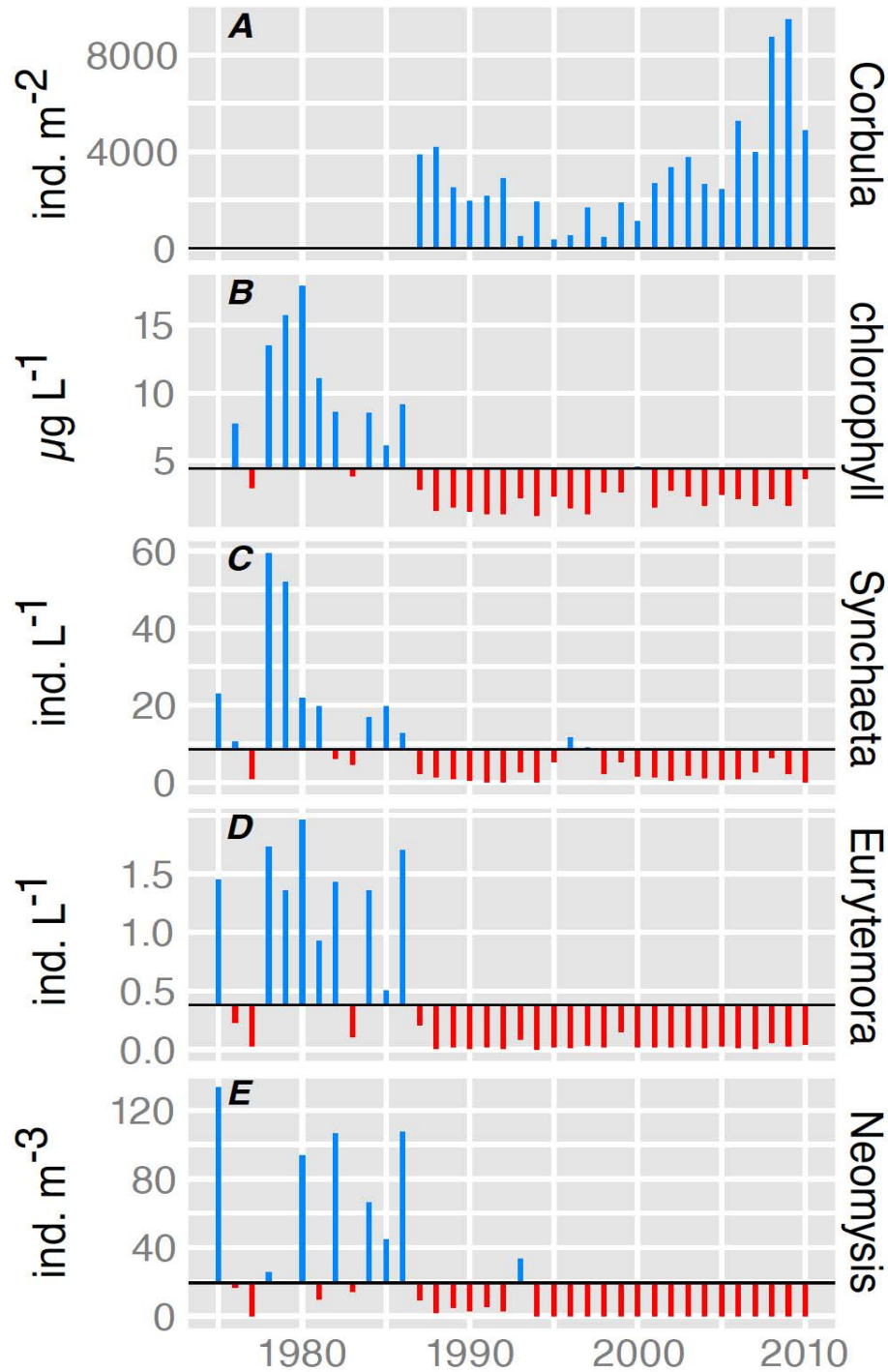
# RESPONSE:



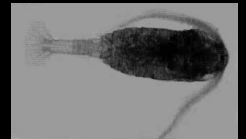
5-fold reduction of phytoplankton biomass and production



food limitation of consumers

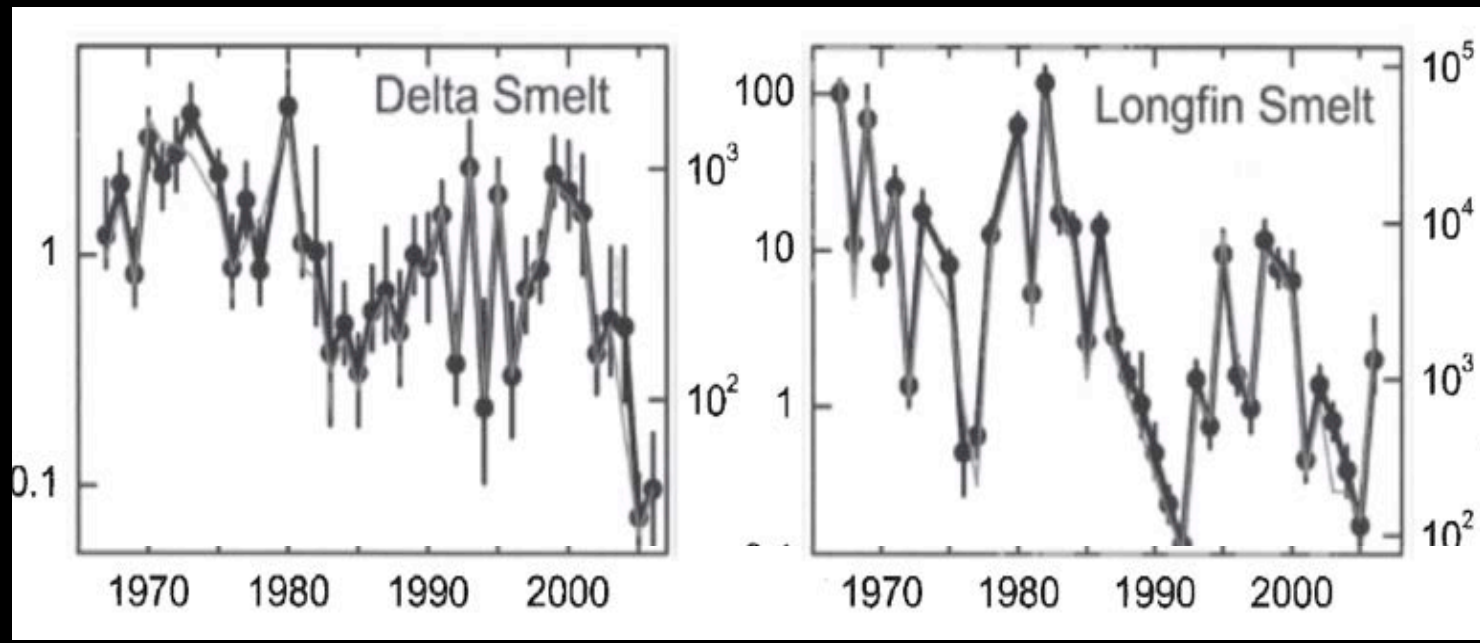
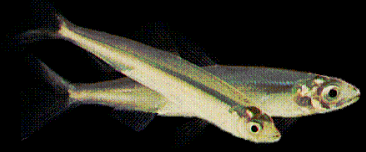


loss of zooplankton





# IMPLICATIONS:







Pacific  
Ocean

South Bay



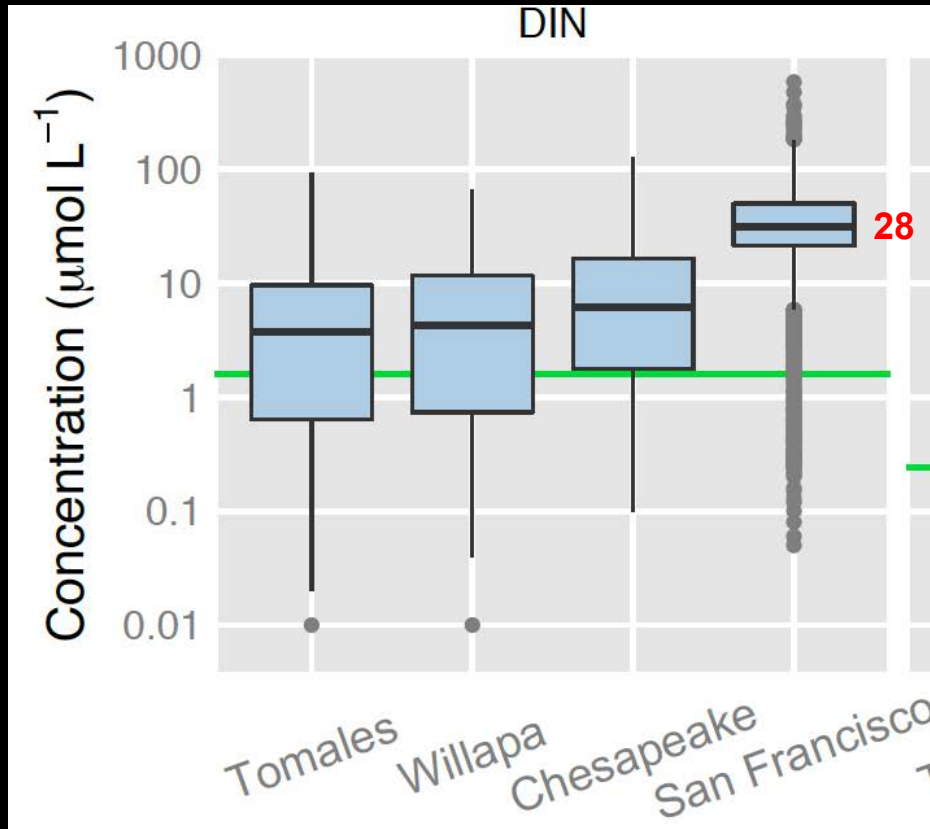
## DRIVER #4: sewage disposal



4 M people  
375 Mgal/day

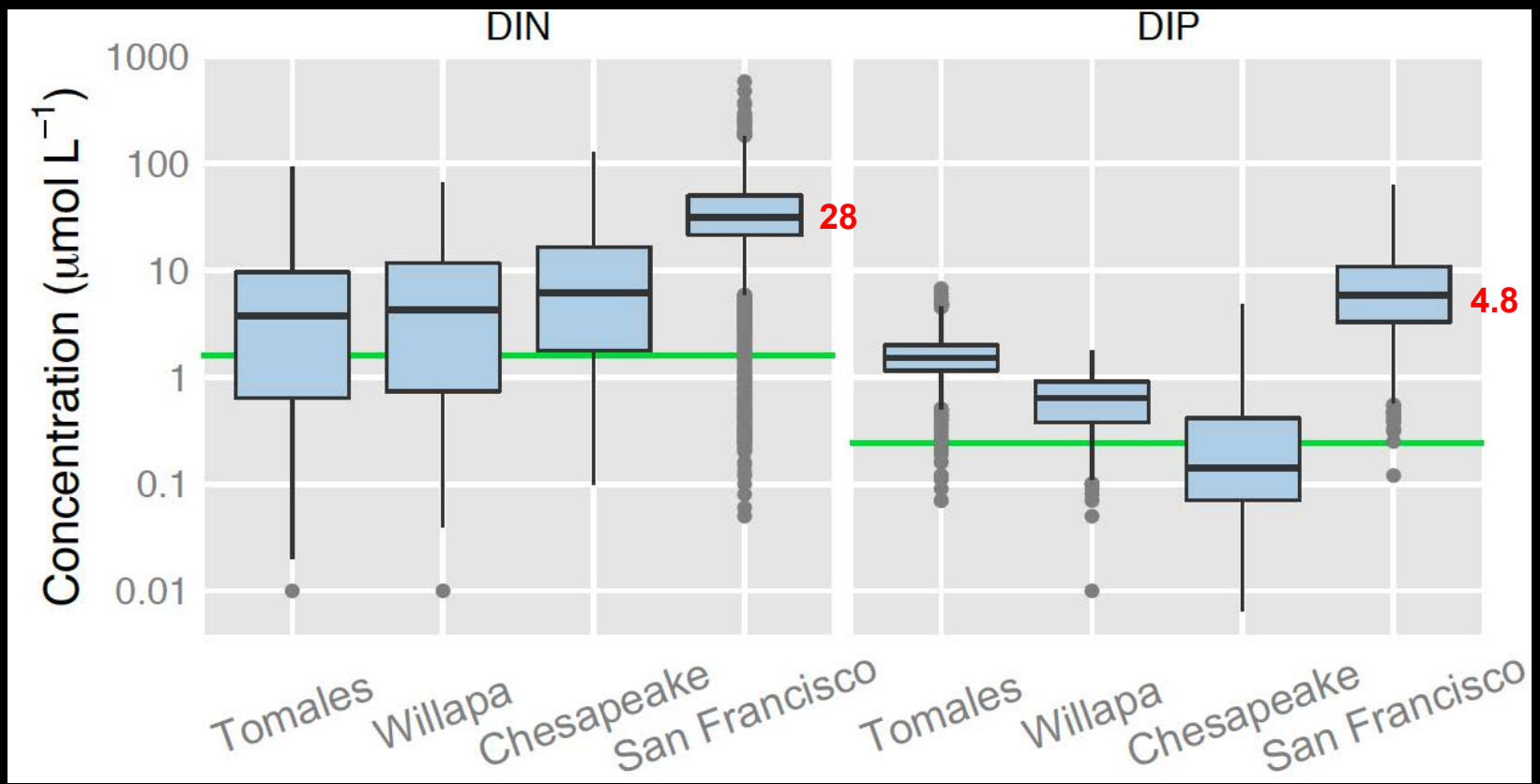
11,000 tons/yr DIN  
1,900 tons/yr DIP

# RESPONSE: high N and P concentrations

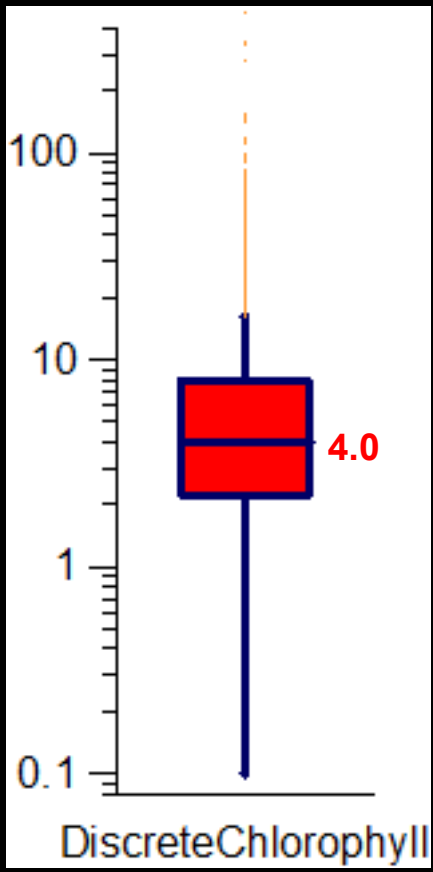




# RESPONSE: high N and P concentrations



# IMPLICATIONS: *potential* for very high phytoplankton biomass



But South SF Bay has low phytoplankton biomass, partly because of strong grazing by bivalves





# DRIVER #5: environmental policy

## Clean Water Act



<b>Full title</b>	Federal Water Pollution Control Amendments of 1972
<b>Acronym</b>	CWA / Clean Water Act
<b>Enacted by the</b>	92nd United States Congress
<b>Effective</b>	October 18, 1972

### Citations

<b>Public Law</b>	<a href="#">P.L. 92-500</a>
<b>Stat.</b>	86 Stat. 816 (1972)

### Codification

<b>Act(s) amended</b>	Federal Water Pollution Control Act
<b>Title(s) amended</b>	33 (Navigable Waters)
<b>U.S.C. sections created</b>	<a href="#">33 U.S.C. § 1251</a> <i>et seq.</i>

### Legislative history

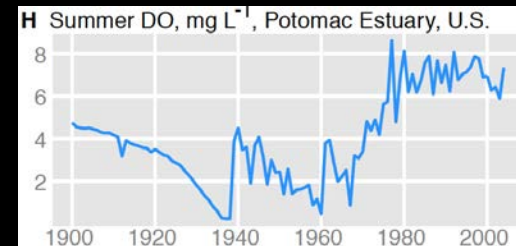
- **Introduced in the Senate as S. 2770 by Edmund Muskie on October 28, 1971**
- **Committee consideration by:** [Senate Public Works Committee](#)
- **Passed the Senate on November 2, 1971** ()
- **Passed the House on March 29, 1972** ()
- **Reported by the joint conference committee on October 4, 1972; agreed to by the House on October 4, 1972 () and by the Senate on October 4, 1972 ()**
- **Vetoed by President Richard Nixon on October 17, 1972**
- **Overridden by the Senate on October 18, 1972** ()
- **Overridden by the House and became law on October 18, 1972** ()

mandated secondary treatment to remove BOD and  $\text{NH}_4$

*"to restore and maintain the chemical, physical and biological integrity of the nation's waters"*

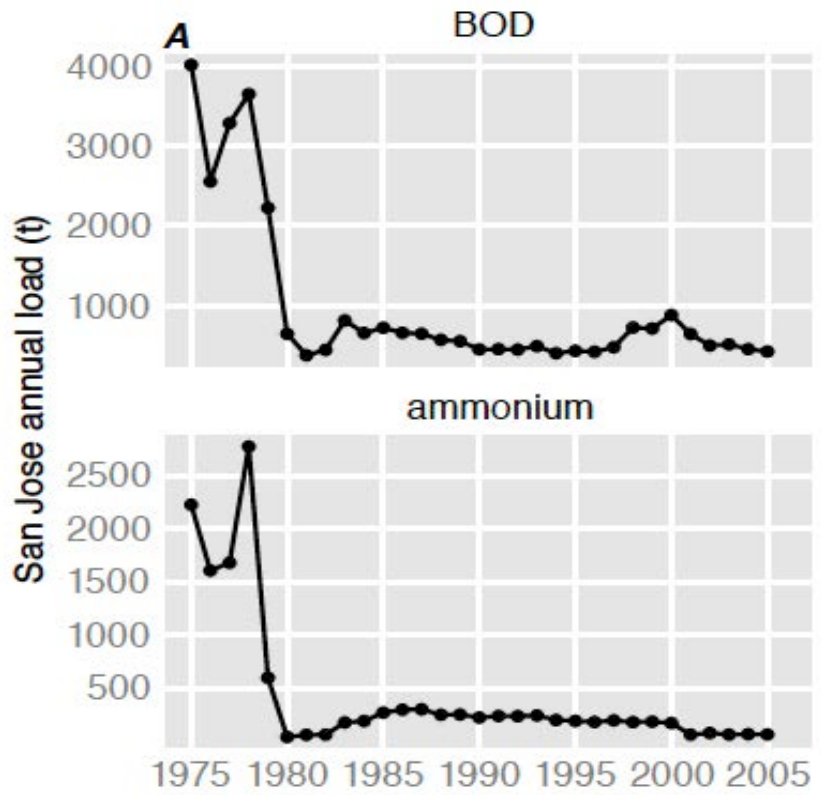
and attain

*"fishable and swimmable waters"*



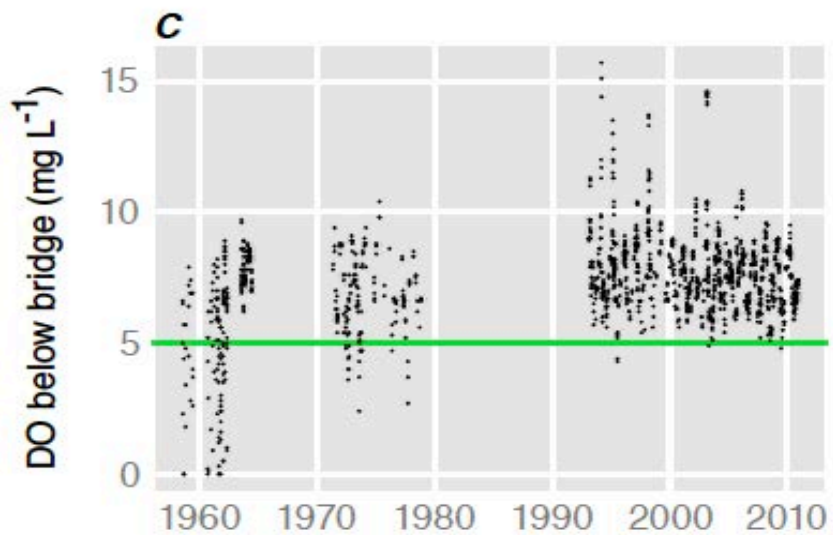
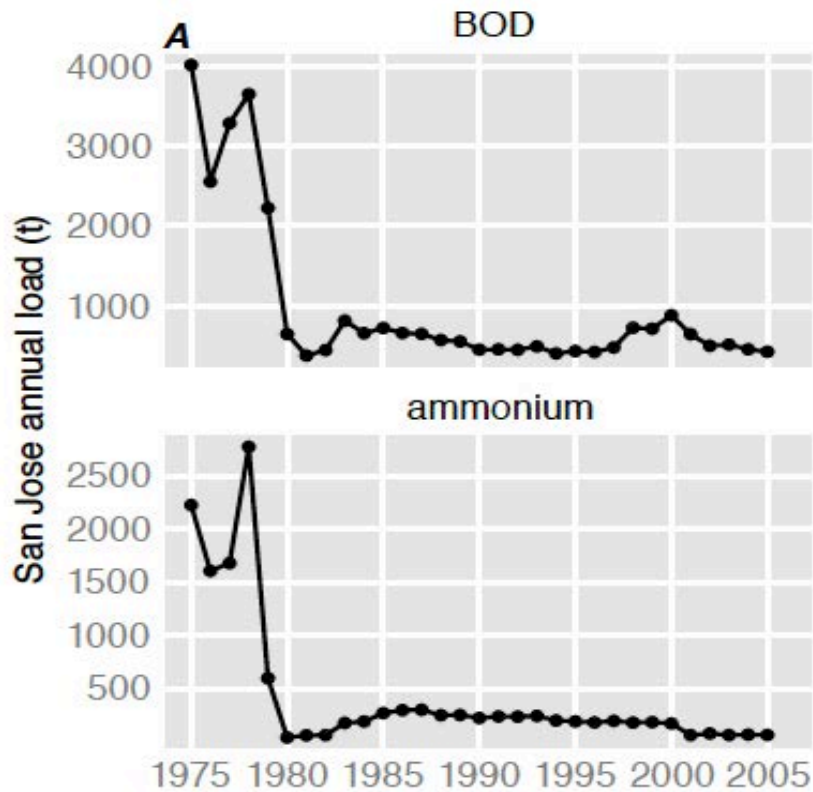
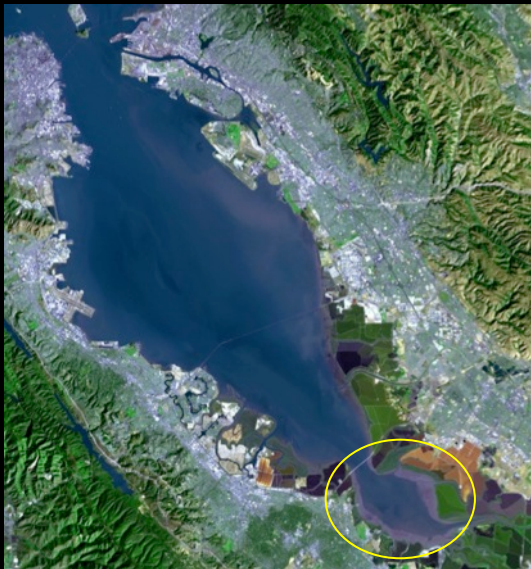


advanced tertiary  
treatment 1980



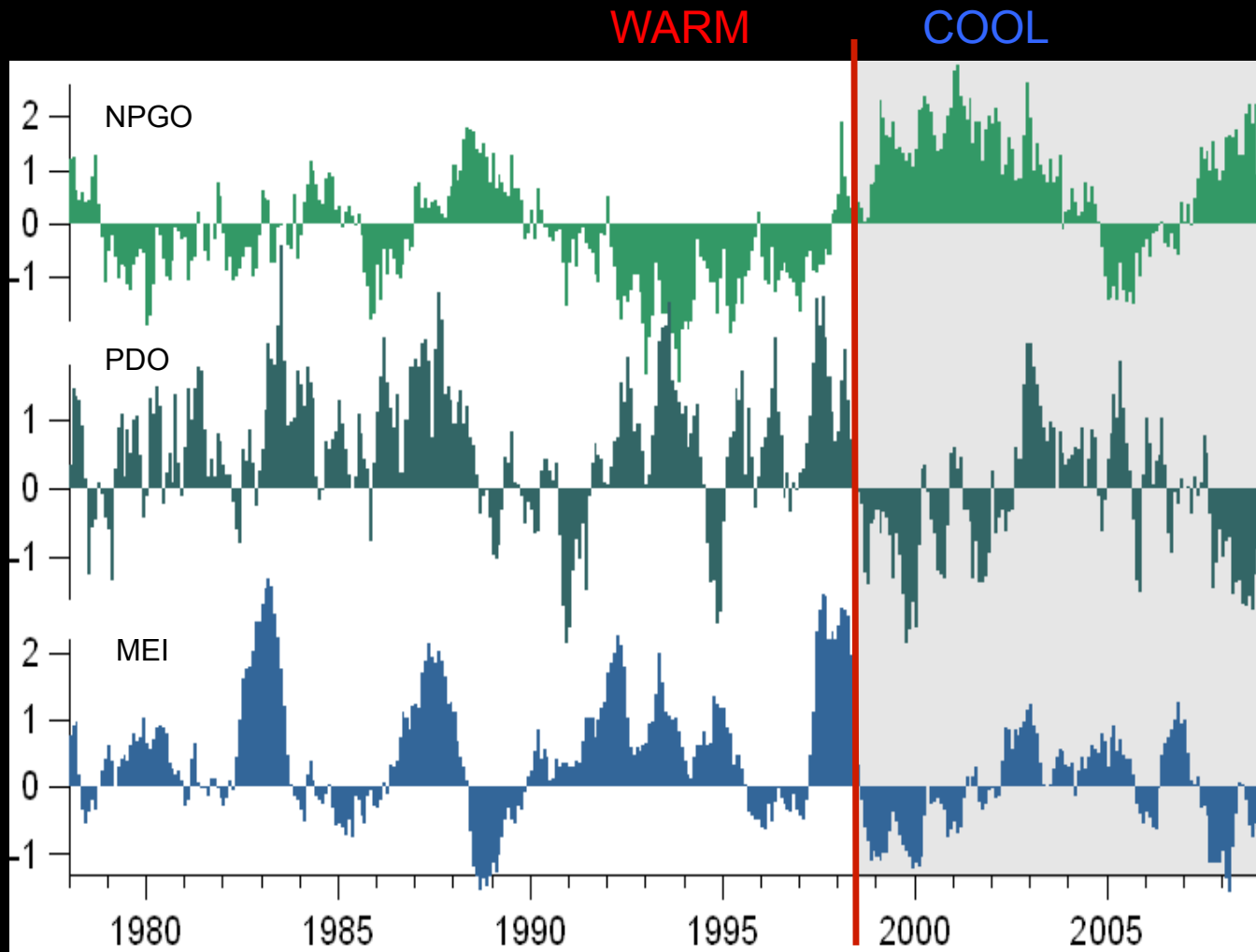


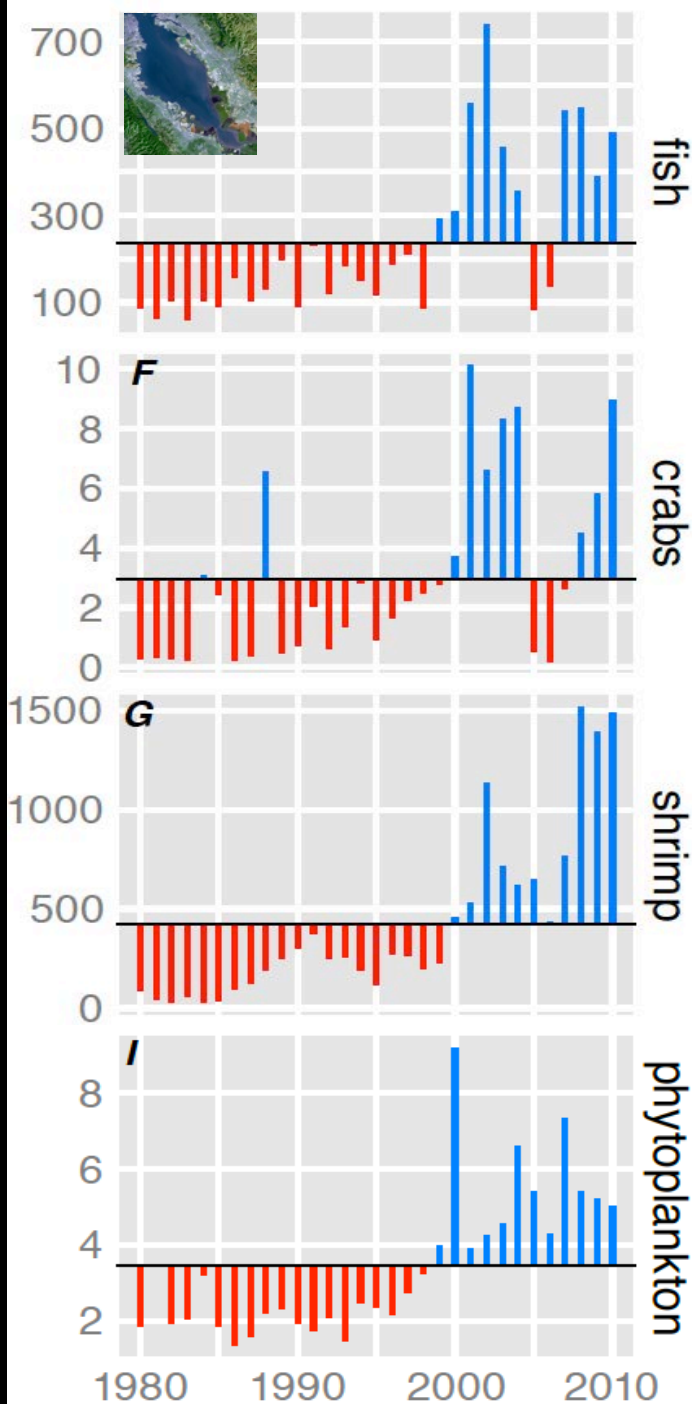
RESPONSE: elimination of summer hypoxia





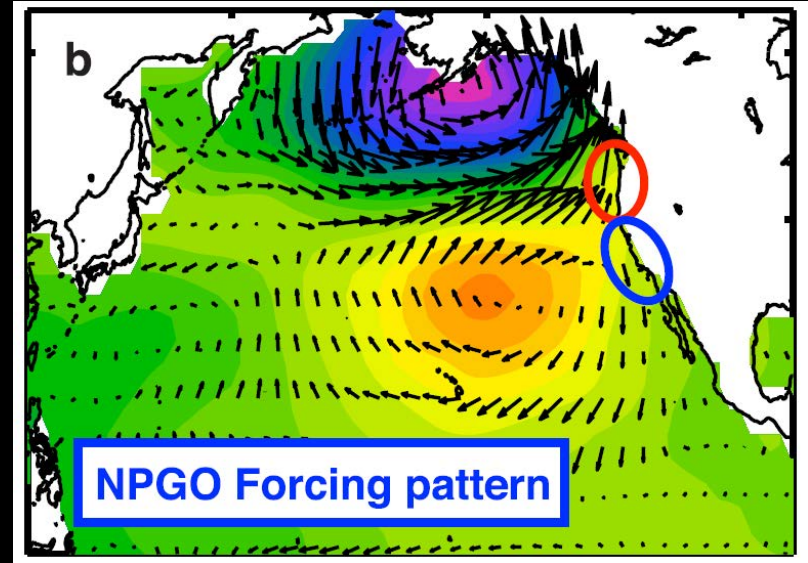
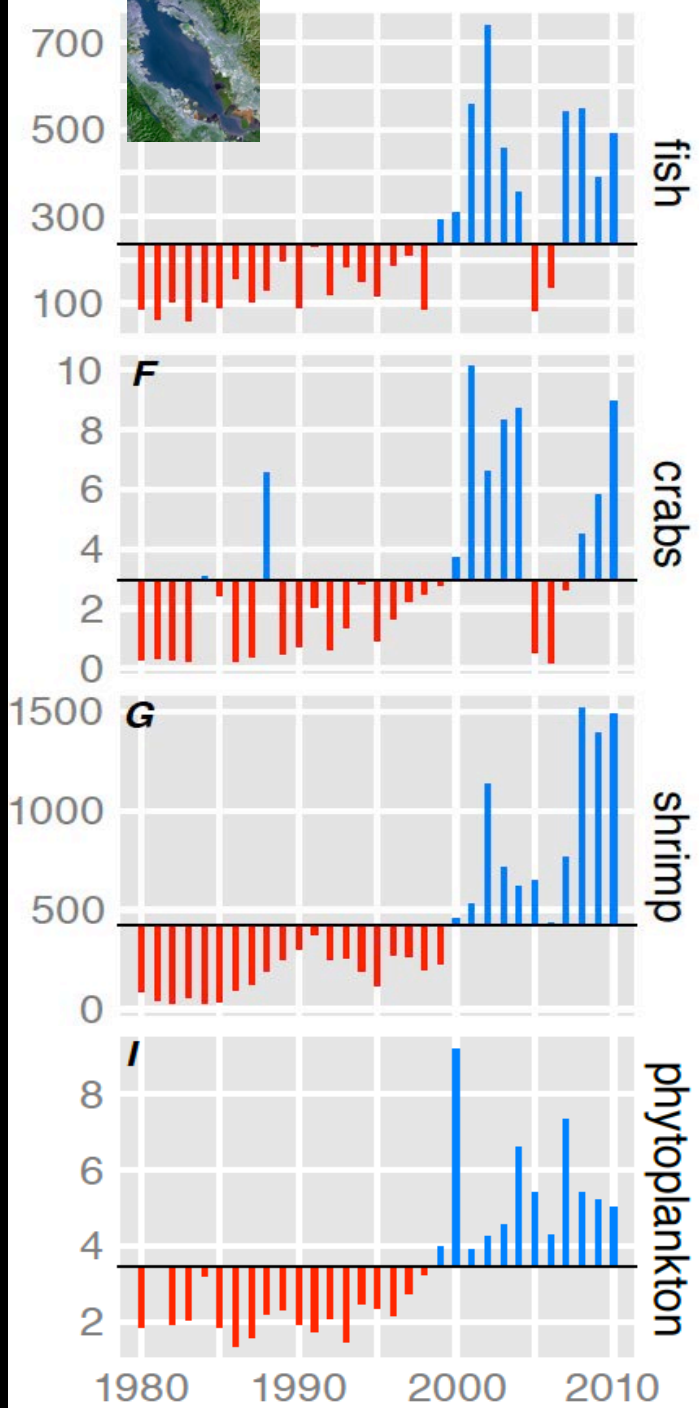
# DRIVER #6: climate shifts





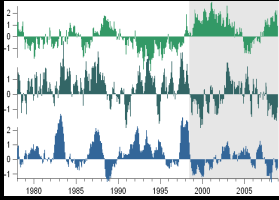
RESPONSE: record-high abundances of (juvenile) flatfish, crabs, shrimp

increasing phytoplankton biomass



because of intensified coastal upwelling and productivity





# Climate-driven trophic cascade

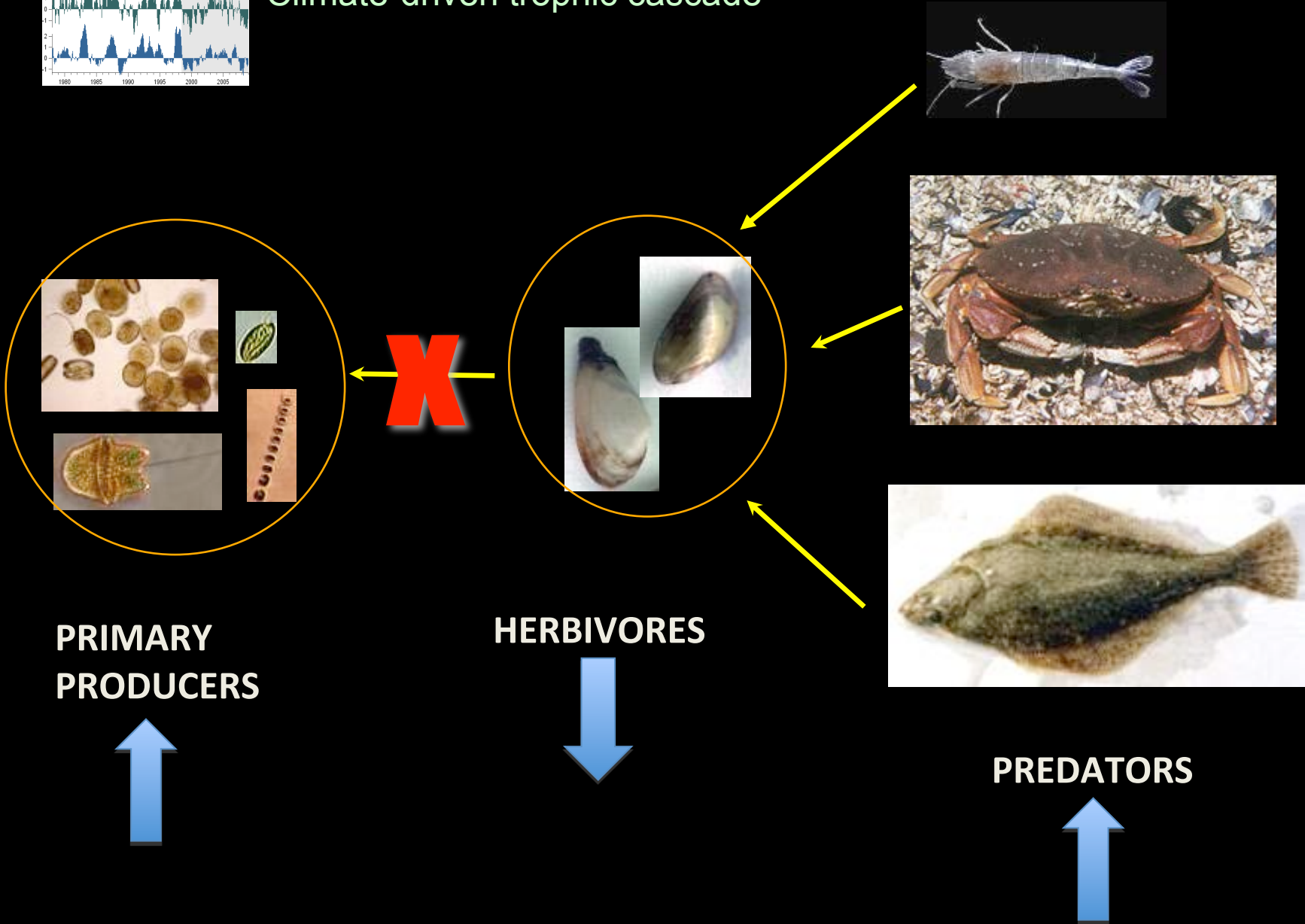


**X**

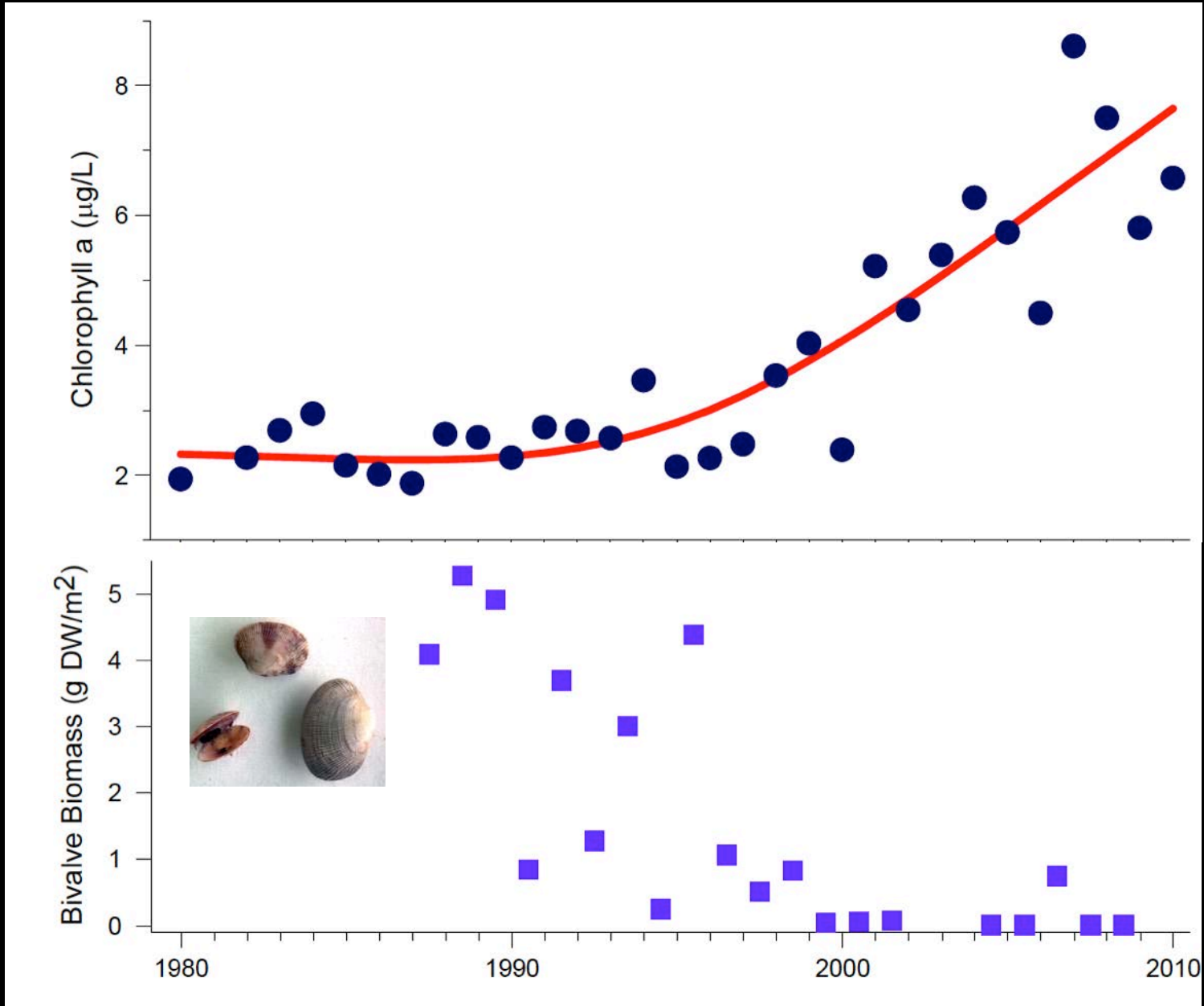
**PRIMARY PRODUCERS**

**HERBIVORES**

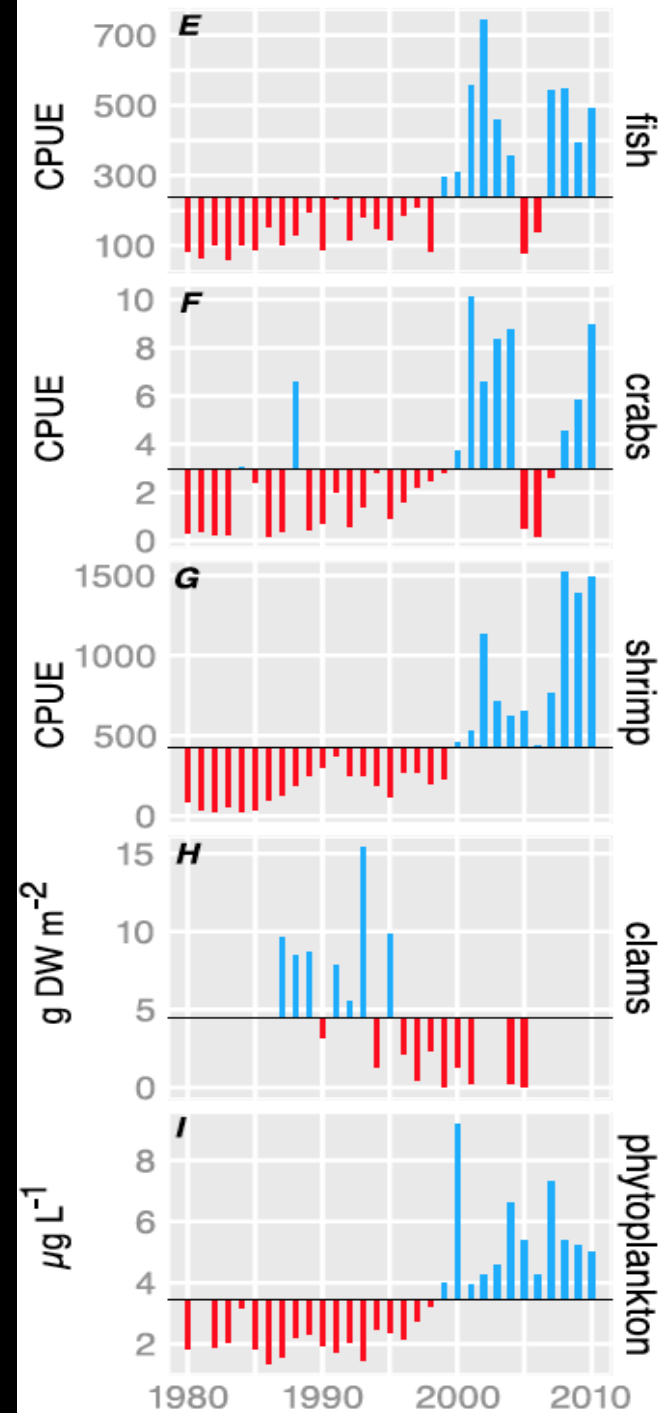
**PREDATORS**



# IMPLICATION: nutrients have become a policy issue



# 5: Nutrient Management in an Ecosystem Context





# 6: The Unique Value of Sustained Observations



The screenshot shows the Chesapeake Bay Program website. At the top left is the logo featuring a yellow sun, a black bird in flight, and blue waves. To the right of the logo is the text "Chesapeake Bay Program" in a large, bold, black font, with the tagline "Science. Restoration. Partnership." underneath. A search bar with a "Search" button is located to the right of the logo. Below the logo and tagline is a dark blue navigation bar with white text for "Home", "Discover THE CHESAPEAKE", "Learn THE ISSUES", "Track THE PROGRESS", "Take ACTION", "In The NEWS", "Bay Resource LIBRARY", and "About The BAY PROGRAM". Below the navigation bar is a large photograph of a green, marshy landscape with a tree in the foreground. A dark blue box with white text "Bay Resource Library" is overlaid on the bottom right of the photograph. Below the photograph is a breadcrumb trail: "Home > Bay Resource Library > Bay Data". To the right of the breadcrumb trail is a "Text Size: A A A" link. On the left side of the page is a vertical sidebar with a dark blue background and white text for "Photos", "Maps", "Videos", "Publications", and "Bay Data". The "Bay Data" link is highlighted with a white arrow pointing to the right. The main content area has a white background and a dark blue header "Data Hub". Below the header is a paragraph of text: "This interface provides access to several types of data related to the Chesapeake Bay. Bay Program databases can be queried based upon user-defined inputs such as geographic region and date range. Each query results in a downloadable, tab- or comma-delimited text file that can be imported to any program (e.g., SAS, Excel, Access) for further analysis. Comments regarding the interface are encouraged. Questions in reference to the data should be addressed to the contact provided on subsequent pages." Below this paragraph is another paragraph: "To insure data accuracy, the Bay Program maintains a Quality Assurance Program that monitors and tracks several environmental data sets that look at pollutants, water quality, land use, algae, fish, crabs and submerged aquatic vegetation." Below this paragraph are three links: "Data Programs | Data Downloads | Data Tools". Below the links is a section header "Data Programs" with a dotted line underneath. Below the section header is a paragraph of text: "**Modeling:** Environmental models are essential for simulating ecosystems that are either too large or too complex to isolate for experiments in the real world. These simulations, called scenarios, allow scientists to predict positive or negative changes within our ecosystem due to management actions such as improved sewage treatment, controlling urban sprawl, or reduced fertilizer or manure application on agricultural lands." Below this paragraph is another paragraph of text: "**Monitoring:** Monitoring the Chesapeake Bay and its tributaries allows Bay Program partners to detect changes that take place; improves our understanding of the natural environment; and reveals trends over time that can provide valuable information to policy makers. The Chesapeake Bay Monitoring Program, which began in 1984, is a Bay-wide cooperative effort involving Maryland, Pennsylvania, Virginia, the District of Columbia, several federal agencies, 10 institutions and over 30 scientists."