Potomac Monitoring Forum

March 10-11, 2008

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CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

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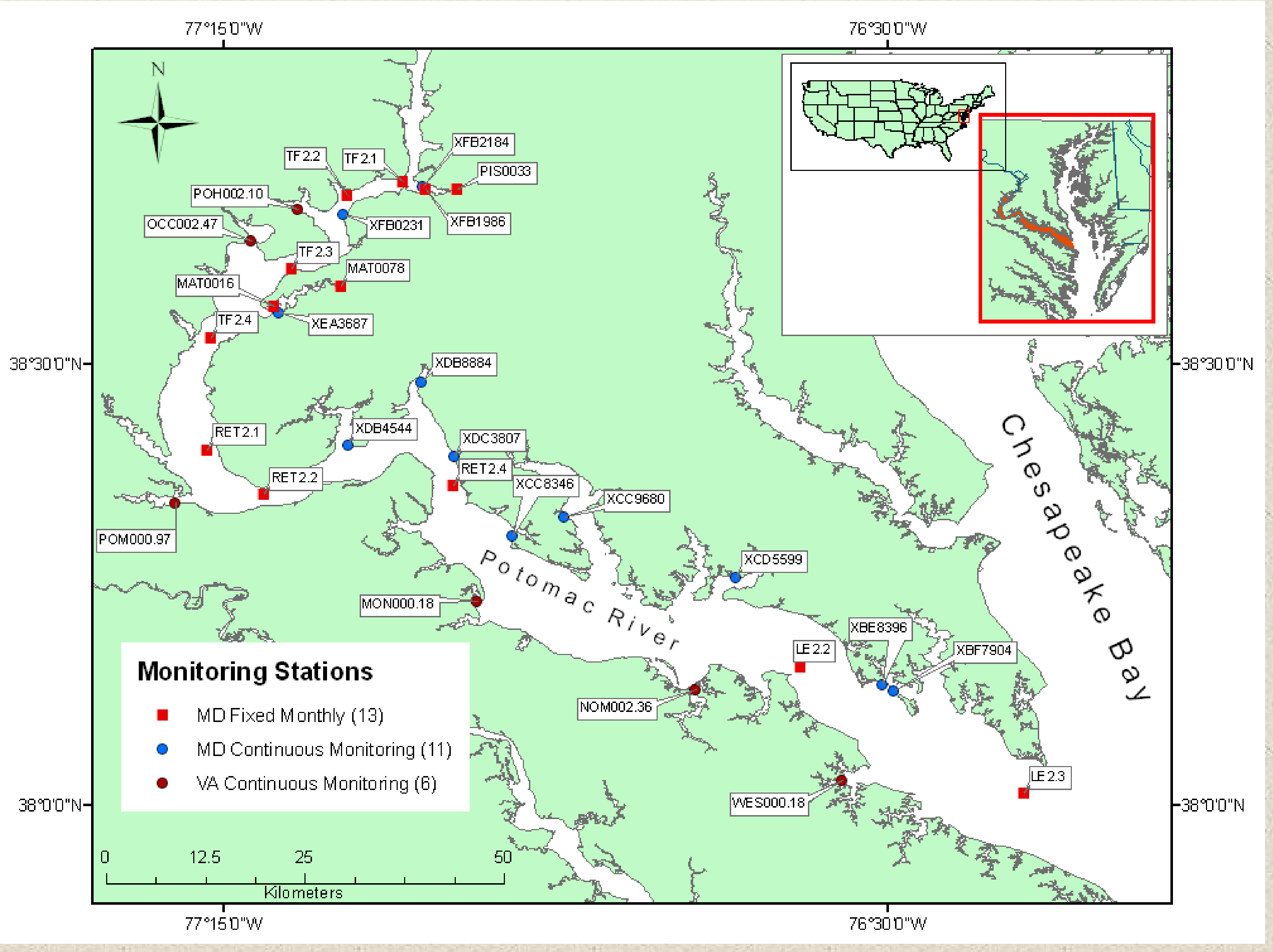
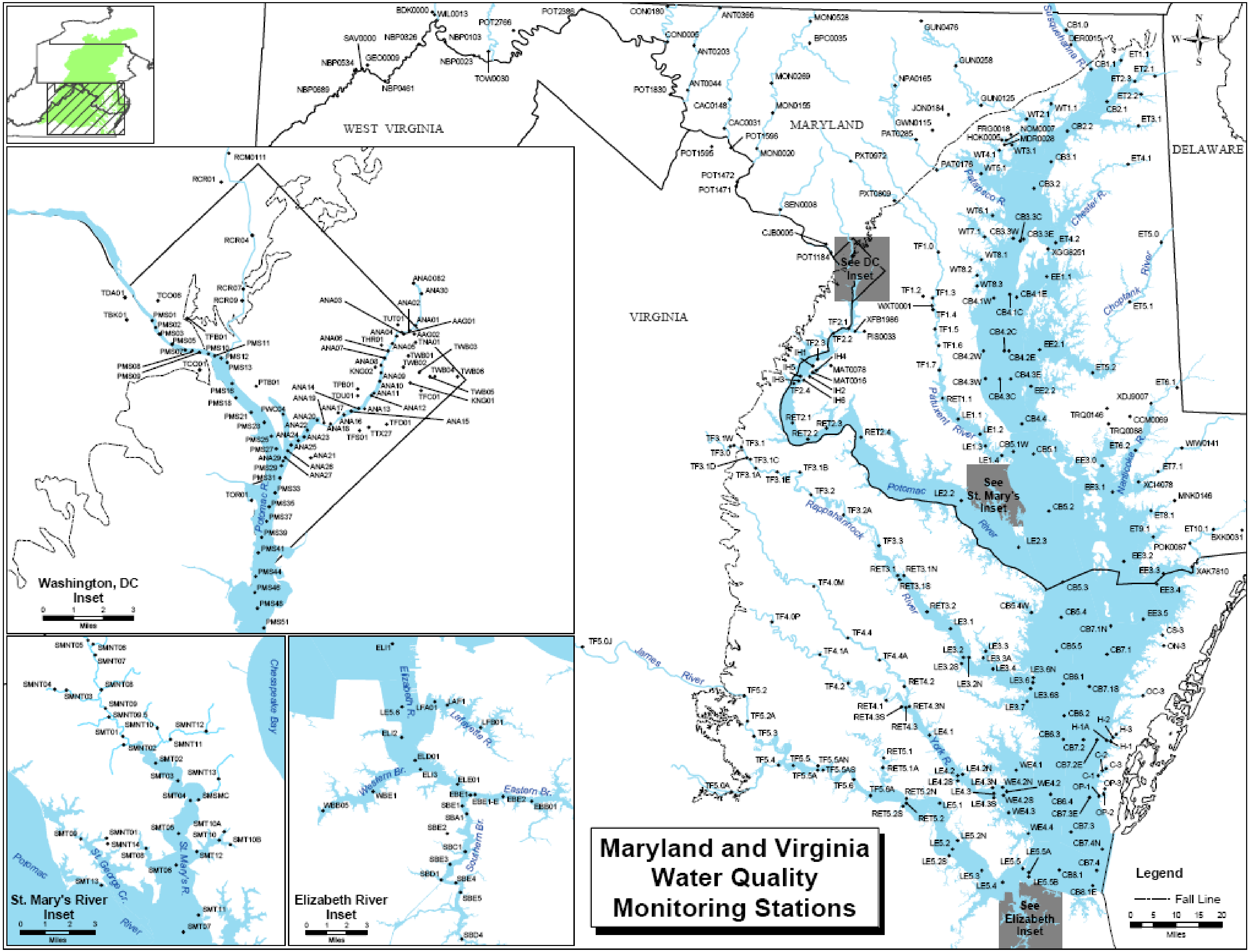
UMCES, NSF, MD-DNR, MD-MDE, NOAA, EPA

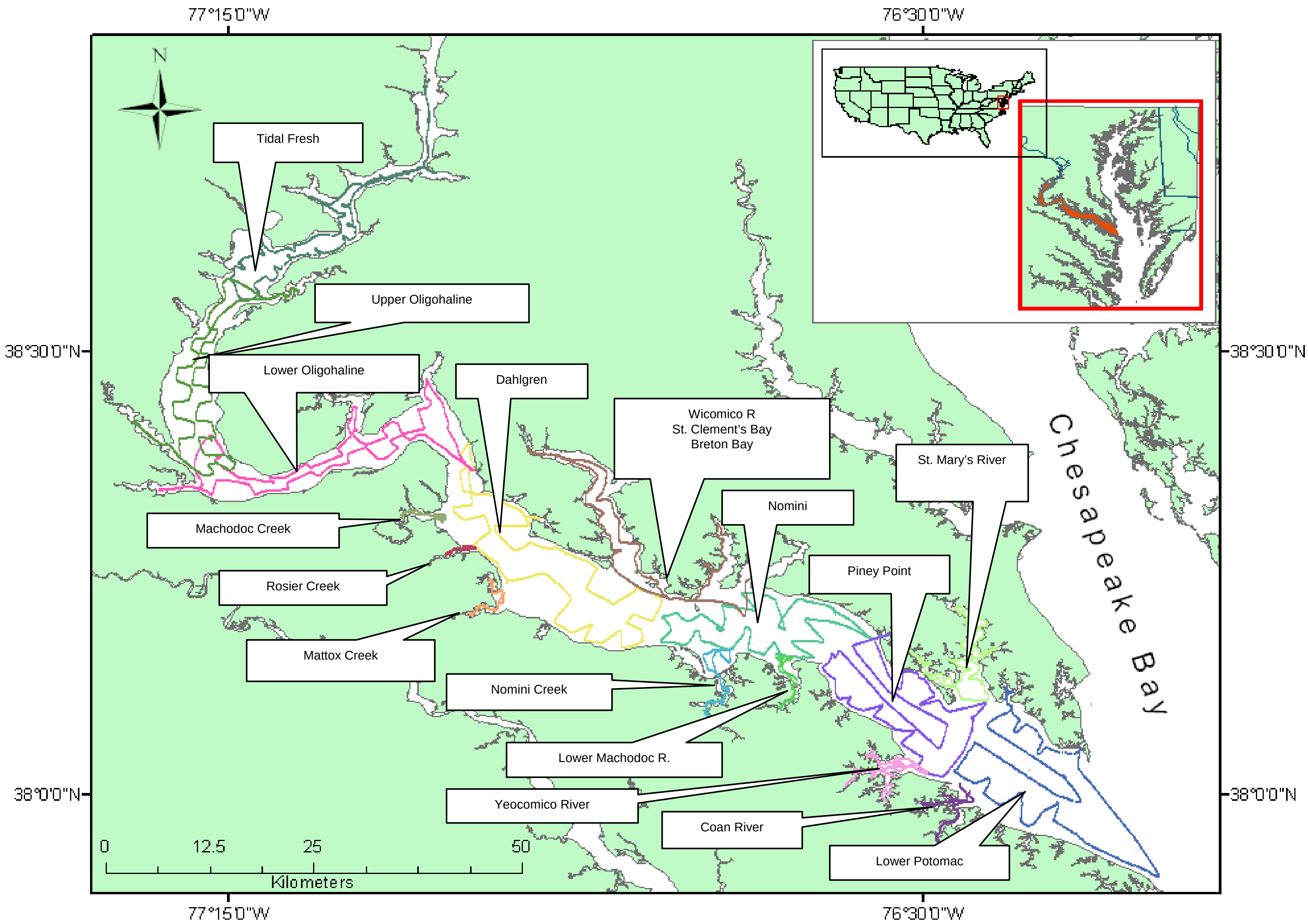
Outline

- Monitoring Programs…lots of water being dipped from the estuary
- Nutrient loads…where were we and where are we now
- Water Quality Conditions (historical and current)
- A short SAV story
- Some special features (blooms, pH, sediment/bloom interactions)
- A budget for N…where does this stuff go?
- Fisheries issues and monitoring
- Some preliminary recommendations

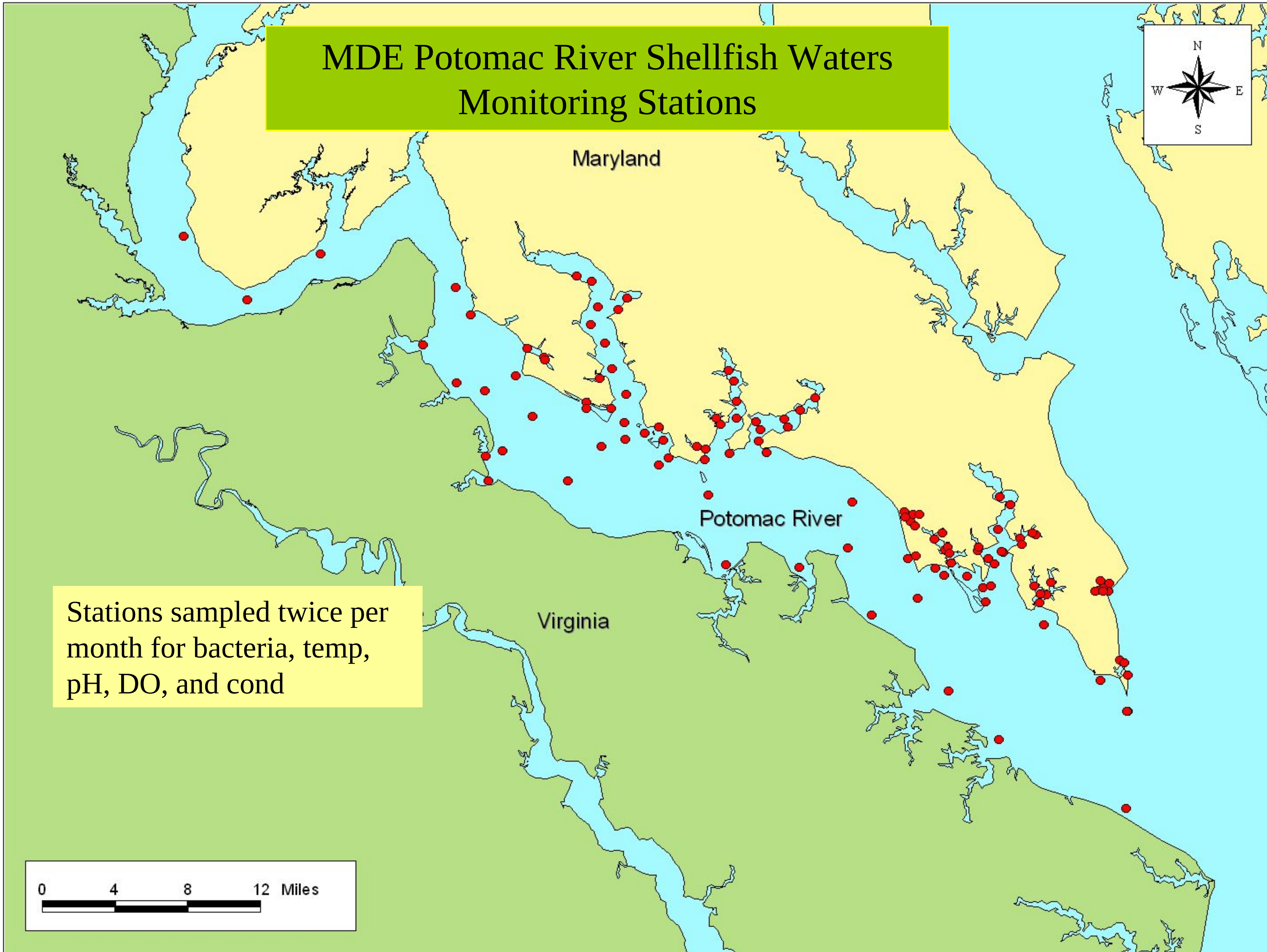


77°15'0"W
76°30'0"W
38°30'0"N
38°0'0"N
N
TF2.2
TF2.1
XFB2184
PIS0033
POH002.10
XFB0231
XFB1986
OCC002.47
TF2.3
MAT0078
MAT0016
TF2.4
XEA3687
XDB8884
XDB4544
RET2.1
XDC3807
RET2.4
RET2.2
XCC8346
XCC9680
POM000.97
Potomac River
Chesapeake Bay
XCD5599
MON000.18
XBE8396
LE2.2
XBF7904
NOM002.36
LE2.3
WES000.18
Monitoring Stations
MD Fixed Monthly (13)
MD Continuous Monitoring (11)
VA Continuous Monitoring (6)
0
12.5
25
50
Kilometers


Maryland and Virginia
Water Quality
Monitoring Stations
WEST VIRGINIA
MARYLAND
DELAWARE
VIRGINIA
See DC Inset
See St. Mary's Inset
See Elizabeth Inset
Washington, DC Inset
St. Mary's River Inset
Elizabeth River Inset
Chesapeake Bay
Potomac River
Rappahannock River
York R.
James River
Patuxent River
Choptank River
Chester R.
Patapsco R.
Susquehanna R.
Nanticoke R.
Elizabeth R.
Lafayette R.
Western Br.
Eastern Br.
Southern Br.
St. Mary's R.
St. George Cr.
Legend
Fall Line
Miles


77°15'0"W
76°30'0"W
38°30'0"N
38°0'0"N
N
Tidal Fresh
Upper Oligohaline
Lower Oligohaline
Dahlgren
Wicomico R
St. Clement's Bay
Breton Bay
St. Mary's River
Nomini
Piney Point
Machodoc Creek
Rosier Creek
Mattox Creek
Nomini Creek
Lower Machodoc R.
Yeocomico River
Coan River
Lower Potomac
Chesapeake Bay
0
12.5
25
50
Kilometers

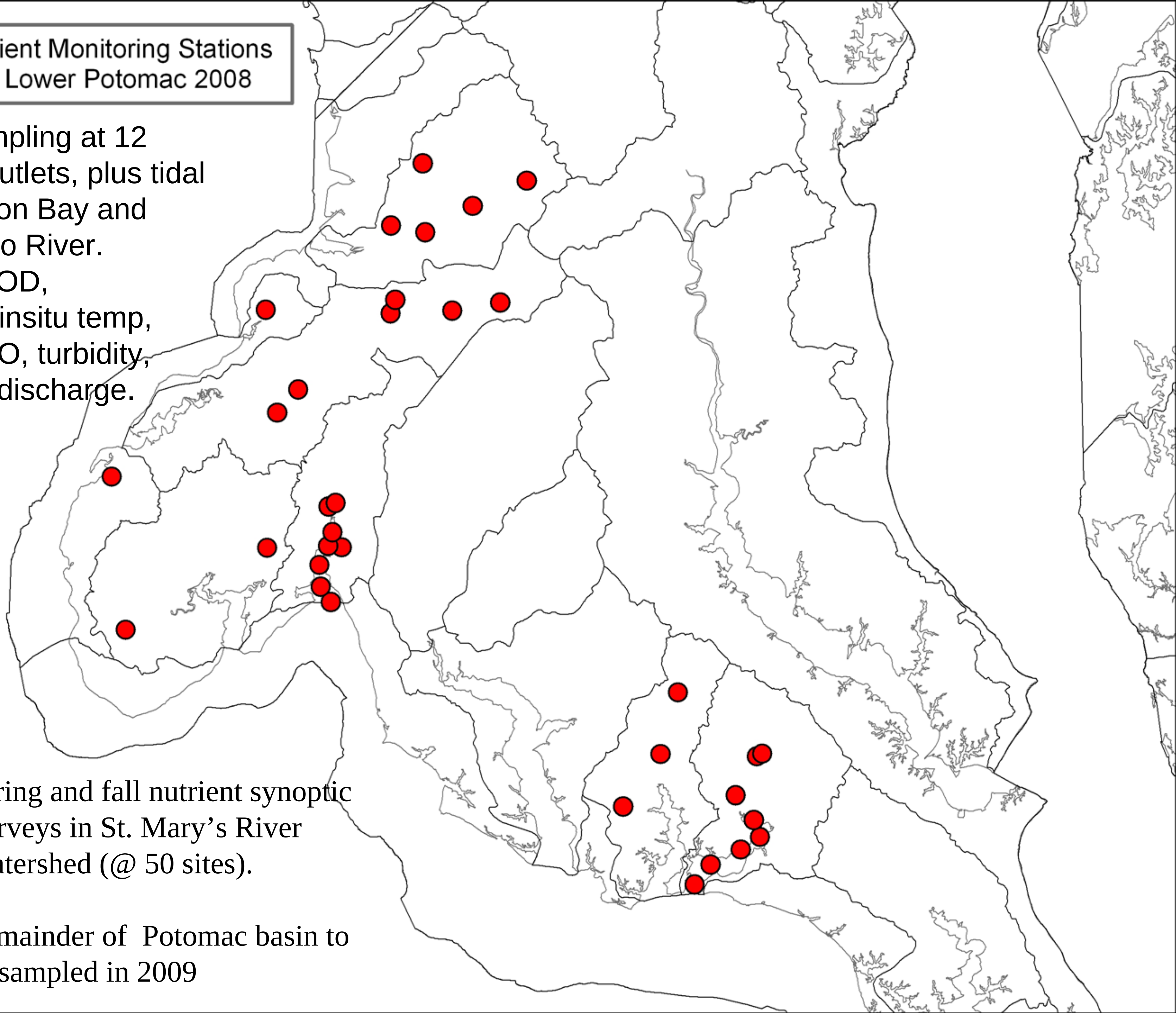
MDE Potomac River Shellfish Waters Monitoring Stations



Stations sampled twice per month for bacteria, temp, pH, DO, and cond

TMDL Nutrient Monitoring Stations Entering Lower Potomac 2008

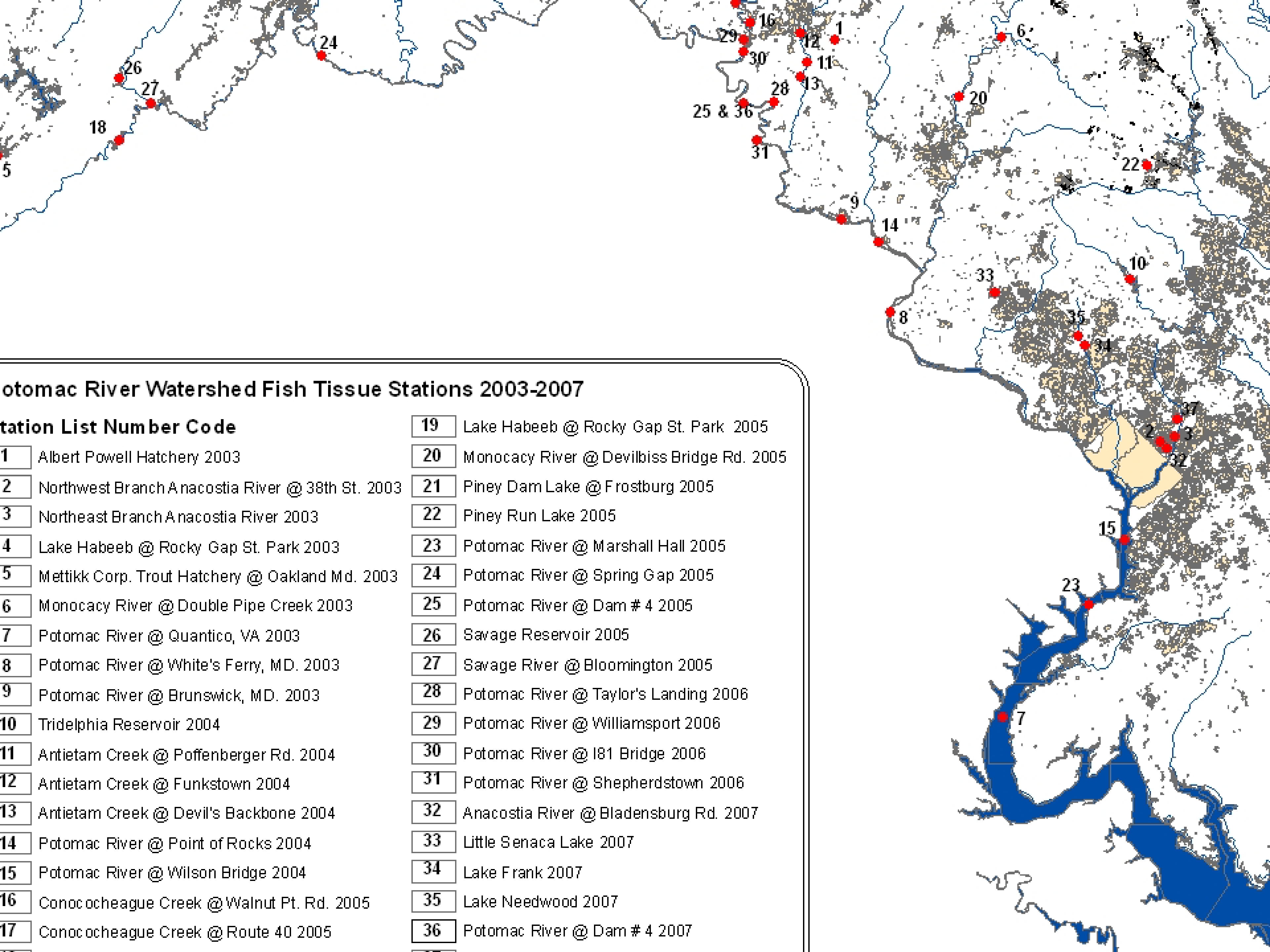
Monthly sampling at 12 digit basin outlets, plus tidal sites in Breton Bay and Port Tobacco River. Nutrients, BOD, chlorophyll, insitu temp, pH, cond, DO, turbidity, salinity and discharge.



Spring and fall nutrient synoptic surveys in St. Mary’s River watershed (@ 50 sites).

Remainder of Potomac basin to be sampled in 2009

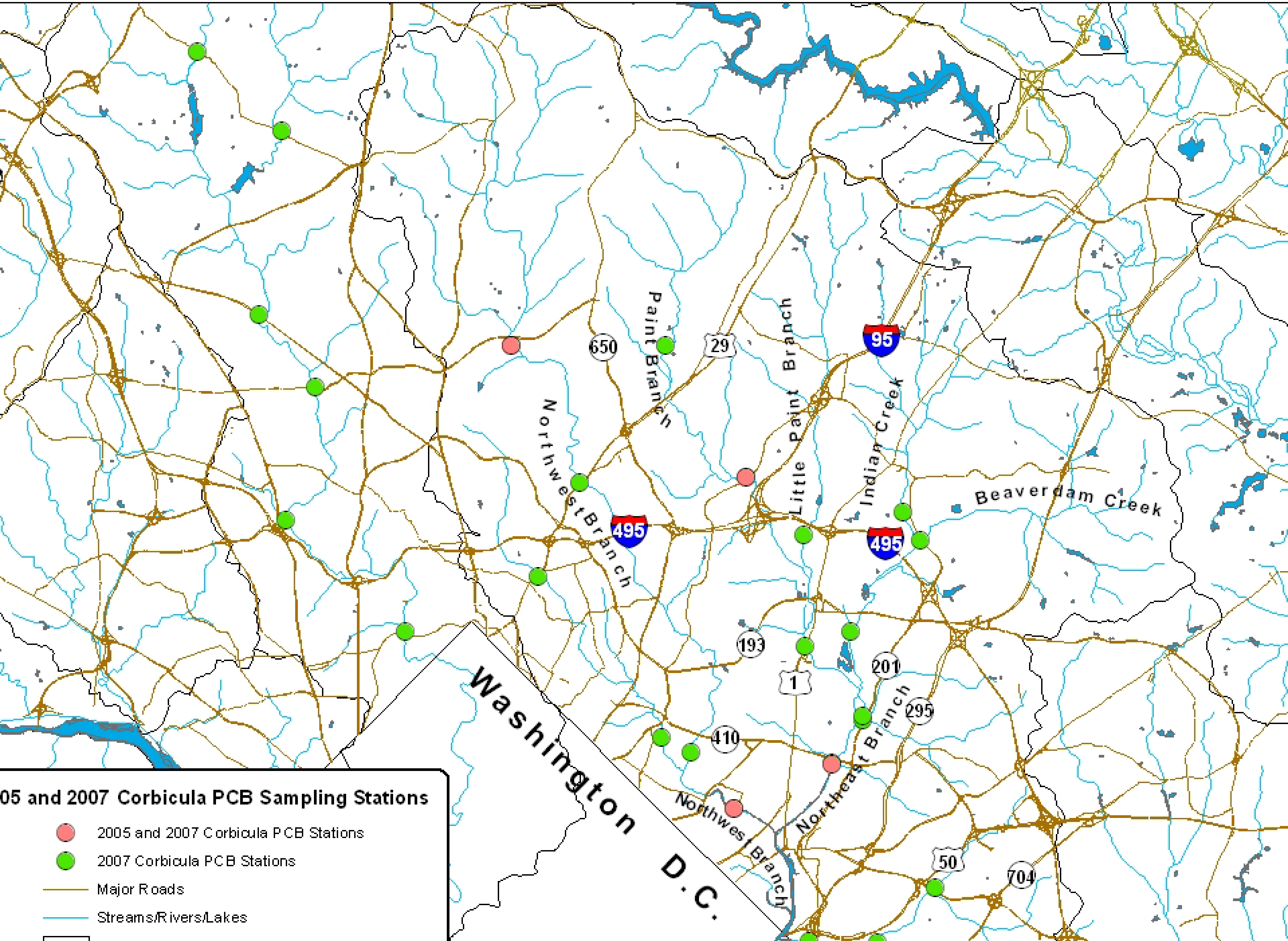
MDE



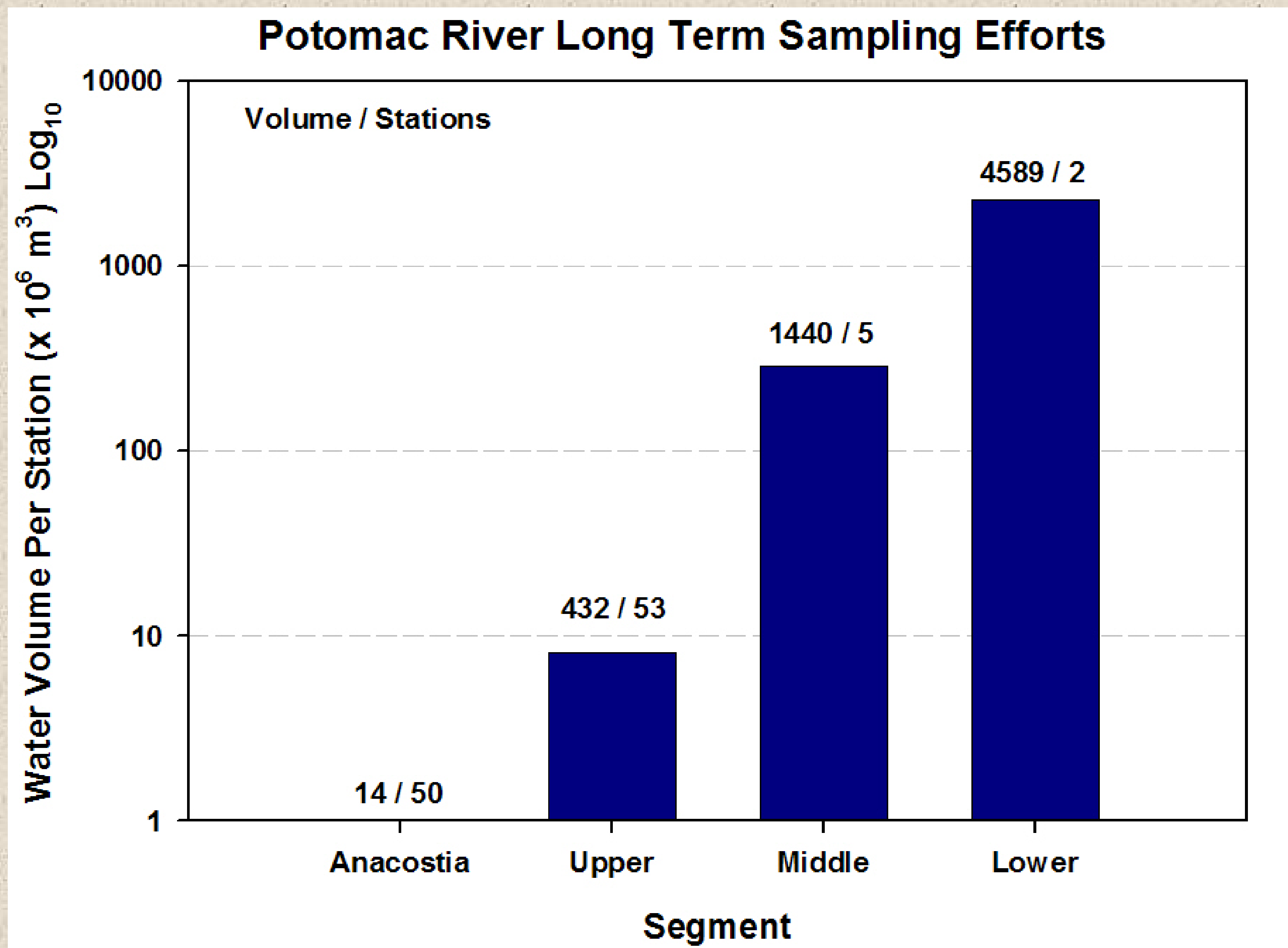
otomac River Watershed Fish Tissue Stations 2003-2007

tation List Number Code

1	Albert Powell Hatchery 2003	19	Lake Habeeb @ Rocky Gap St. Park 2005
2	Northwest Branch Anacostia River @ 38th St. 2003	20	Monocacy River @ Devilbiss Bridge Rd. 2005
3	Northeast Branch Anacostia River 2003	21	Piney Dam Lake @ Frostburg 2005
4	Lake Habeeb @ Rocky Gap St. Park 2003	22	Piney Run Lake 2005
5	Mettikk Corp. Trout Hatchery @ Oakland Md. 2003	23	Potomac River @ Marshall Hall 2005
6	Monocacy River @ Double Pipe Creek 2003	24	Potomac River @ Spring Gap 2005
7	Potomac River @ Quantico, VA 2003	25	Potomac River @ Dam # 4 2005
8	Potomac River @ White's Ferry, MD. 2003	26	Savage Reservoir 2005
9	Potomac River @ Brunswick, MD. 2003	27	Savage River @ Bloomington 2005
10	Tridelphia Reservoir 2004	28	Potomac River @ Taylor's Landing 2006
11	Antietam Creek @ Poffenberger Rd. 2004	29	Potomac River @ Williamsport 2006
12	Antietam Creek @ Funkstown 2004	30	Potomac River @ I81 Bridge 2006
13	Antietam Creek @ Devil's Backbone 2004	31	Potomac River @ Shepherdstown 2006
14	Potomac River @ Point of Rocks 2004	32	Anacostia River @ Bladensburg Rd. 2007
15	Potomac River @ Wilson Bridge 2004	33	Little Senaca Lake 2007
16	Conococheague Creek @ Walnut Pt. Rd. 2005	34	Lake Frank 2007
17	Conococheague Creek @ Route 40 2005	35	Lake Needwood 2007
		36	Potomac River @ Dam # 4 2007



Paint Branch
Little Paint Branch
Indian Creek
Beaverdam Creek
Northwest Branch
Northeast Branch
Washington D.C.
650
29
95
495
495
193
1
201
295
410
50
704
05 and 2007 Corbicula PCB Sampling Stations
2005 and 2007 Corbicula PCB Stations
2007 Corbicula PCB Stations
Major Roads
Streams/Rivers/Lakes


Potomac River Long Term Sampling Efforts
Volume / Stations
Water Volume Per Station (x 10^6 m^3) Log10
10000
1000
100
10
1
14 / 50
432 / 53
1440 / 5
4589 / 2
Anacostia
Upper
Middle
Lower
Segment

Our Nation's Most Prominent Rivers

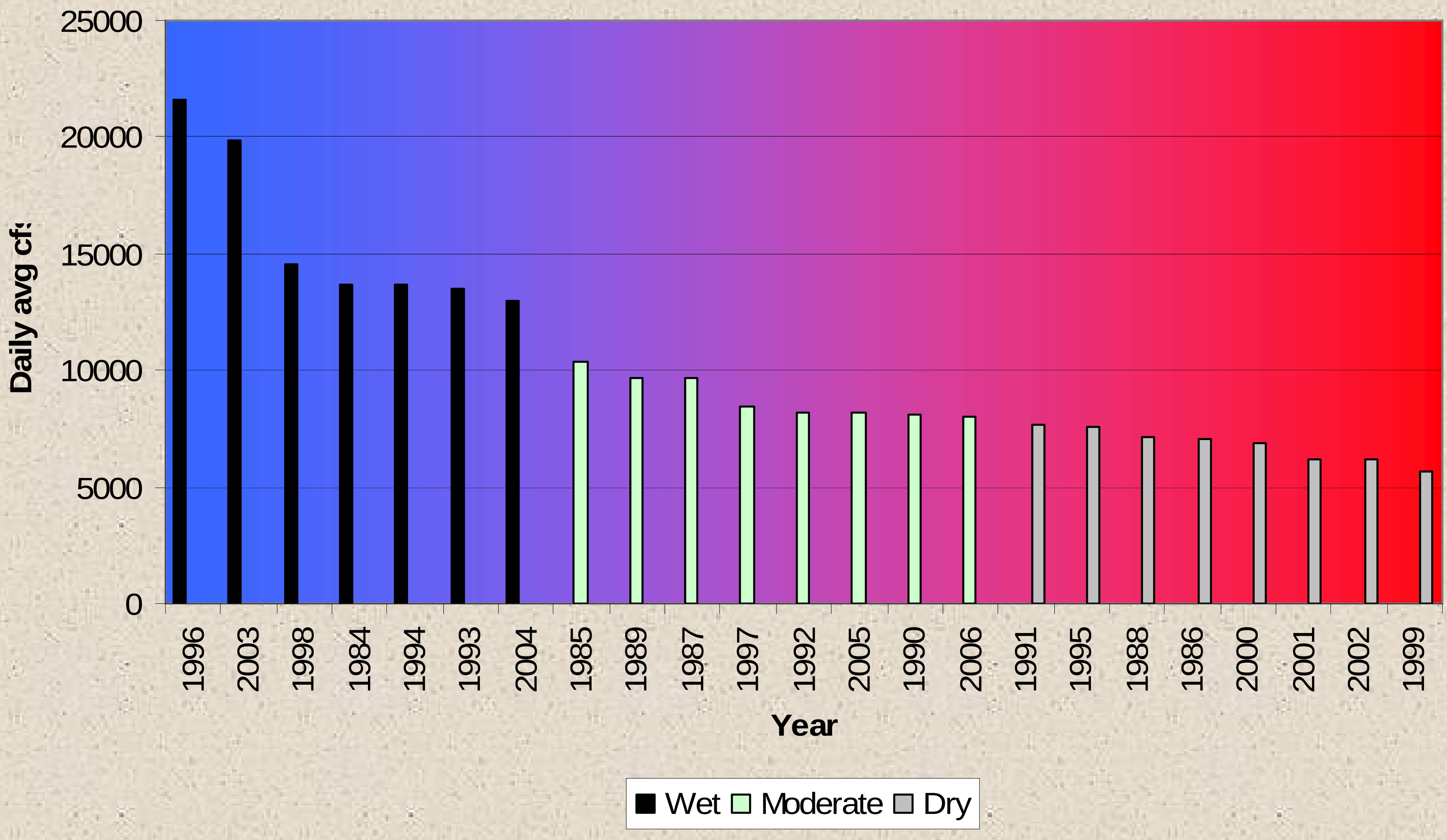
River	ISI References
Columbia	3,263
Mississippi	2,921
Colorado	2,195
Hudson	1,193
Missouri	826
Potomac	309

J. Julian AL-CES

Potomac in Flood

Potomac NOT in Flood

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

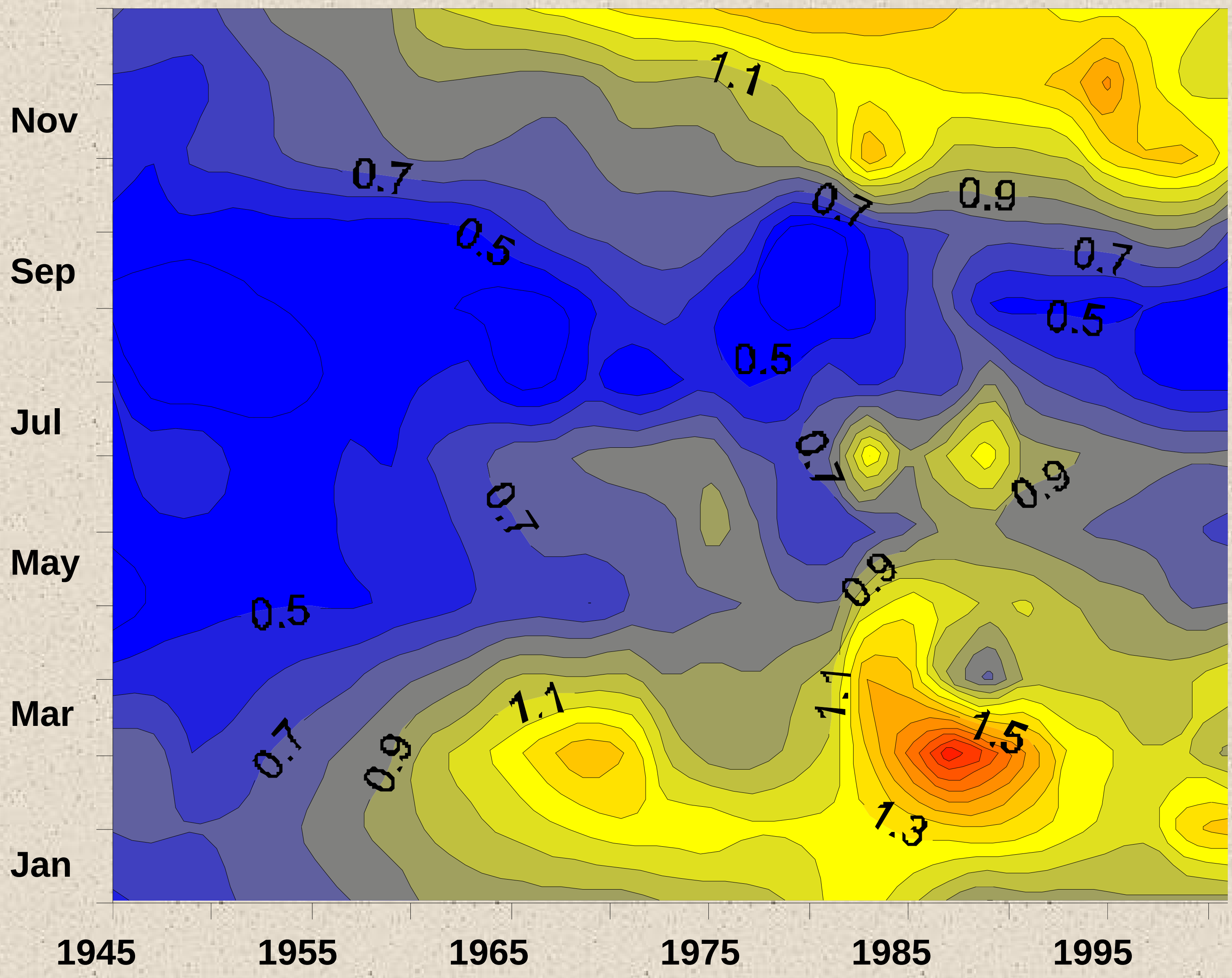


4X variability in flow during 23 year record

From P. Tango

Nitrate Concentration

Susquehanna River at Harrisburg, PA

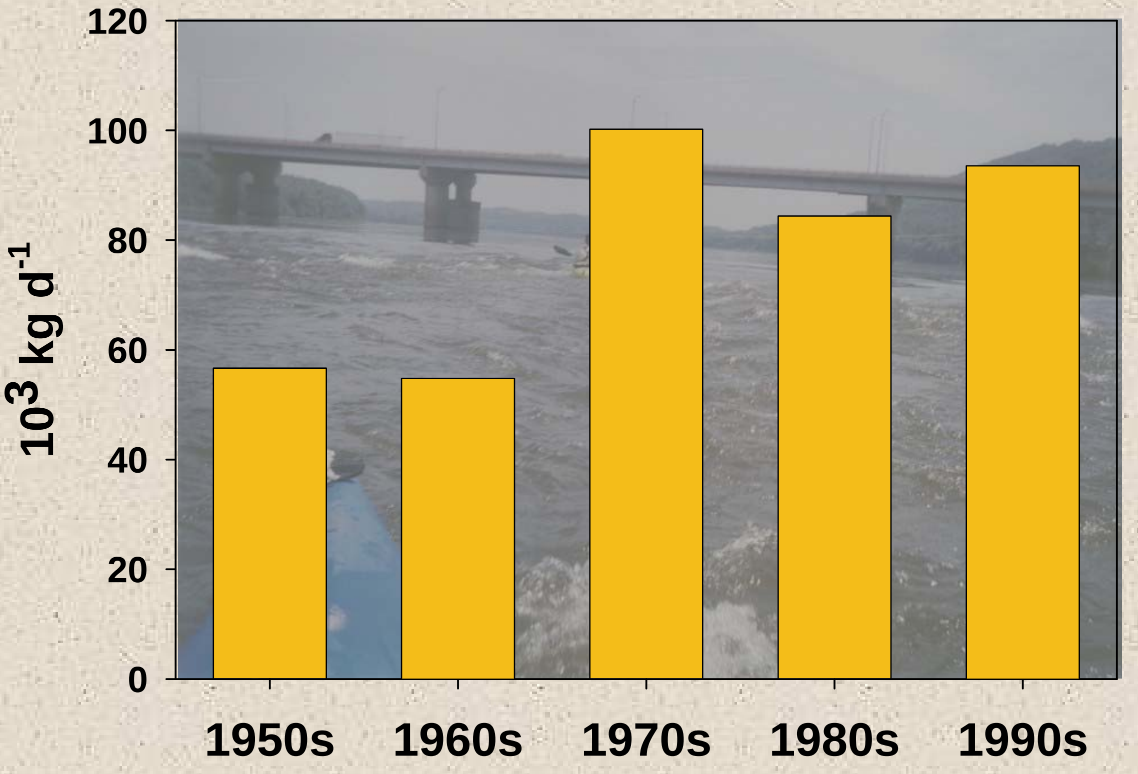


- Based on NO_3 measurements, modeled trends, seasonality, and trends in seasonality
- Highest seasonal concentrations during periods of highest flow
- N-loads have doubled since 1970

Adapted from Hagy et al 2004

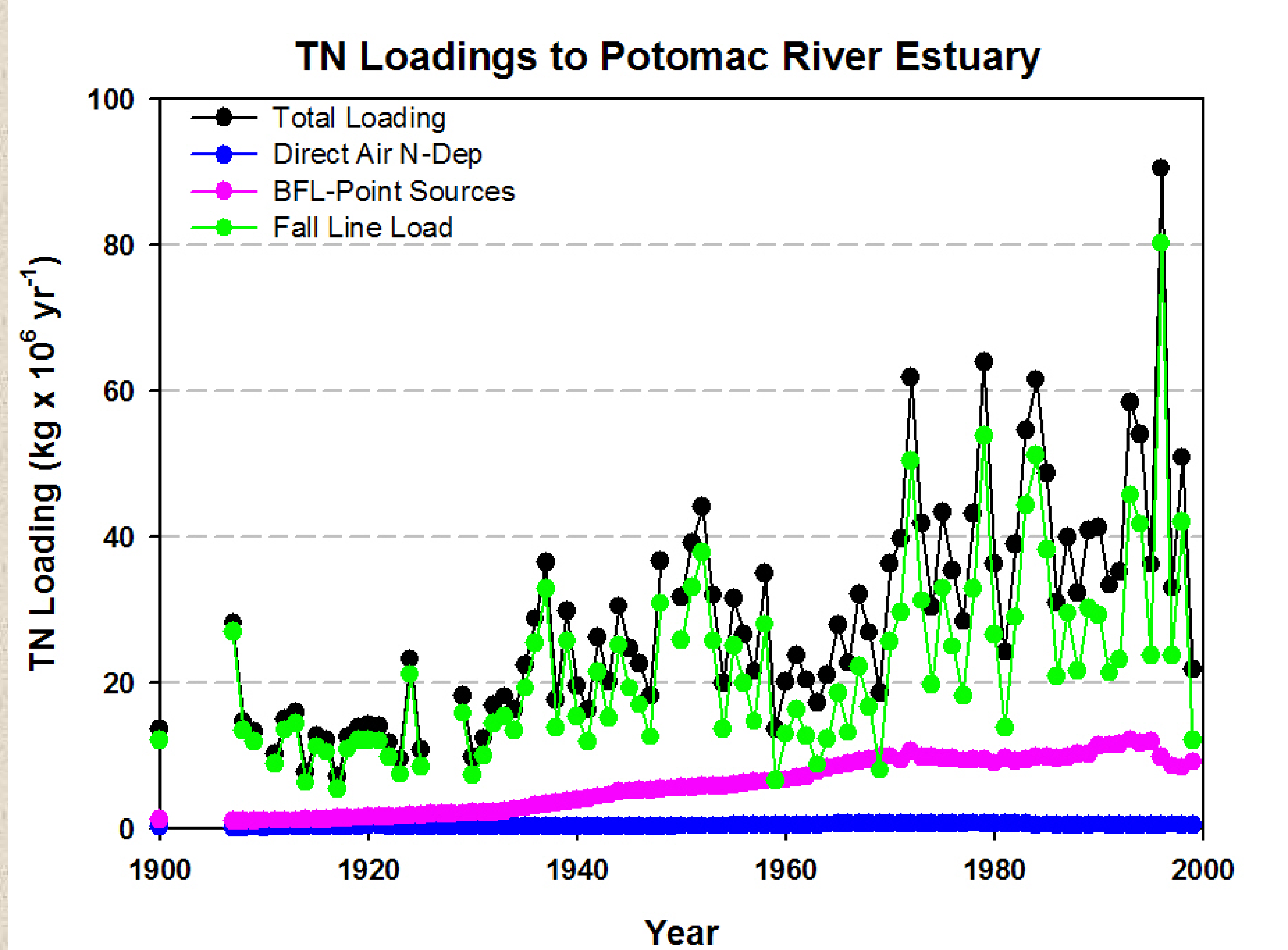
Susquehanna Nitrate Loading

Harrisburg, PA

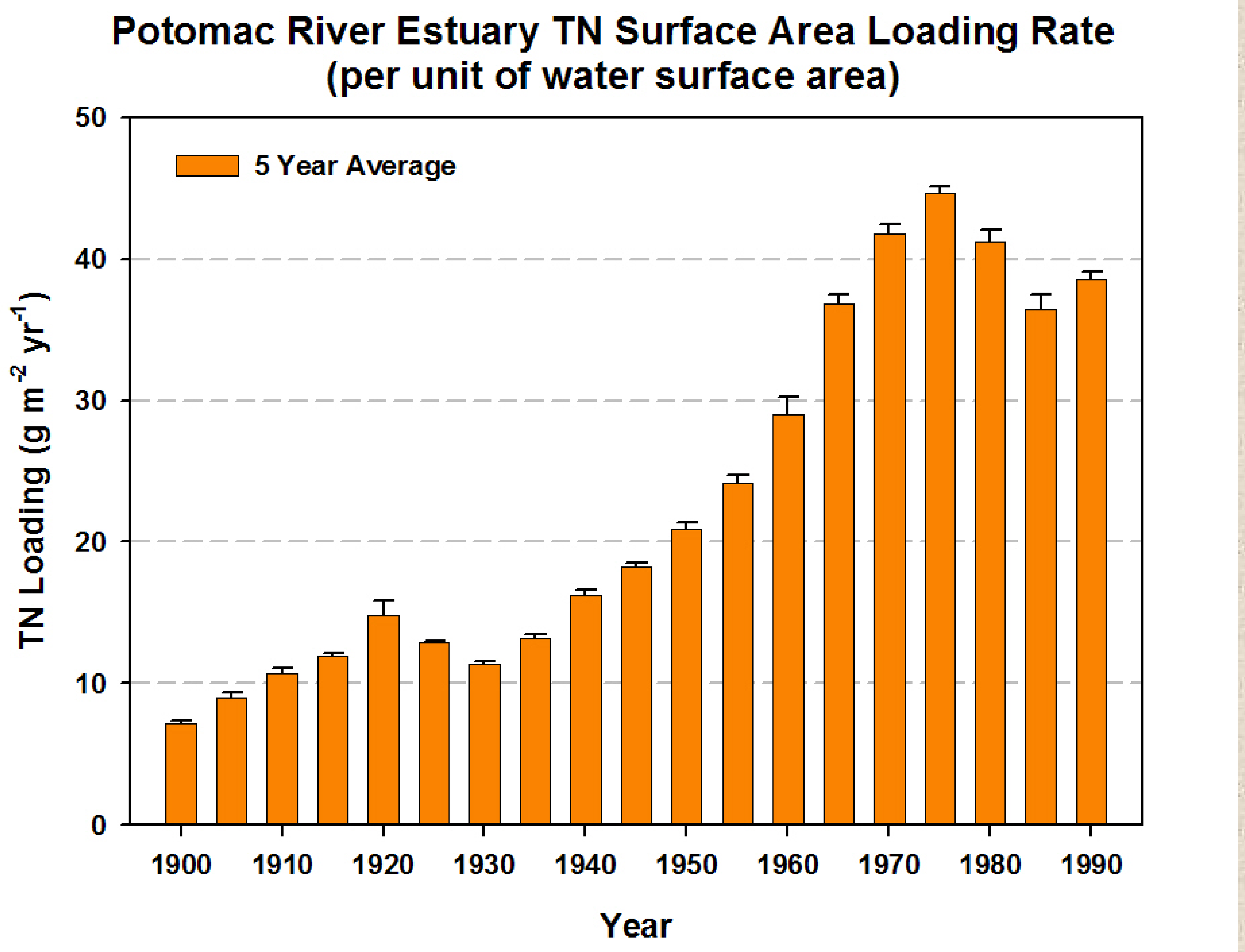


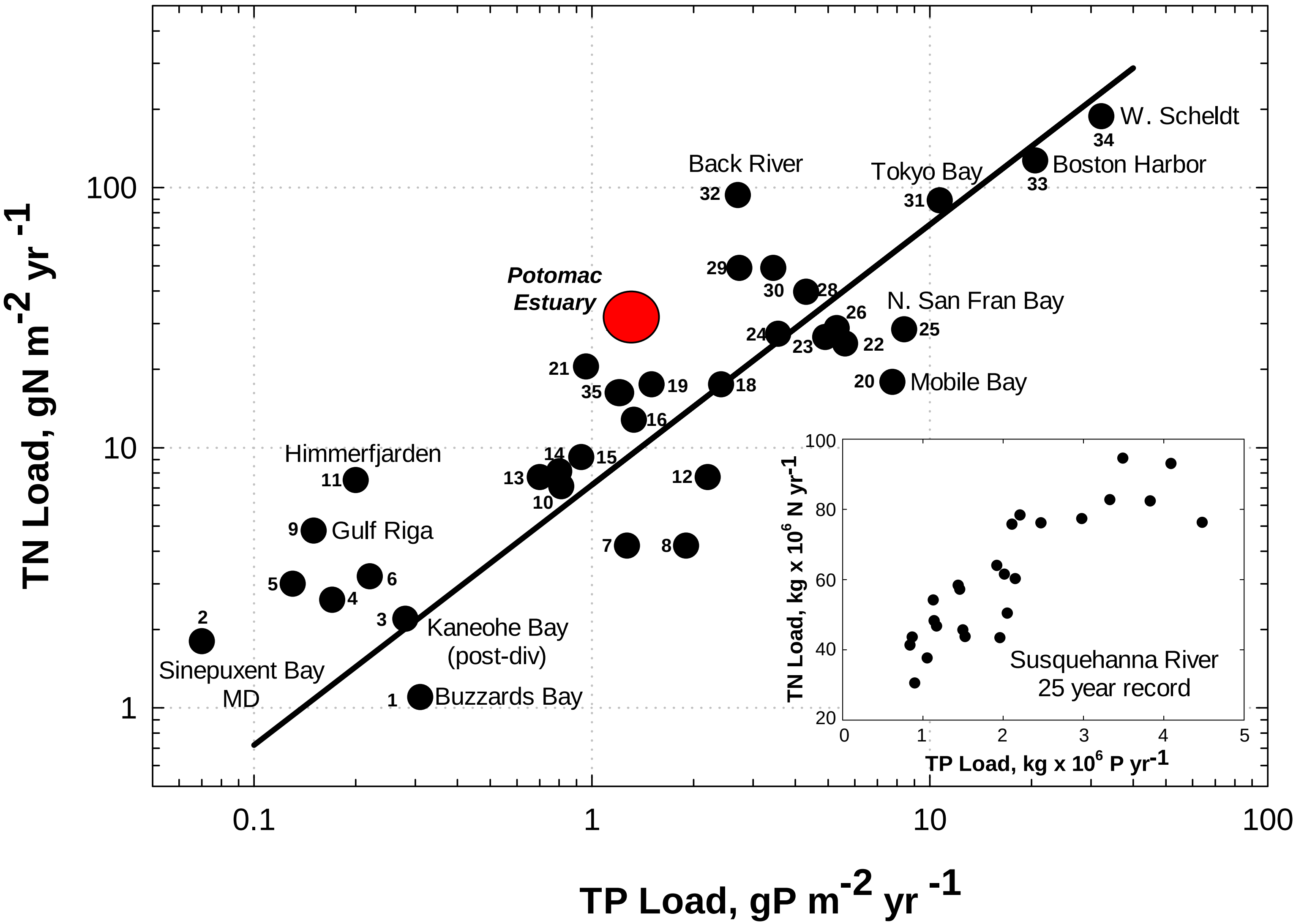
- **N loading from Susquehanna increased substantially in early 1970's.**
- **Subsequently, no major trend.**

From Hagy 2002



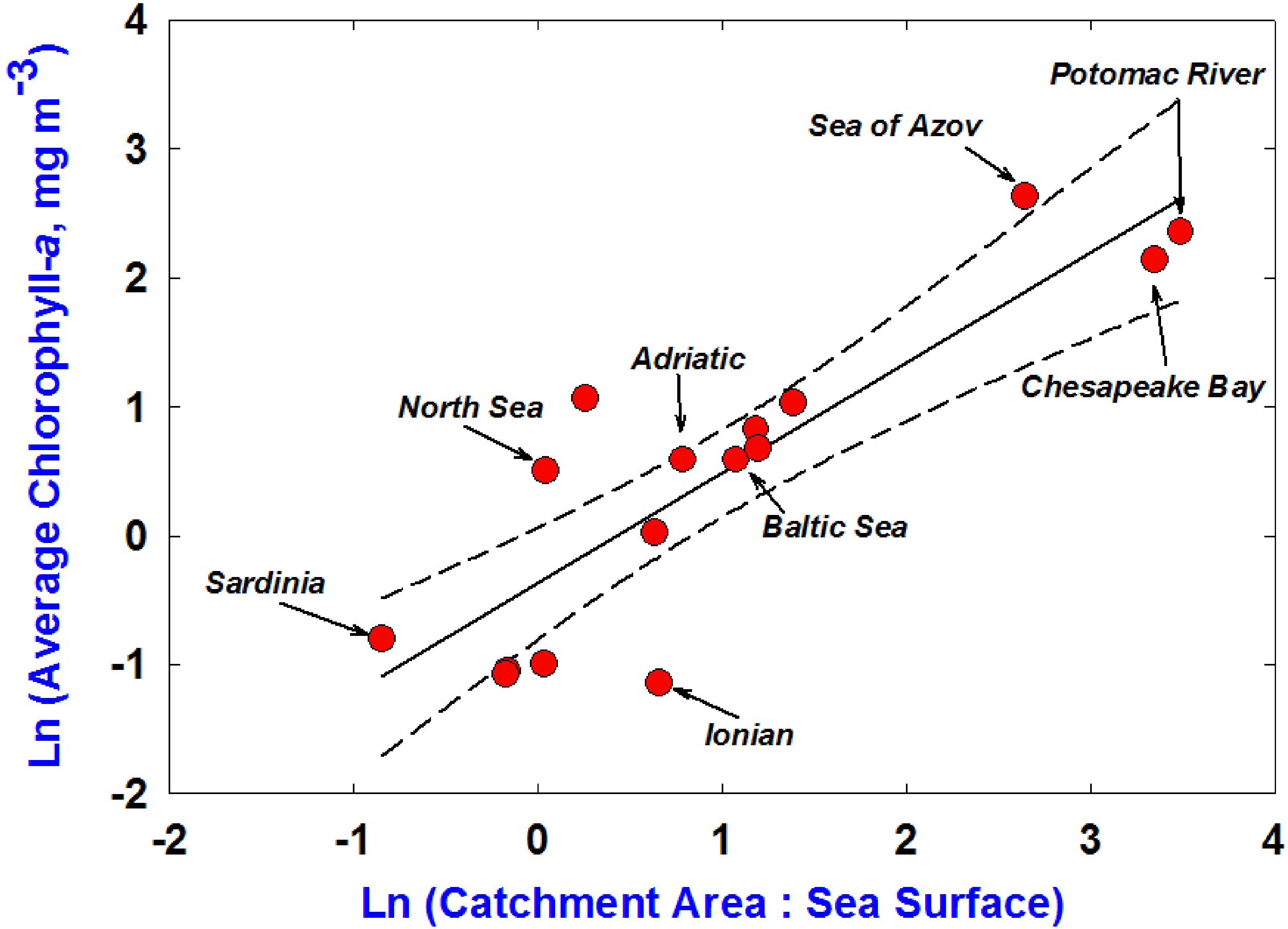
N. Jaworski 2007


Potomac River Estuary TN Surface Area Loading Rate
(per unit of water surface area)
5 Year Average
TN Loading (g m-2 yr-1)
Year
0
10
20
30
40
50
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990

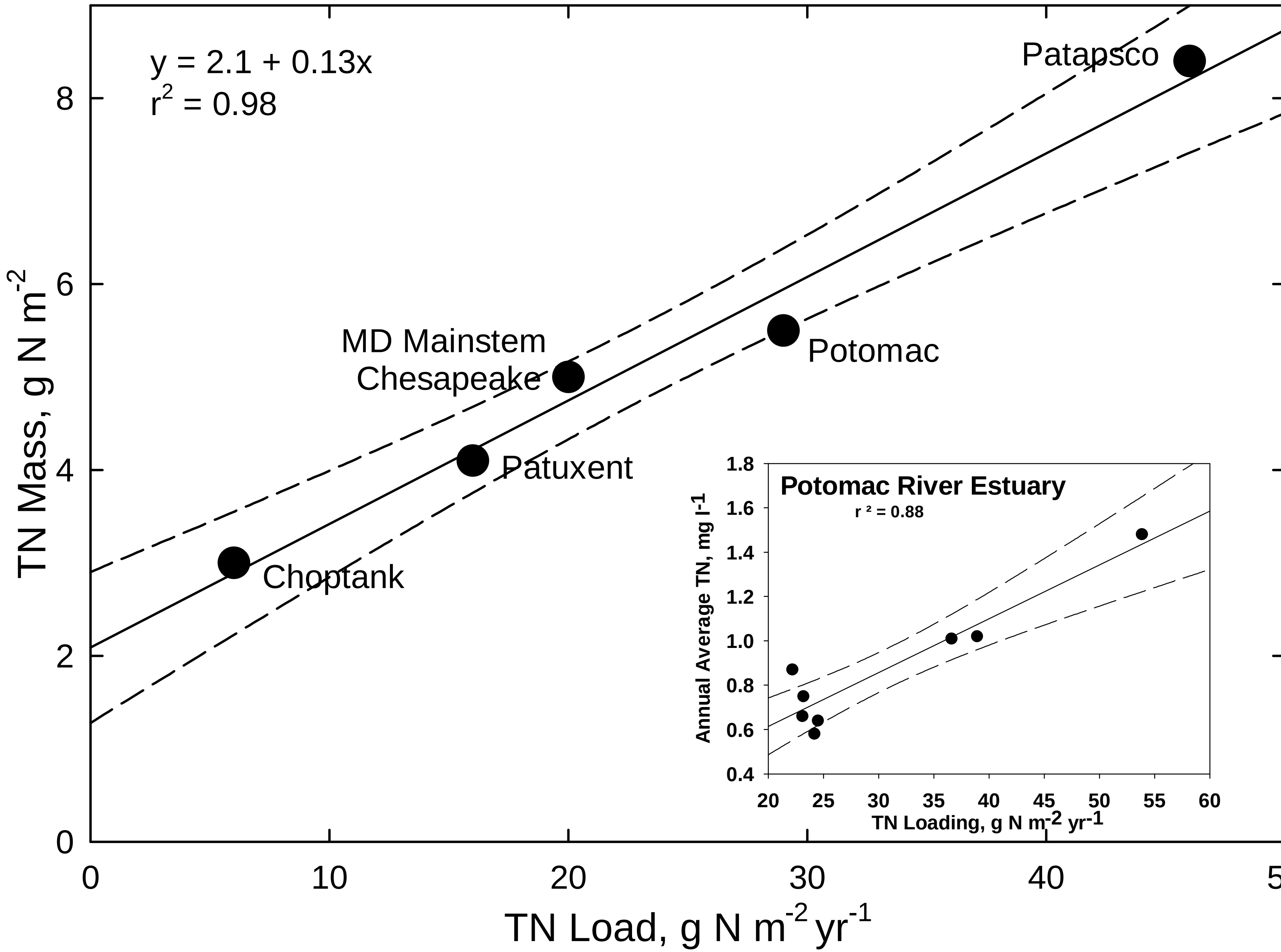


TN Load, gN m-2 yr -1
TP Load, gP m-2 yr -1
0.1
1
10
100
W. Scheldt
Boston Harbor
Tokyo Bay
Back River
Potomac Estuary
N. San Fran Bay
Mobile Bay
Himmerfjarden
Gulf Riga
Kaneohe Bay (post-div)
Sinepuxent Bay MD
Buzzards Bay
TN Load, kg x 10^6 N yr-1
TP Load, kg x 10^6 P yr-1
Susquehanna River 25 year record

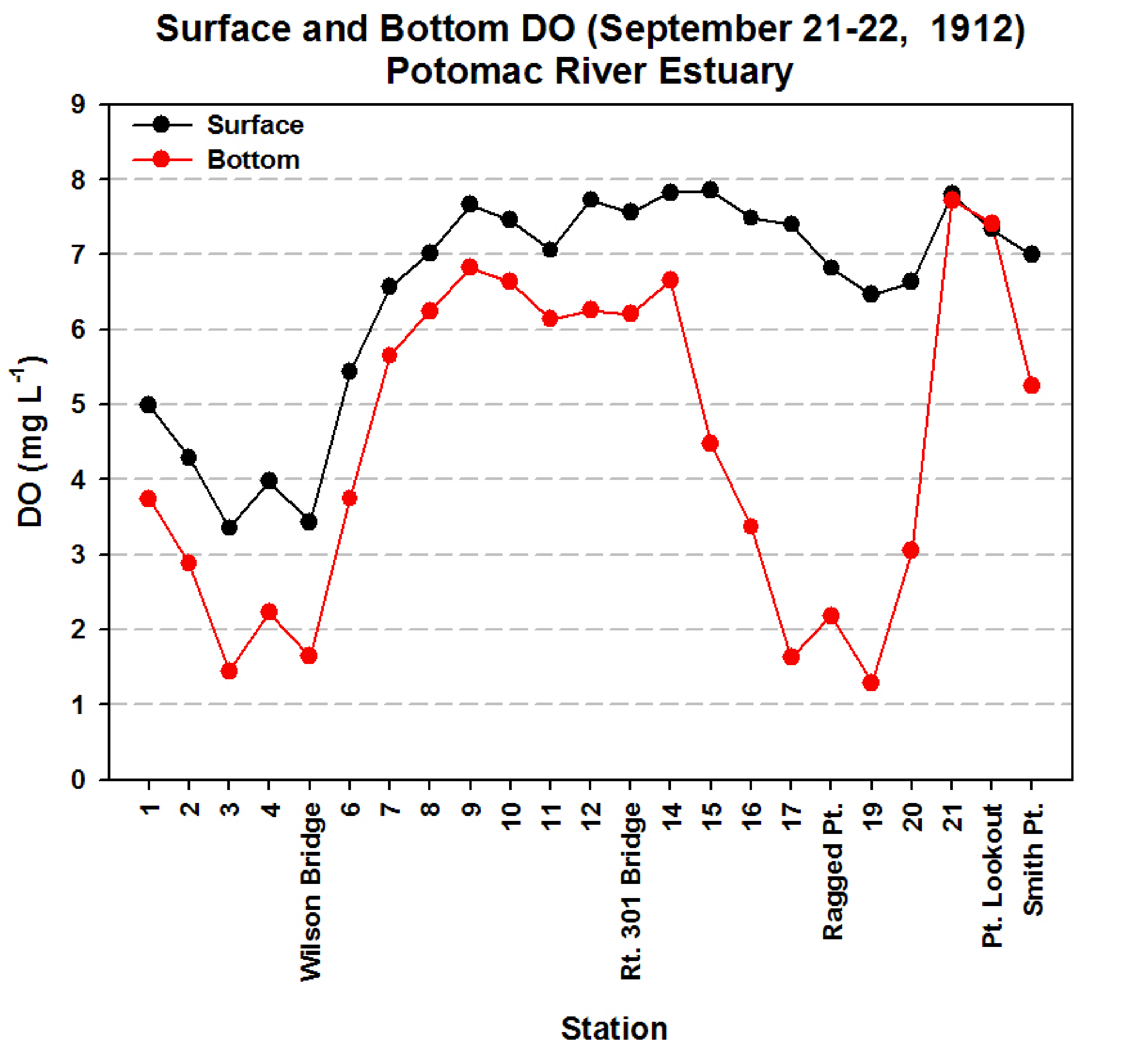
Land Effects vs Algal Biomass

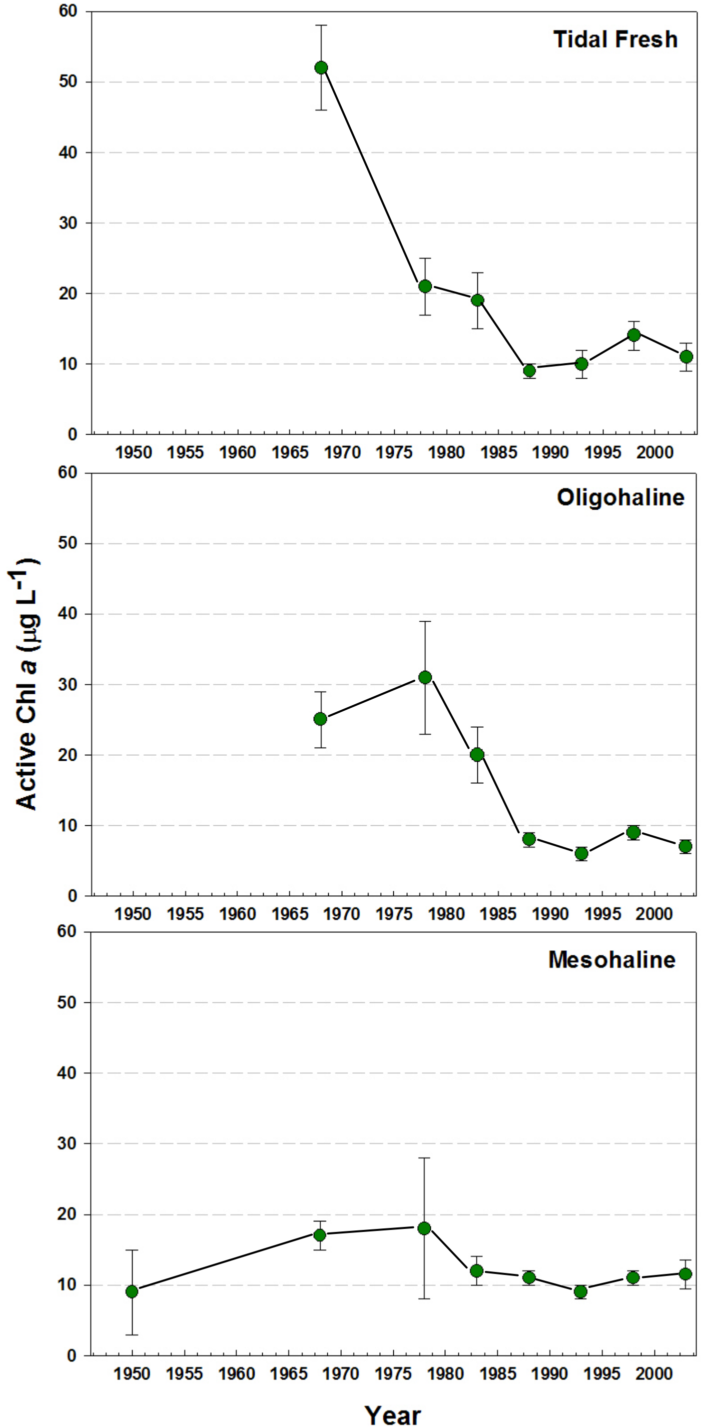


Adapted from Moreno et al. 2000



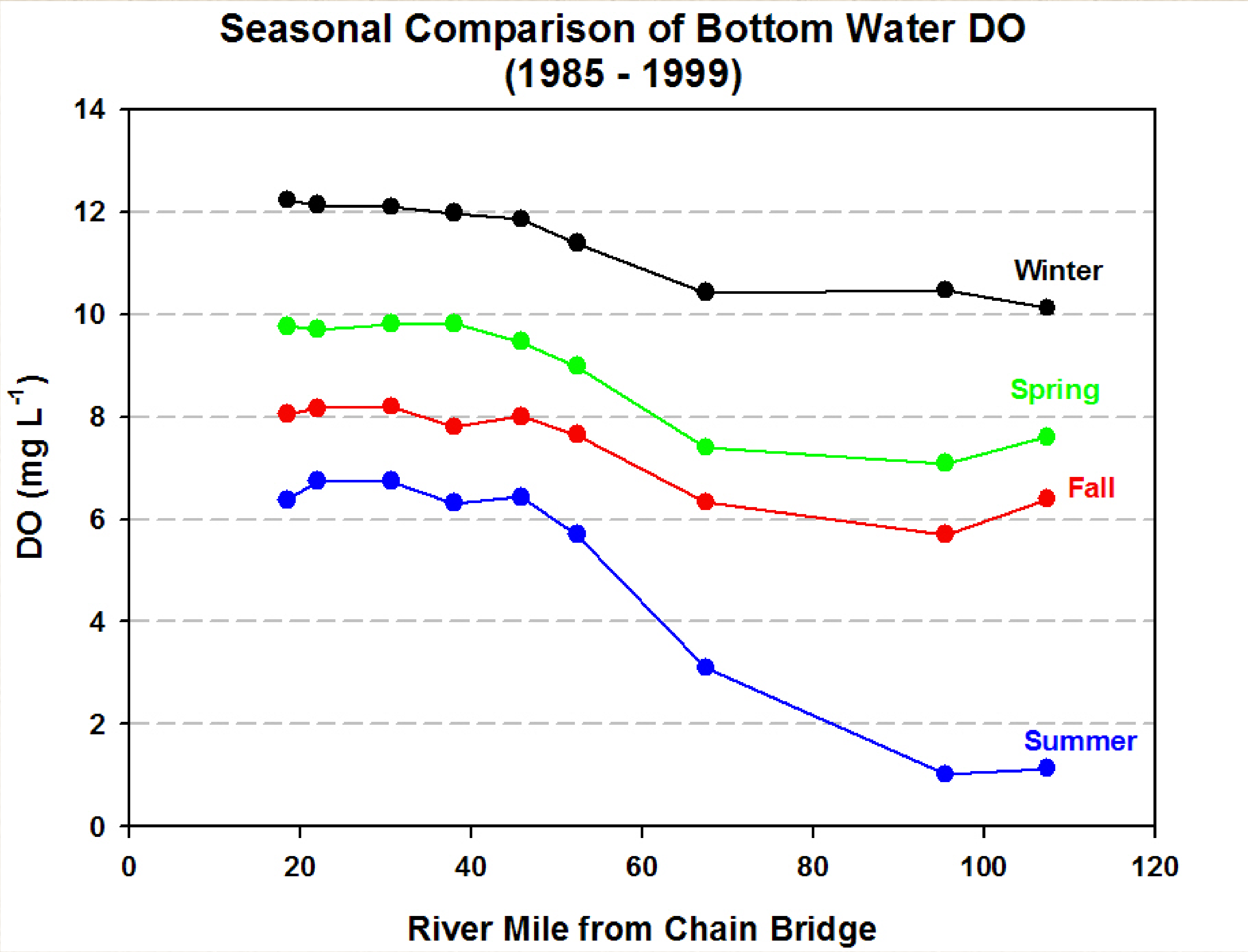
y = 2.1 + 0.13x
r² = 0.98
Patapsco
MD Mainstem
Chesapeake
Potomac
Patuxent
Choptank
TN Mass, g N m-2
TN Load, g N m-2 yr-1
0
2
4
6
8
0
10
20
30
40
50
Potomac River Estuary
r ² = 0.88
Annual Average TN, mg l-1
TN Loading, g N m-2 yr-1
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
20
25
30
35
40
45
50
55
60

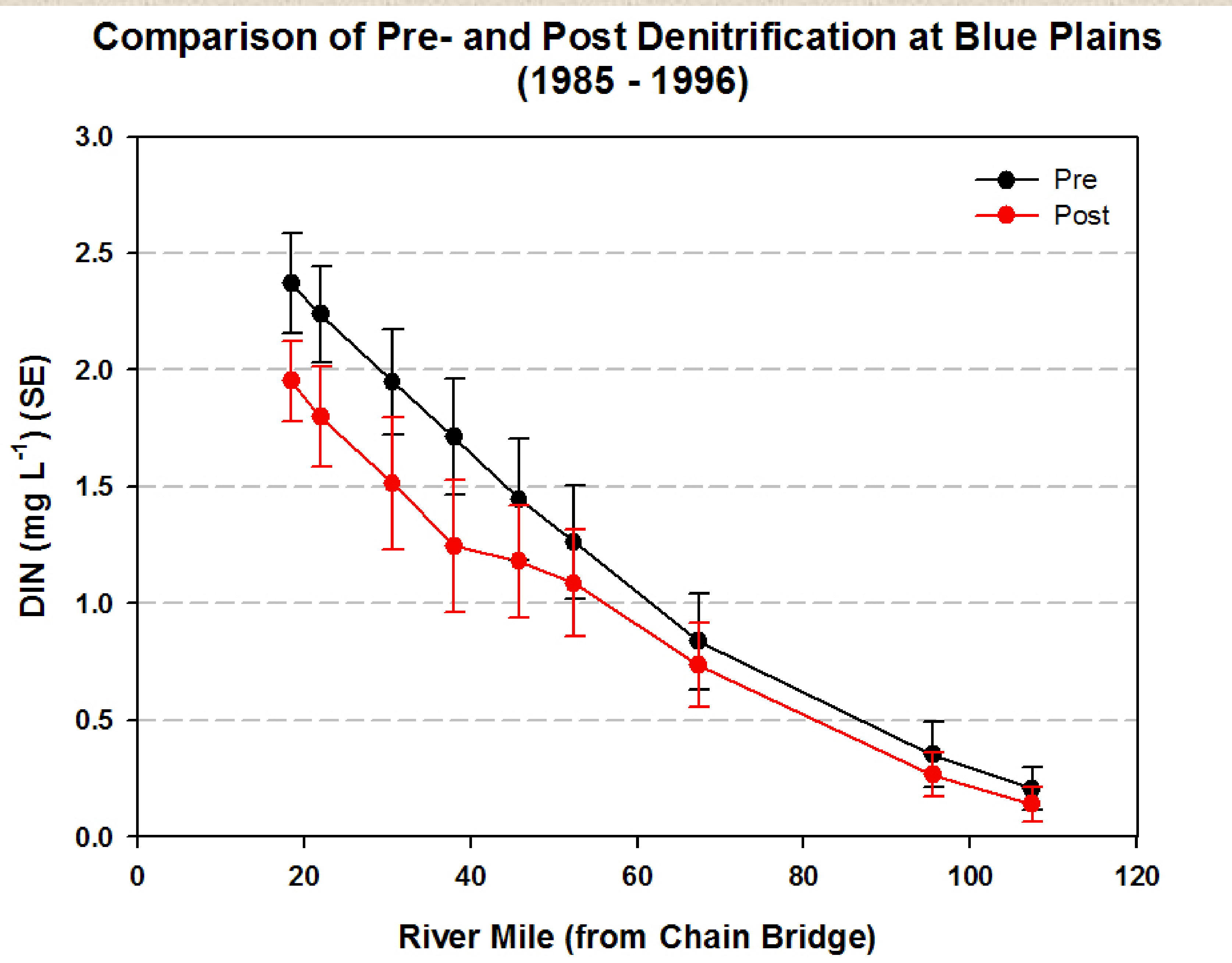

Surface and Bottom DO (September 21-22, 1912)
Potomac River Estuary
Surface
Bottom
DO (mg L-1)
Station
0
1
2
3
4
5
6
7
8
9
1
2
3
4
Wilson Bridge
6
7
8
9
10
11
12
Rt. 301 Bridge
14
15
16
17
Ragged Pt.
19
20
21
Pt. Lookout
Smith Pt.



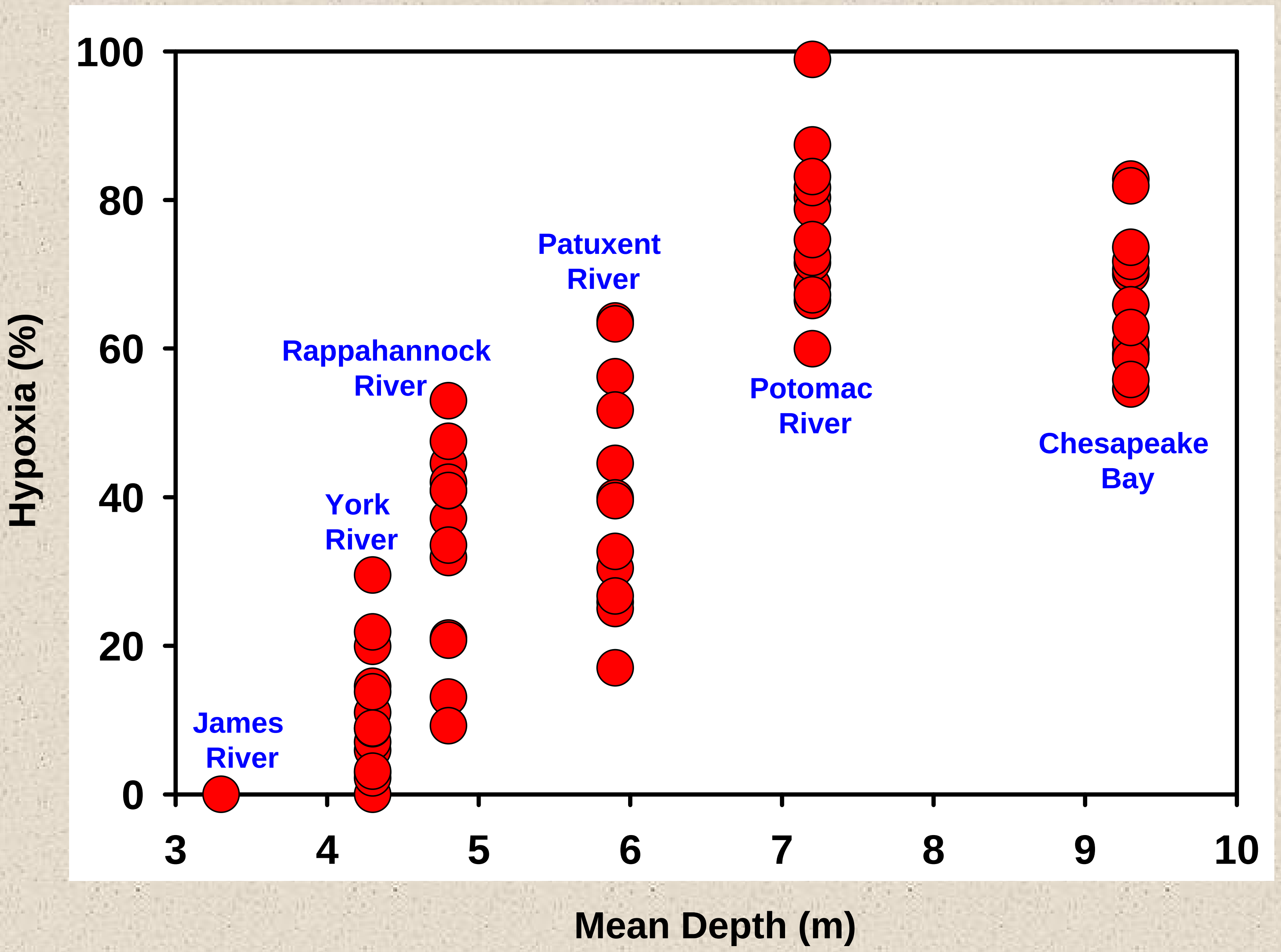
Potomac River Estuary Chlorophyll-a Trends 1950 - 2003

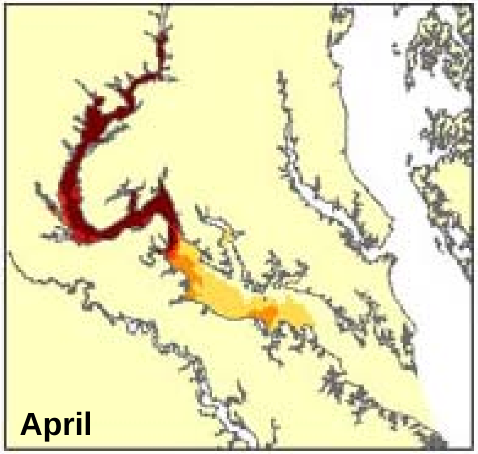
- Some very large declines in chlorophyll-a
- Most notable in the upper estuary
- Some indications of time-lags along the axis of the estuary

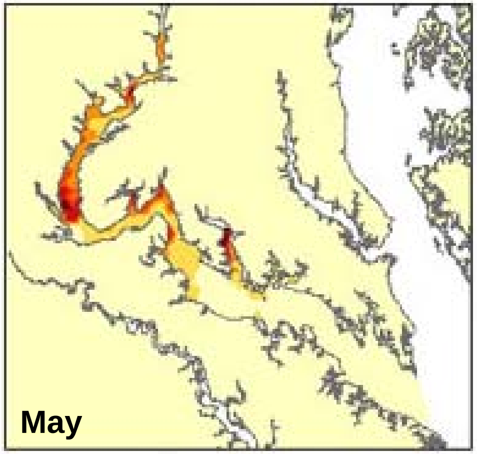

Seasonal Comparison of Bottom Water DO
(1985 - 1999)
DO (mg L-1)
River Mile from Chain Bridge
Winter
Spring
Fall
Summer
0
2
4
6
8
10
12
14
0
20
40
60
80
100
120

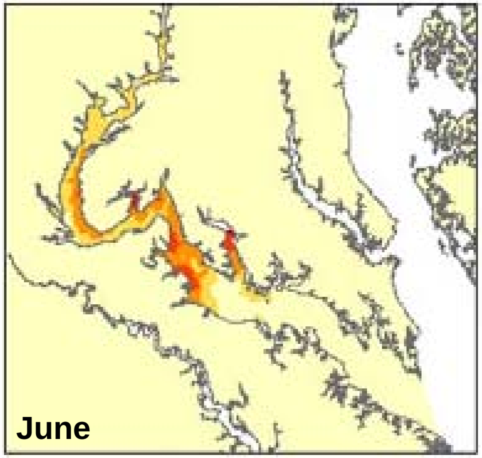

Comparison of Pre- and Post Denitrification at Blue Plains
(1985 - 1996)
Pre
Post
DIN (mg L-1) (SE)
River Mile (from Chain Bridge)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120

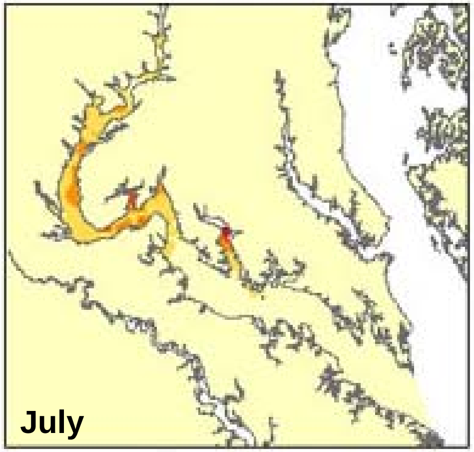
Hypoxia vs. Mean Depth in Chesapeake Bay and Tributaries 1986-1998

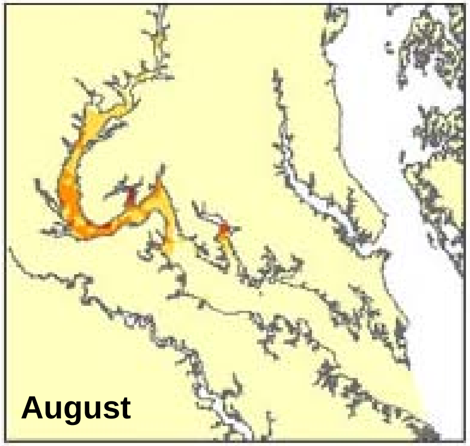


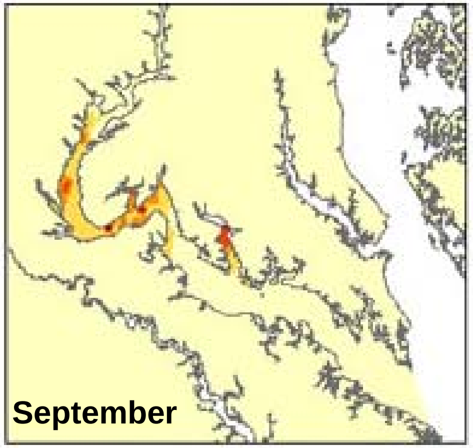


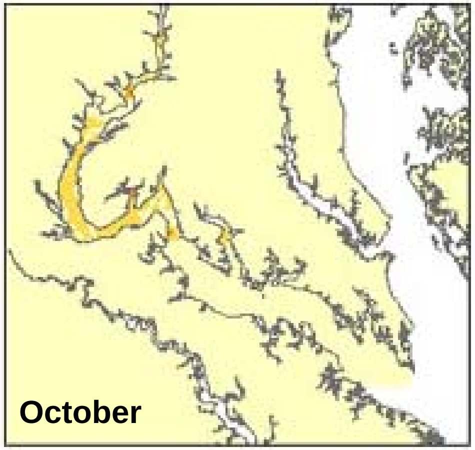






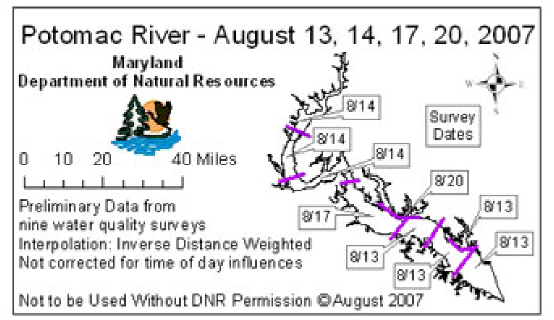




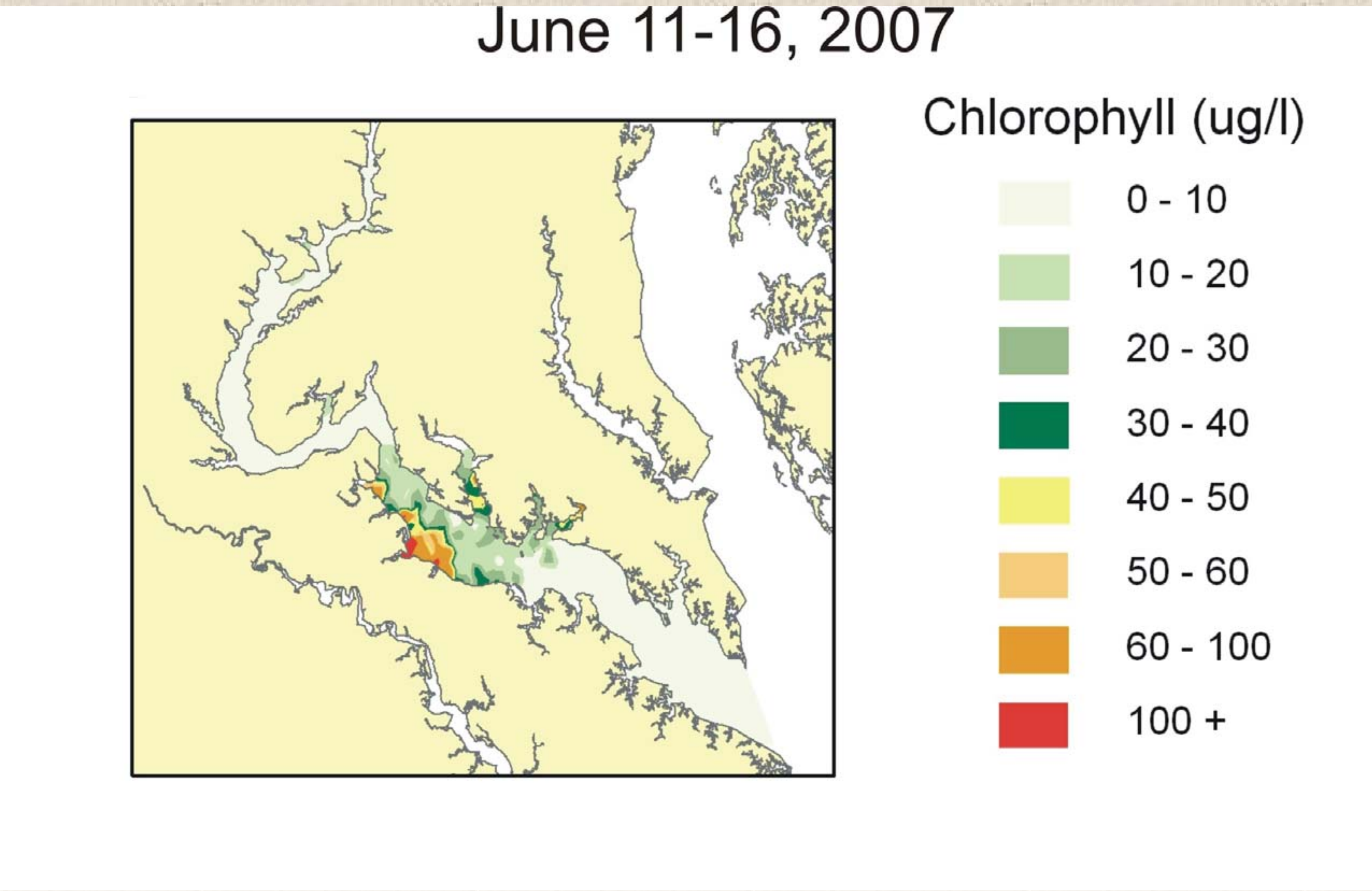


Potomac River
Surface Water Turbidity
2007

Turbidity (NTU)
0 - 7.5
7.5 - 15
15 - 22.5
22.5 - 30
30 - 37.5
37.5 - 52.4

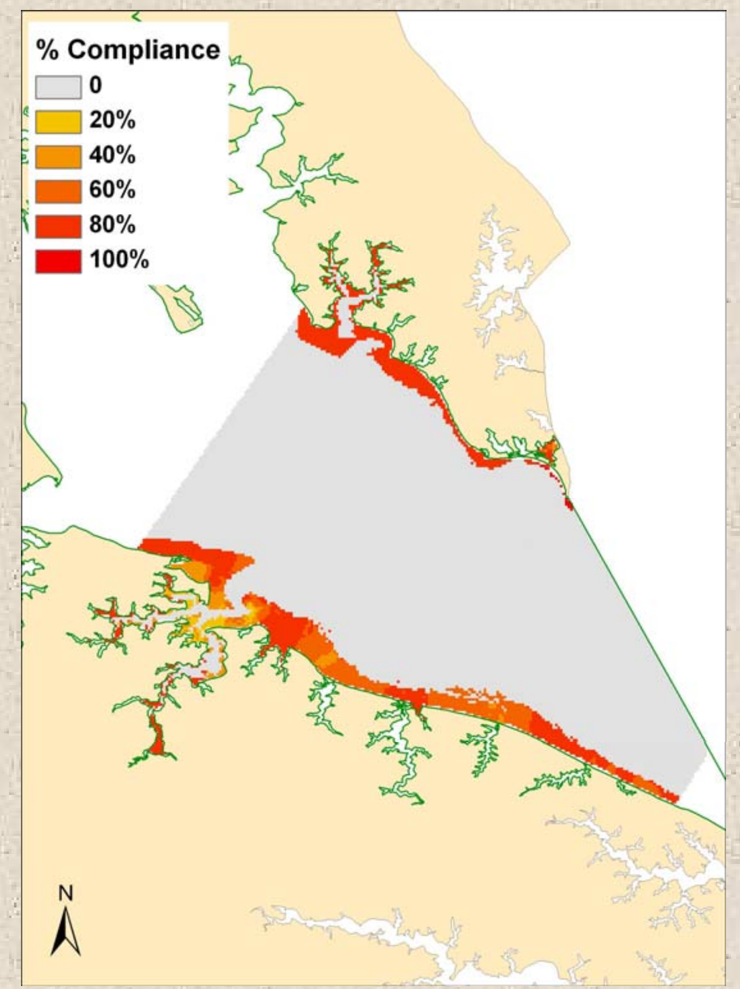


Identification of "HOT-SPOTS" with intensive spatial sampling

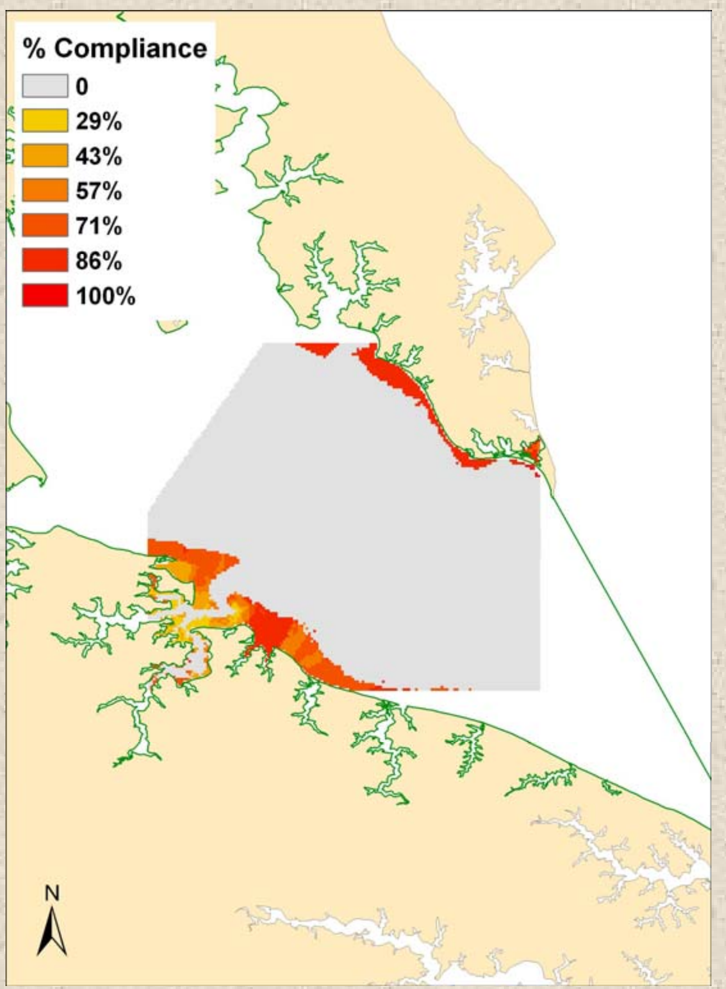


2006 Spatially Intensive Shallow Water Quality Monitoring of the Potomac River

SAV Habitat Hotspots - Mesohaline



% of DATAFLOW Cruises (n=5) where pixel meets all habitat criteria
(Sept. & Oct. excluded)

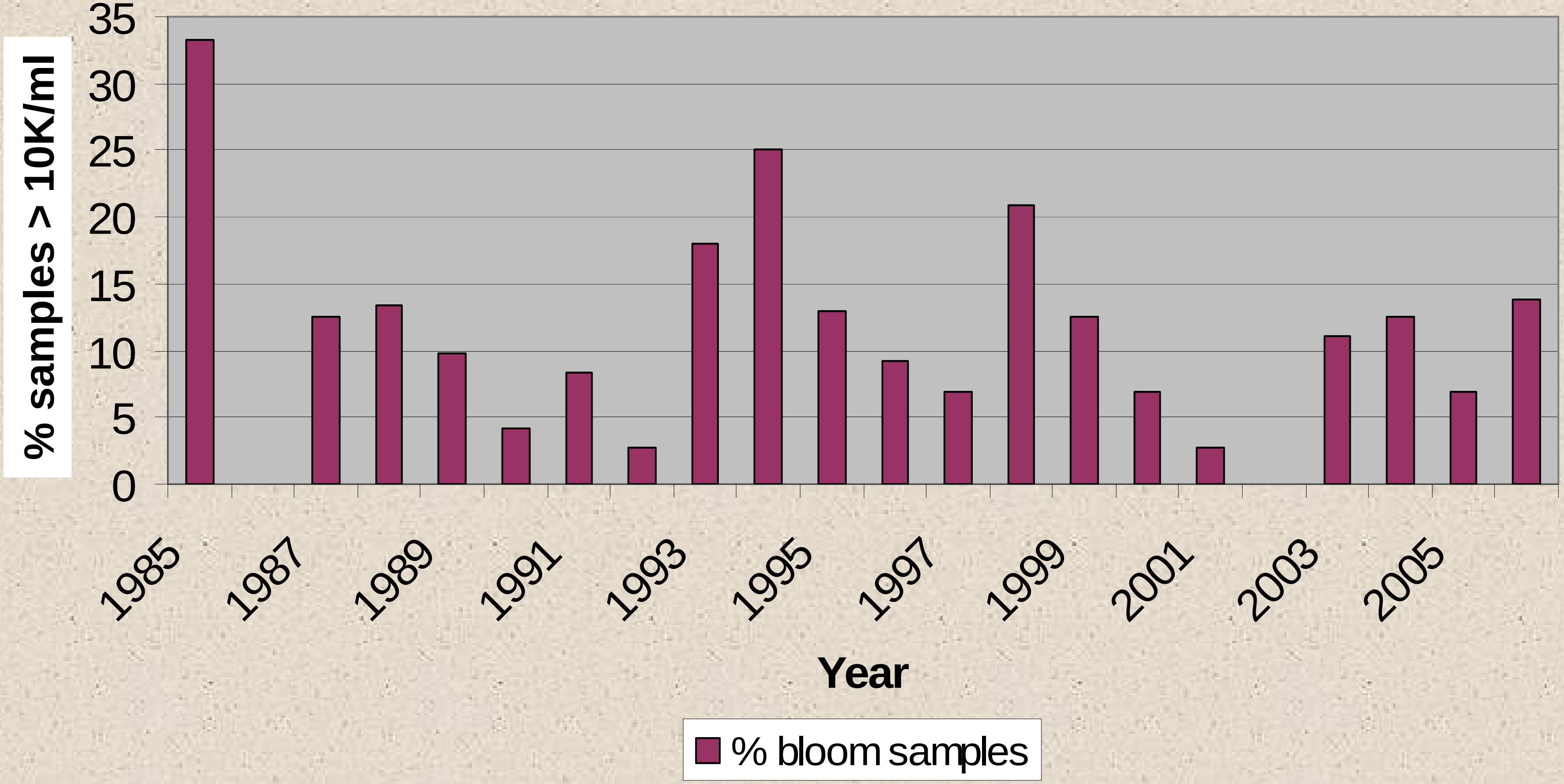


% of DATAFLOW Cruises (n=7) where pixel meets all habitat criteria

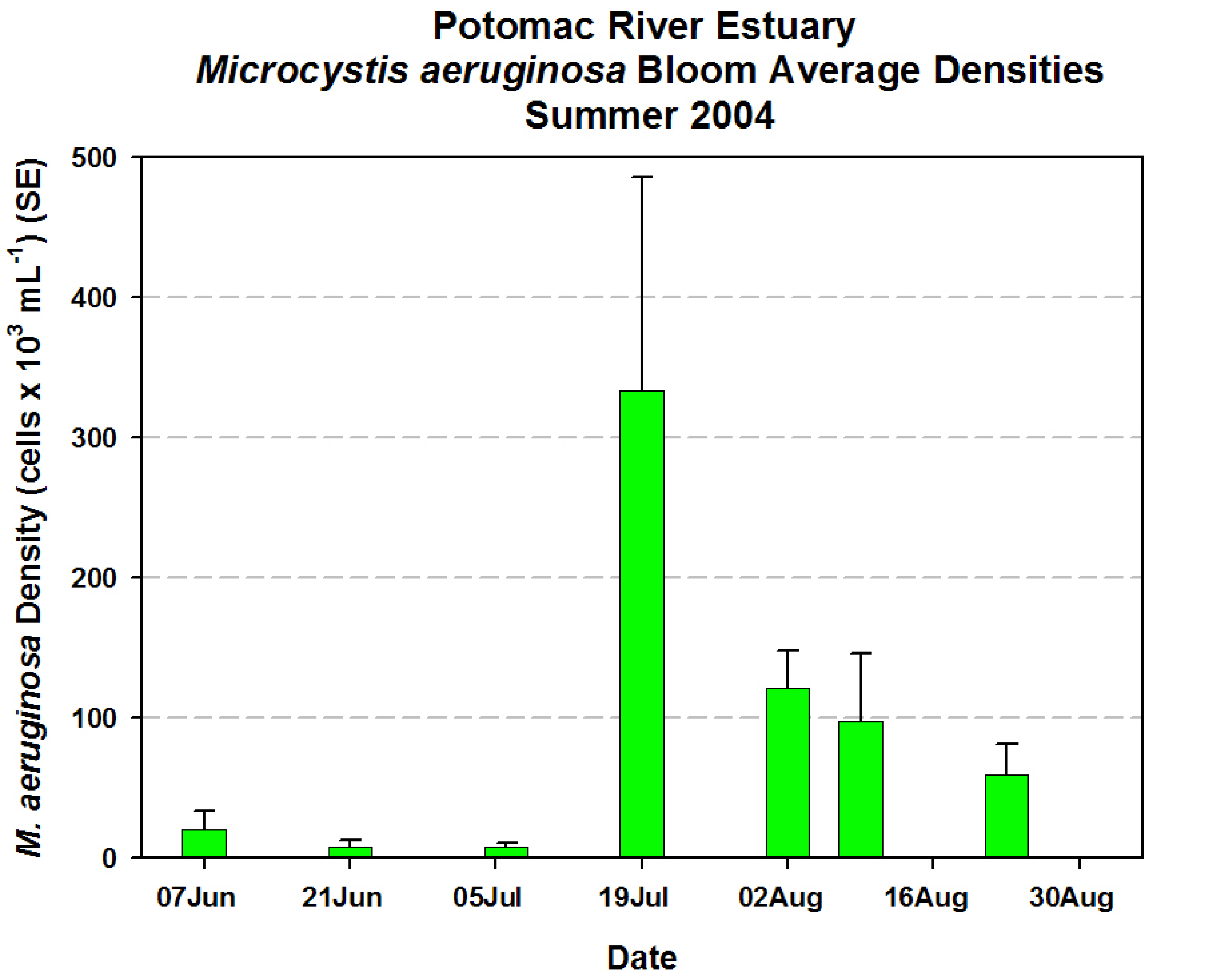
Microcystis Bloom 2004

(P. Tango, MDDNR)

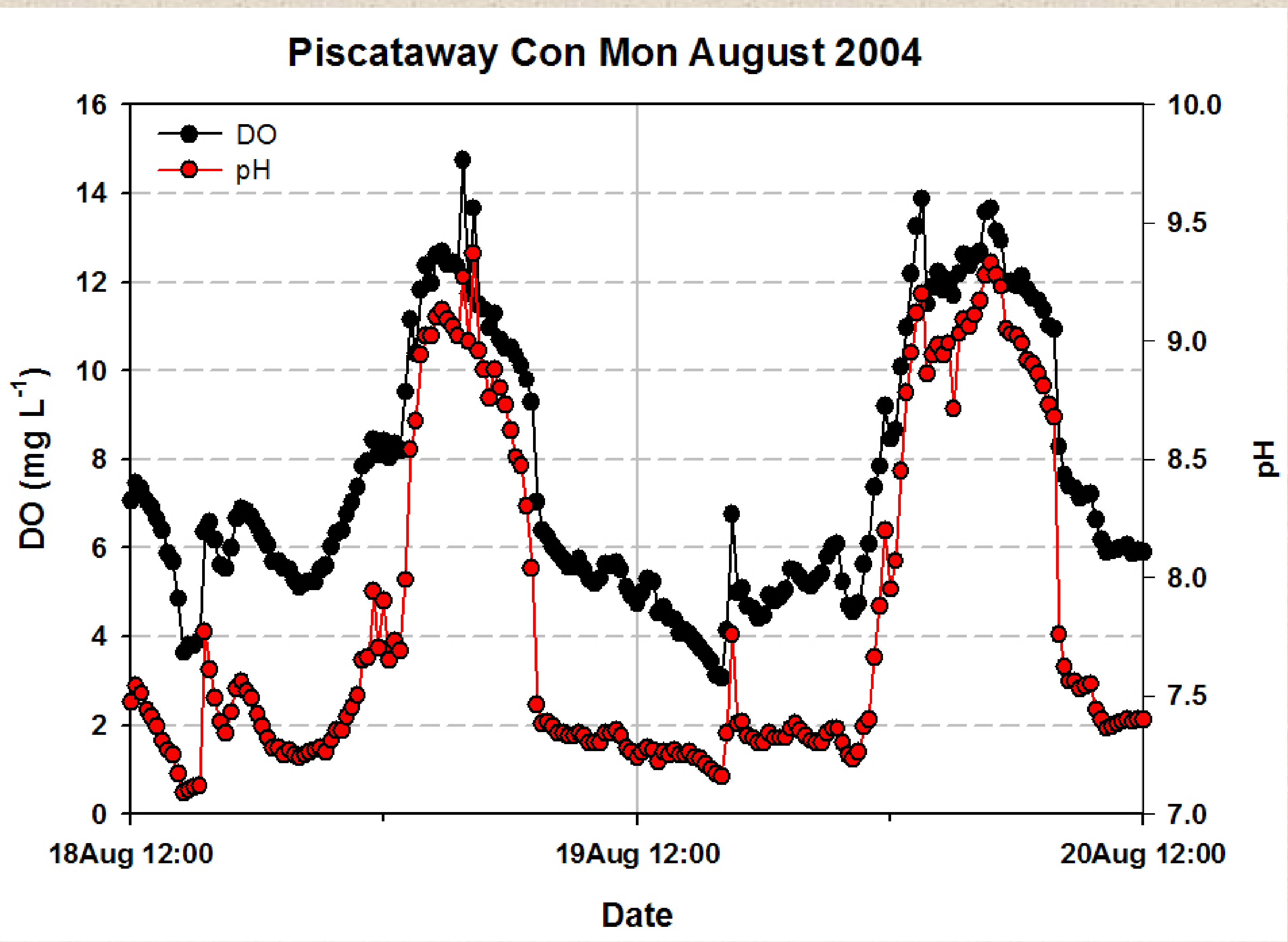
Summer (June-September) % bloom samples (>10,000 cells/milliliter *Microcystis*) for 9 Potomac River stations, 1985-2006.



P. Tango, pers comm.

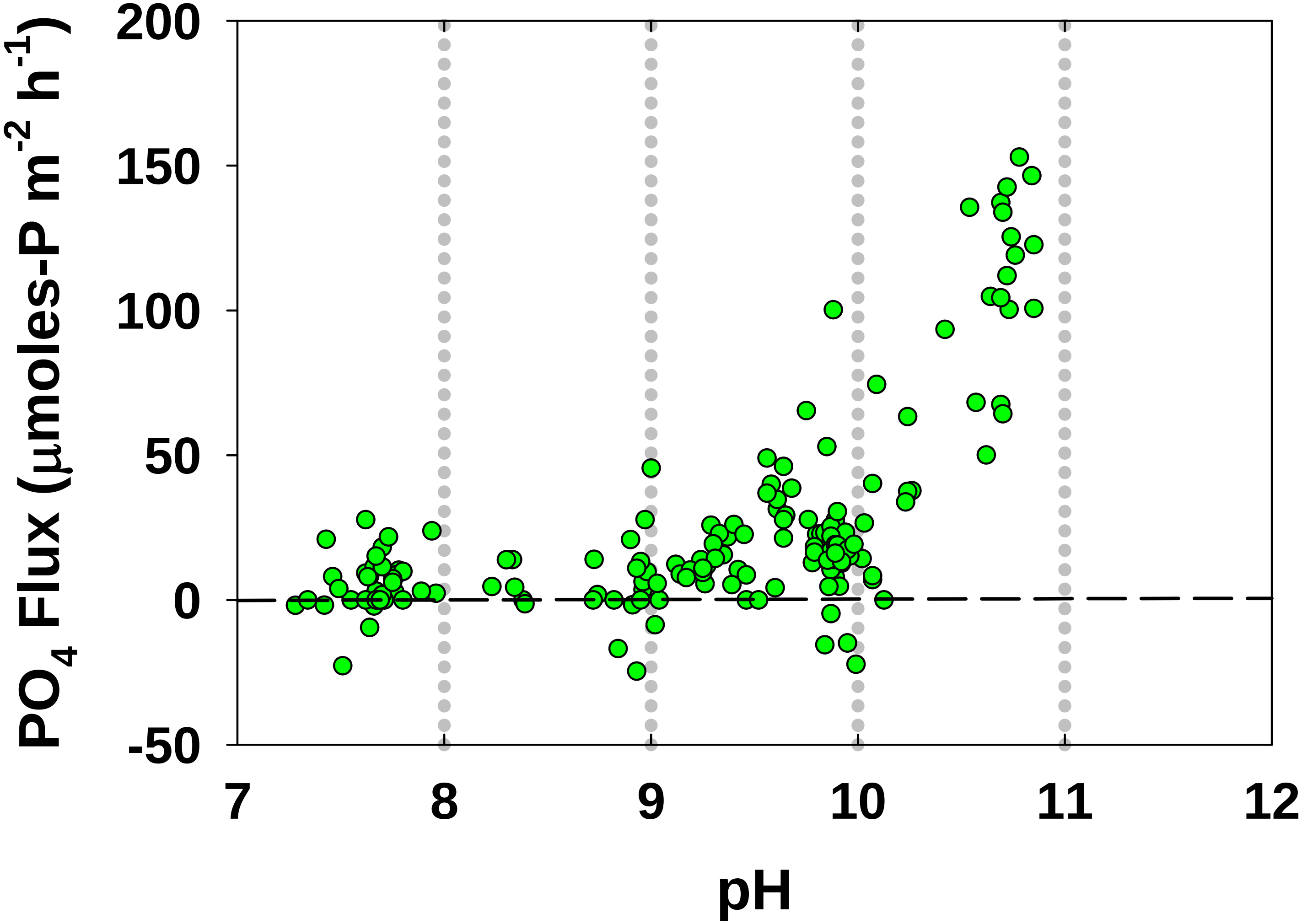

Potomac River Estuary
Microcystis aeruginosa Bloom Average Densities
Summer 2004
M. aeruginosa Density (cells x 10^3 mL^-1) (SE)
500
400
300
200
100
0
07Jun
21Jun
05Jul
19Jul
02Aug
16Aug
30Aug
Date

Bloom Year

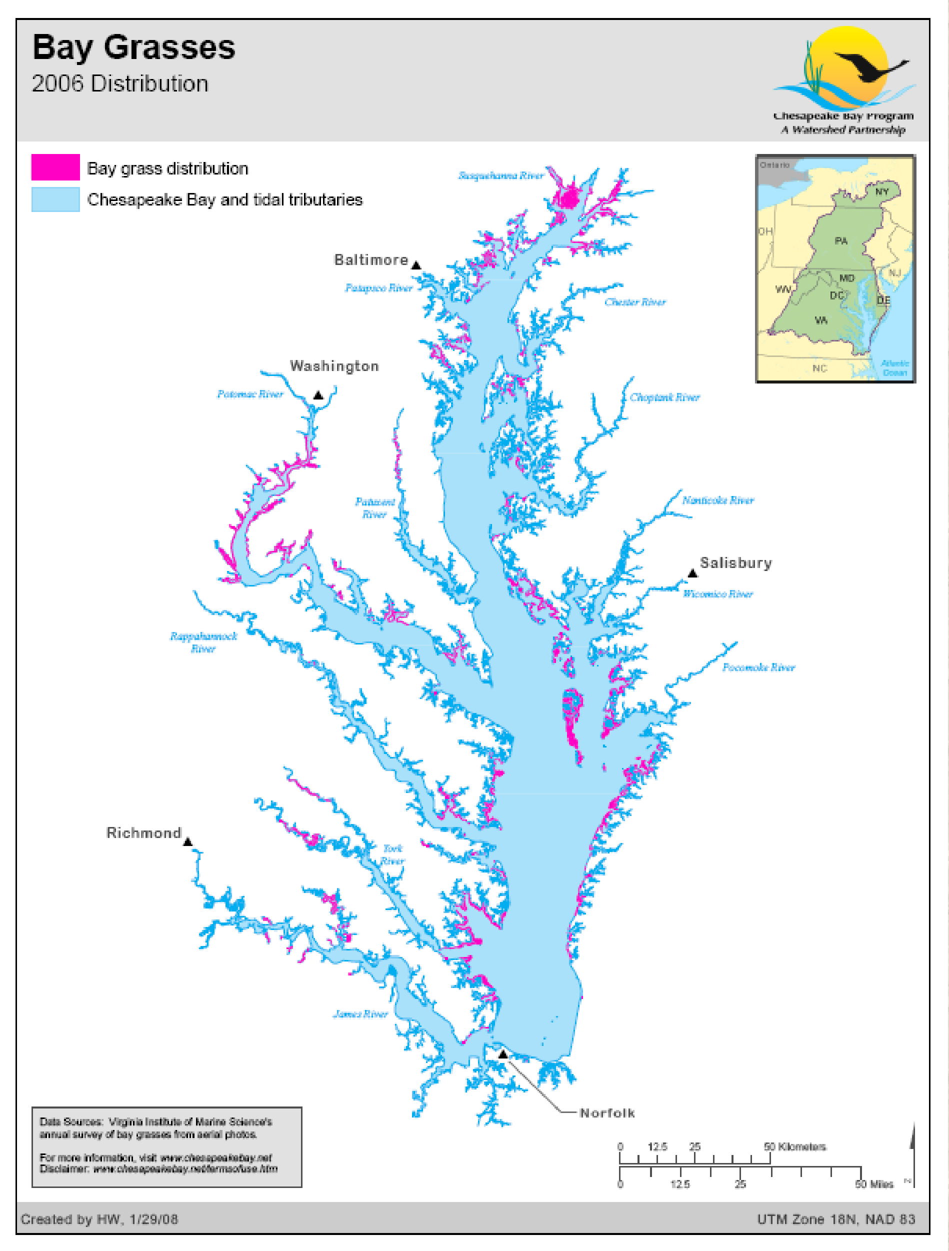


Piscataway Con Mon August 2004
DO
pH
DO (mg L-1)
pH
16
14
12
10
8
6
4
2
0
10.0
9.5
9.0
8.5
8.0
7.5
7.0
18Aug 12:00
19Aug 12:00
20Aug 12:00
Date

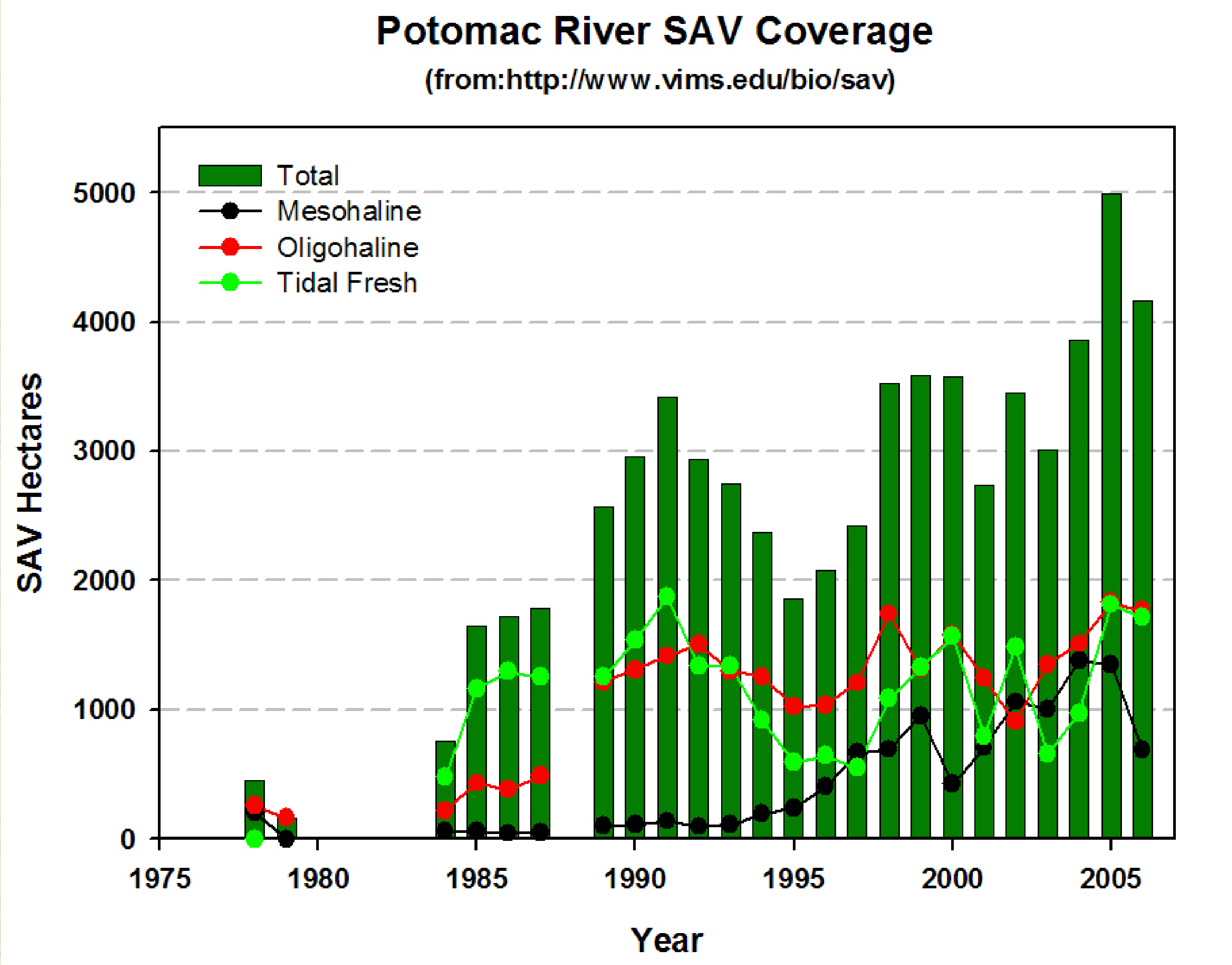
Potomac Sediment PO_4 Flux



From Bailey et al. 2006

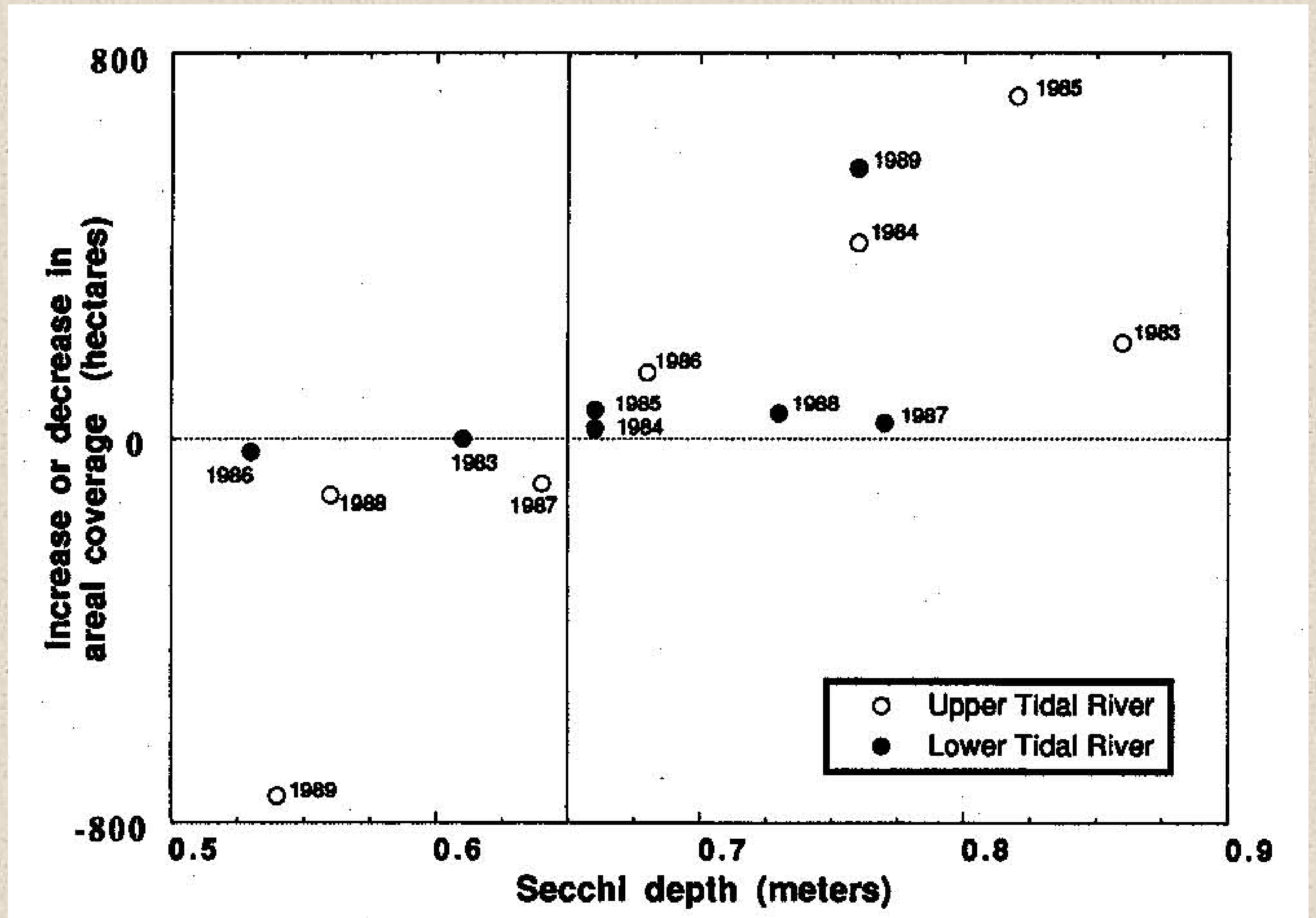


Potomac Estuary SAVs



Potomac River SAV Coverage
(from:http://www.vims.edu/bio/sav)
Total
Mesohaline
Oligohaline
Tidal Fresh
SAV Hectares
0
1000
2000
3000
4000
5000
1975
1980
1985
1990
1995
2000
2005
Year

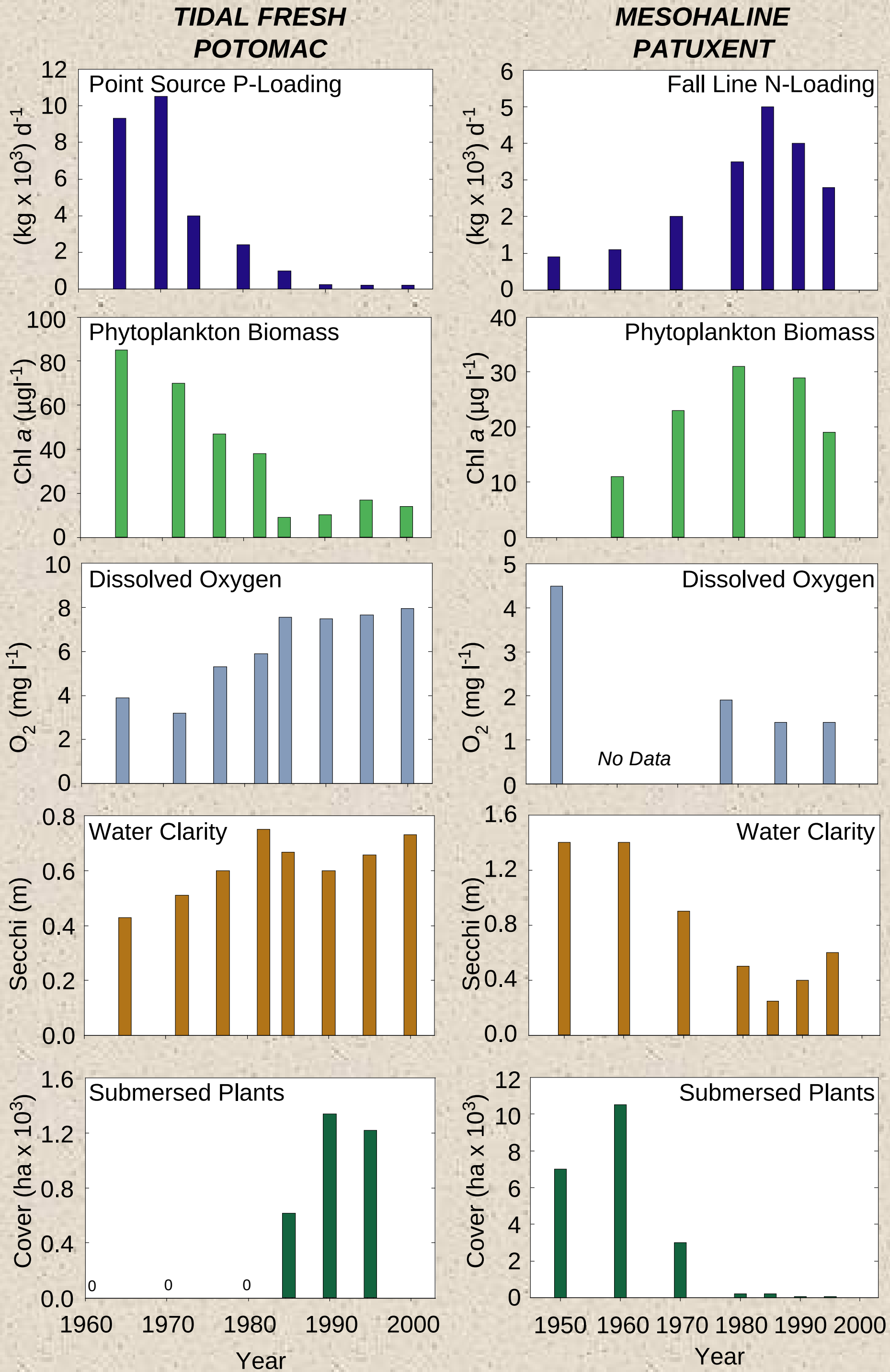
SAV Coverage and Secchi Depth
Tidal Potomac River Estuary
(1983 – 1989)



From Carter et al. 1994

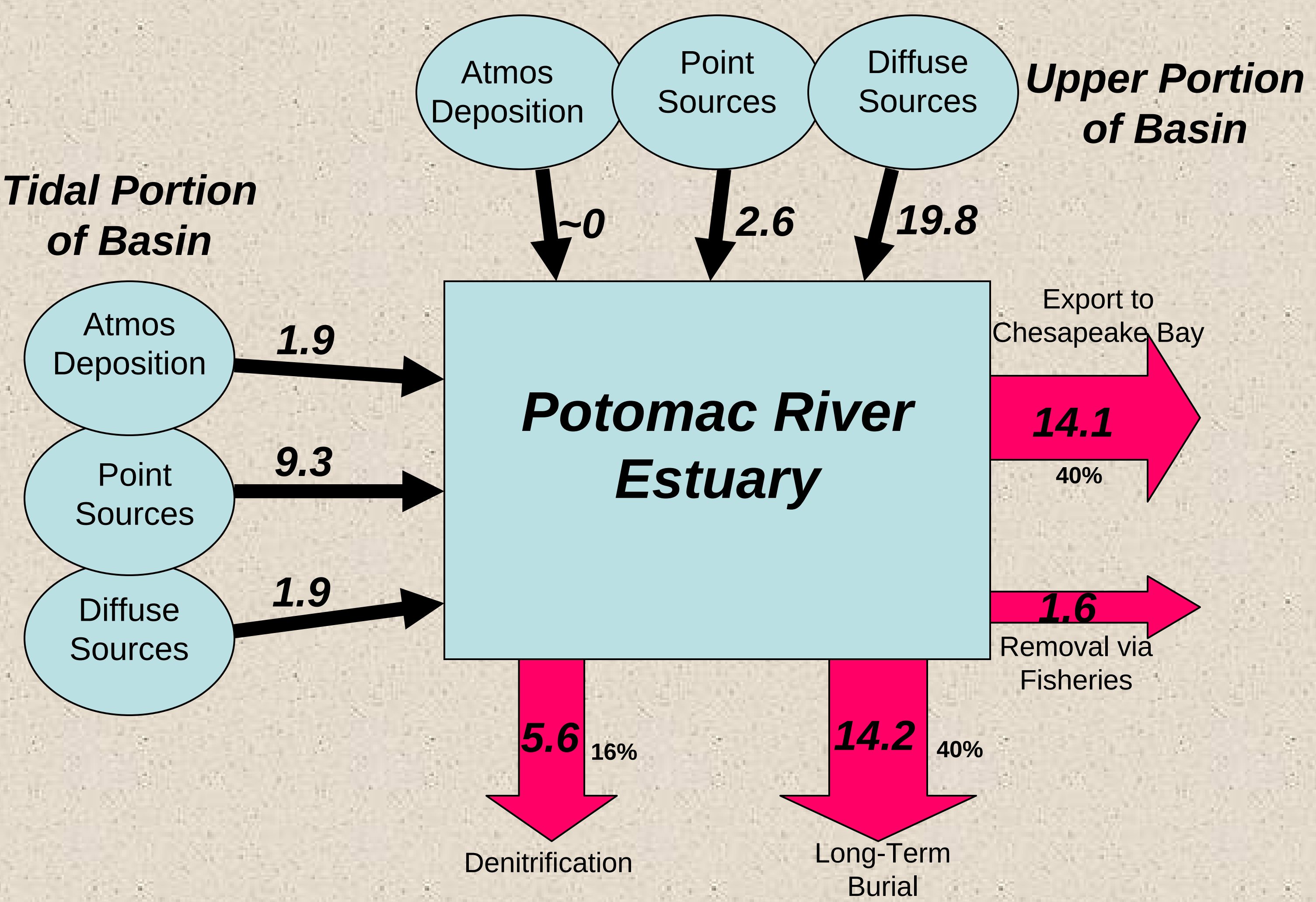
A Tale of Two Estuaries

- Potomac and Patuxent SAV responses differ
- Salinity zone important
- Issue of duel nutrient controls



Potomac River Estuary Nitrogen Budget

(1985-1986)

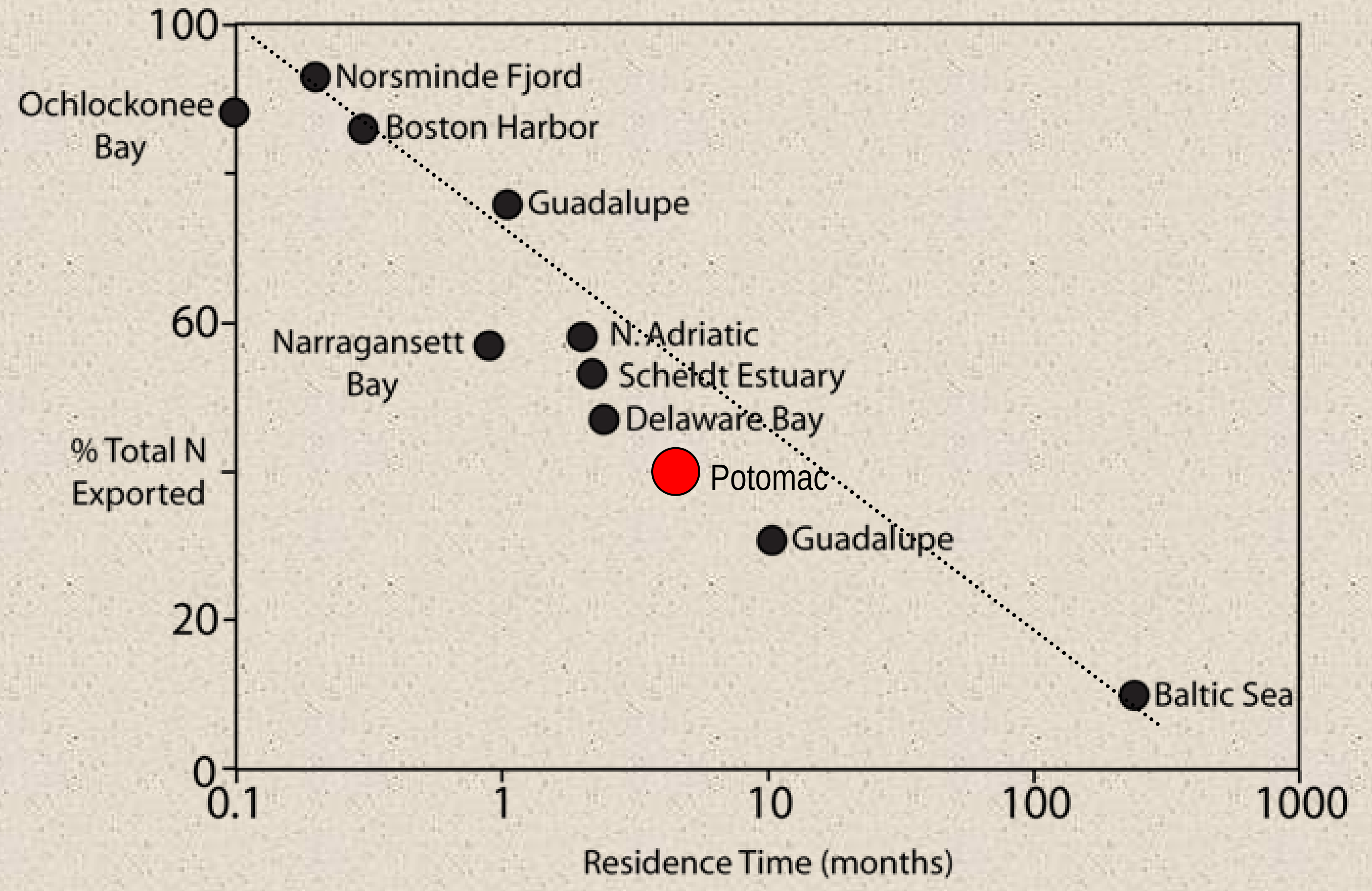


Boynton et al 1995

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

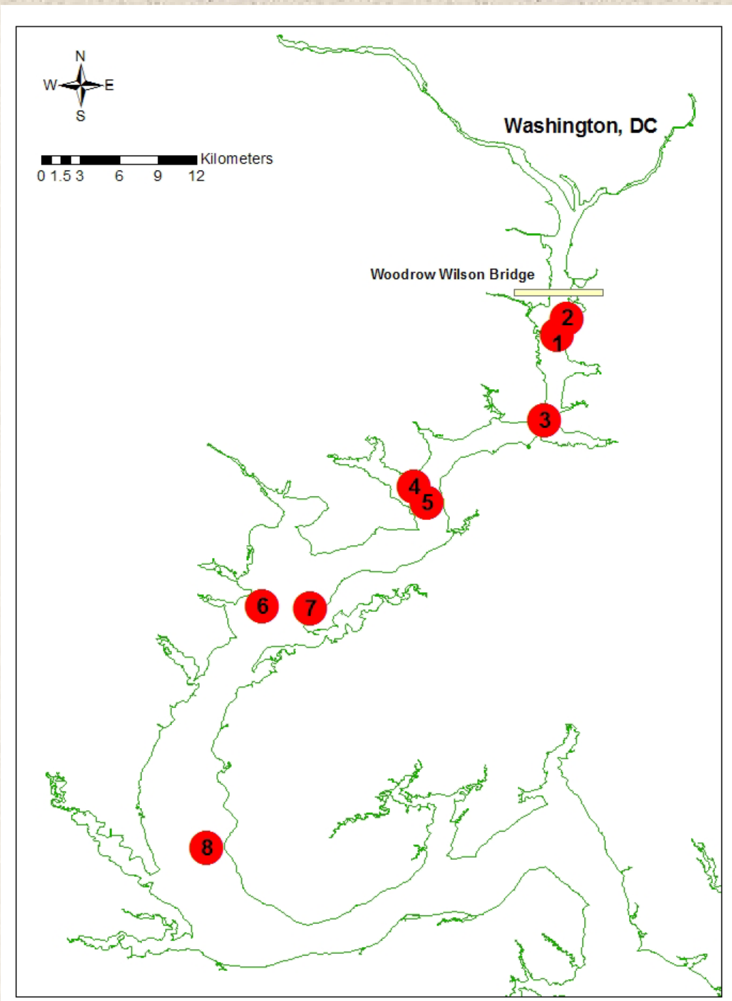
Estuarine Nitrogen Export

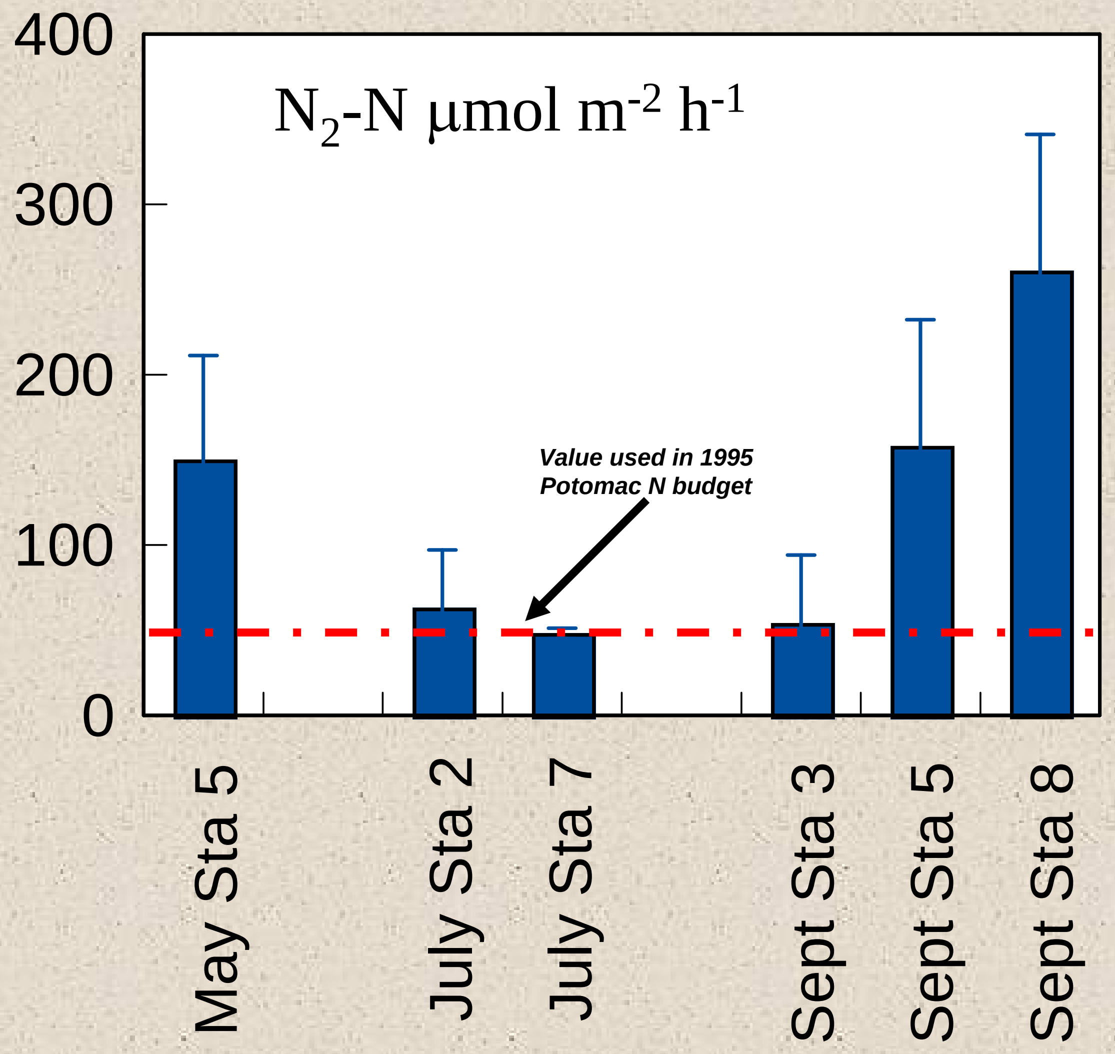
The percent of TN input that is exported is inversely related to water residence time



From Nixon et al., 1996

Denitrification Results



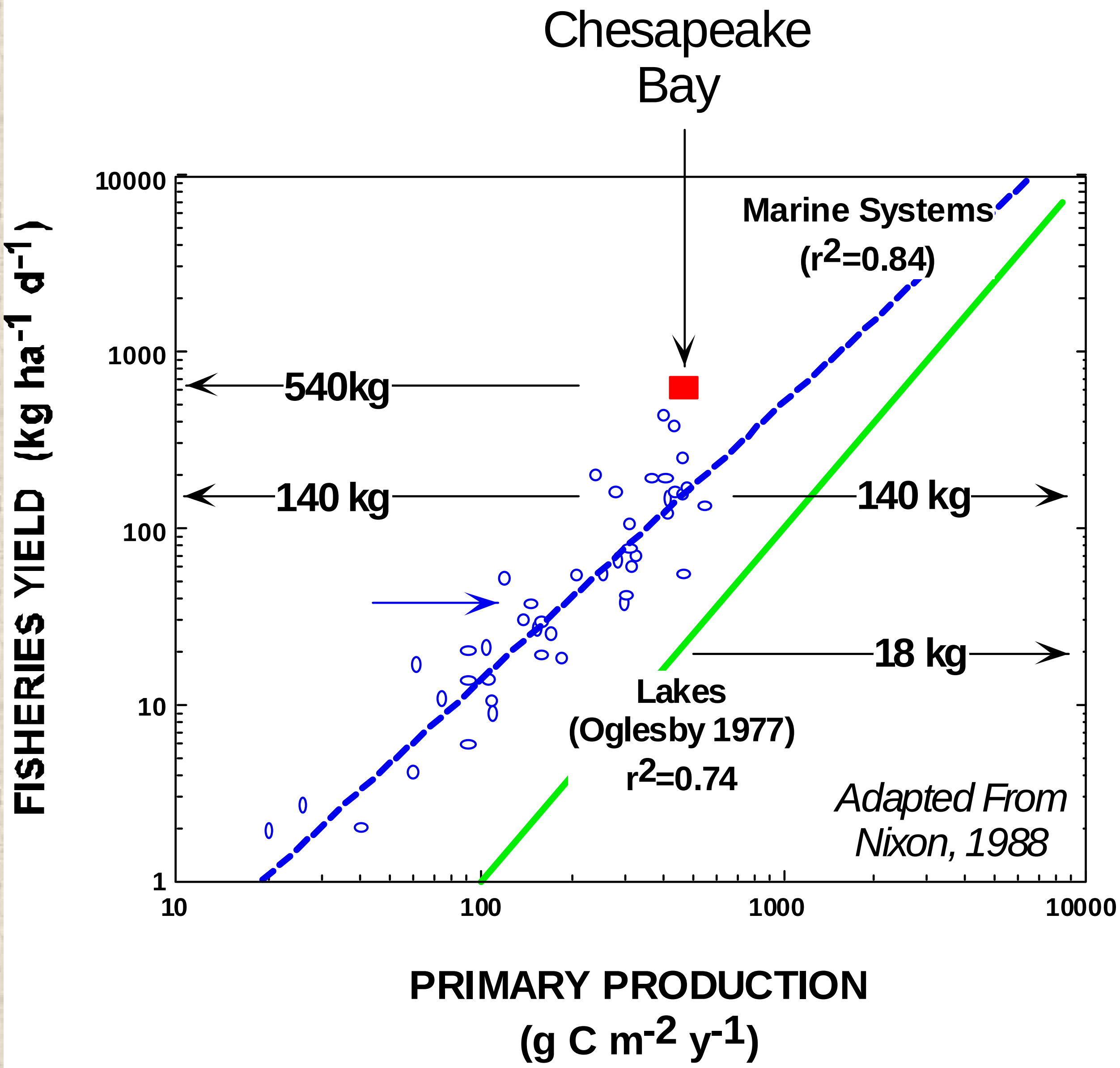


Measurements used N_2:Ar technique
Dr. J. Cornwall HPL-CES

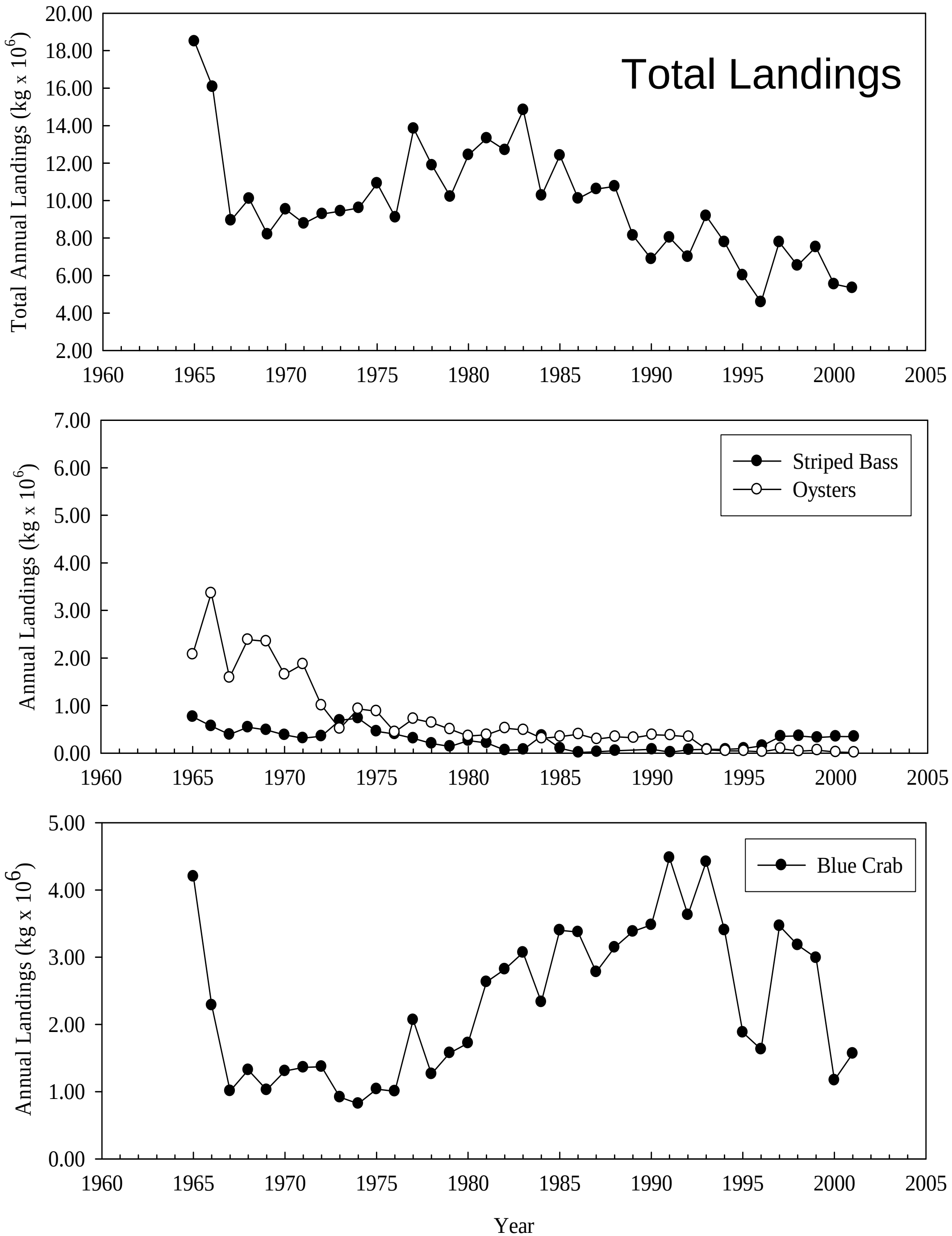
Potomac River Fish Monitoring

- Another issue the public cares about

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



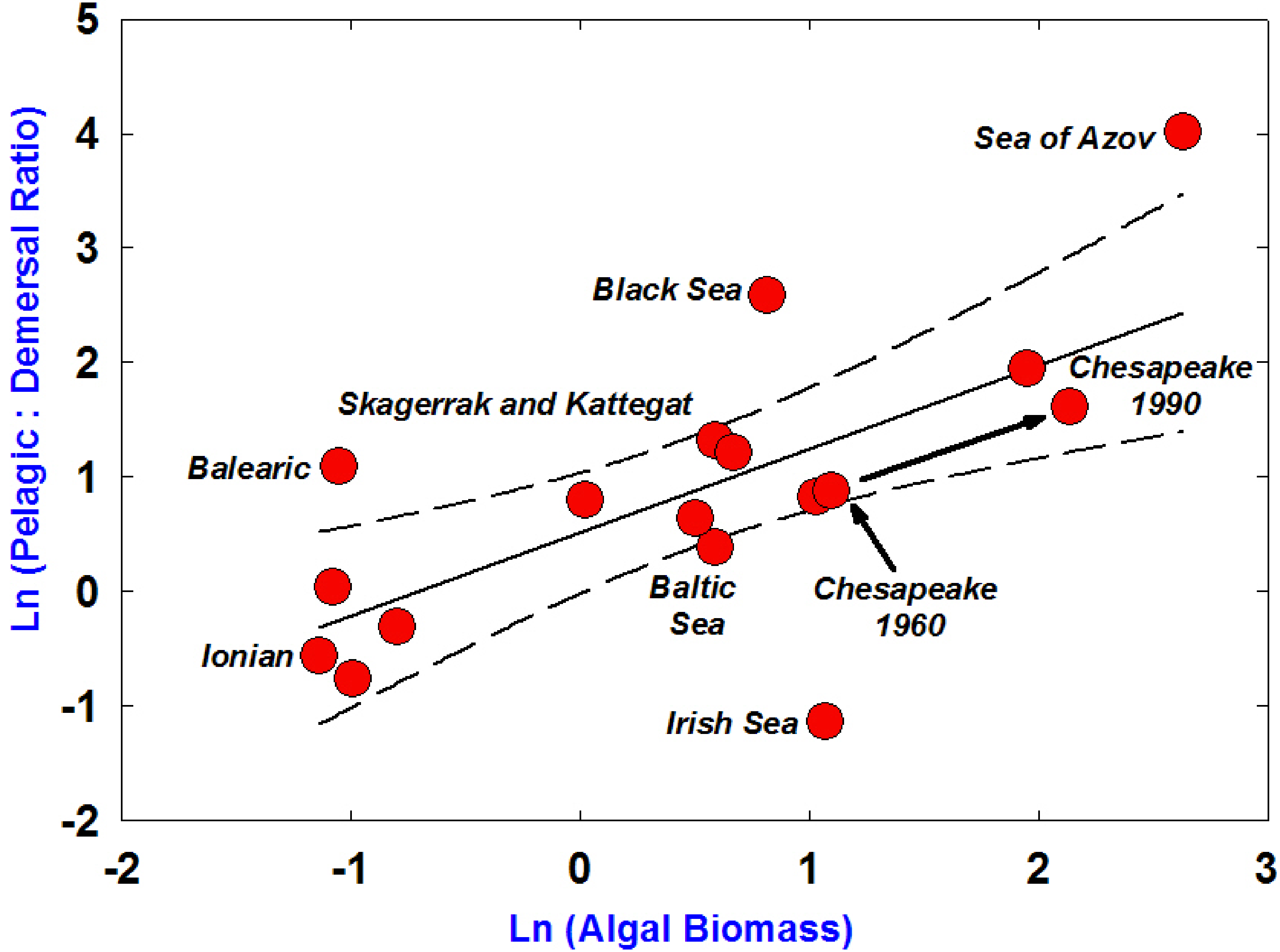
Chesapeake Bay yields 30 times more fish than an average lake with the same primary production ...



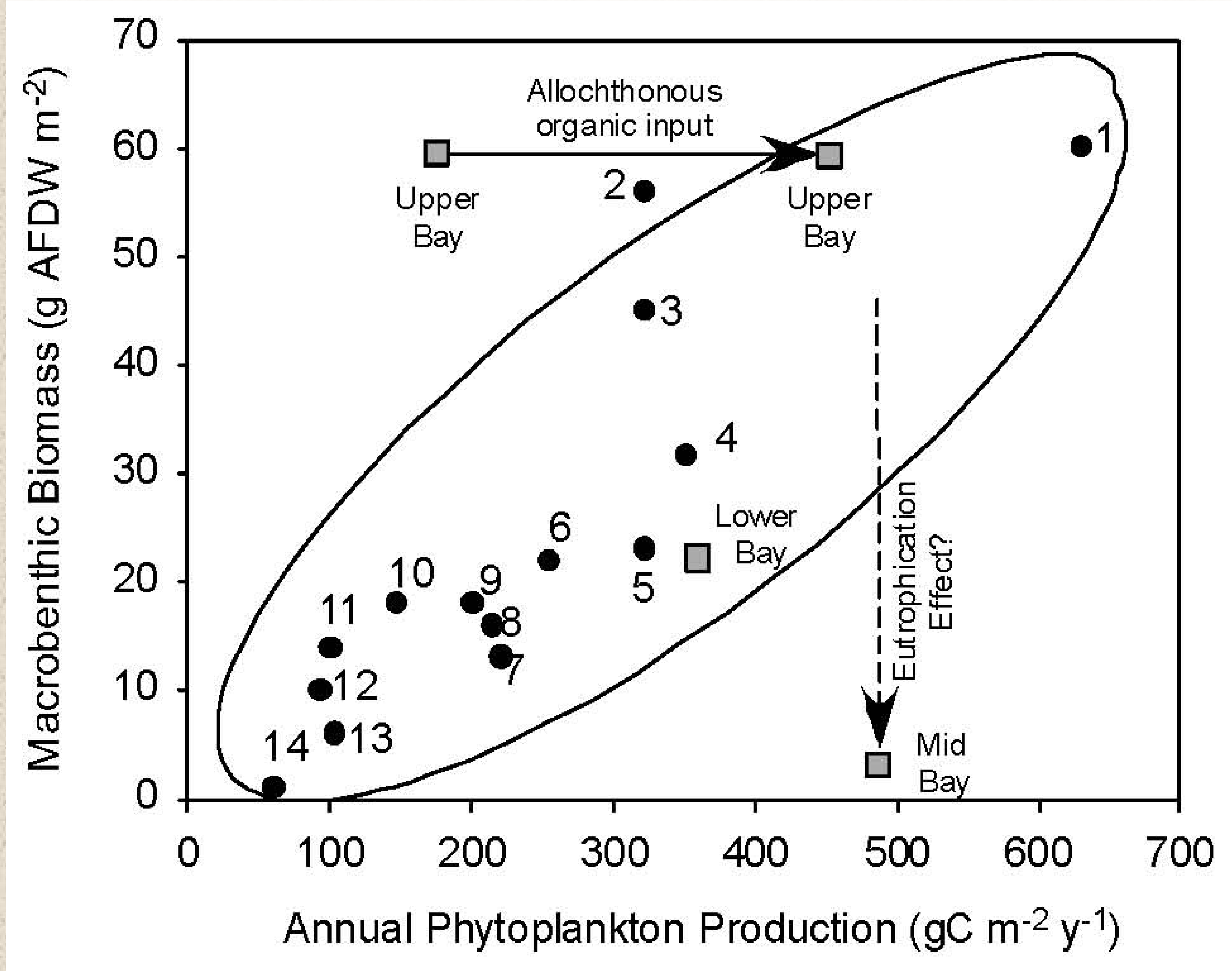
Potomac River Estuary Commercial Fishery Yields 1965 - 2001

- 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

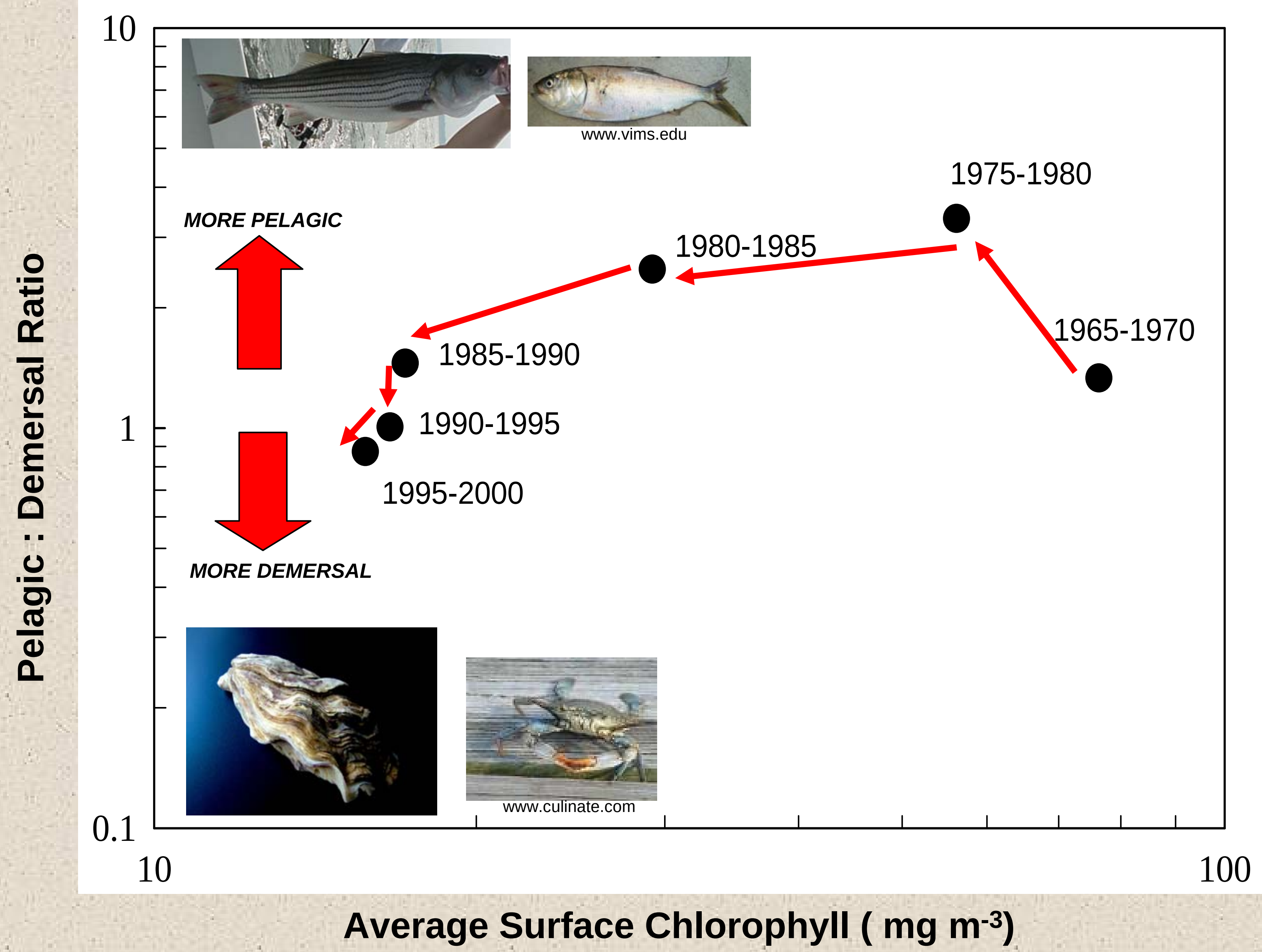


Adapted from Moreno et al. 2000 and Houde et al. 1999

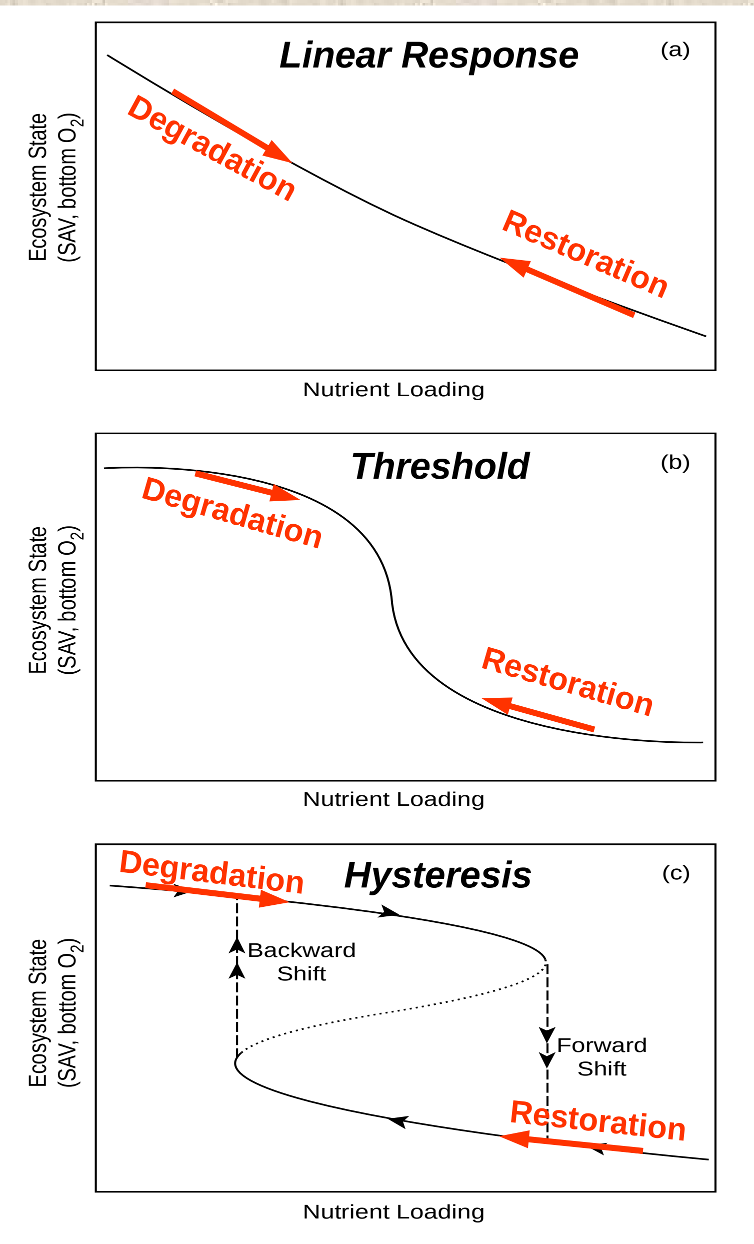


Macrobenthic Biomass (g AFDW m-2)
Annual Phytoplankton Production (gC m-2 y-1)
0
10
20
30
40
50
60
70
0
100
200
300
400
500
600
700
Allochthonous
organic input
Upper
Bay
Upper
Bay
Lower
Bay
Mid
Bay
Eutrophication
Effect?
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Potomac River Estuary
Pelagic vs Demersal Catches



Trajectories of Response to Nutrient Loading



- Theory suggests alternative ecosystem response to changes in environmental conditions (e.g., nutrient loading, climate)

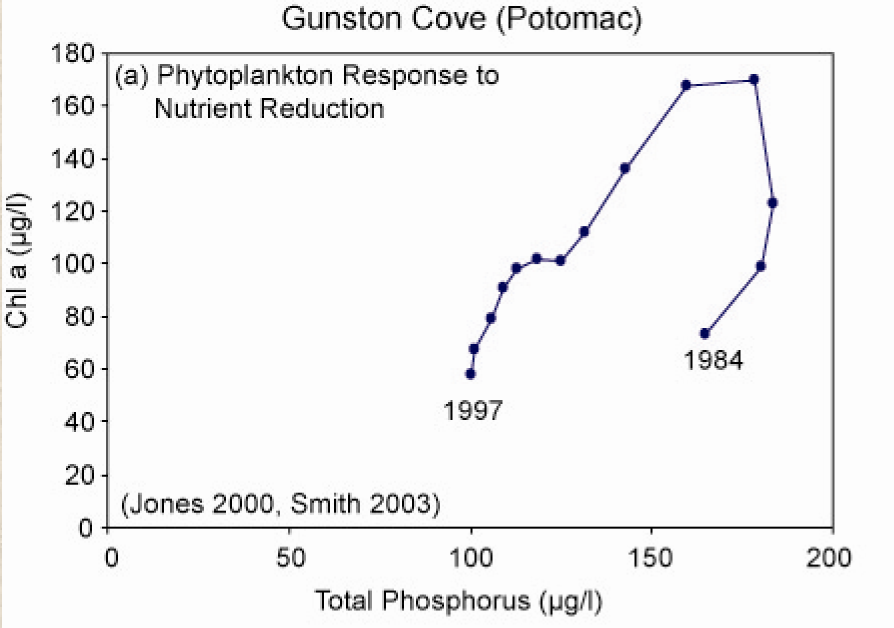
- Responses can follow ~*linear* pathways with direct proportional response (a)

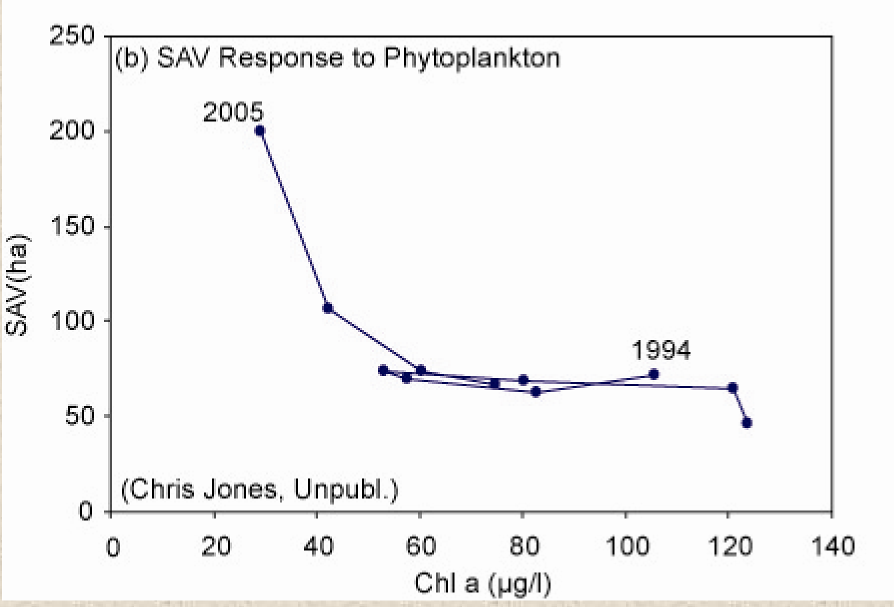
- Responses can follow "sigmoidal" shape with apparent *threshold shift* within narrow range of environmental conditions

- Responses can exhibit *multiple stable states* with abrupt transitions and *hysteretic* patterns where degradation and restoration follow different trajectories

From Scheffer et al. 2001

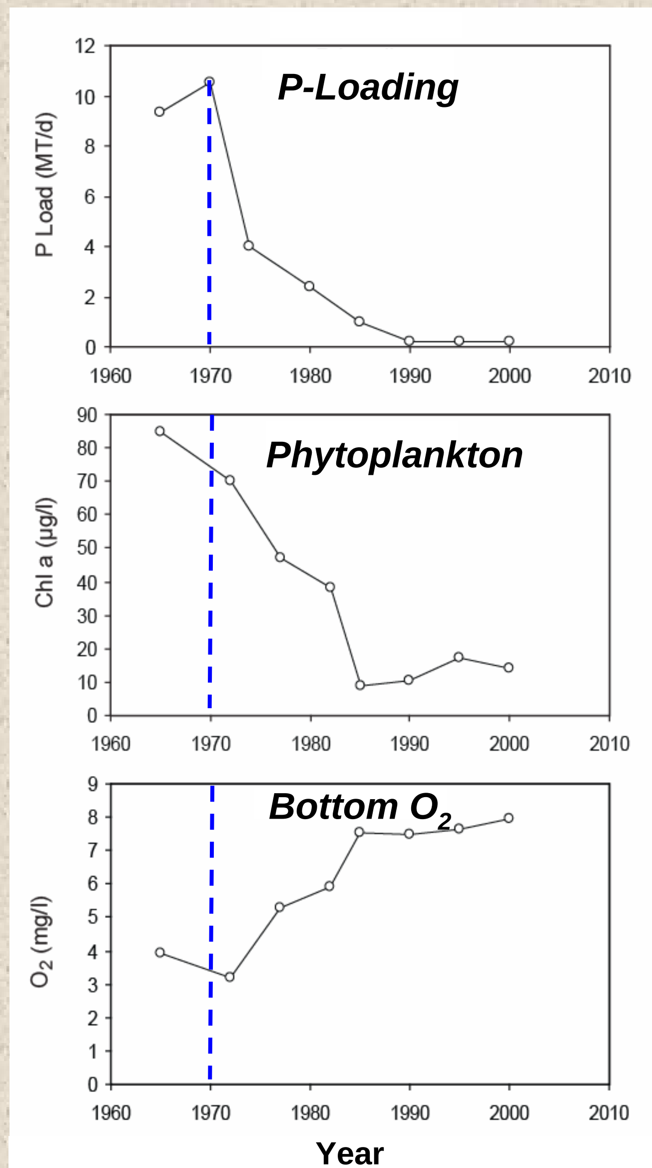
Responses to N&P-Reduction: Gunston Cove



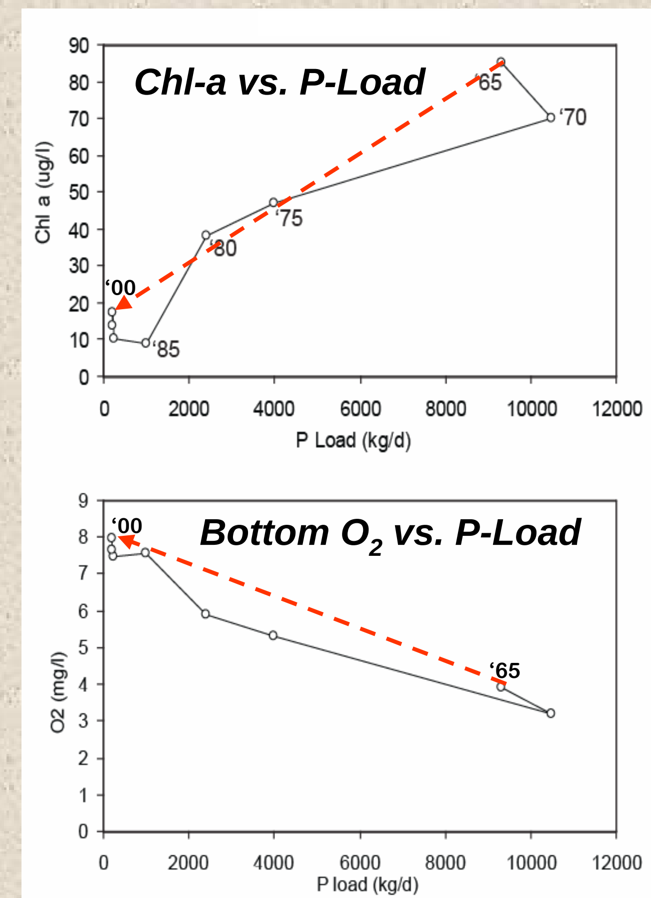


- *Gunston Cove* is in the lower tidal freshwater region of Potomac R.
- Major WWTP (*Blue Plains*) above *GC* was upgraded for P-removal in 1970s & continued into late 1980s
- Chl-*a* has been decreasing since 1988 along *hysteretic trajectory* with Chl-a levels per unit P above those during 1984-1987
- SAV populations in GC have been recovering since the 1990s with reductions in phytoplankton Chl-*a*
- SAV recovery following trajectory with apparent *threshold shape* around 30-40 μg/l

Responses to N&P-Reduction: Potomac Tidal Fresh



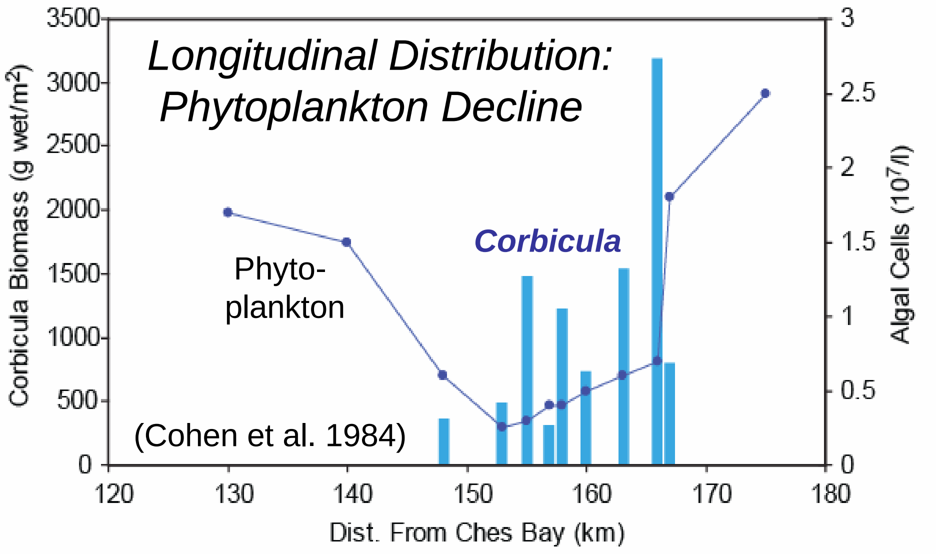
- Advanced Tertiary Treatment at *Blue Plains* WWTP reduces P-loads by >90% in 30 years
- Phytoplankton Chl-*a* and bottom O_2 respond rapidly
- N-load is also reduced by smaller fraction

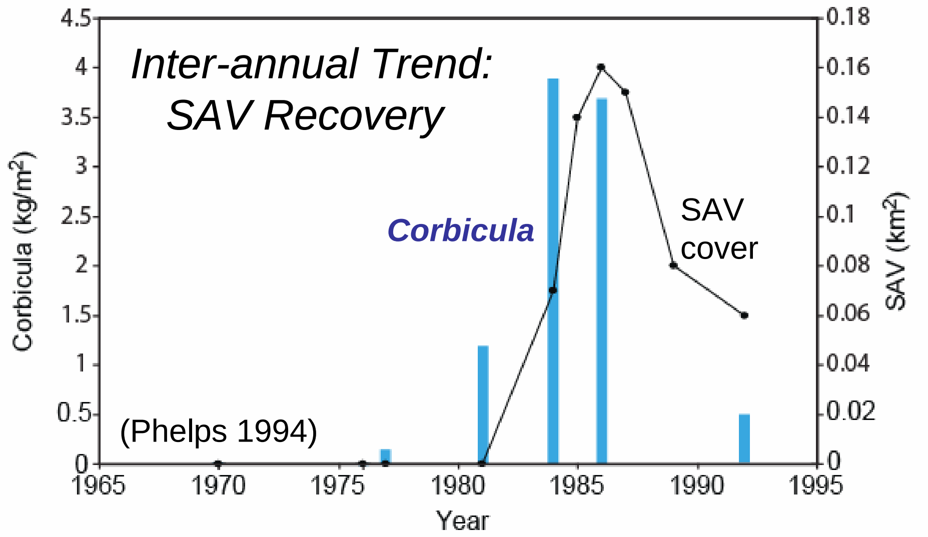


- Chl-a followed a direct ~ linear response to P-loading
- Bottom water O_2 followed inverse ~linear to P-loading
- No signs of thresholds or hysteresis

From Kemp et al. 2005

Feedback Effects: (2) Benthic Filter-Feeders





- Invasion of Asiatic clam (*Corbicula fluminea*) in early 1980s in Tidal freshwater Potomac (z ~ 2 m)

- Large (75%) reduction in phytoplankton in 30 km stretch of estuary due to clam filtration

- Clams persisted for a decade causing substantial increases in water clarity

- Improved water clarity led to SAV recovery in region and increased waterfowl abundance

Summary of Nutrient-Related Feedbacks in Bay Ecosystem

•Positive & negative feedbacks control paths of ecosystem change with Bay degradation

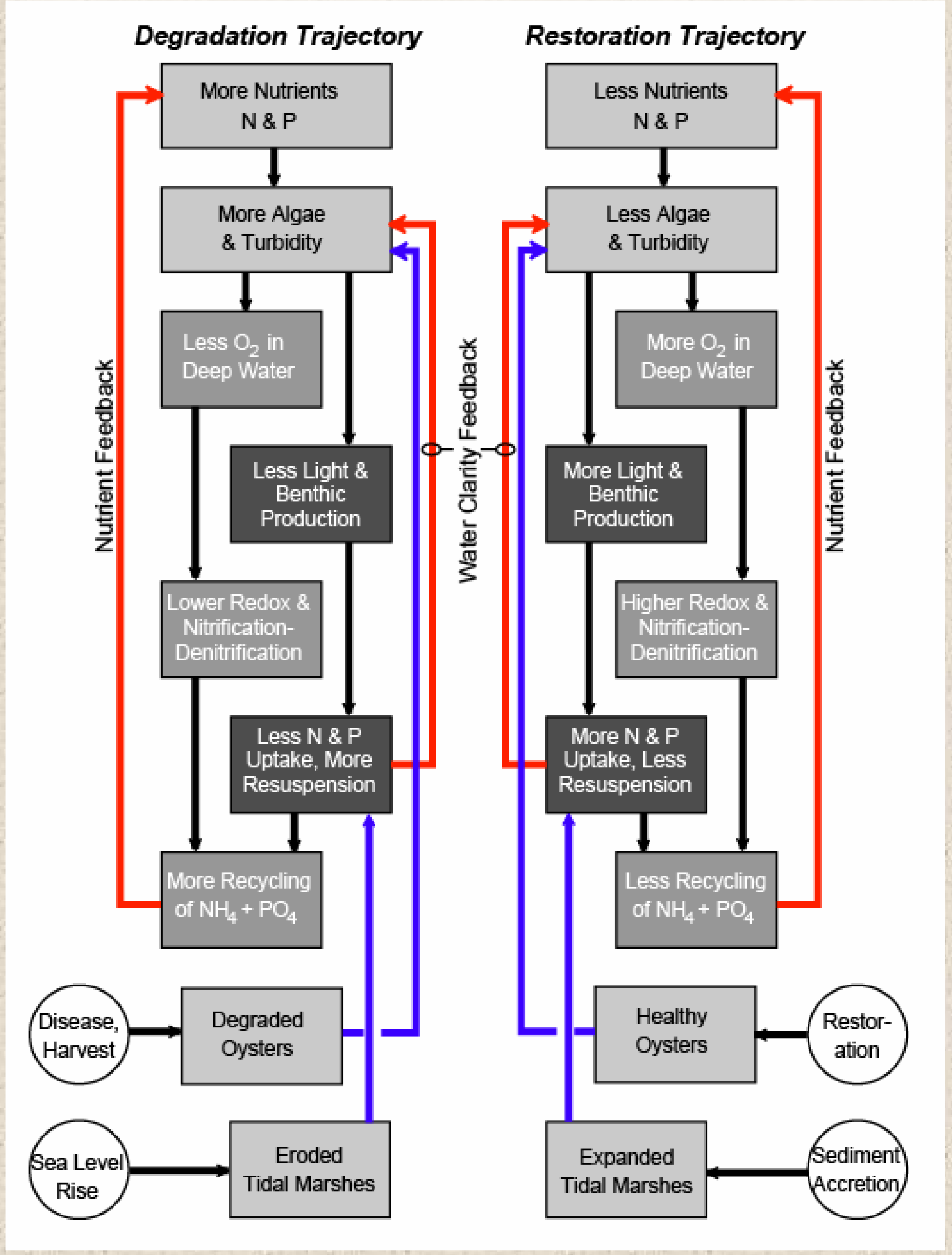
•Among other mechanisms, input of nutrients affects hypoxia & light

• Hypoxia leads to more nutrients, more algae, & more hypoxia

• Turbidity leads to less SAV causing more turbidity, less SAV

• Oysters & marshes tend to reinforce these feedbacks

•Processes reverse w/ restoration, thus reinforcing trends



From Kemp et al. 2005

Summary and Recommendations

- There are “Weak-Spots” in the monitoring regime (e.g., lower estuary)
- Multiple “processes” are poorly measured and controlling mechanisms not fully understood (e.g., denitrification, fish stock size and dynamics). There is a need to incorporate process measurements into monitoring programs
- Are “In-Estuary” restoration schemes possible (e.g., reefs, augmentation of fringing wetlands)
- Need continued effort at analysis and synthesis of old and new data with empahsis on solutions to water quality issues and forecasting
- What are the likely recovery trajectories…we need to know!!
- There are a ton of things I don’t know about that also need attention…that’s one reason why we are here!!!

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