# Nutrient Loading and River Responses in the Tidal Potomac

**March 18, 2008**

**W. R. Boynton**

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

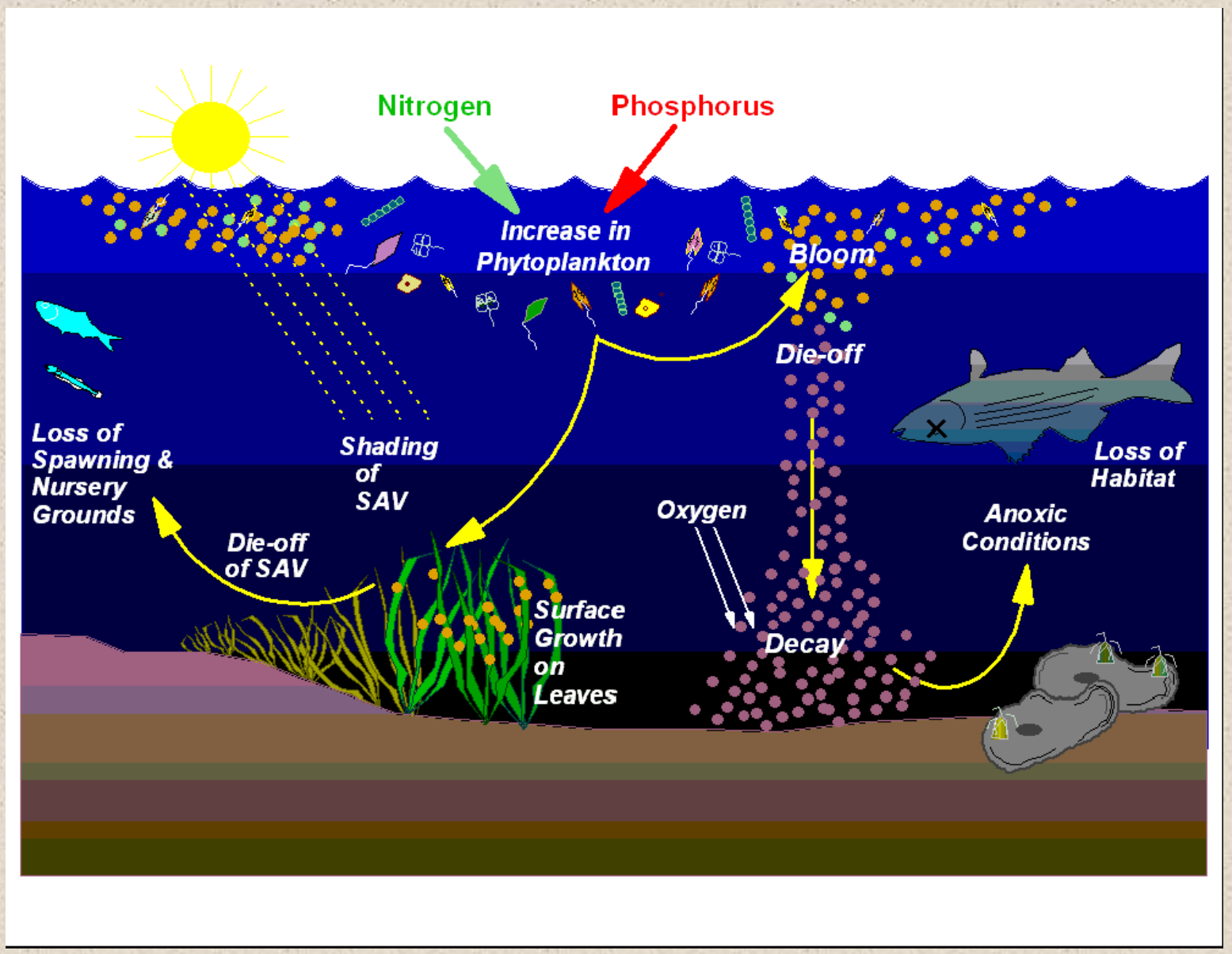
**Work supported by**

**UMCES, NSF, MD-DNR, MD-MDE, NOAA, EPA**

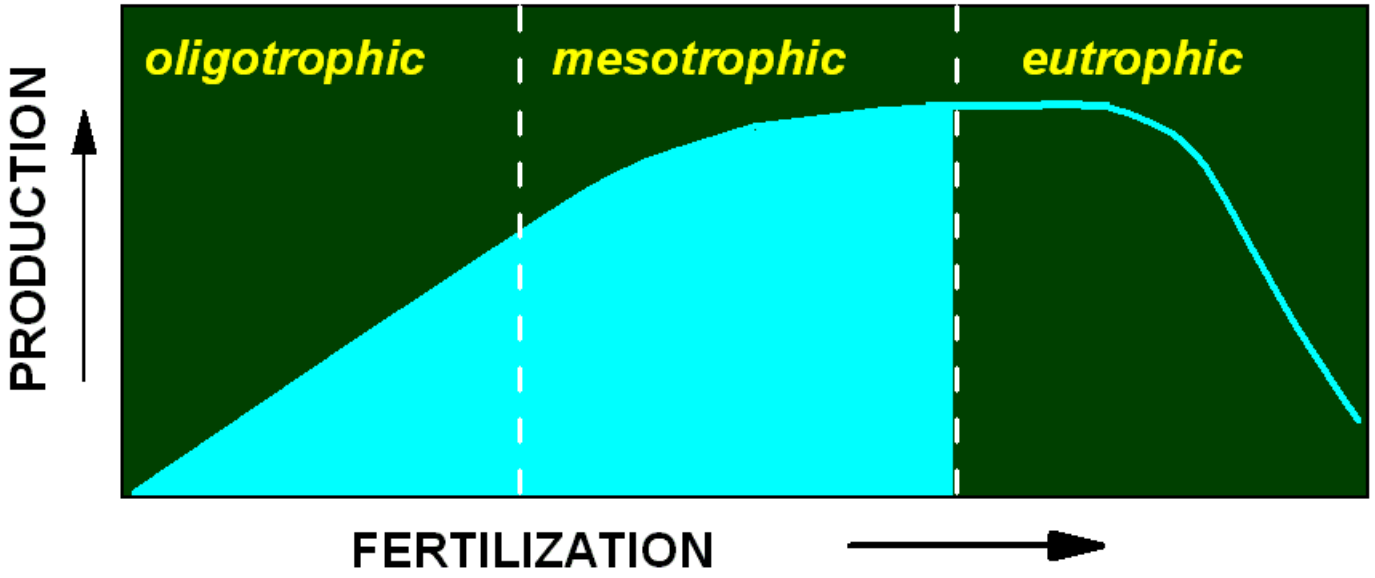
# Outline

- Some Background and Definitions
- Nutrient loads…Past and Present
- Water Quality Conditions (historical and current)
- A short SAV story
- Some special features (blooms, pH, sediment/bloom interactions)
- A budget for Nitrogen…where does this stuff go?
- Chesapeake and Potomac Fisheries
- Some concluding remarks

# Eutrophication

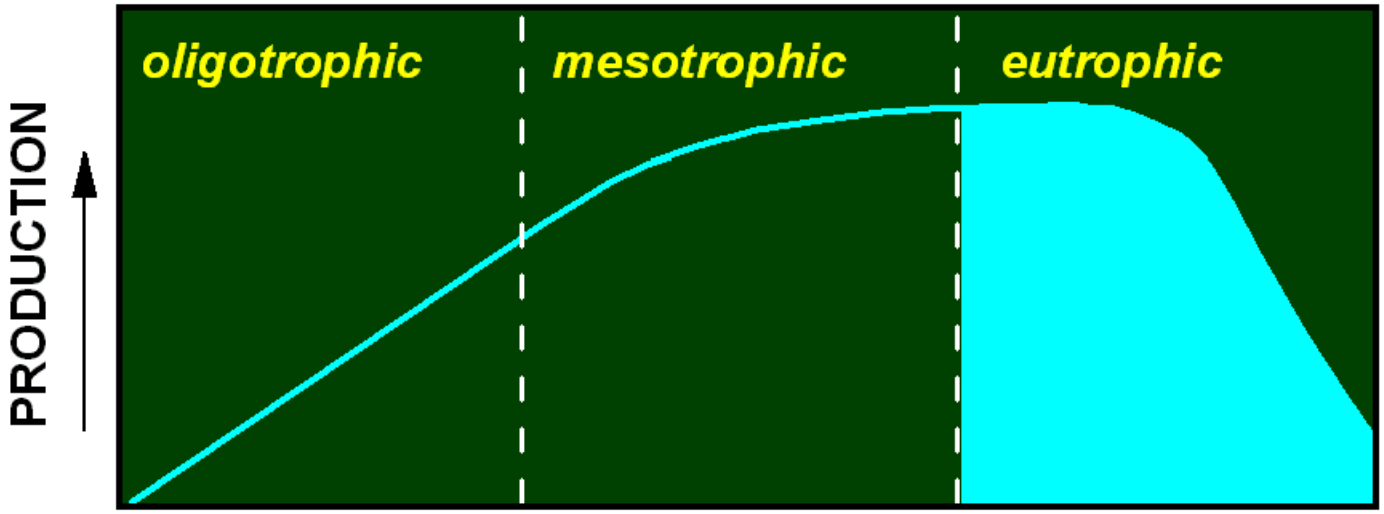


# POSITIVE EFFECTS

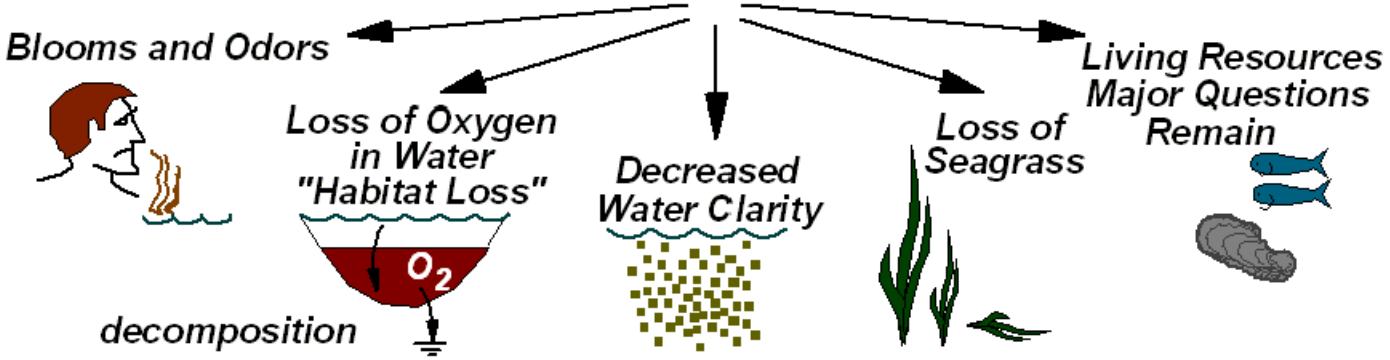



- Essential for plant growth. In most estuaries and the open ocean microscopic plants provide the basic food supply.
- Within limits, increased fertilization increases food supply and production of other organisms.

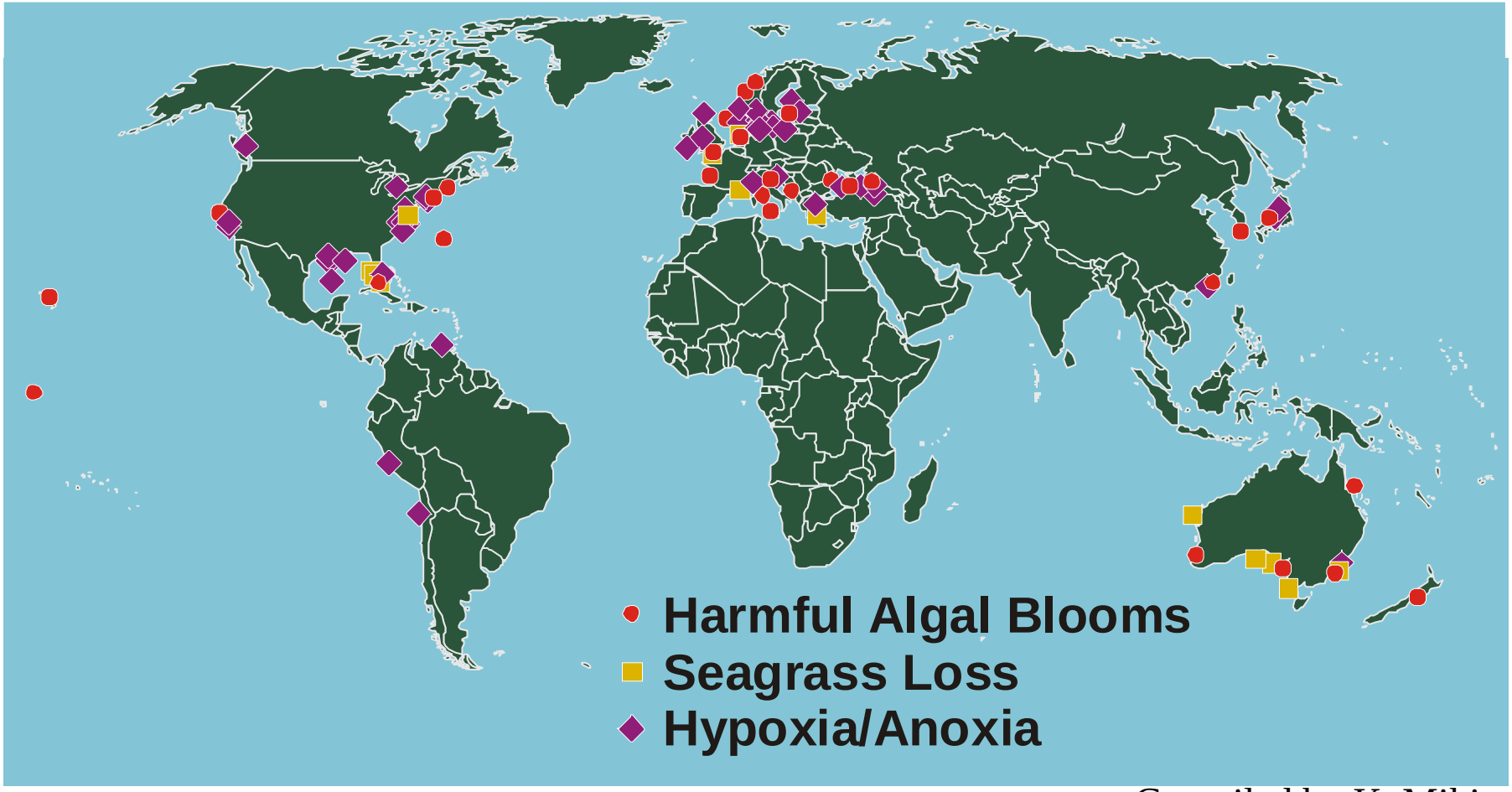
# NEGATIVE EFFECTS



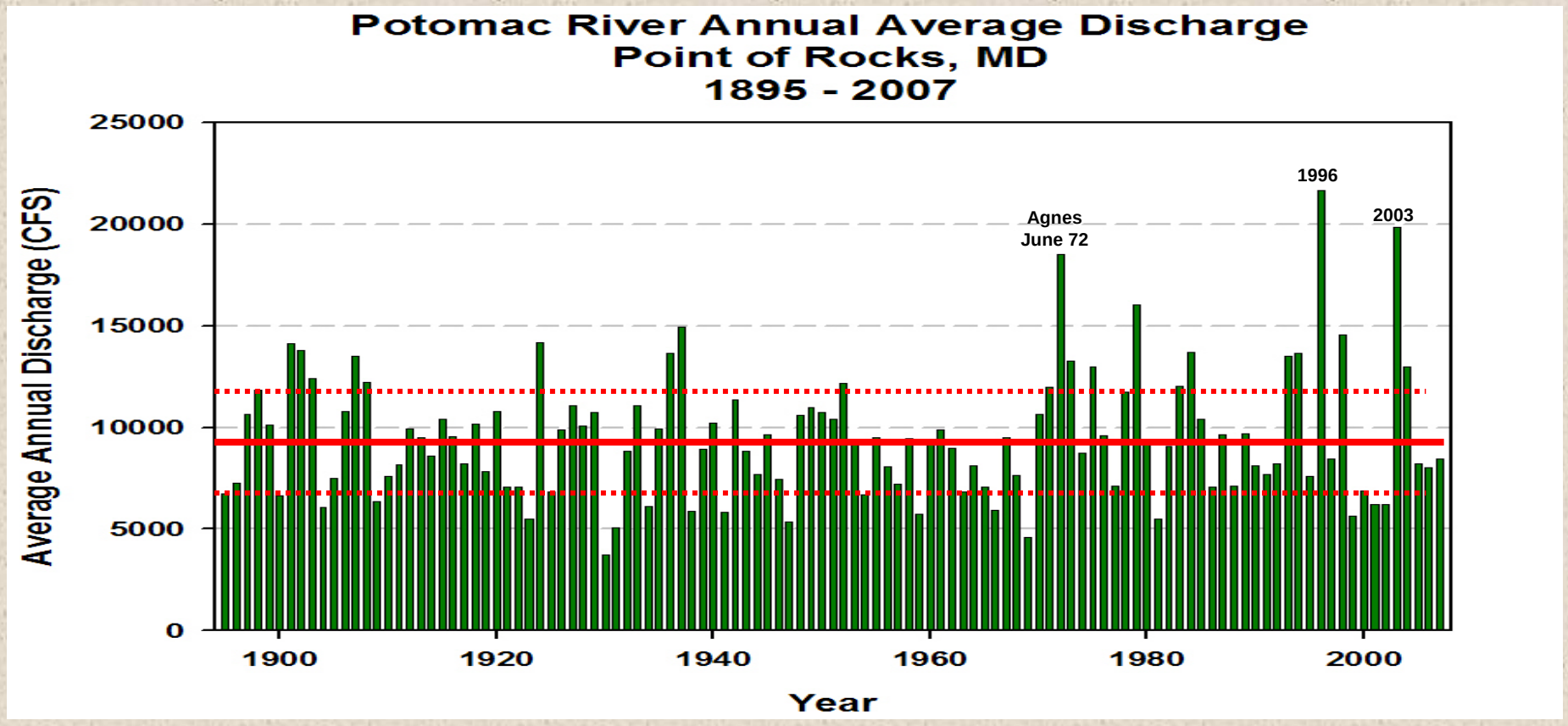

High levels of NUTRIENT ADDITIONS



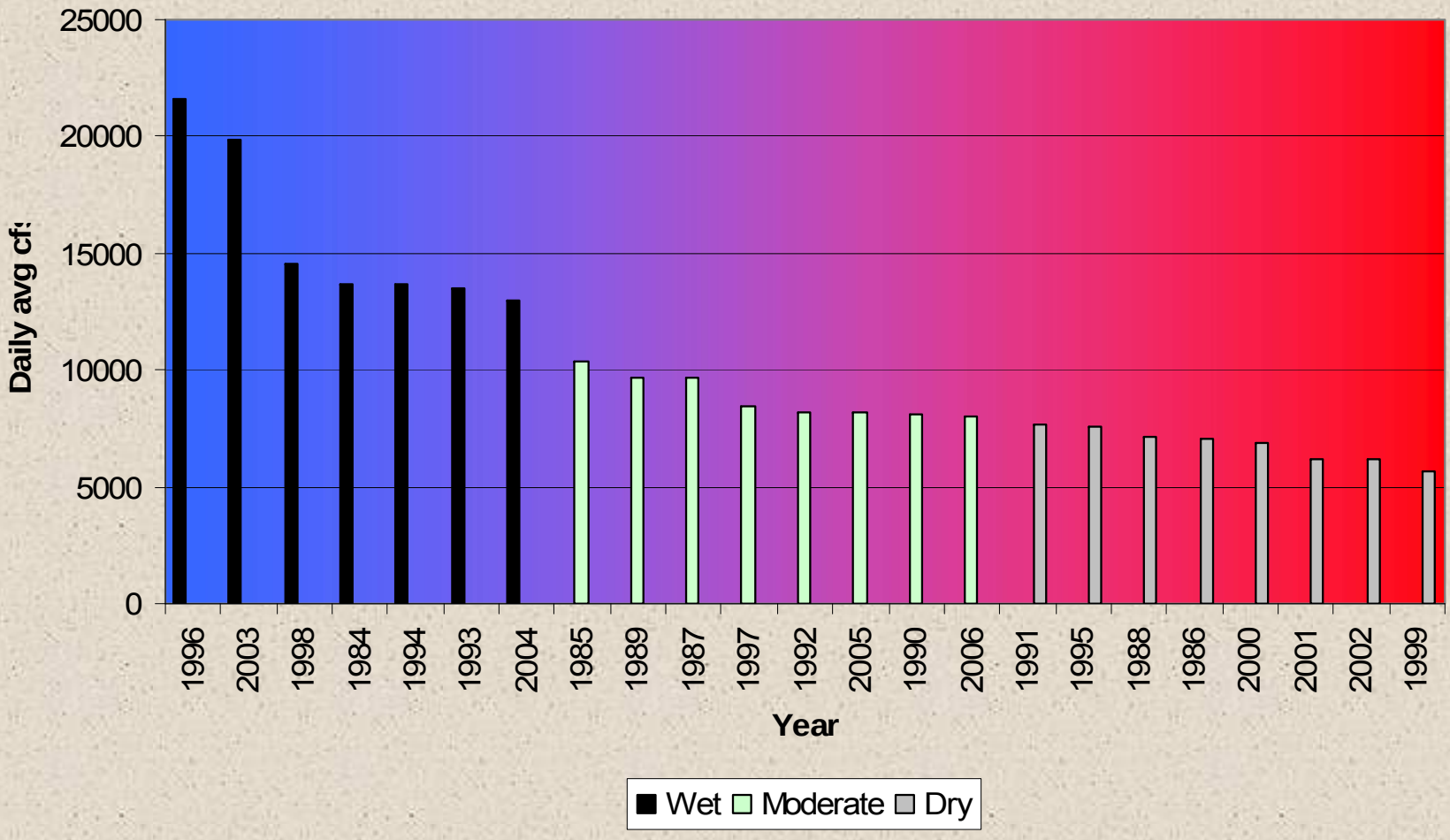
# A Global Issue




Compiled by K. Mikita


Potomac River Annual Average Discharge
Point of Rocks, MD
1895 - 2007
Average Annual Discharge (CFS)
25000
20000
15000
10000
5000
0
1900
1920
1940
1960
1980
2000
Year
Agnes
June 72
1996
2003

# Potomac River Point of Rocks
## Ranked Flow Data
## Daily Average Cubic Feet Per Second (cfs)




4X variability in flow during 23 year record

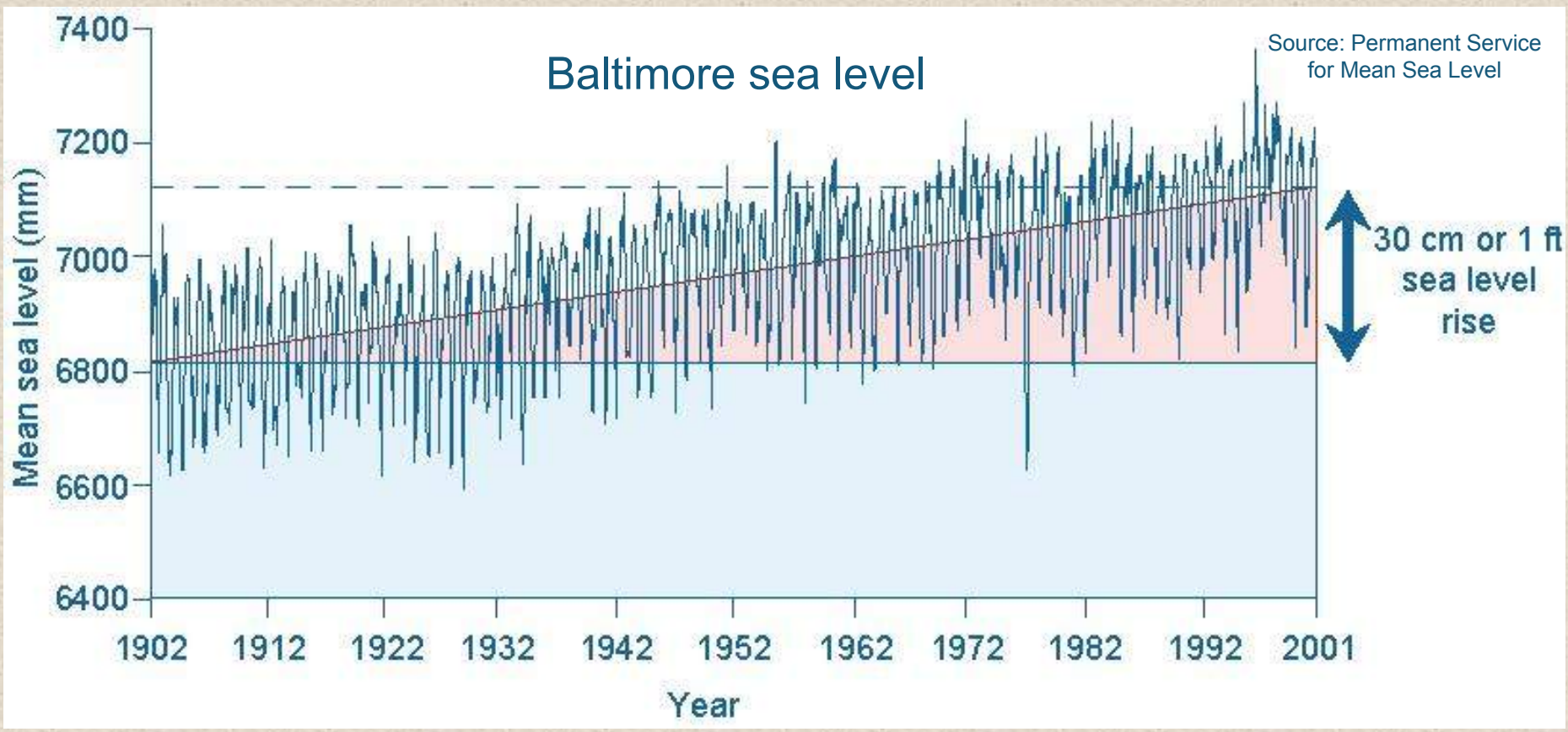
**From P. Tango**

# Potomac in Flood

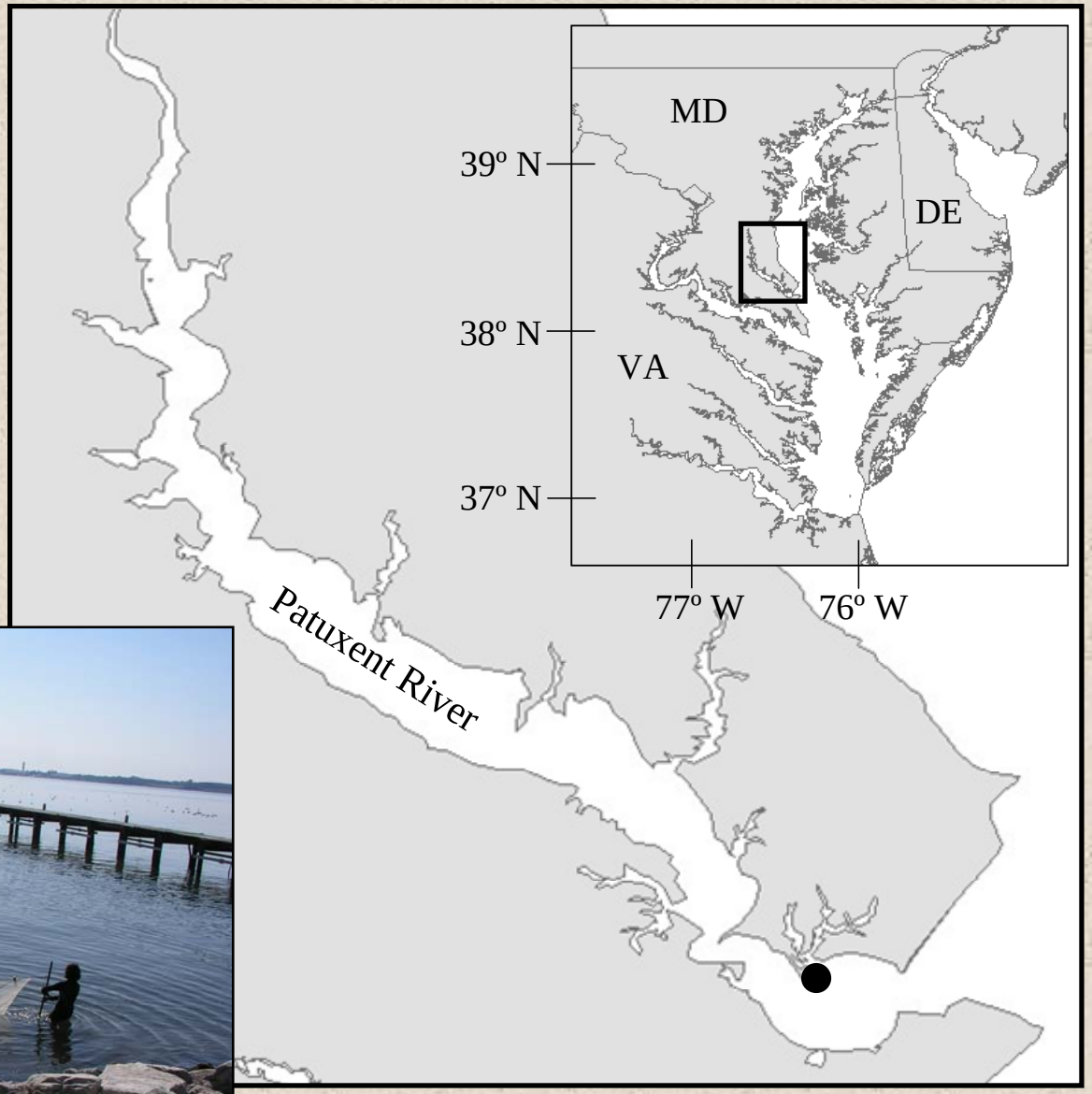
# Potomac NOT in Flood

# Sea level is rising in Chesapeake Bay

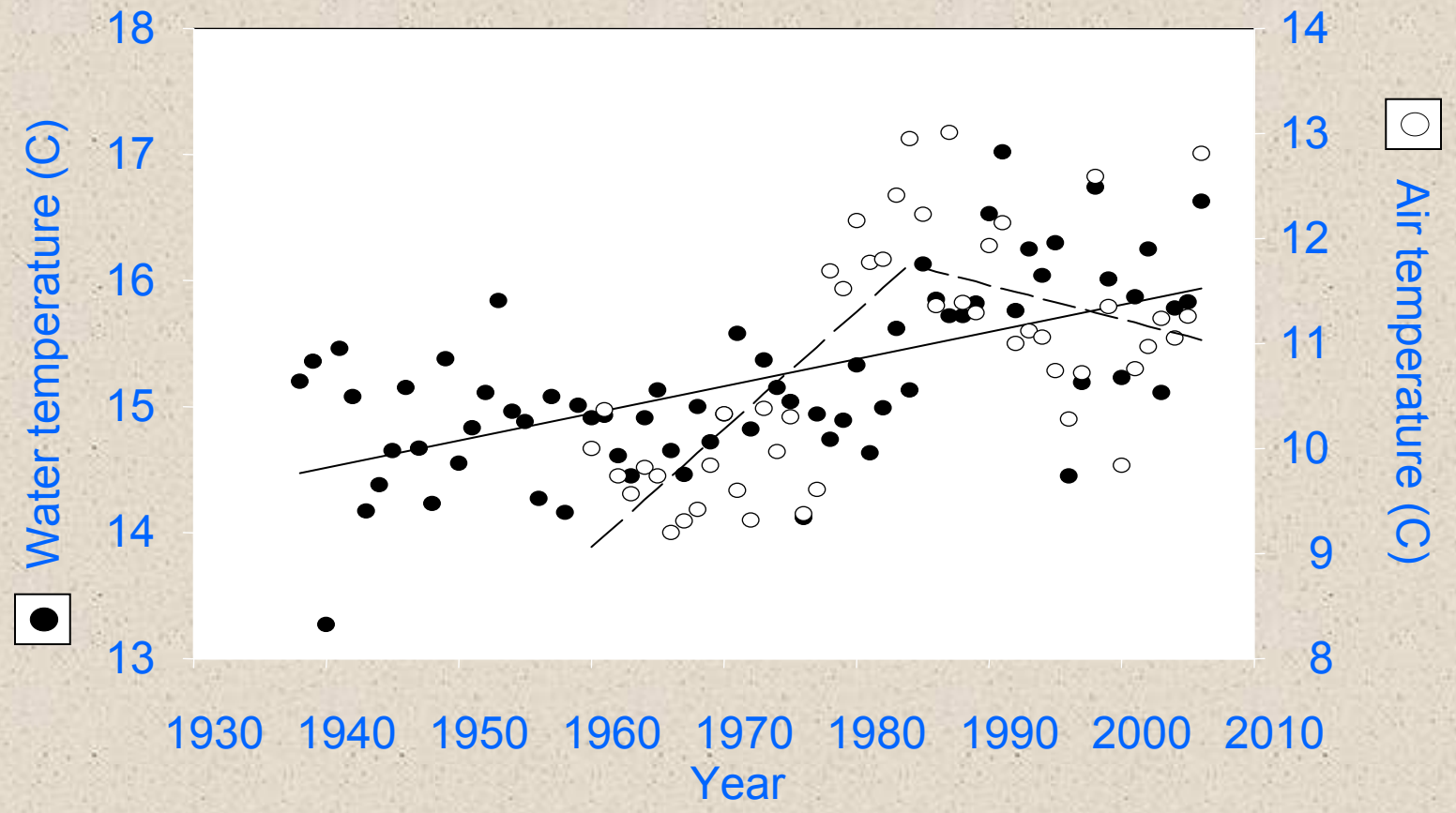
(from J C Stevenson)



# *Issue of Long-term Water Temperature Change*

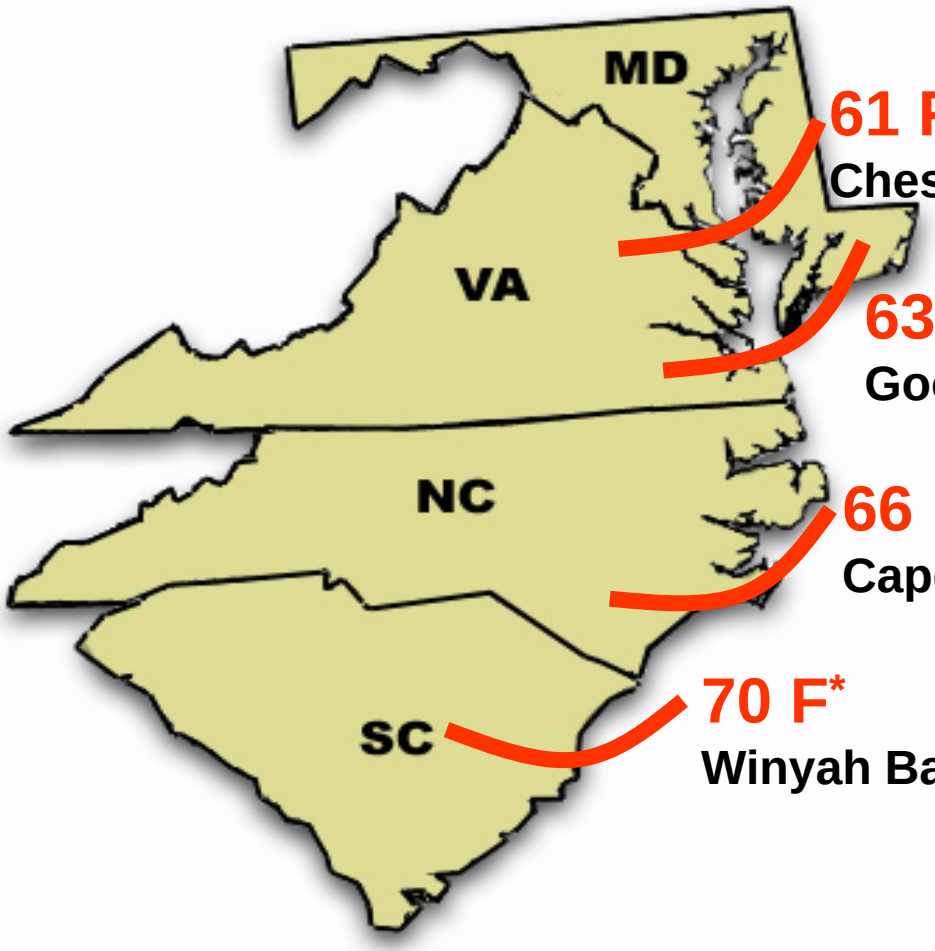


**CBL Pier Data Set**
1938-2006
Water Temperature (solid symbol)
+0.22 C per decade
1.5 C increase from 1938 to 2006
Five warmest years ≥ 1990




Secor and Wingate. In review

# Warming in the Chesapeake: Heading South??




**61 F*** Ches. Biol. Lab

**63 F*** Goodwin Isl.

**66 F*** Cape Fear

**70 F*** Winyah Bay

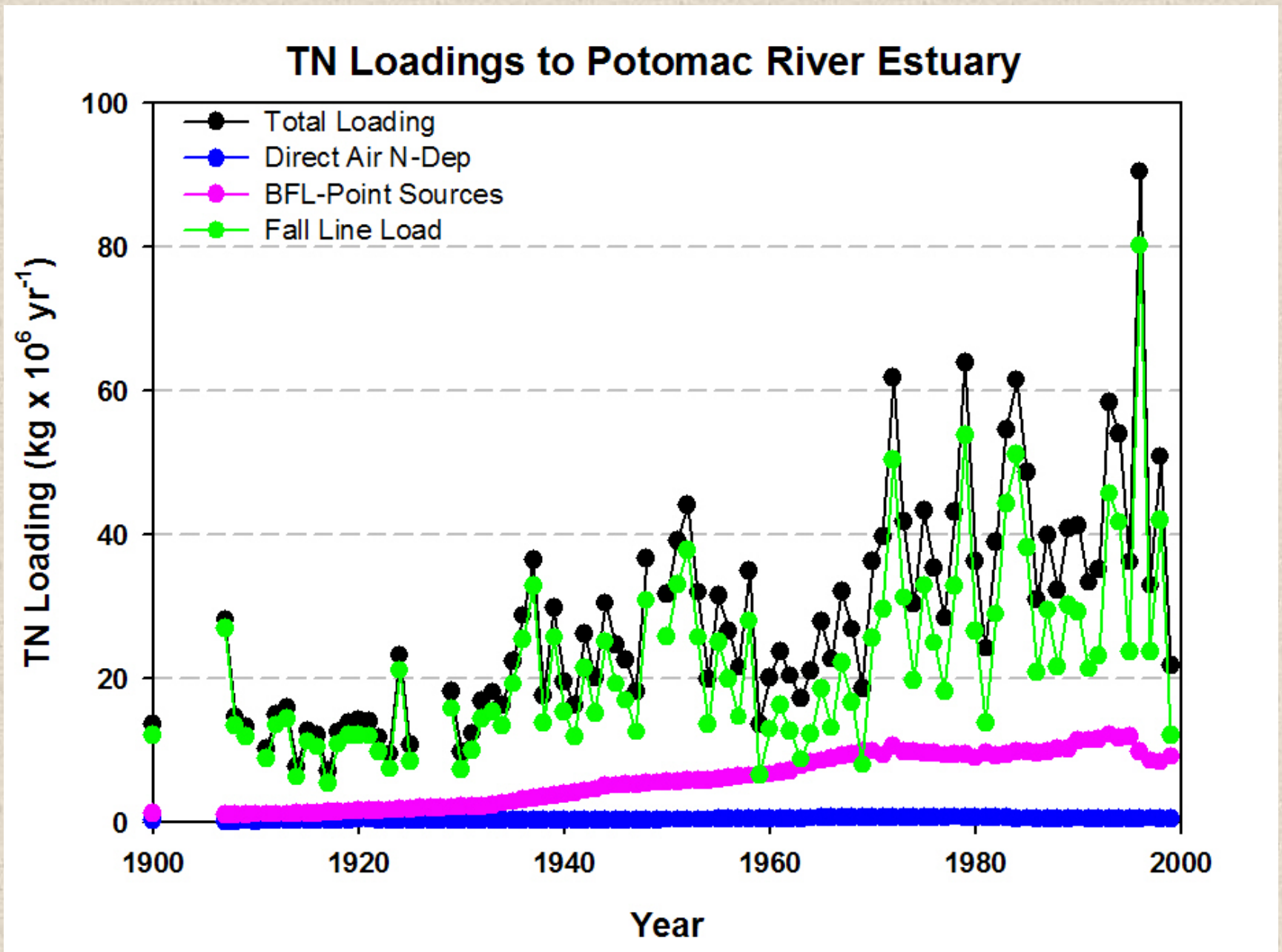
**2050** **+3 F**

**2100** **+7 F**

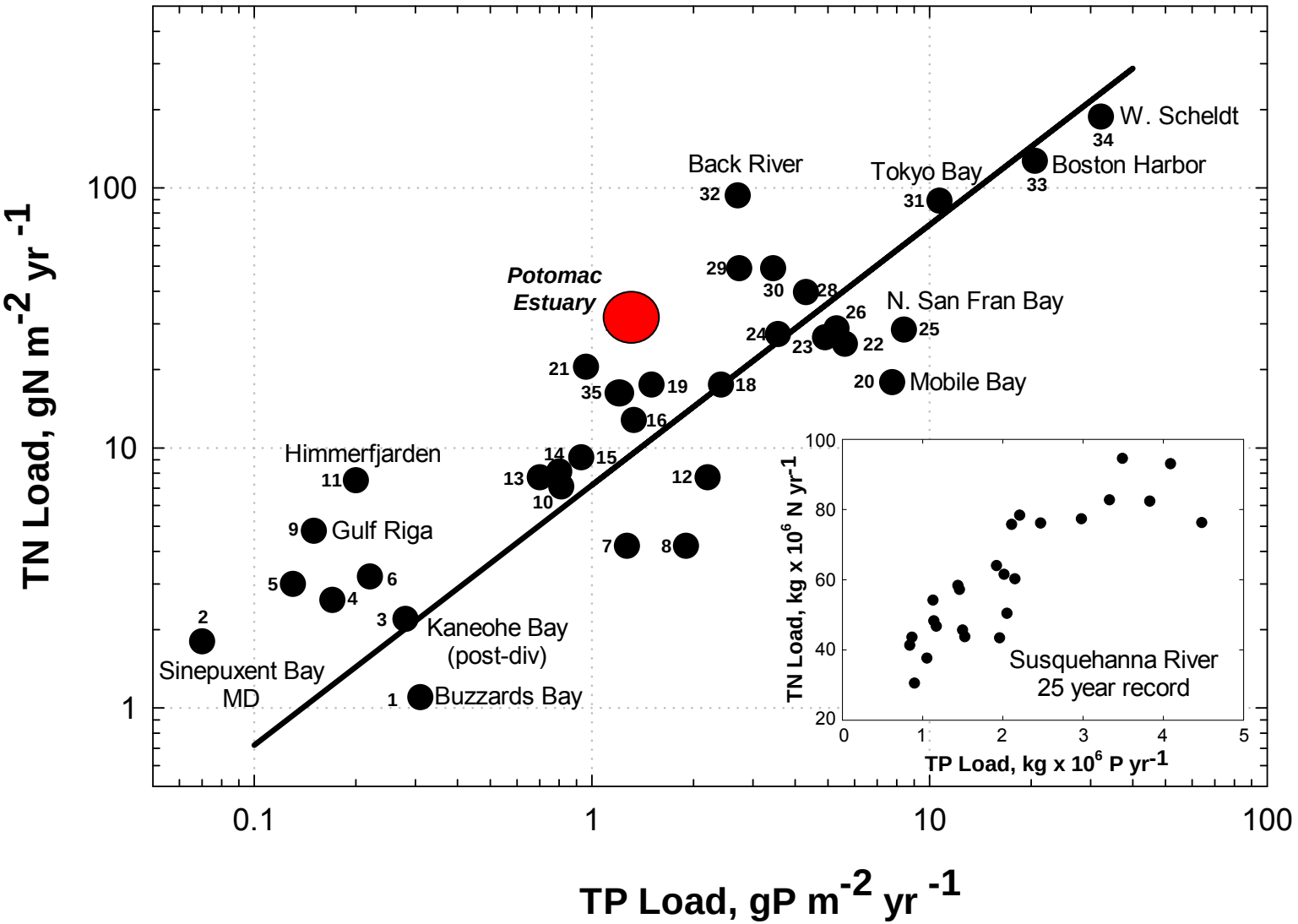


* Average Annual Temperature, 2006

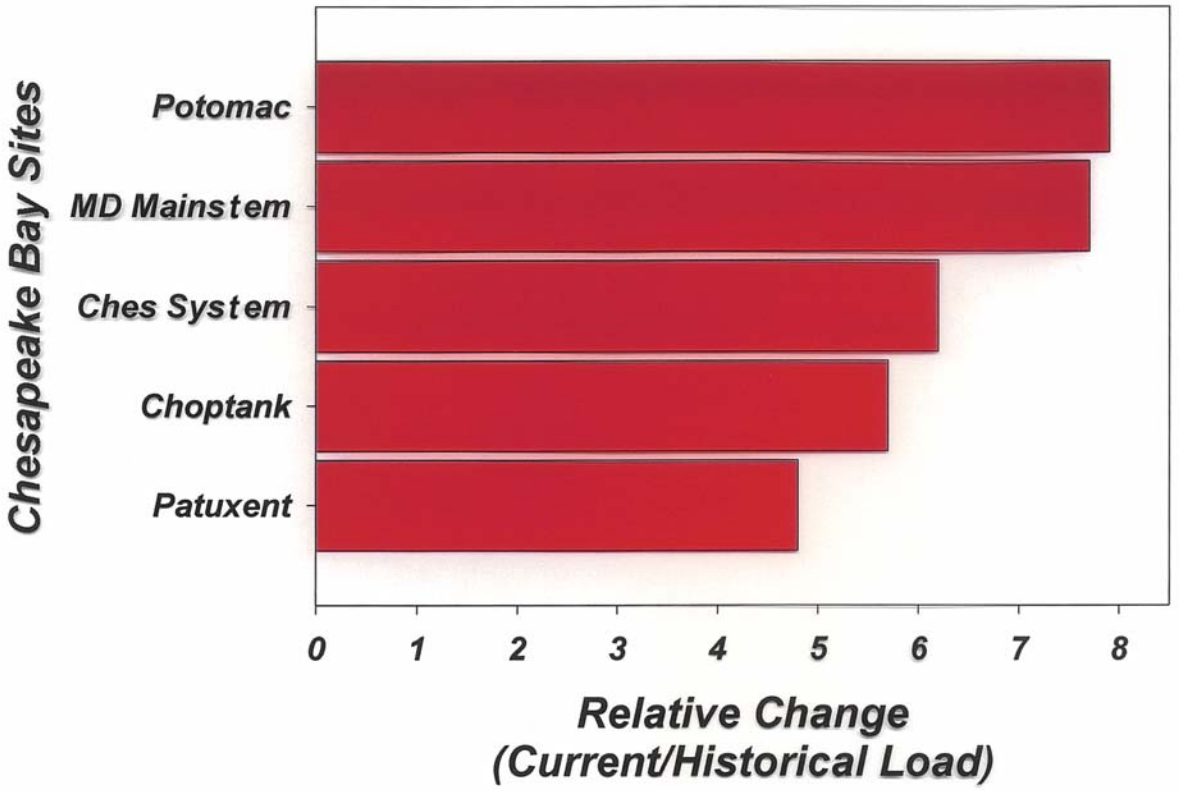
# 7-8 F rise in temp – A new ecosystem!?




N. Jaworski 2007

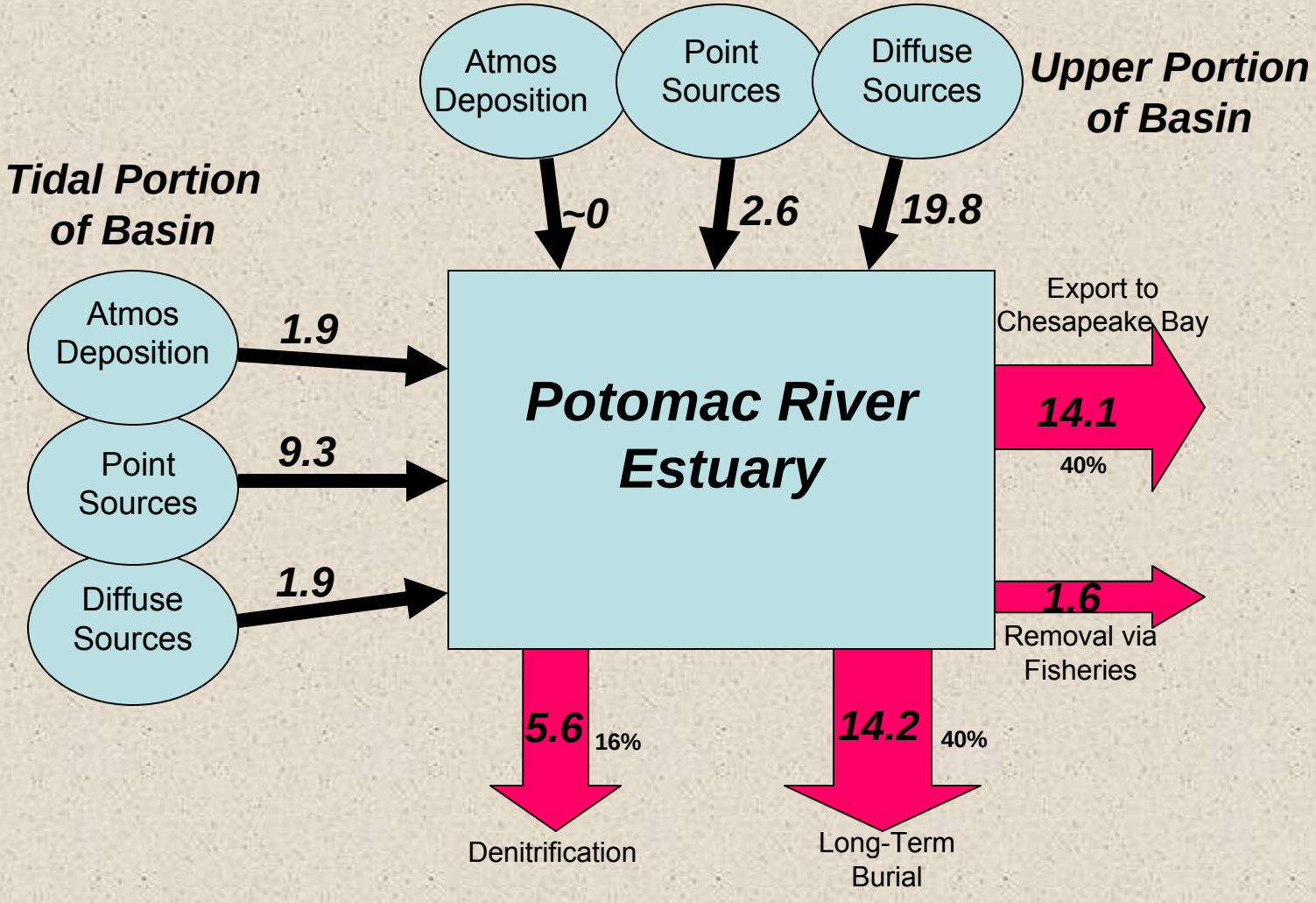

TN Load, gN m-2 yr-1
TP Load, gP m-2 yr-1
100
10
1
0.1
1
10
100
W. Scheldt
34
Boston Harbor
33
Tokyo Bay
31
Back River
32
Potomac
Estuary
N. San Fran Bay
25
26
24
23
22
29
30
28
21
35
19
18
20
Mobile Bay
16
Himmerfjarden
11
14
15
13
10
12
9
Gulf Riga
7
8
5
6
4
3
2
Kaneohe Bay
(post-div)
Sinepuxent Bay
MD
1
Buzzards Bay
TN Load, kg x 10^6 N yr-1
TP Load, kg x 10^6 P yr-1
Susquehanna River
25 year record

# RELATIVE CHANGE IN TN LOADS TO CHESAPEAKE SYSTEMS (Mid-1980's / Pre-European Settlement)



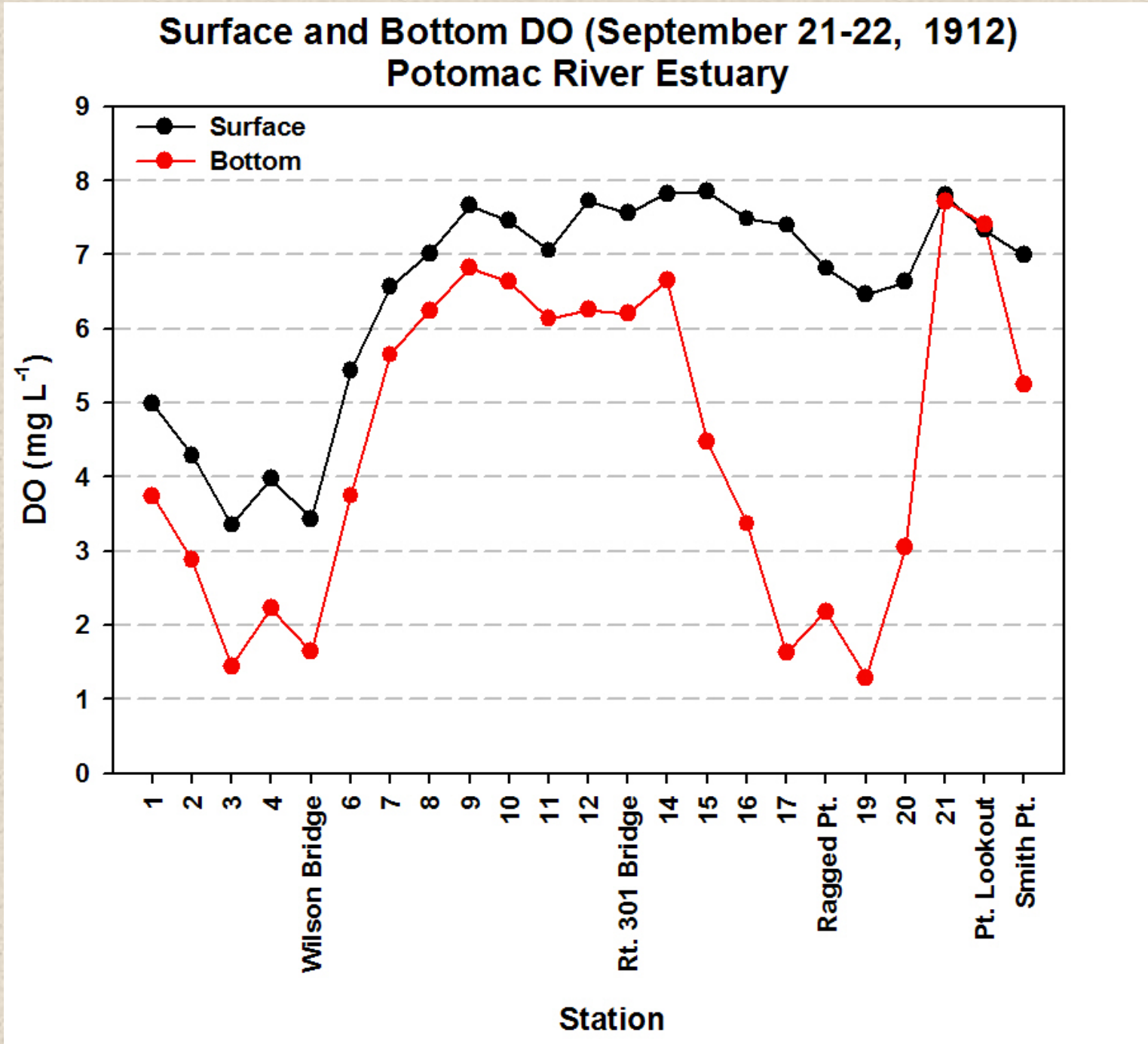
# *Potomac River Estuary Nitrogen Budget*

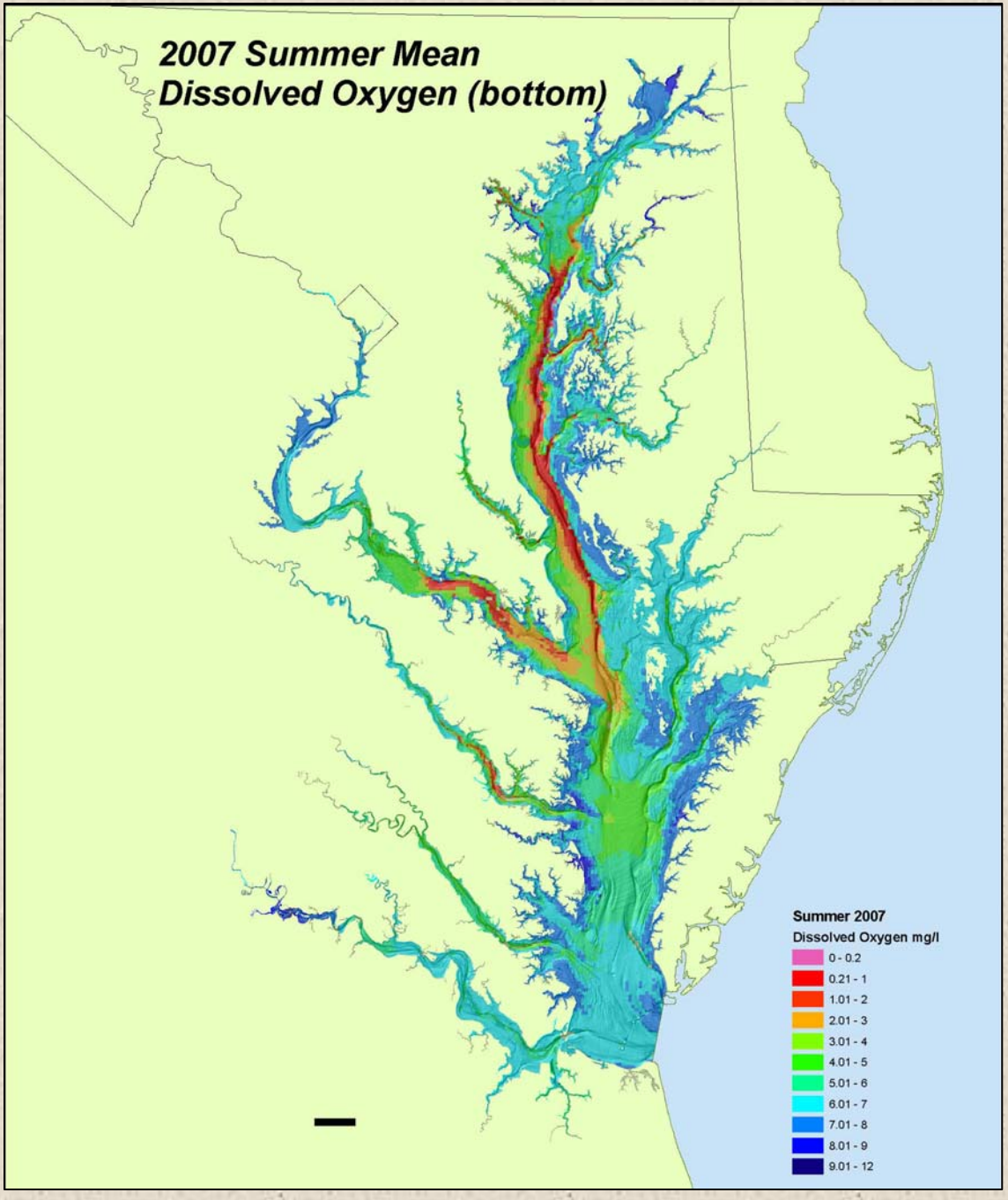
(1985-1986)



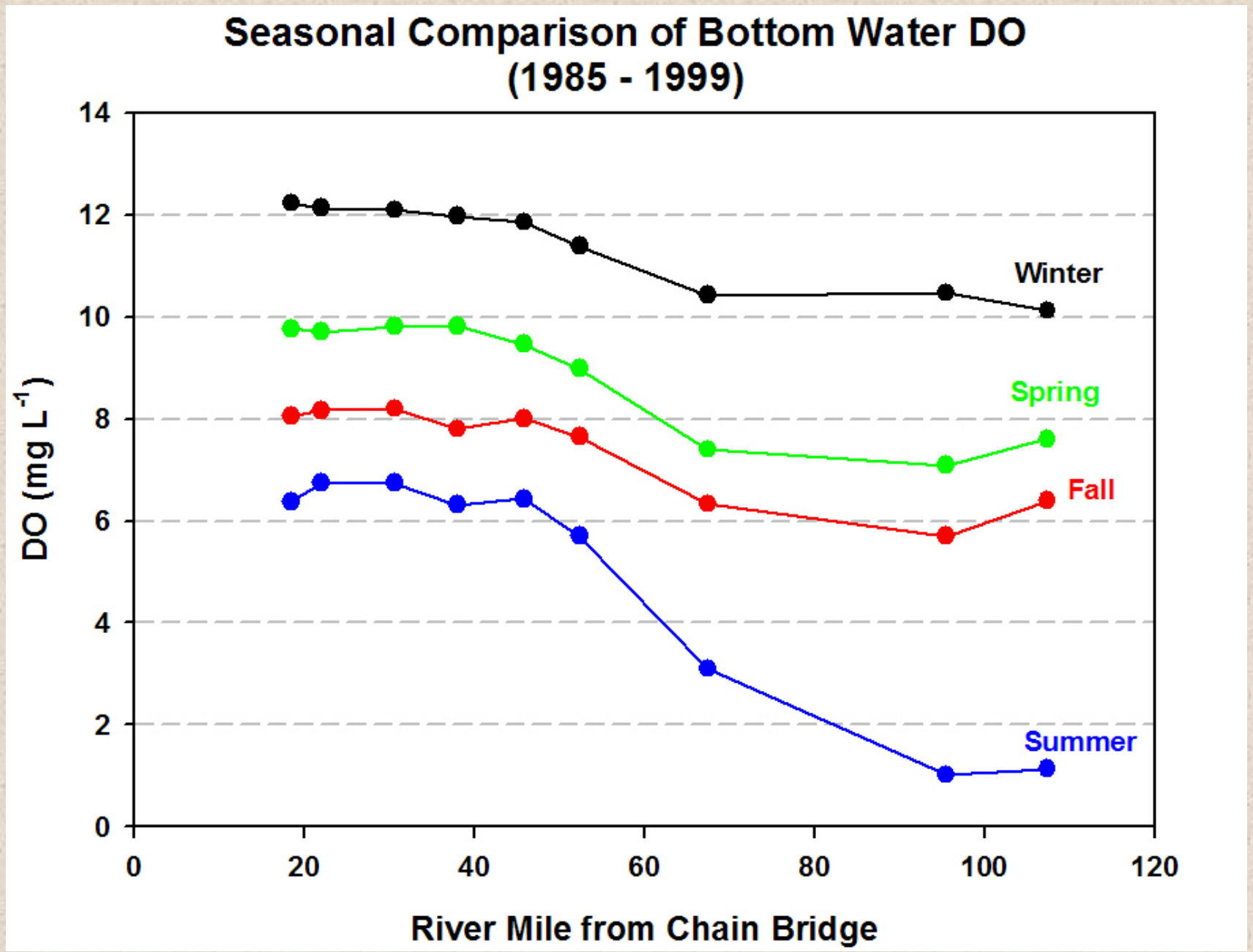

Boynton et al 1995

***Total Load = 30-35 g $m^{-2}$ $yr^{-1}$***

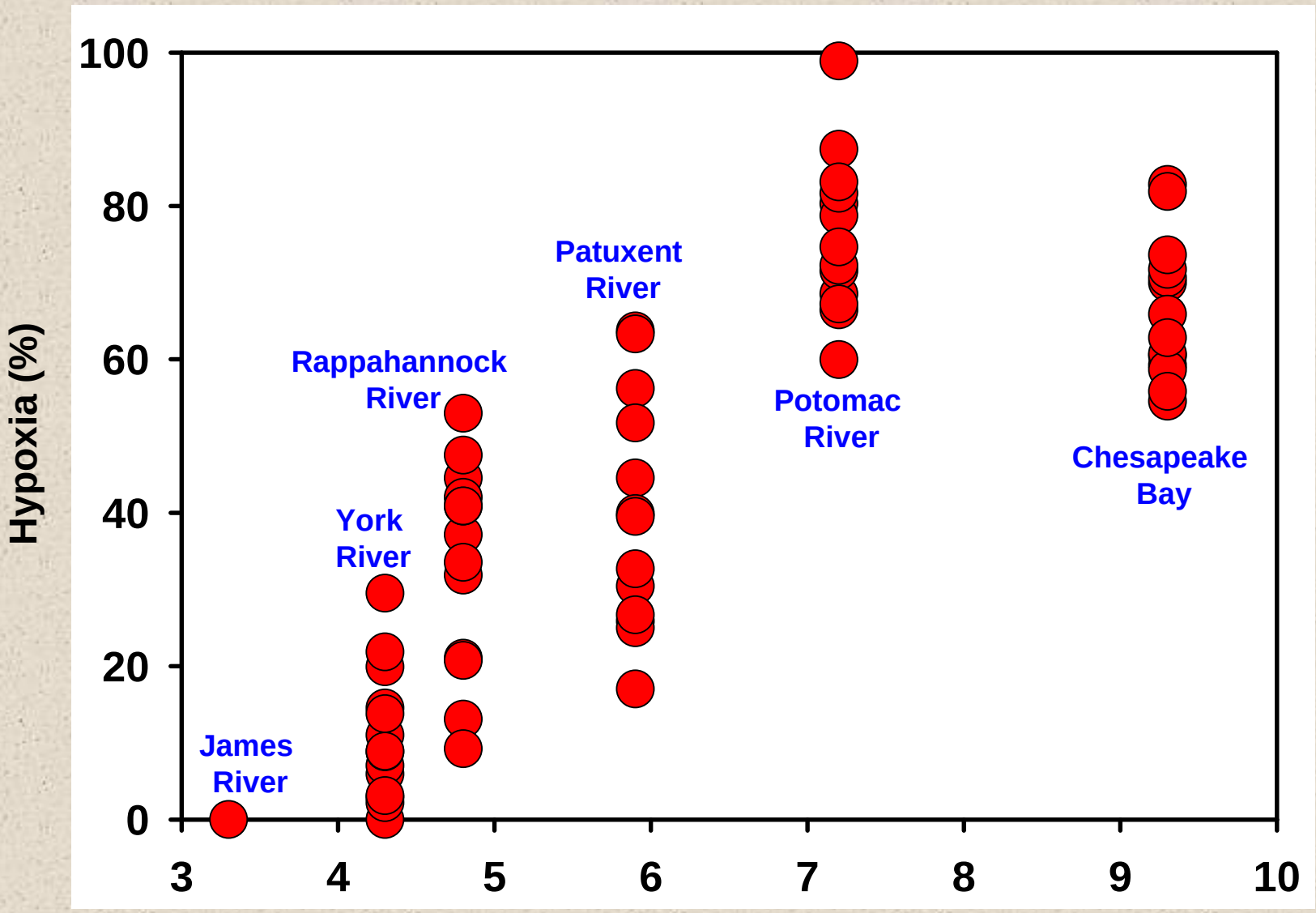

Surface and Bottom DO (September 21-22, 1912)
Potomac River Estuary
Surface
Bottom
DO (mg L-1)
0
1
2
3
4
5
6
7
8
9
1
2
3
4
Wilson Bridge
6
7
8
9
10
11
12
Rt. 301 Bridge
14
15
16
17
Ragged Pt.
19
20
21
Pt. Lookout
Smith Pt.
Station



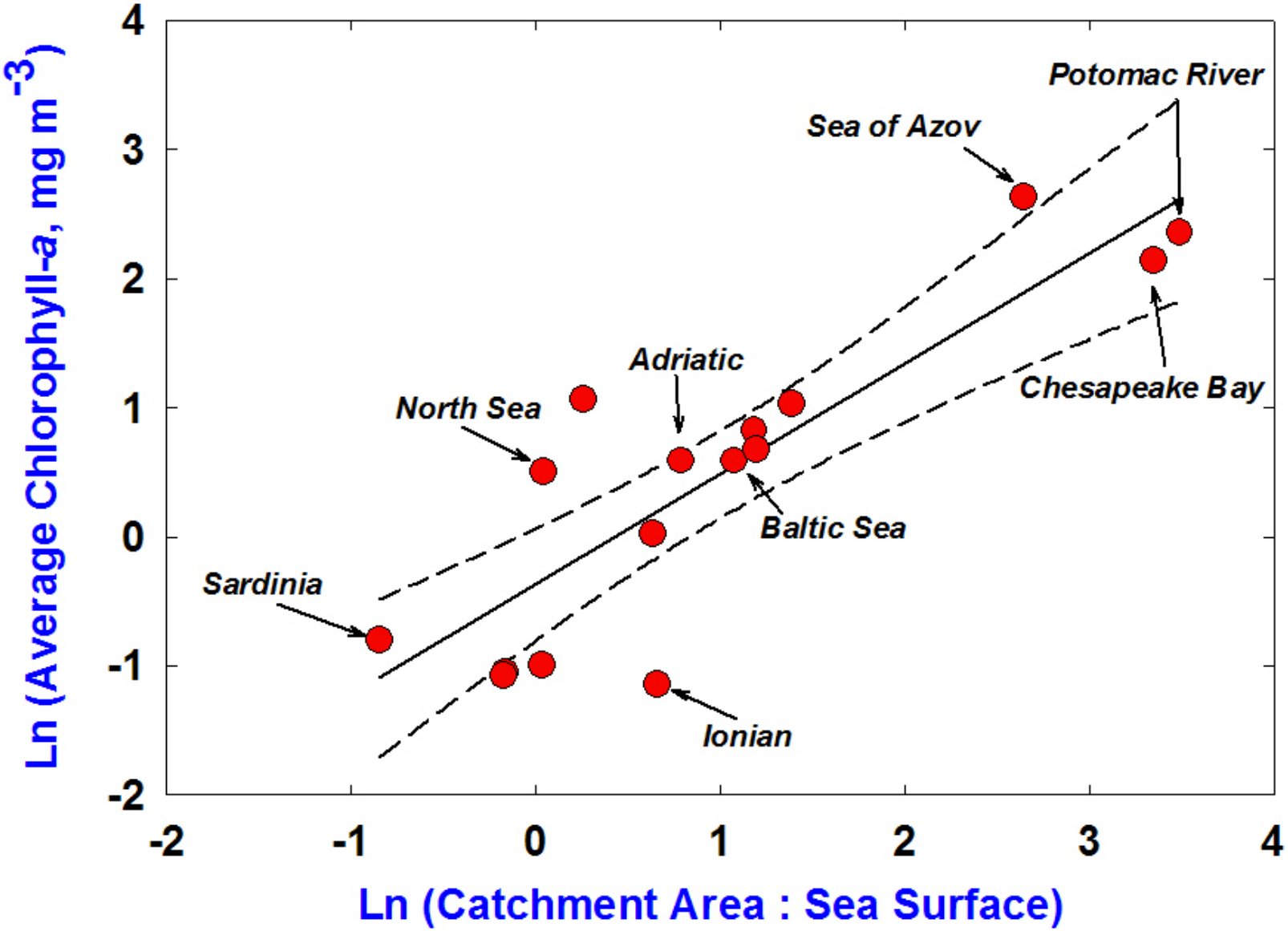

- Hypoxia in 2007 was not particularly severe…but not good
- Potomac one of the large hypoxic zones of the Bay system
- Note the disconnect between the Bay and Potomac low DO waters


Seasonal Comparison of Bottom Water DO
(1985 - 1999)
DO (mg L-1)
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
River Mile from Chain Bridge
Winter
Spring
Fall
Summer

# Hypoxia vs. Mean Depth in Chesapeake Bay and Tributaries 1986-1998



# Land Effects vs Algal Biomass

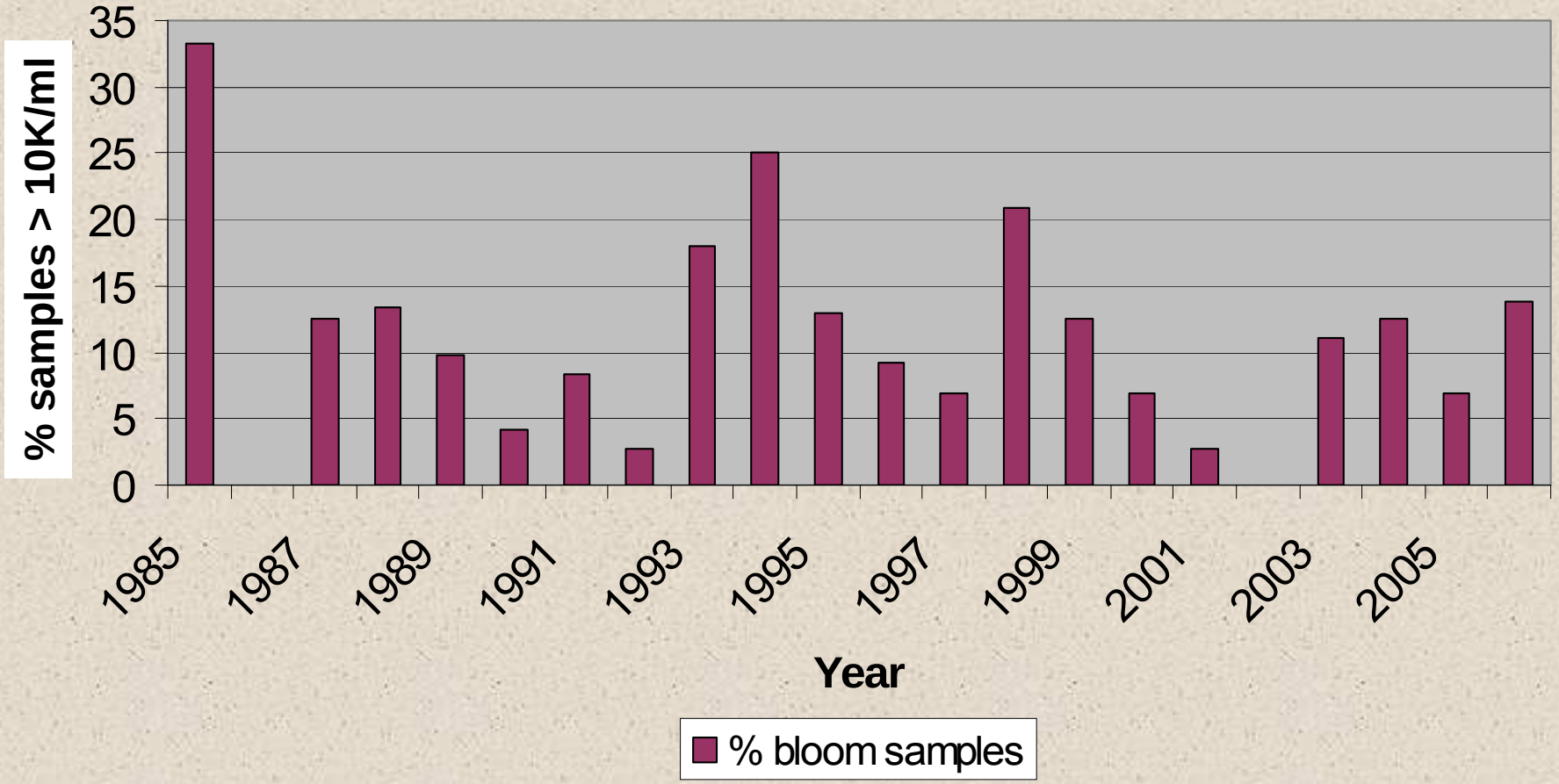



Adapted from Moreno et al. 2000

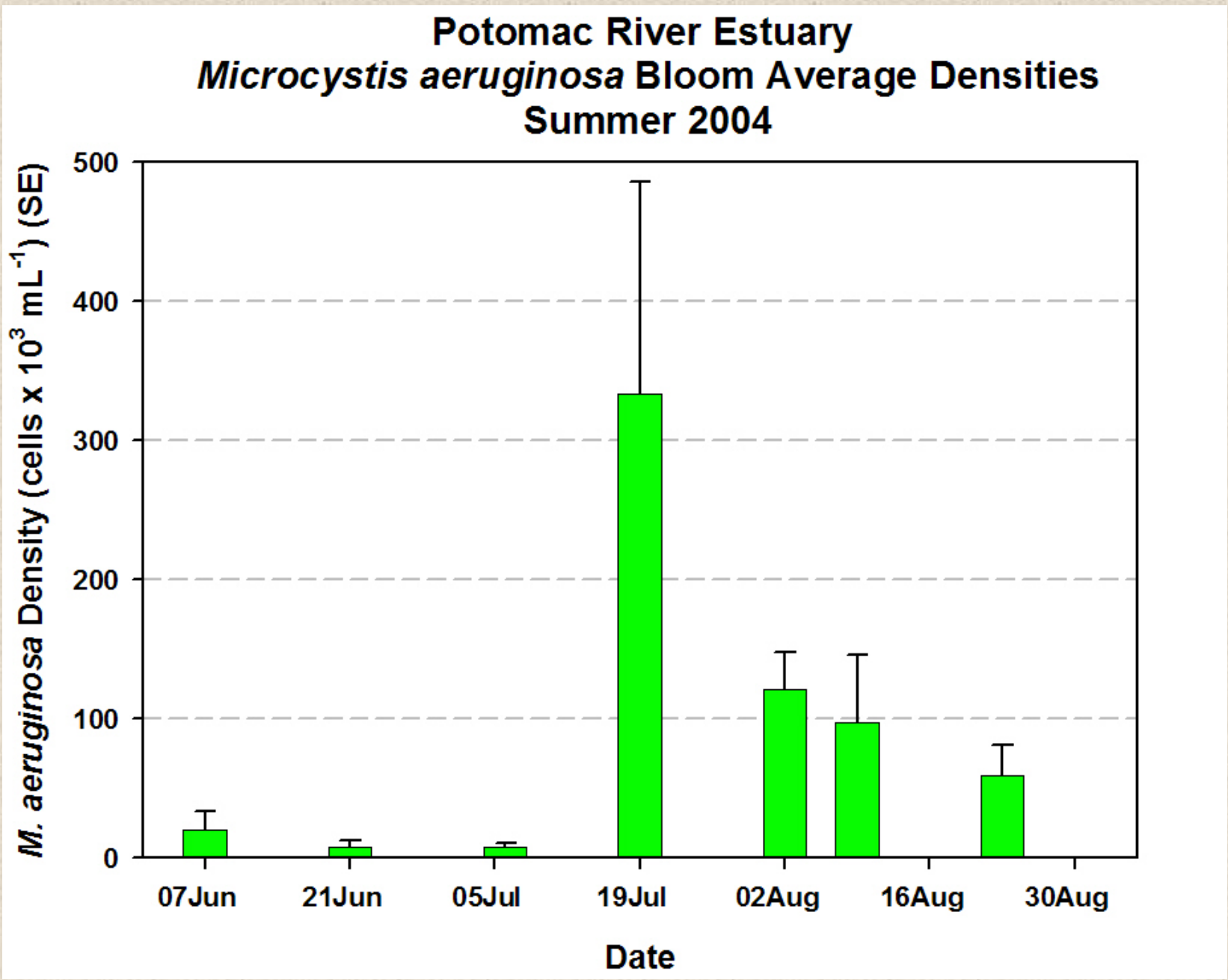
# *Microcystis Bloom 2004*

**(P. Tango, MDDNR)**

**Summer (June-September) % bloom samples (>10,000 cells/milliliter *Microcystis*) for 9 Potomac River stations, 1985-2006.**

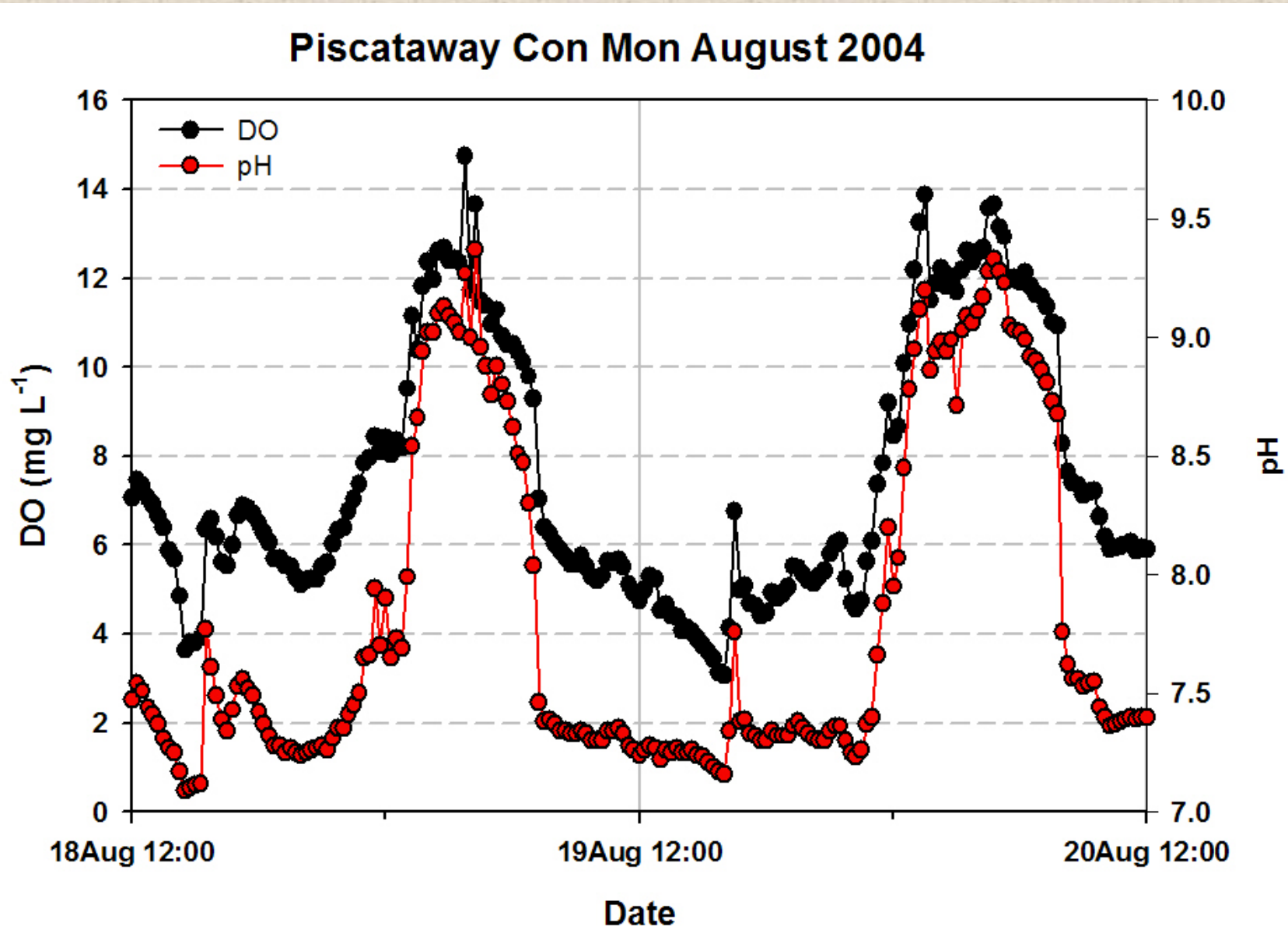



P. Tango, pers comm.


Potomac River Estuary
Microcystis aeruginosa Bloom Average Densities
Summer 2004
M. aeruginosa Density (cells x 10^3 mL^-1) (SE)
500
400
300
200
100
0
07Jun
21Jun
05Jul
19Jul
02Aug
16Aug
30Aug
Date

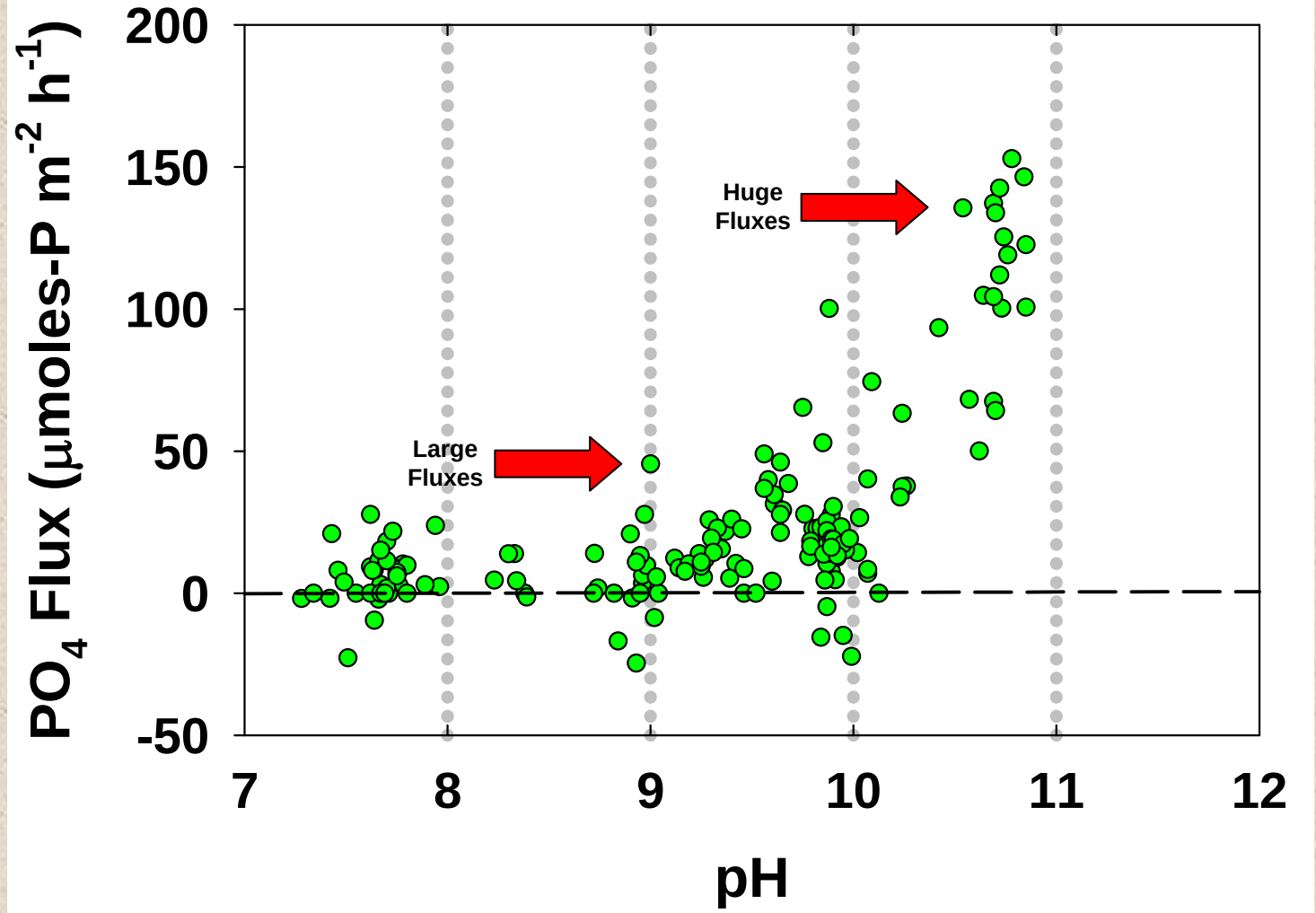
# “Gotta Love these Babies”

# Bloom Year

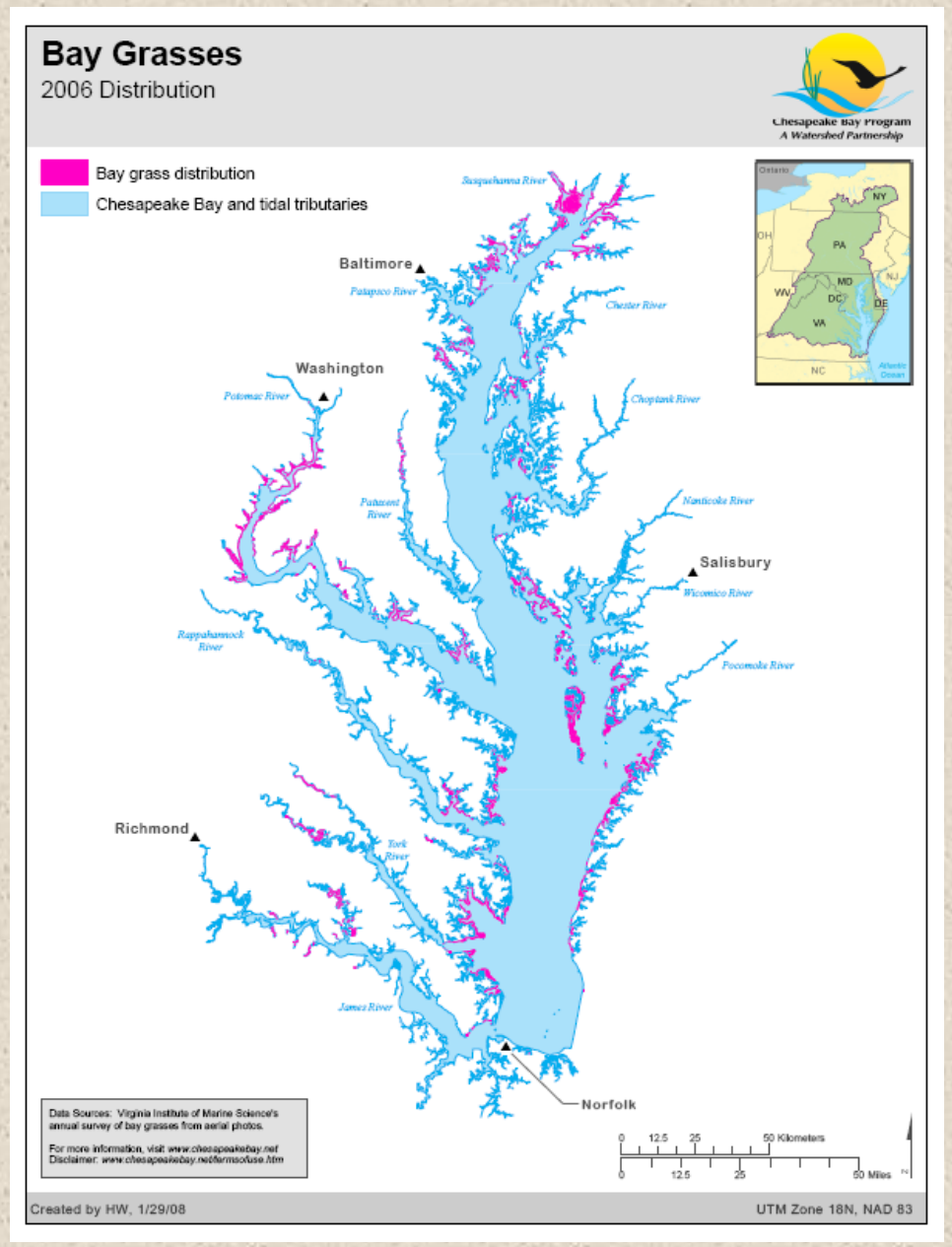

Piscataway Con Mon August 2004
DO
pH
DO (mg L-1)
pH
16
14
12
10
8
6
4
2
0
10.0
9.5
9.0
8.5
8.0
7.5
7.0
18Aug 12:00
19Aug 12:00
20Aug 12:00
Date

# Potomac Sediment $PO_4$ Flux

A case where bad gets worse…and fast!




From Bailey et al. 2006




# Potomac Estuary SAVs

# Patuxent River Estuary
# Circa 1832

- “Of all the bright rivers that flow into it (Chesapeake Bay) there is not one which excels the Clearwater (Patuxent) in the purity of its waters.”

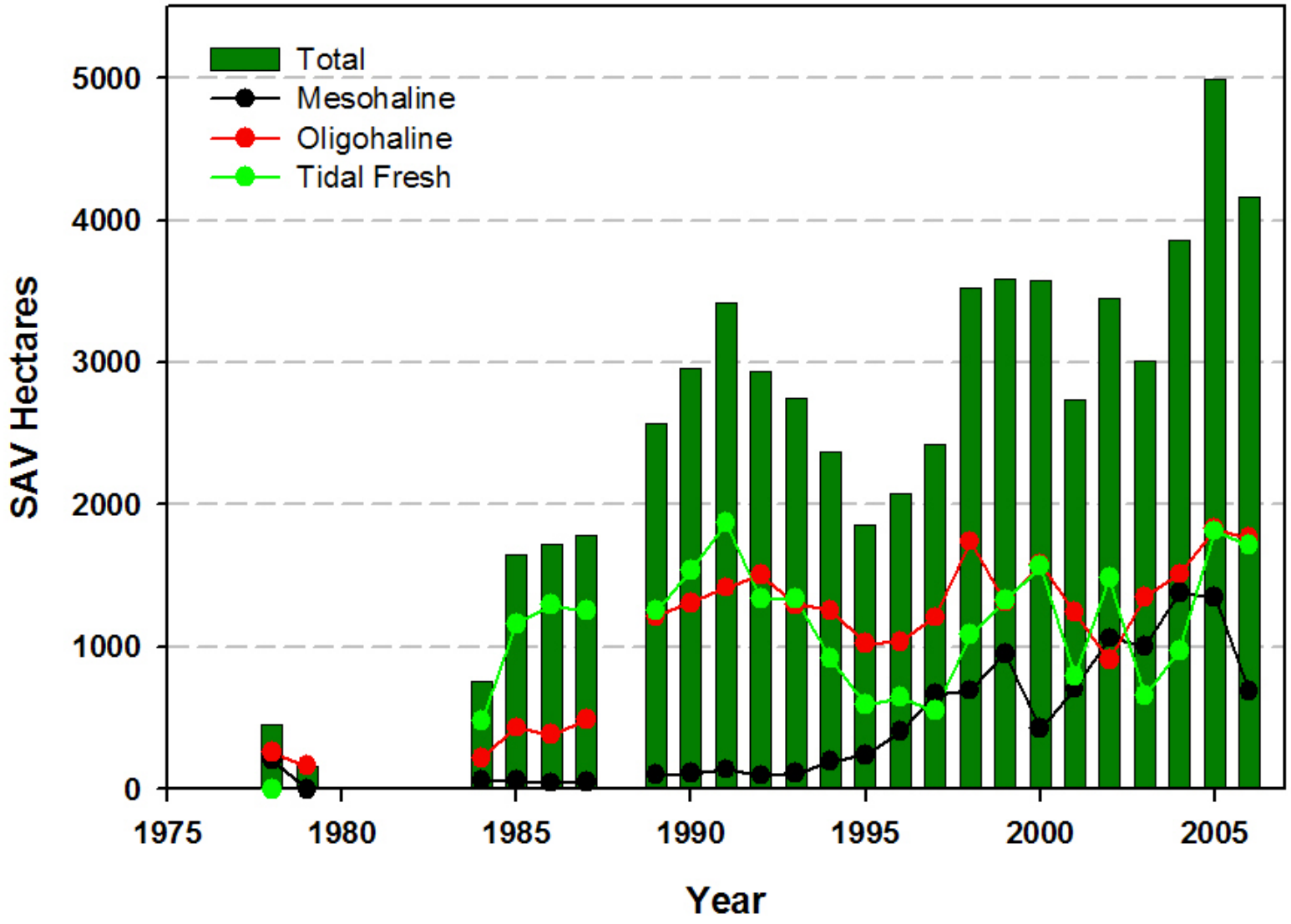
- “So transparent are its waters that far out from shore you may see, in the openings of the sea-weed forest, on its bottom the flashing sides of the finny tribe as they glide over the pearly sands.” *The Old Plantation by Hungerford (1859)*

# Solomons Island SAV - 1933

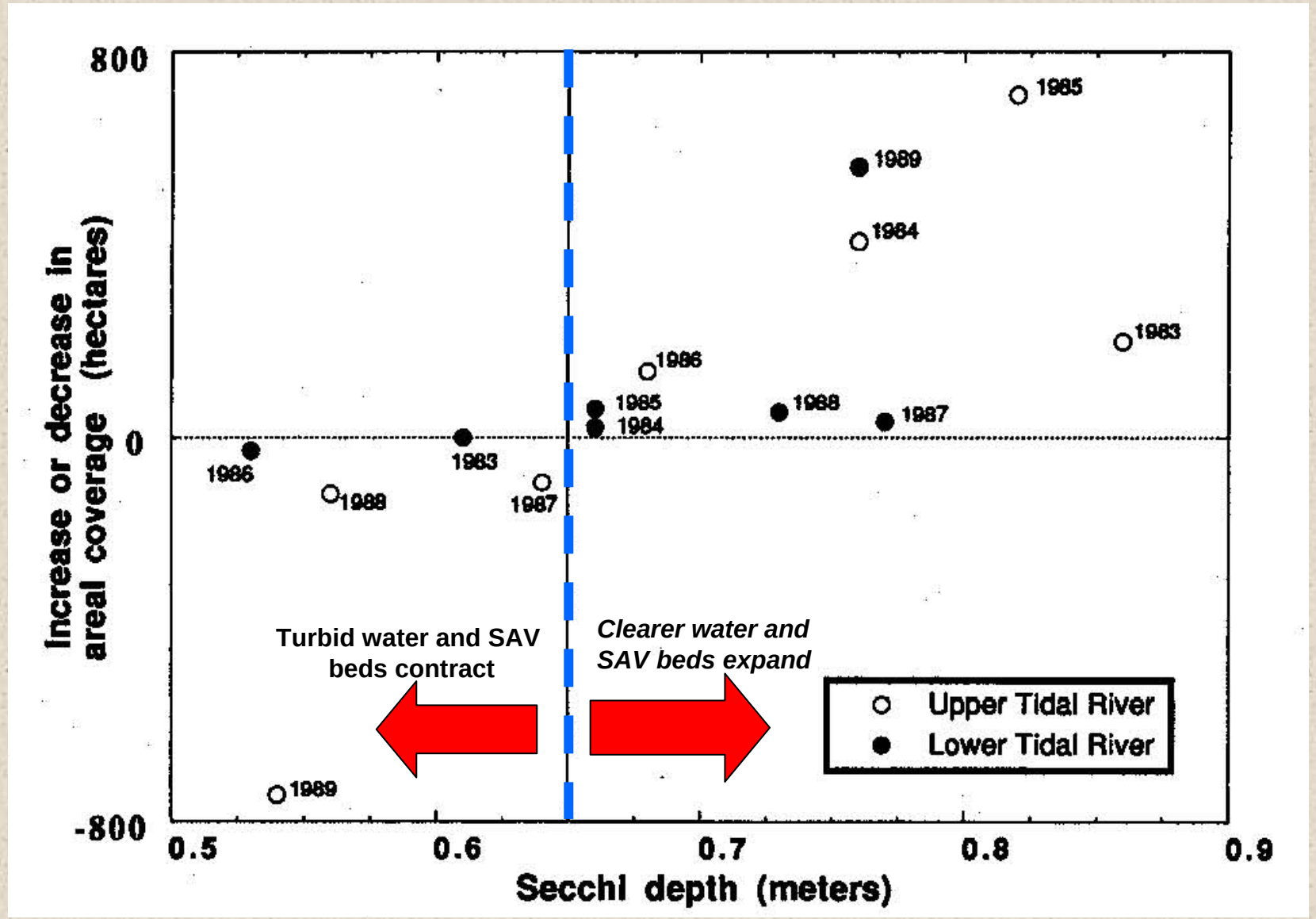
# Solomons Island SAV - 1963

# Potomac River SAV Coverage

(from:http://www.vims.edu/bio/sav)



# *SAV Coverage and Secchi Depth*
# *Tidal Potomac River Estuary*
# *(1983 – 1989)*




From Carter et al. 1994

# Have you seen this invasive plant?

## Water Lettuce (Pistia stratiotes)

Water lettuce is a floating aquatic plant native to the tropics and has been spotted in Mattawoman Creek on the Potomac River. It is an invasive species that produces seeds and spreads rapidly. Once established, water lettuce can wipe out native bay grasses, lower dissolved oxygen by covering the water surface, prevent boating and fishing and create breeding grounds for mosquitoes.

If you have seen this species of floating aquatic vegetation, remove it when possible and contact Mark Lewandowski at 410-260-8634 or email mlewandowski@dnr.state.md.us

MARYLAND DEPARTMENT OF NATURAL RESOURCES

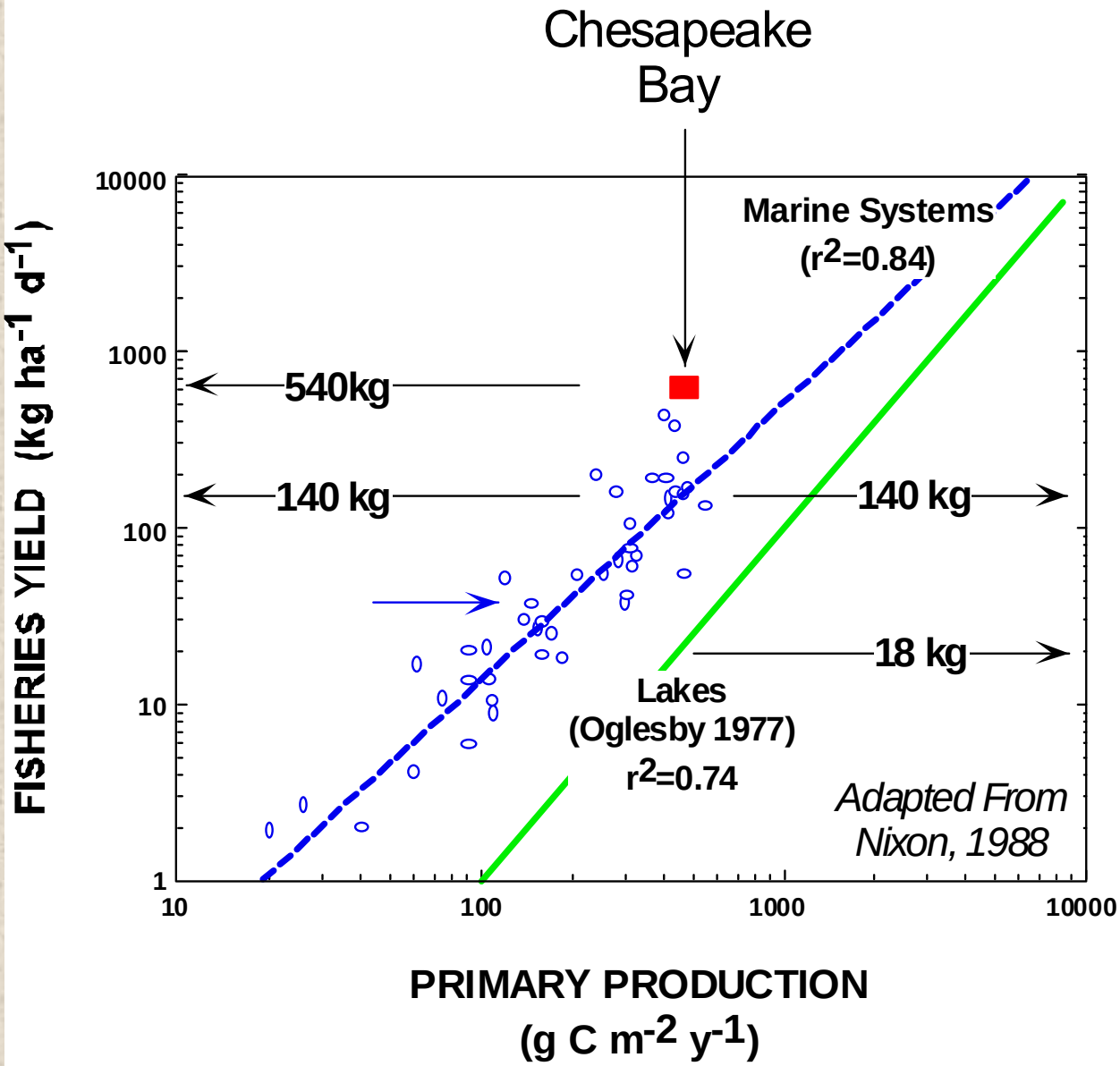
INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

USGS science for a changing world

# Potomac River Fisheries

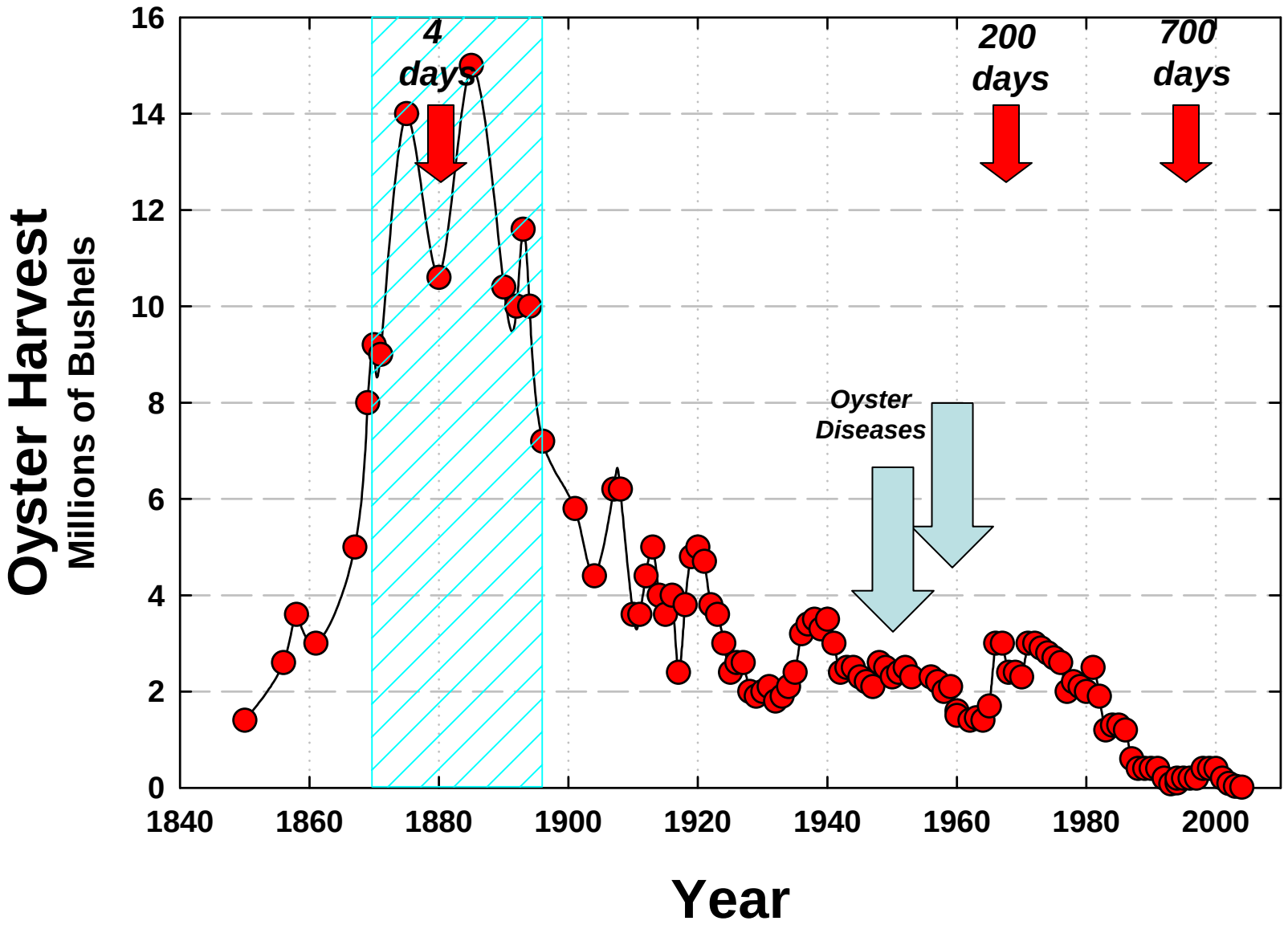
- Another issue the public cares about

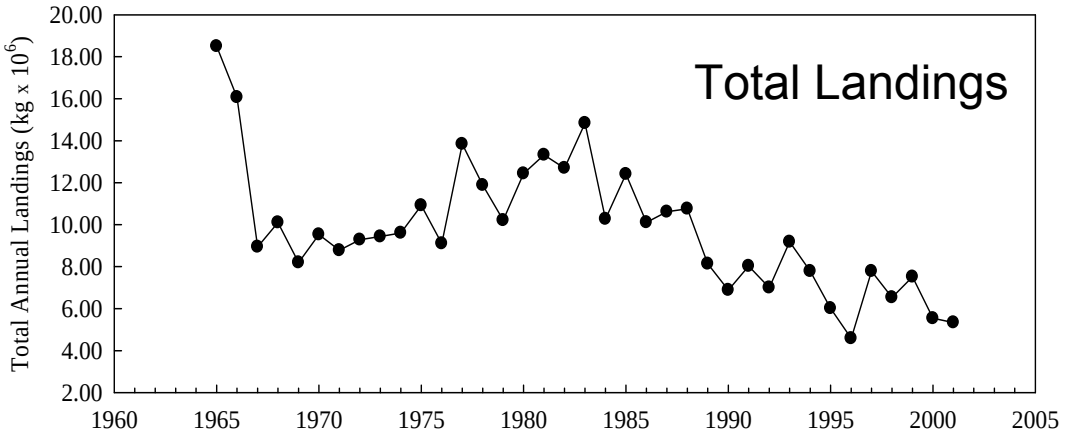
- Possibly a catch…hug…and release fishery is the answer

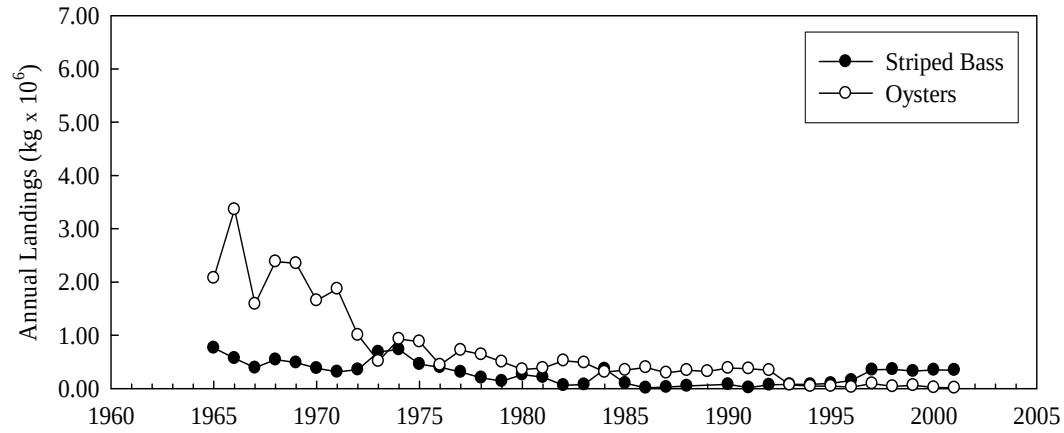


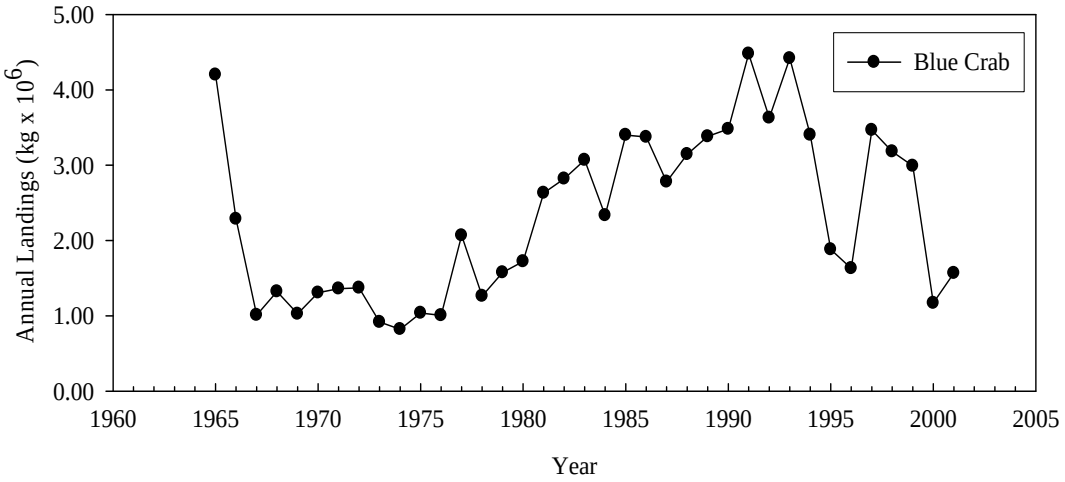

**Chesapeake Bay yields 30 times more fish than an average lake with the same primary production ...**

# MARYLAND OYSTER HARVEST





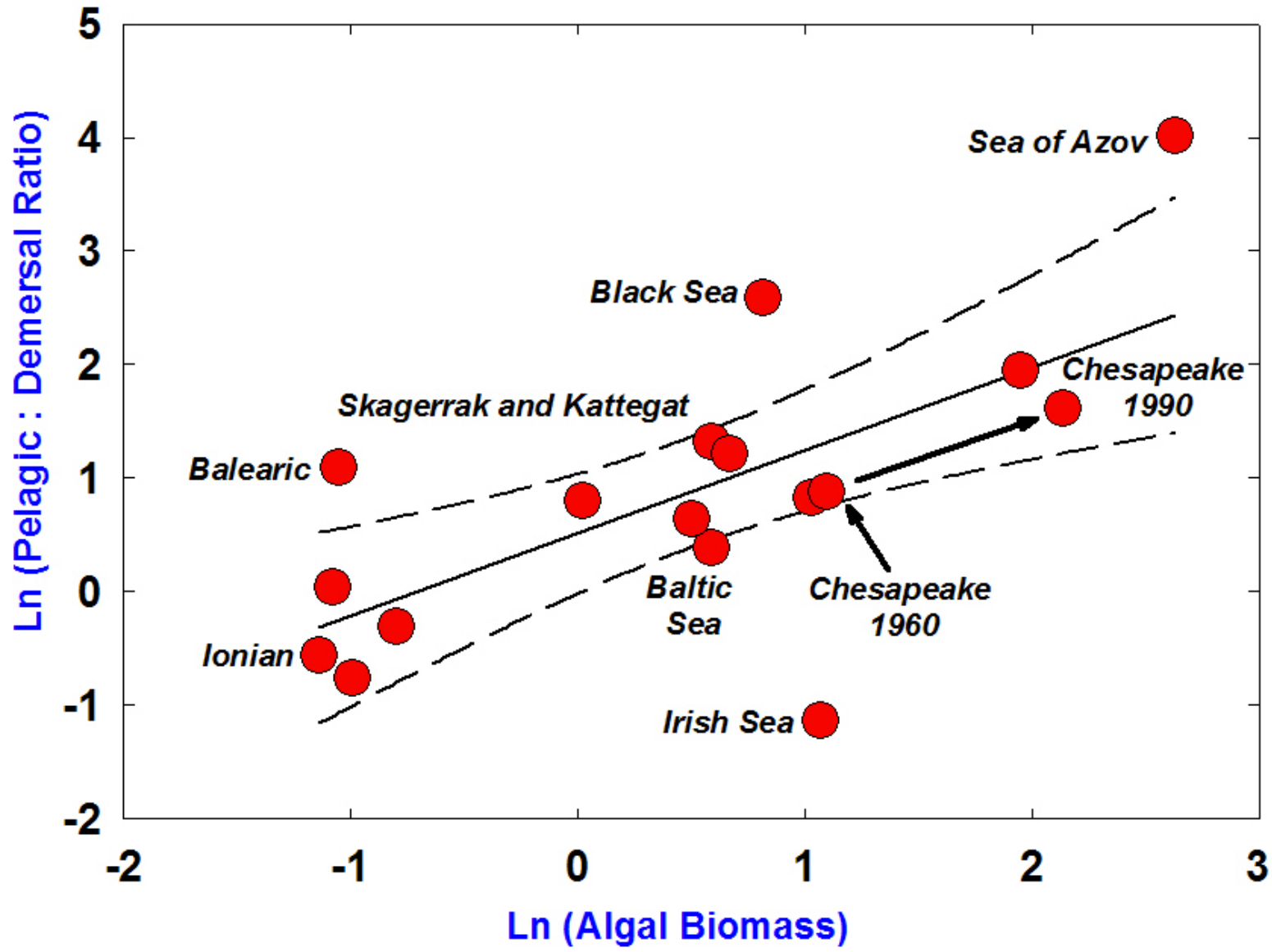



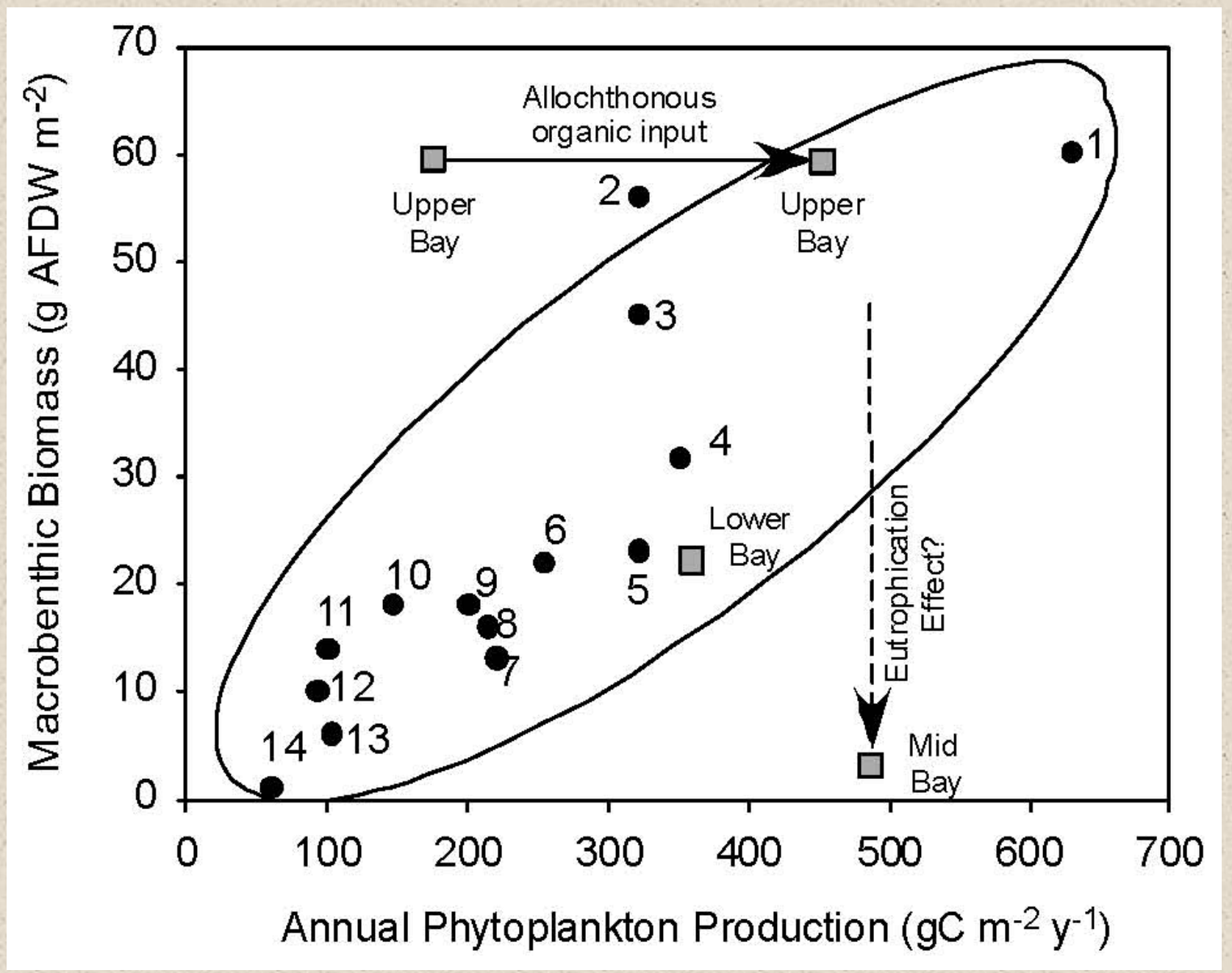

# Potomac River Estuary Commercial Fishery Yields 1965 - 2001

- General downward trend since mid-1980's
- Variable amount know concerning these trends
- What do we know about stock size and fishing effort?
- Potomac River Fisheries Commission has detailed spatial catch data…the best in the Bay region

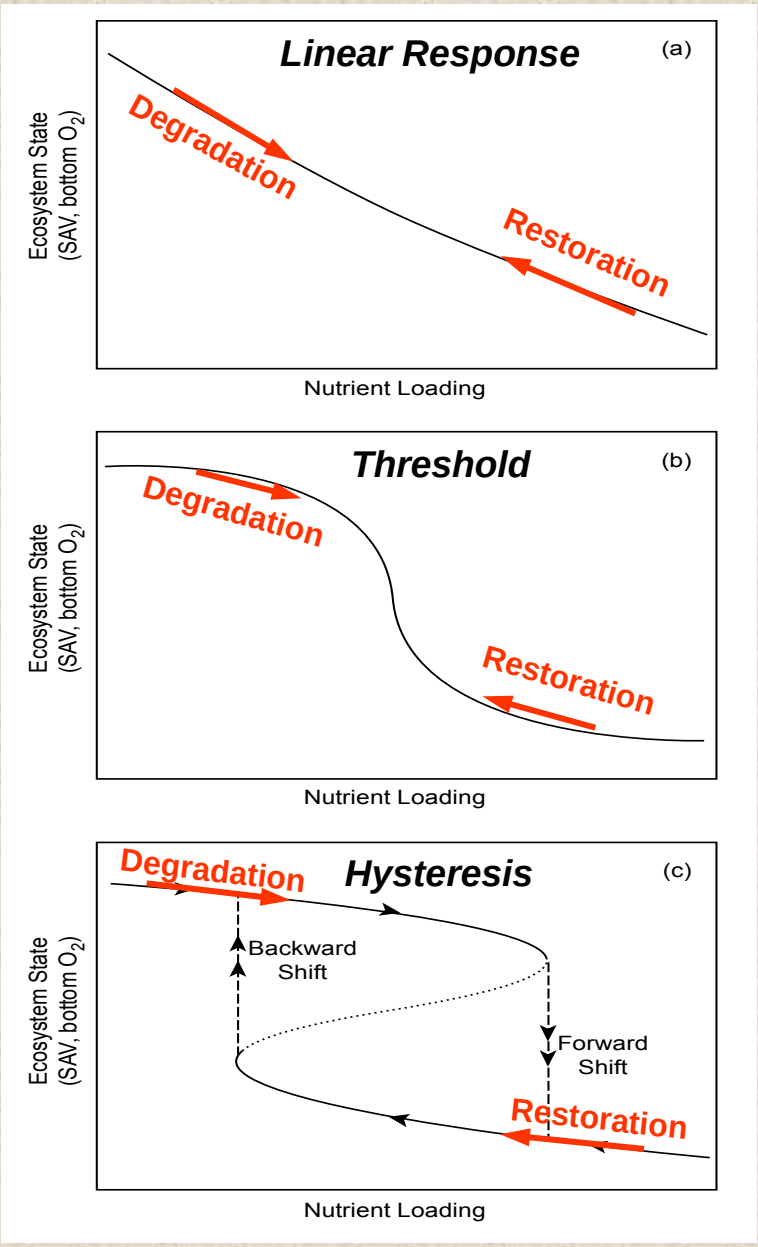
# Habitat Quality vs Fisheries Harvests




Adapted from Moreno et al. 2000 and Houde et al. 1999


Macrobenthic Biomass (g AFDW m-2)
Annual Phytoplankton Production (gC m-2 y-1)
0
10
20
30
40
50
60
70
0
100
200
300
400
500
600
700
Allochthonous
organic input
Upper
Bay
Upper
Bay
Lower
Bay
Mid
Bay
Eutrophication
Effect?
1
2
3
4
5
6
7
8
9
10
11
12
13
14

# *Trajectories of Response to Nutrient Loading*




- Theory suggests alternative ecosystem response to changes in environmental conditions (e.g., nutrient loading, climate)
- Responses can follow ~*linear* pathways with direct proportional response (a)
- Responses can follow "sigmoidal" shape with apparent *threshold shift* within narrow range of environmental conditions
- Responses can exhibit *multiple stable states* with abrupt transitions and *hysteretic* patterns where degradation and restoration follow different trajectories

**From Scheffer et al. 2001**

# Summary and Recommendations

- The Potomac is a typical“OVER-ENRICHED” estuary…too much of a good thing
- Nutrient inputs need to be reduced by a large margin…there has been success with P and now N reductions need attention
- Climate variability and change are emerging issues and complicate forecasts
- Upper estuary SAV recovery very positive; lower estuary habitats are still degraded
- What are the likely recovery trajectories…we need to know for better management planning!!

# Acknowledgements

**Figures, maps, photos and data with help from:**

**J. Cornwell (UMCES-HPL)**

**L. Wainger (UMCES-CBL)**

**J. Anderson (MERC)**

**J. Julian (UMCES-APL)**

**N. Rybiki (USGS)**

**M. Kemp (UMCES-HPL)**

**M. Hall (MDDNR)**

**P. Tango (USGS/CHPO)**

**N. Jaworski**