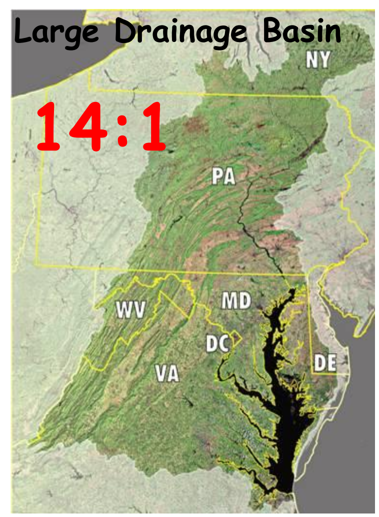
POSITIVE SIGNS OF CHANGE IN CHESAPEAKE BAY

What are the Causes and Can We Hang On?

Chesapeake Bay Commission

January 2017

- 17 Million people
- Mixed land uses
- Shallow but seasonally stratified
- Estuary "flushes" slowly (4-6 mo)
- Many rivers connect land to Bay



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Chesapeake Biological Lab, Center for Environmental Science, Univ MD

Topics for Today

- Examples of Bay SUCCESS STORIES
- TIPPING POINTS in Bay Restoration
- CHALLENGES for NOW and the FUTURE
- All this in 30 minutes…so let's get going!
- Questions welcome…let's have a discussion

Major Nutrient Sources…a reminder

Agriculture

Urban/Suburban Run-off

Point Sources

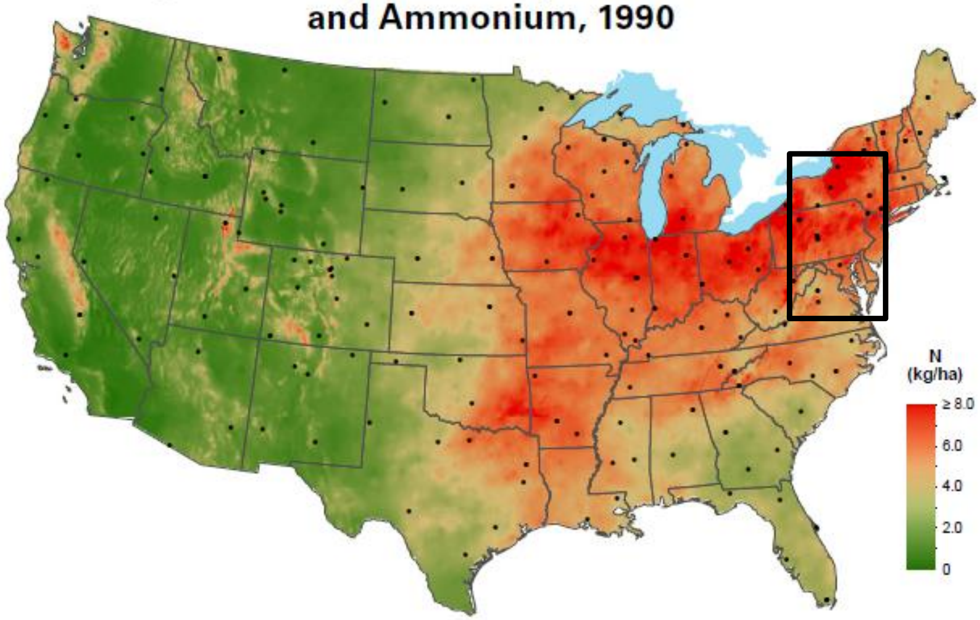
Power generation (atmospheric deposition)

Auto exhaust

Summary

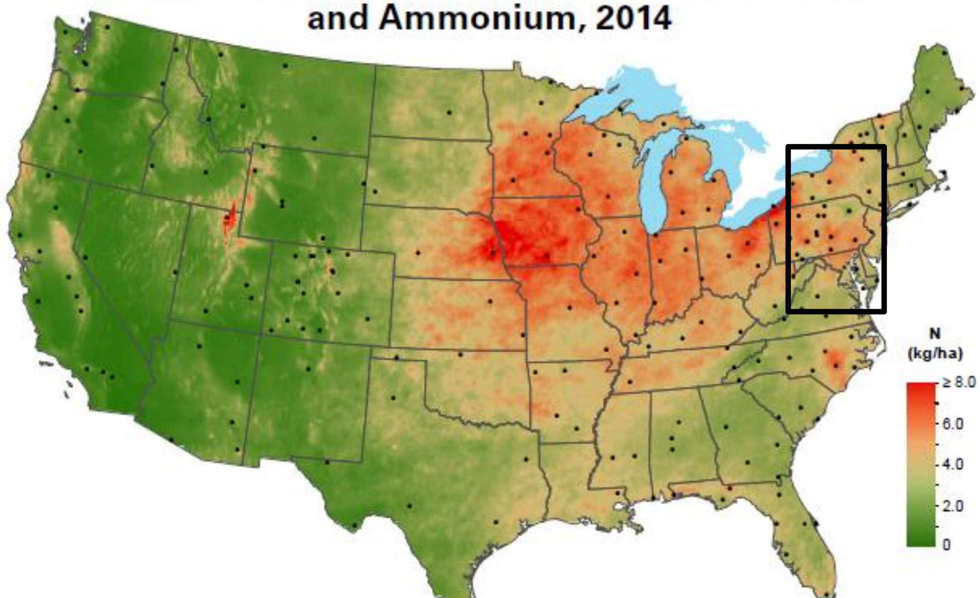
- All have increased during last 70 yrs
- Importance varies widely with location
- Reductions are now being achieved

Inorganic Nitrogen Wet Deposition from Nitrate and Ammonium, 1990



Declining Nitrate (NO_3) and Ammonia (NH_3) deposition concentrations across the Bay watershed

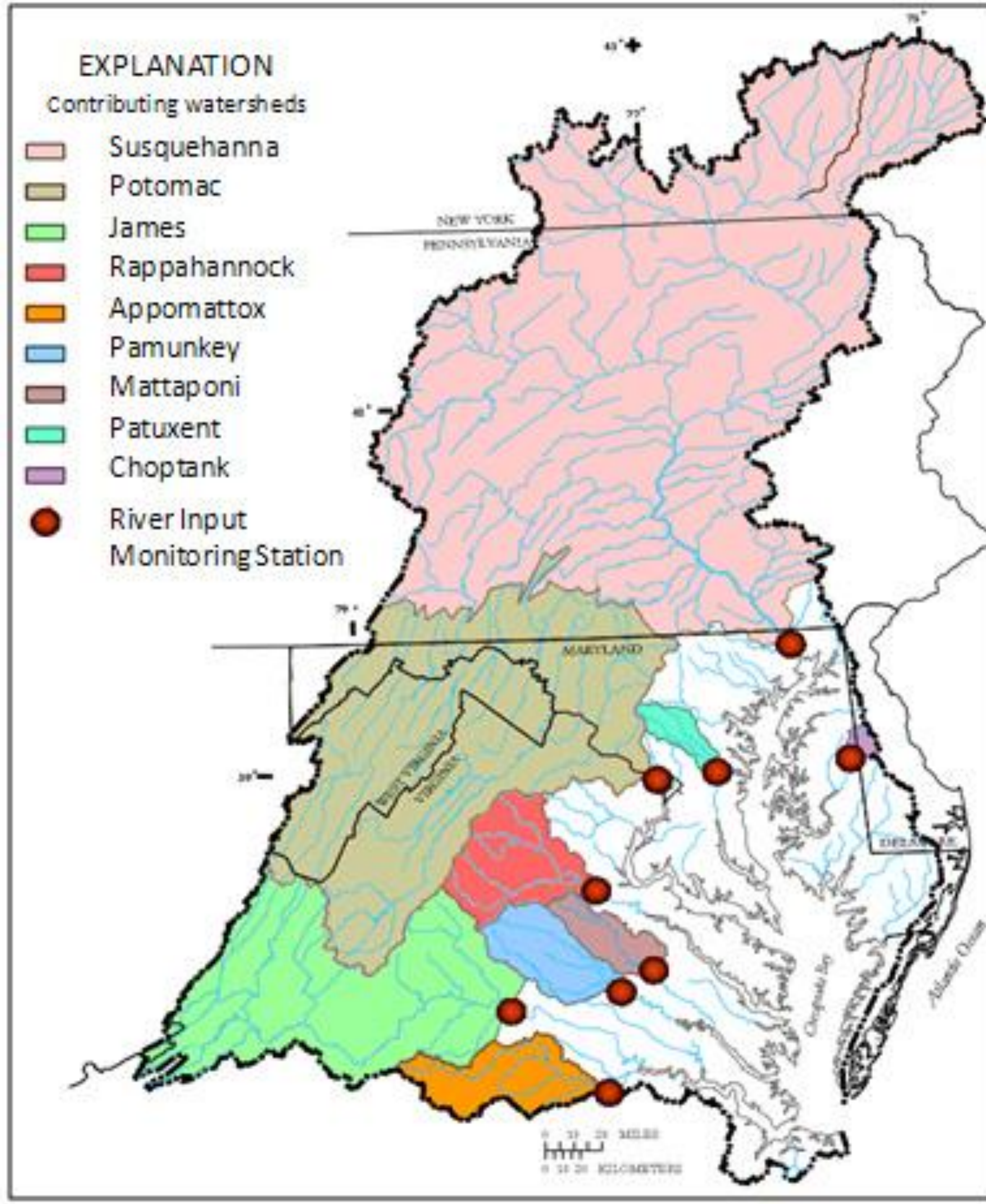
Inorganic Nitrogen Wet Deposition from Nitrate and Ammonium, 2014

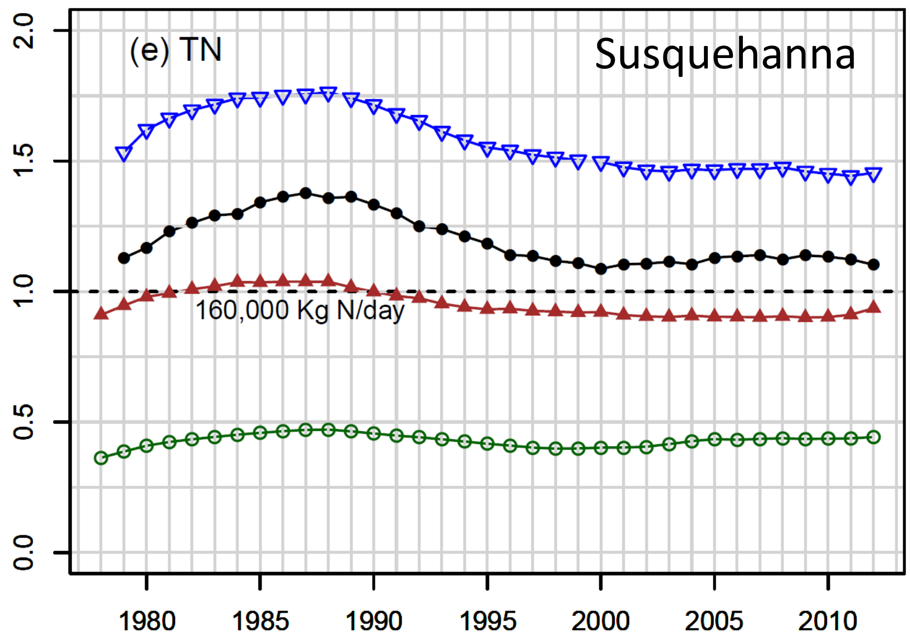


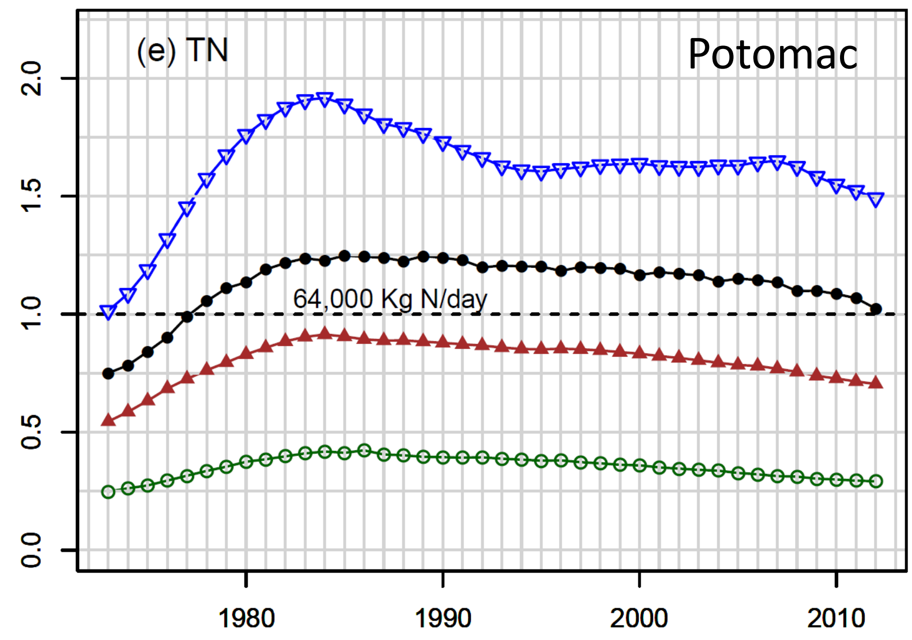
National Atmospheric Deposition Program

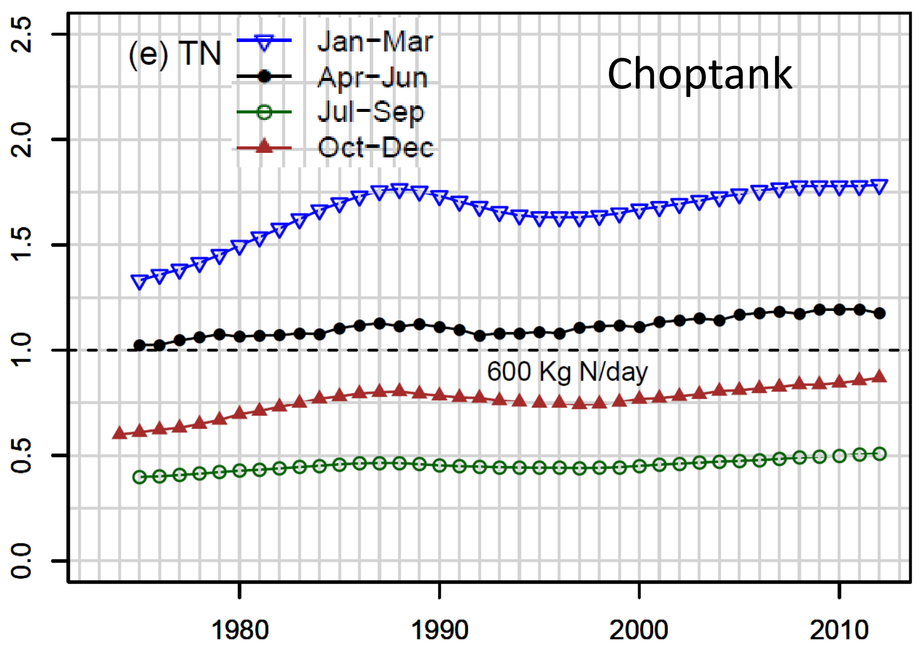
Trends in Nutrient Loads from Long-Term Monitoring Sites in Chesapeake Bay

- 9 major rivers monitored for inputs to the Bay
- About 82% of entire watershed monitored by these sites
- Monitoring record includes last 3 decades…more in some cases









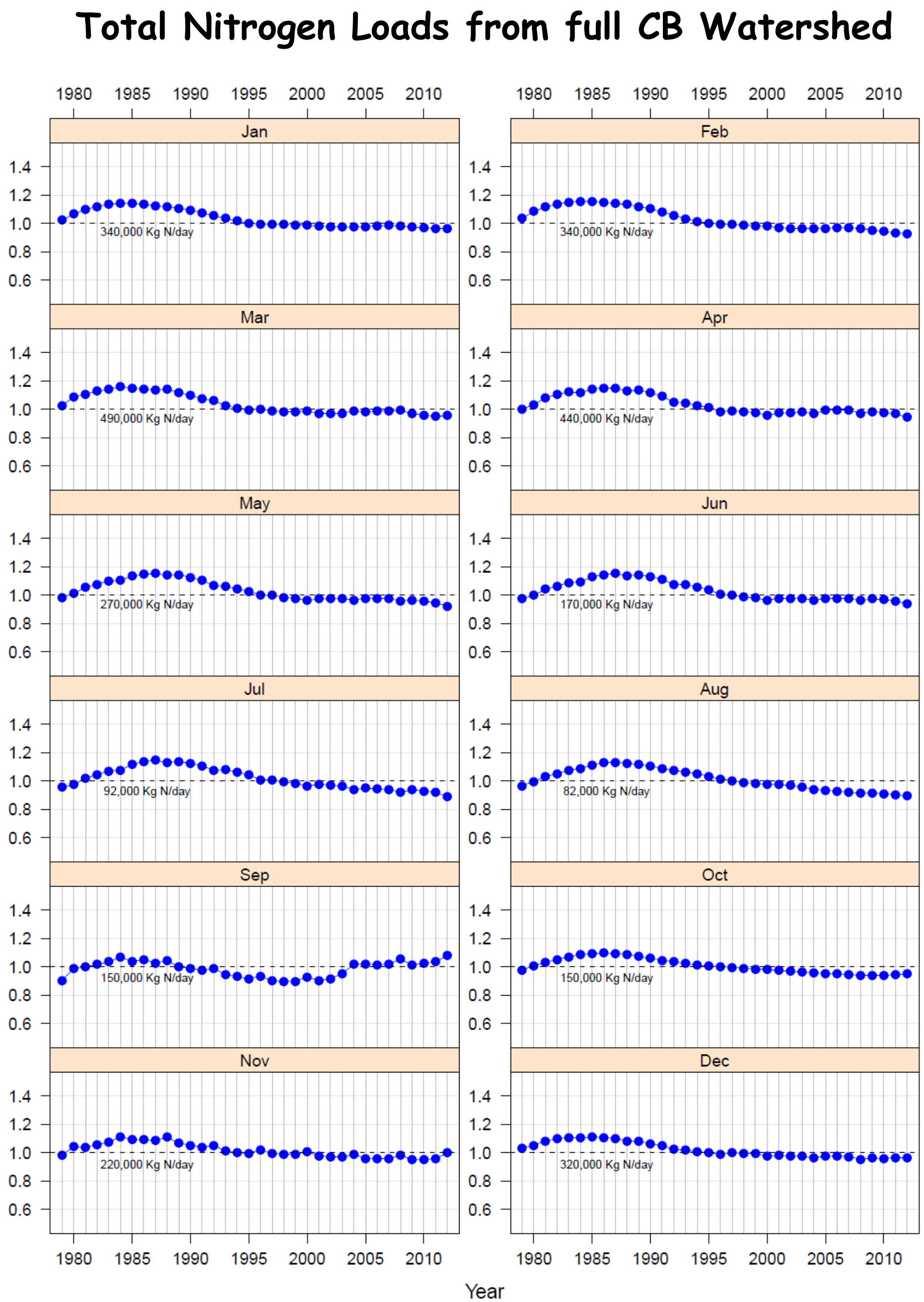
- Dissolved nutrient inputs to the Bay are decreasing at all but one site

- Decreasing trends for all seasons, especially the winter when river flows are highest

- Note "Flow-normalized" Nutrient Loads

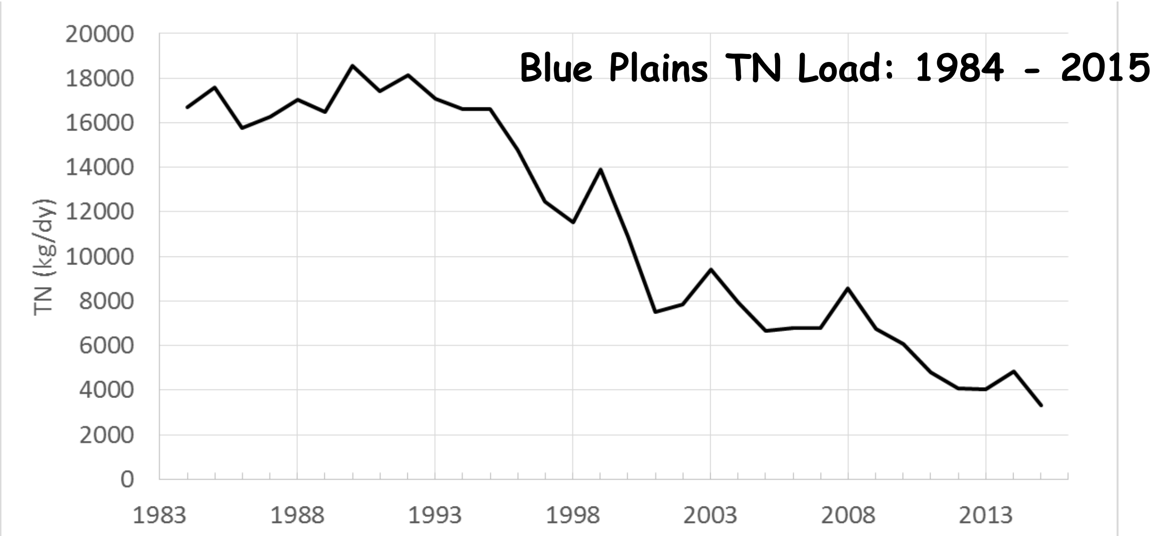
- Loads to the Choptank River continue to increase

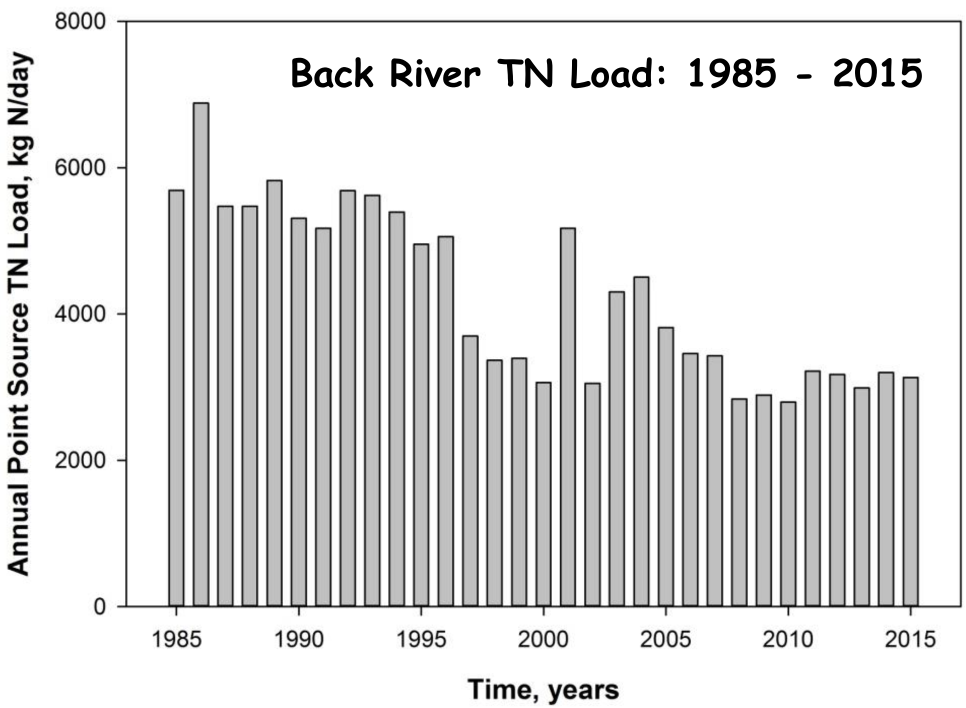
Monthly Total Nitrogen Loads from all Major Tributaries



- Loads decreasing post 1990 in all months except September
- Loads decreasing even in high flow months (Feb – Mar)
- Load declines have slowed in recent years

Point Source N and P loads are decreasing





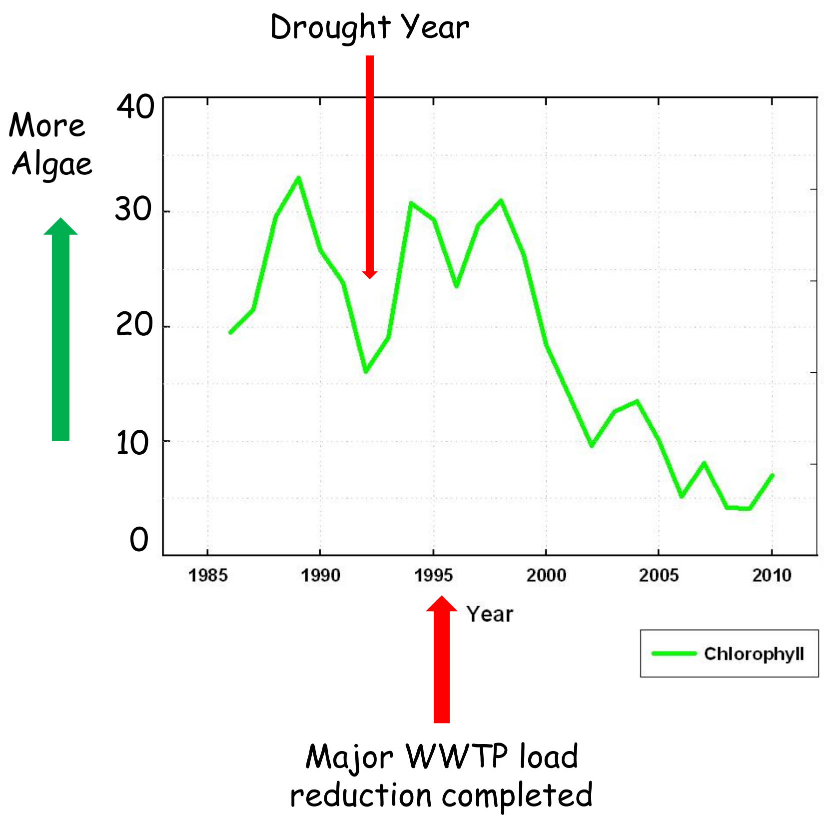
- Huge decline in both TN and TP loads to the Potomac River from Blue Plains
- Back River (Baltimore, MD) TN loads reduced by ~ 50%
- In January, 2017 Back River loads will again be reduced by a further 50%
- Most P loads were reduced before N loads were reduced

Restoration of Mattawoman Creek: Potomac River estuary tributary

- strongly impacted by nutrients from 1970 – mid-1990s
- large and persistent algal blooms, sea grasses rare
- WWTP load reductions stimulated restoration

Photo from Elena Gilroy

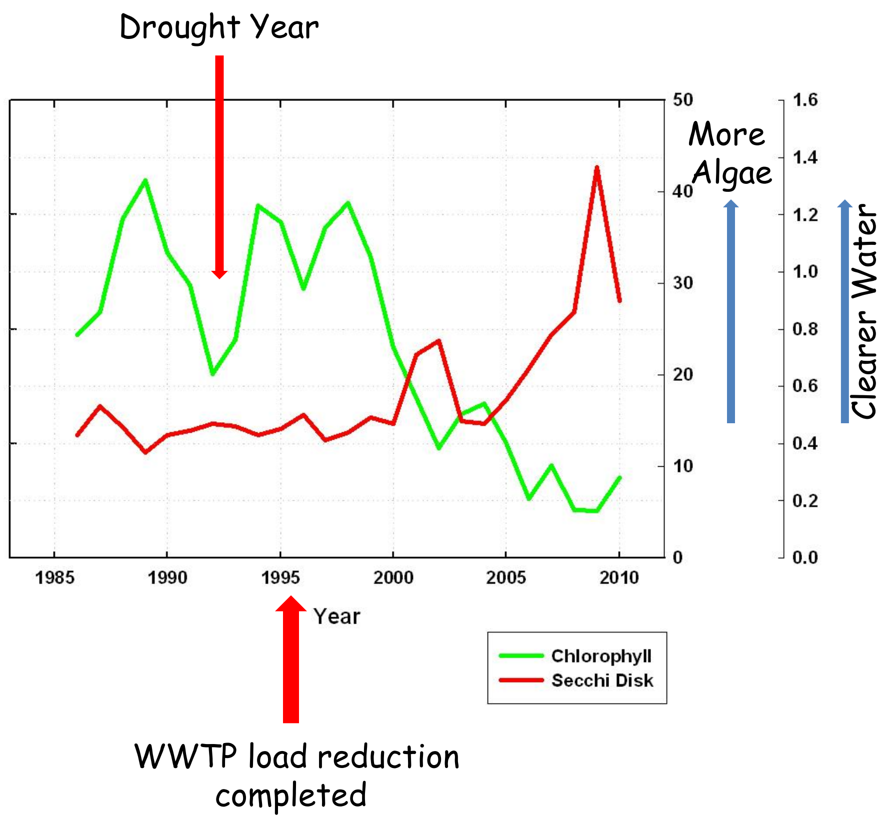
Algal Biomass Decreased...with Substantial Lag Time



- No clear response for about 4 years followed by sharp decline in algae

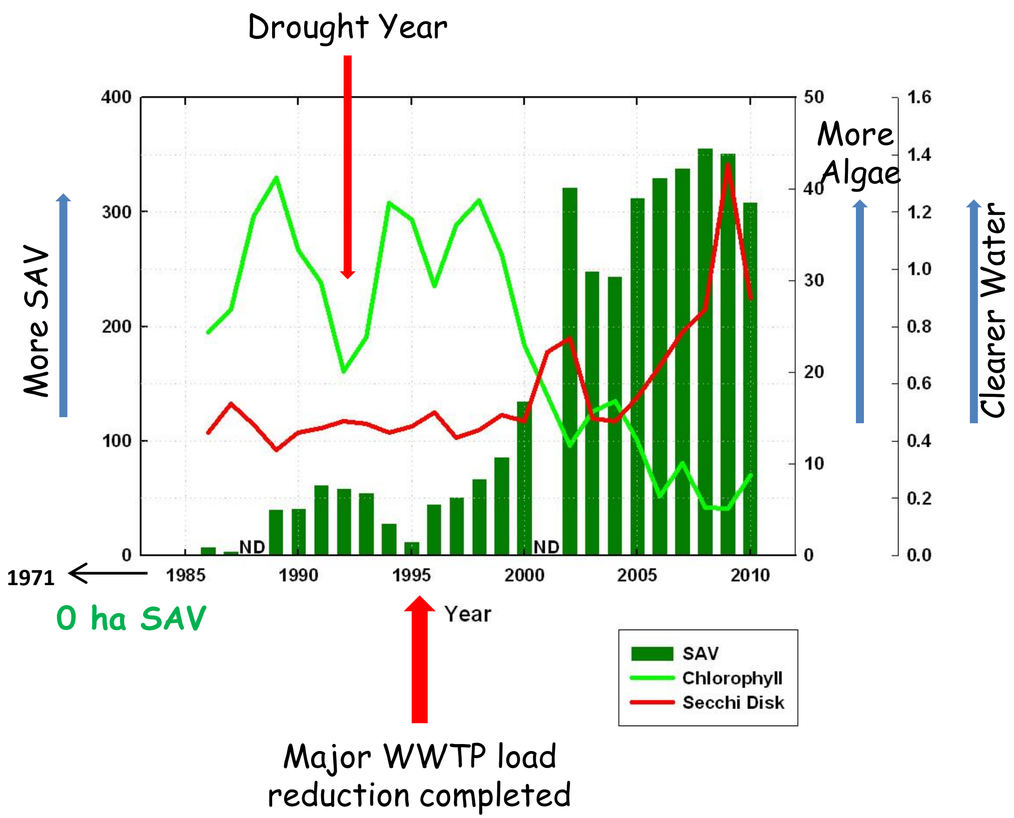
- After 2005 low levels of algae became normal

Water Clarity Increased...also with a Lag Time



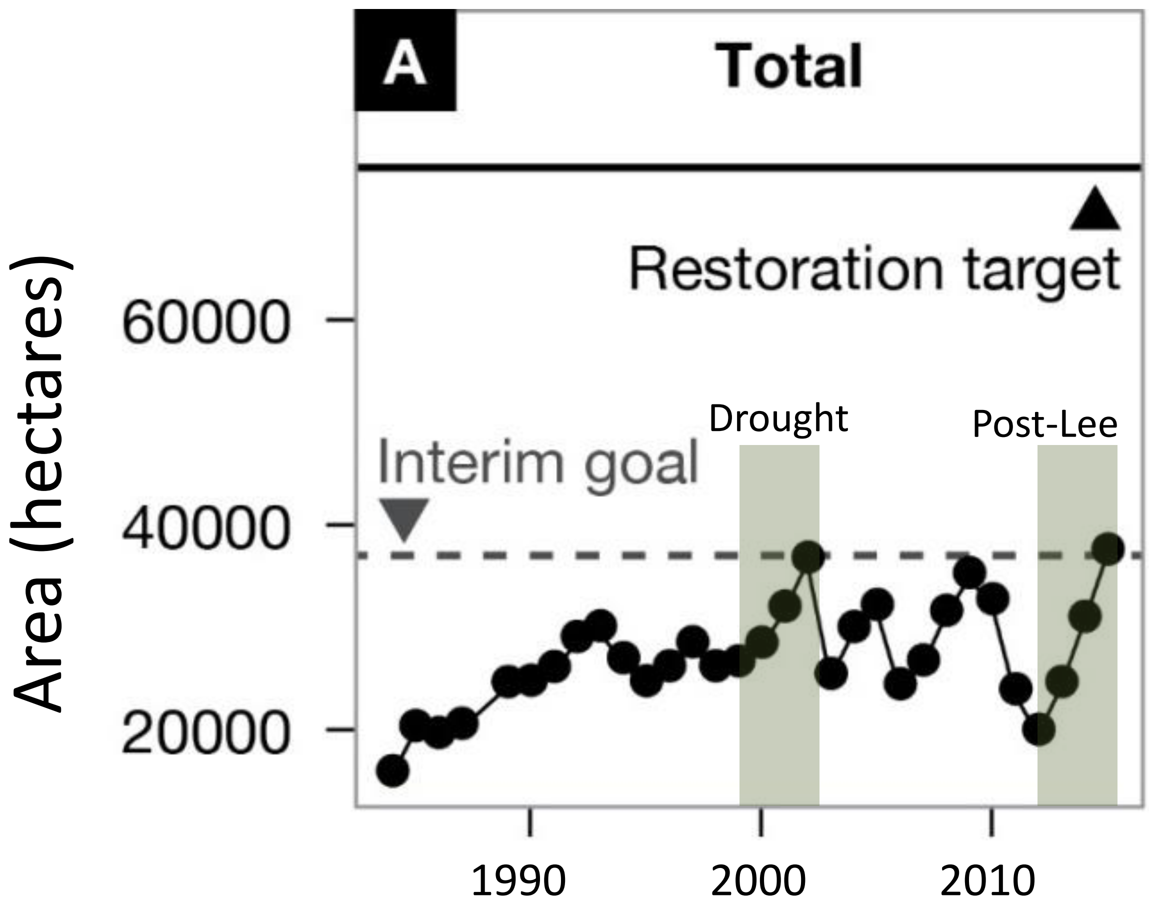
- No clear increase for about 8 years followed by sharp increase in clarity
- Water clarity and algae highly correlated in shallow Chesapeake Bay systems

SAV Increased...Shorter Lag with Threshold Response

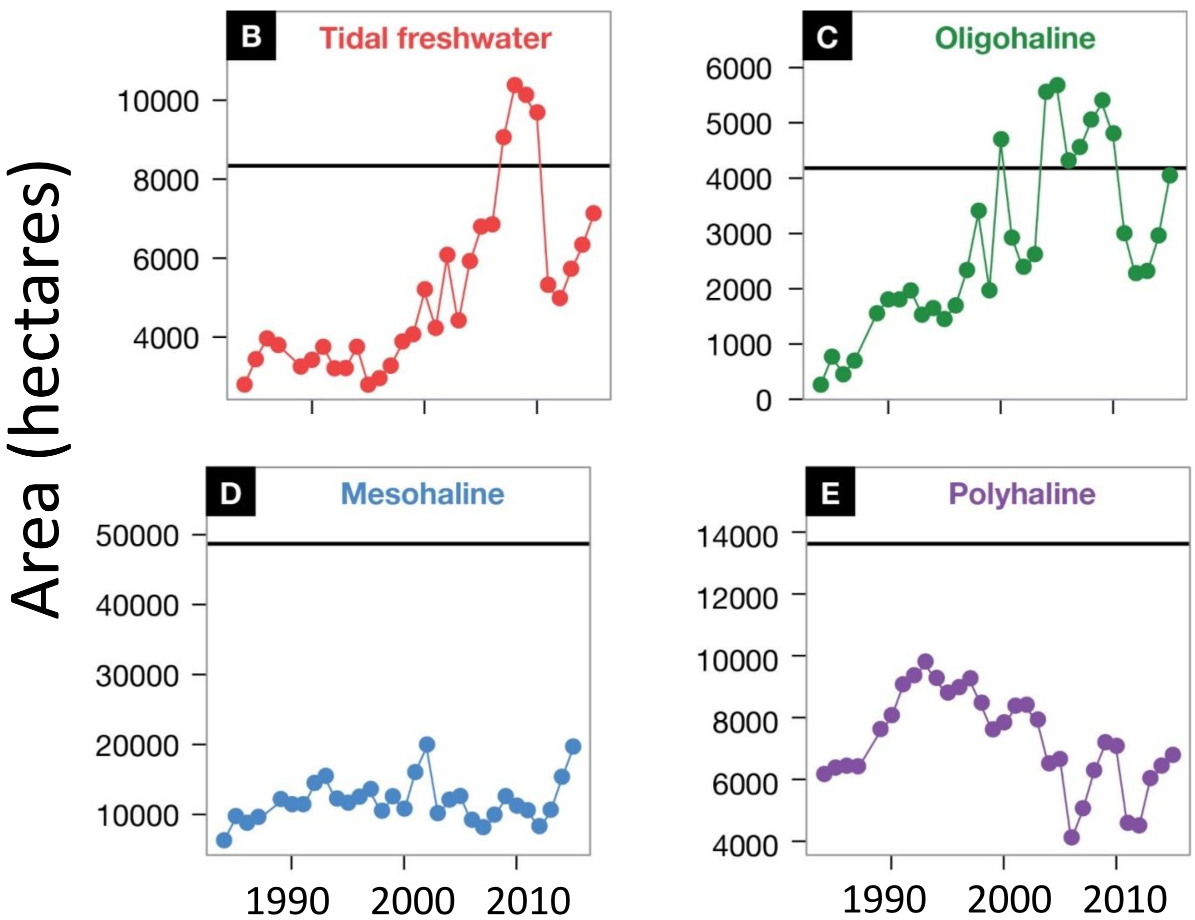


- Very low levels of SAV were present prior to nutrient load reductions
- Major expansion of SAV in 2002, a severe drought year
- SAV relatively stable after 2002; lag in SAV relatively short

Baywide SAV Pattern: Slow increases with strong inter-annual variability. Note strong increases during 1999-2002 drought and post-tropical storm Lee (2011)



The “WHERE” of SAV Recovery…or not



- Note likely response to tropical storm Lee in freshwater and Oligohaline (low salinity) areas of the Bay

- Negative trend in Polyhaline (salty) portions of Bay likely related to temperature stress

Orth et al., in review

SAV off Poplar Island in late summer 2015

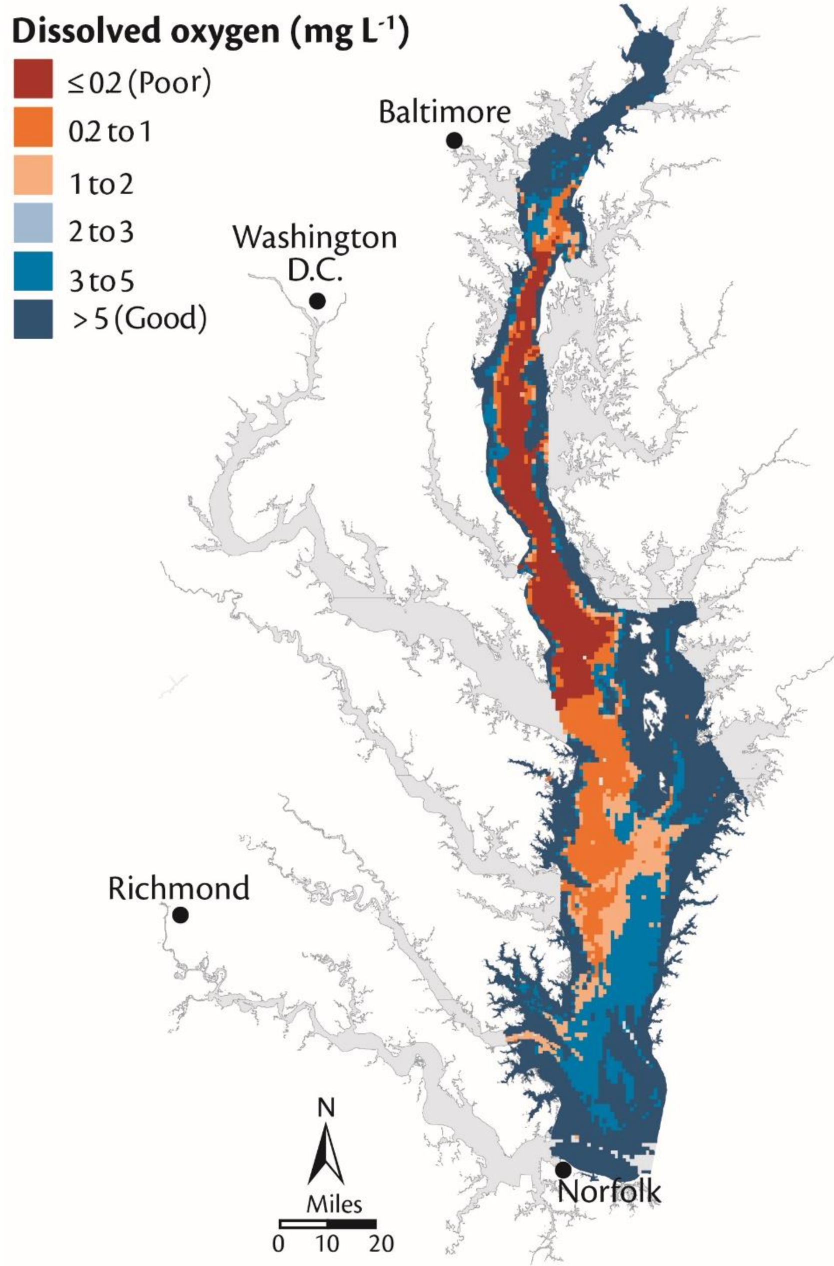
Late Summer Anoxia *Declining* in Mainstem Bay

- *Anoxia ("no oxygen") occurs in the deepest Bay water*

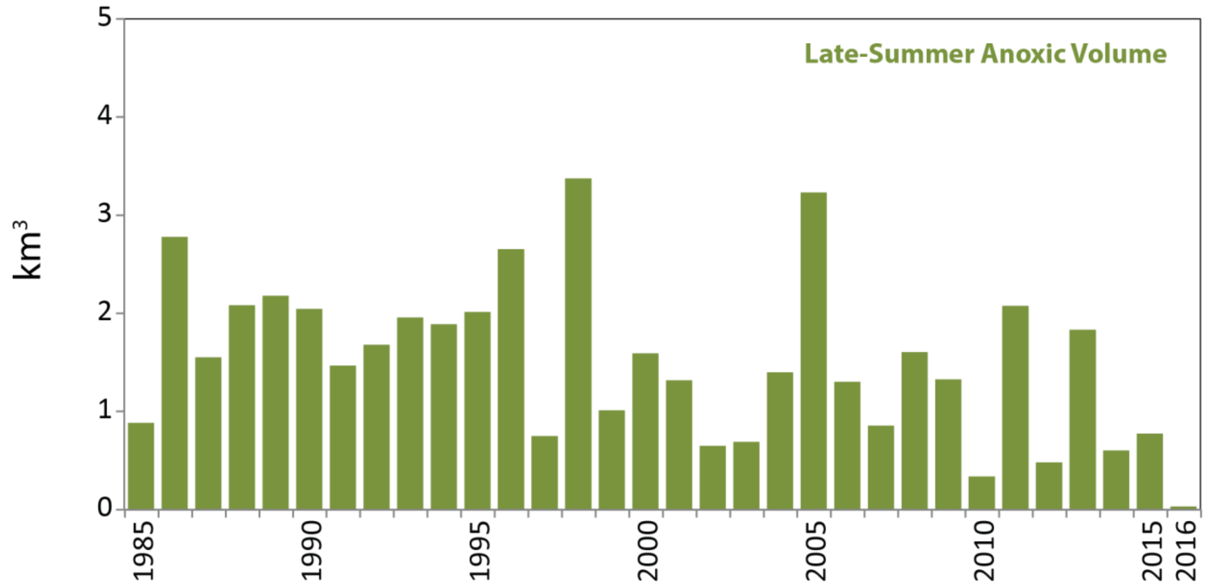
- No multicellular organisms in CB can tolerate these conditions

- *Size of anoxic zone varies from year to year*

Maximum amount of hypoxia and anoxia both occurred in late July 2011.



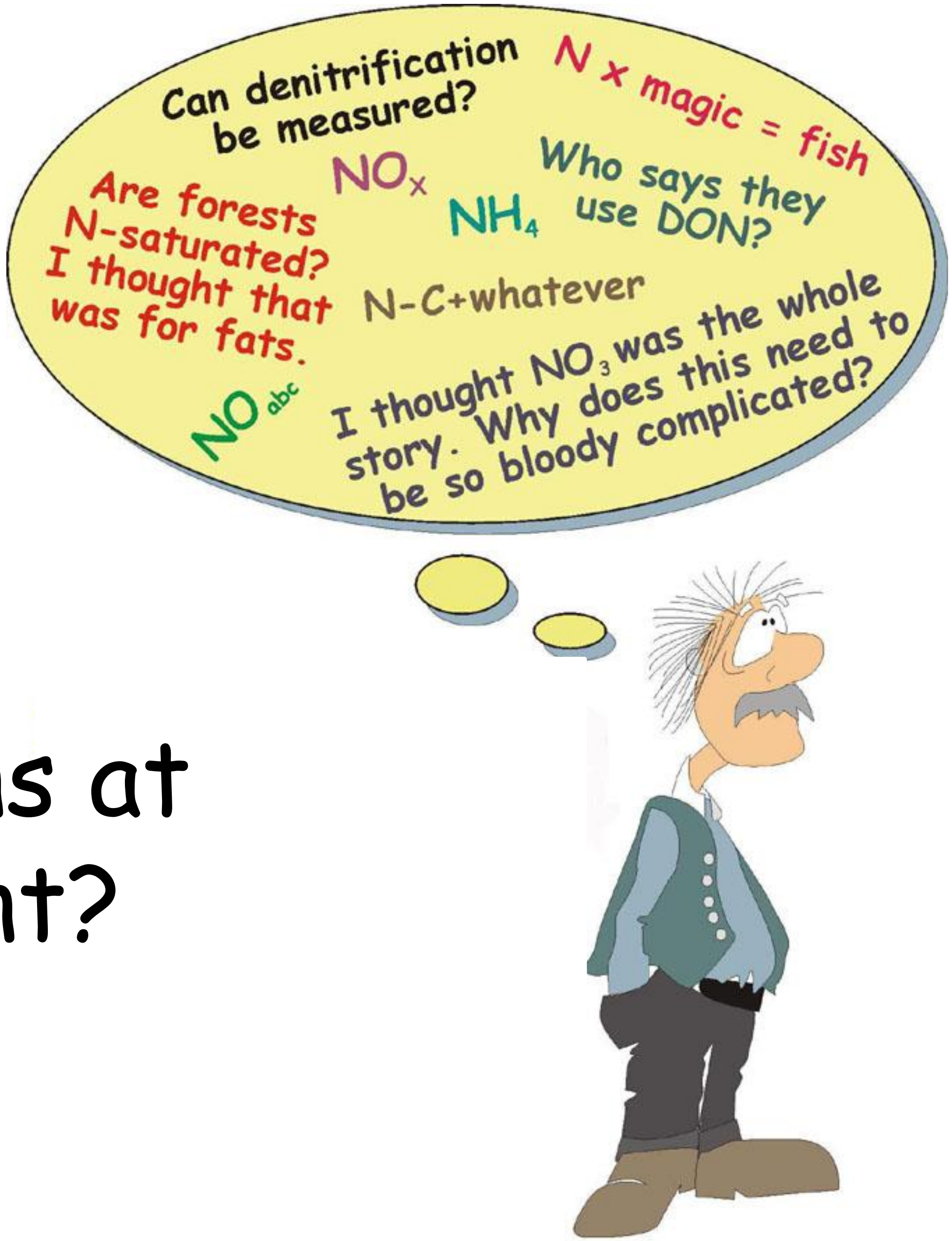
Late Summer Anoxia *Declining* in Mainstem Bay



- Long-term decline in late summer anoxia ("no oxygen")

- This decline larger than expected from modest declines in load

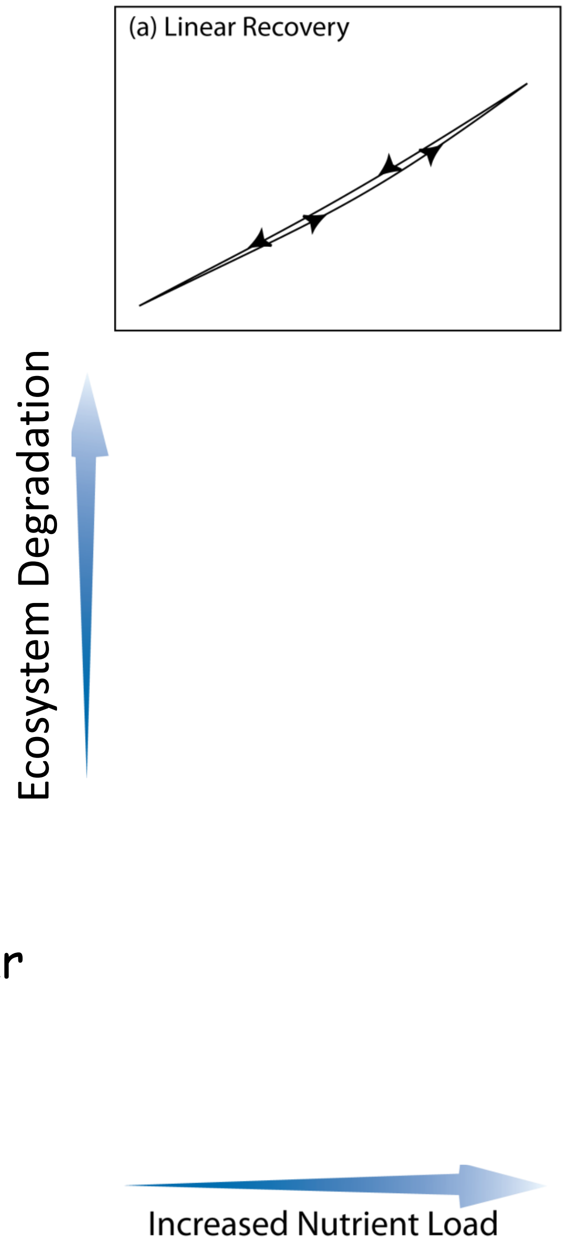
- Clear explanation remains elusive



So, any questions at this point?

Tipping Points: *Points where a system shifts from one stable state to another*

- Some ecosystems recover from eutrophication in the same way as they degraded



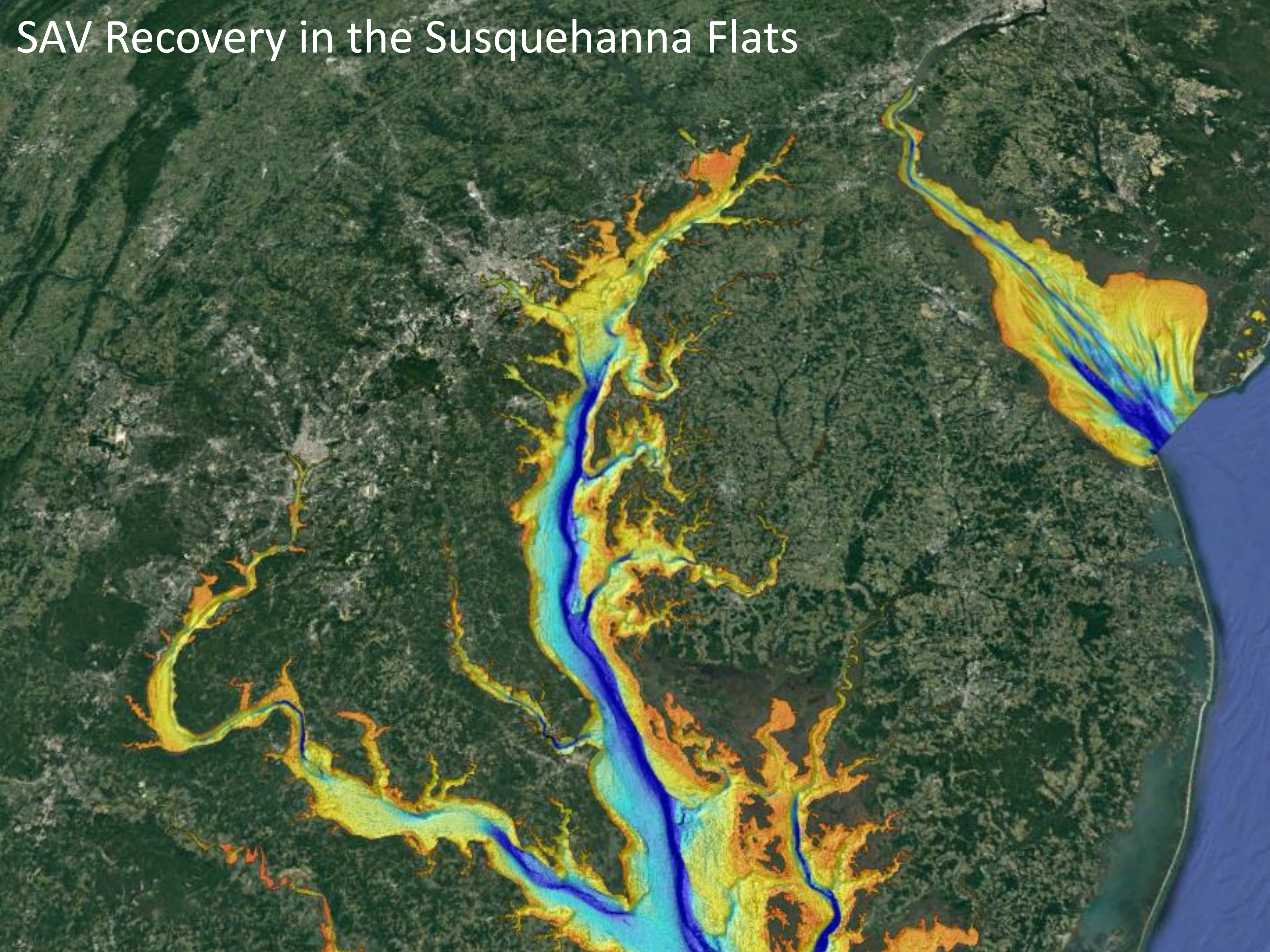
Delaware River,
NY Harbor

- Other respond positively to load reductions, but the response only occurs upon reaching a threshold reduction

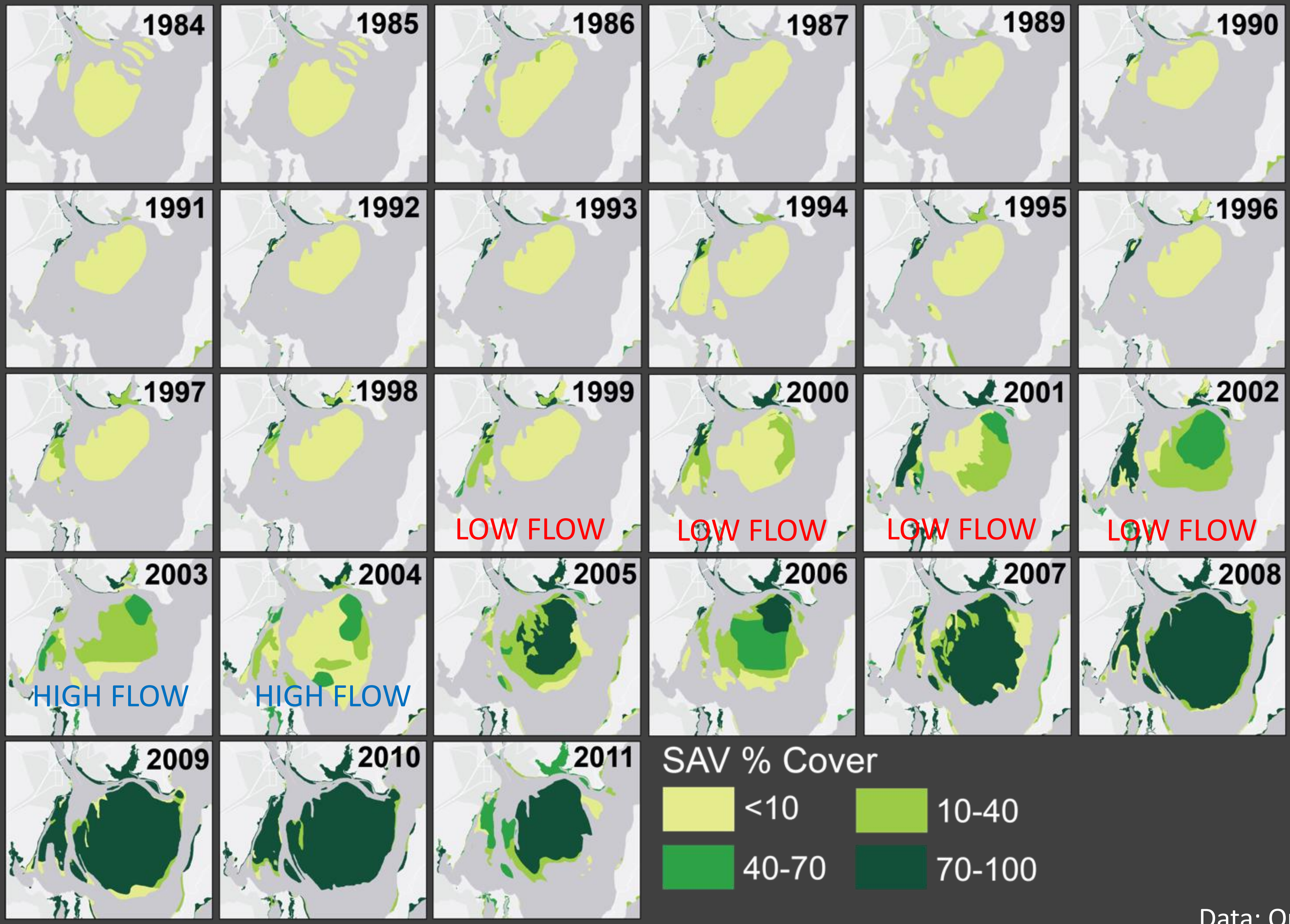
Mattawoman Creek,
Susquehanna Flats,
Gunston Cove

- Recovery may also follow a similar trajectory as degradation, but only after a delay…a lag time

SAV Recovery in the Susquehanna Flats



SAV in the Upper Chesapeake Bay: Drought response and storm resilience

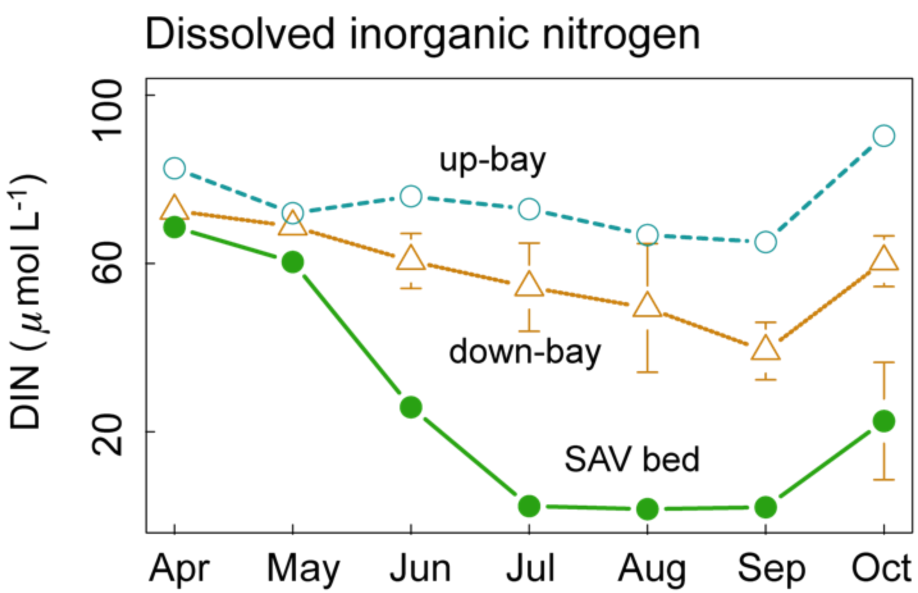


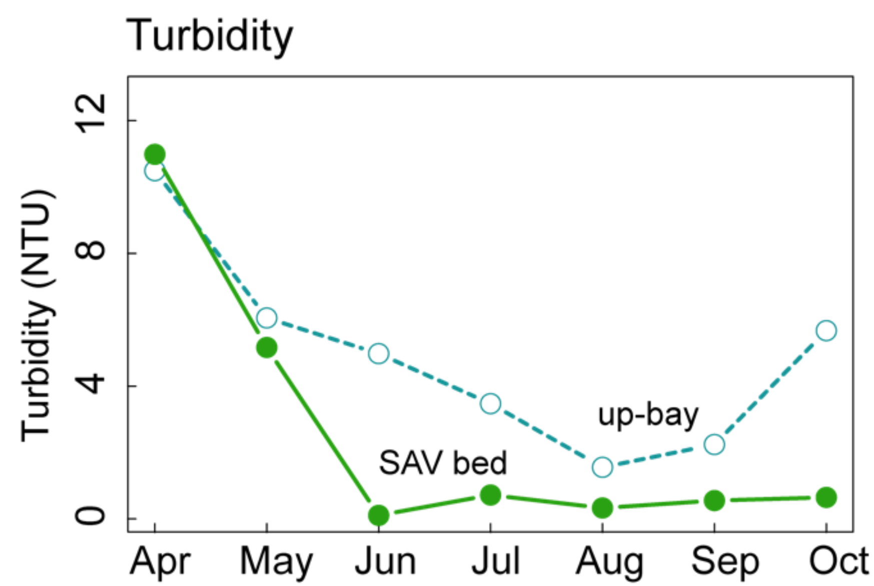
Data: Orth/VIMS

Strong Feedbacks influence Tipping Points

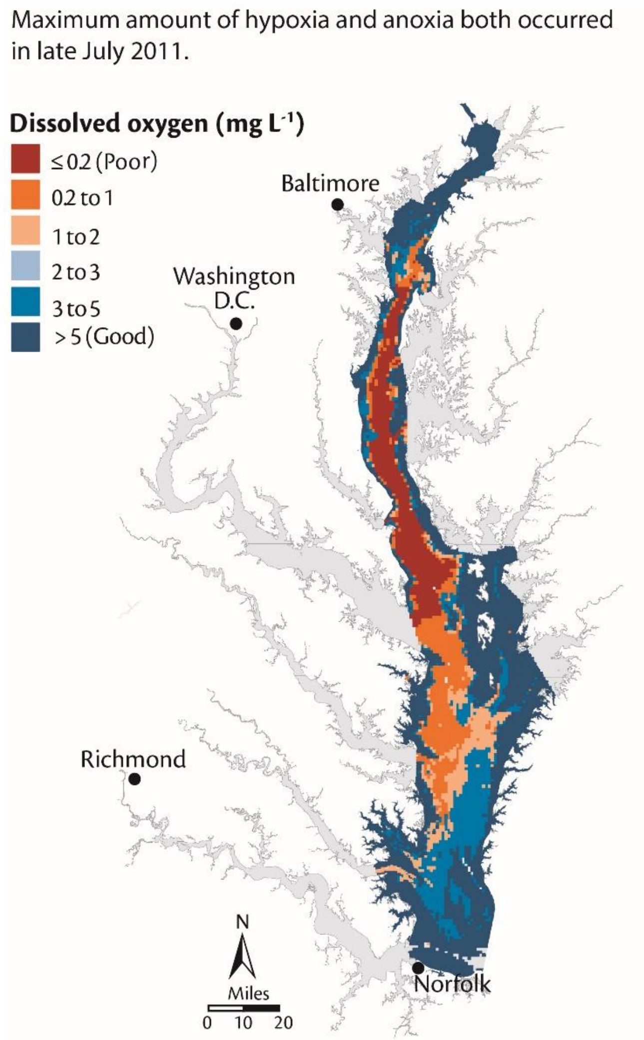
- SAV bed strongly reduces nutrients in the bed and even reduces nutrients downstream of the bed

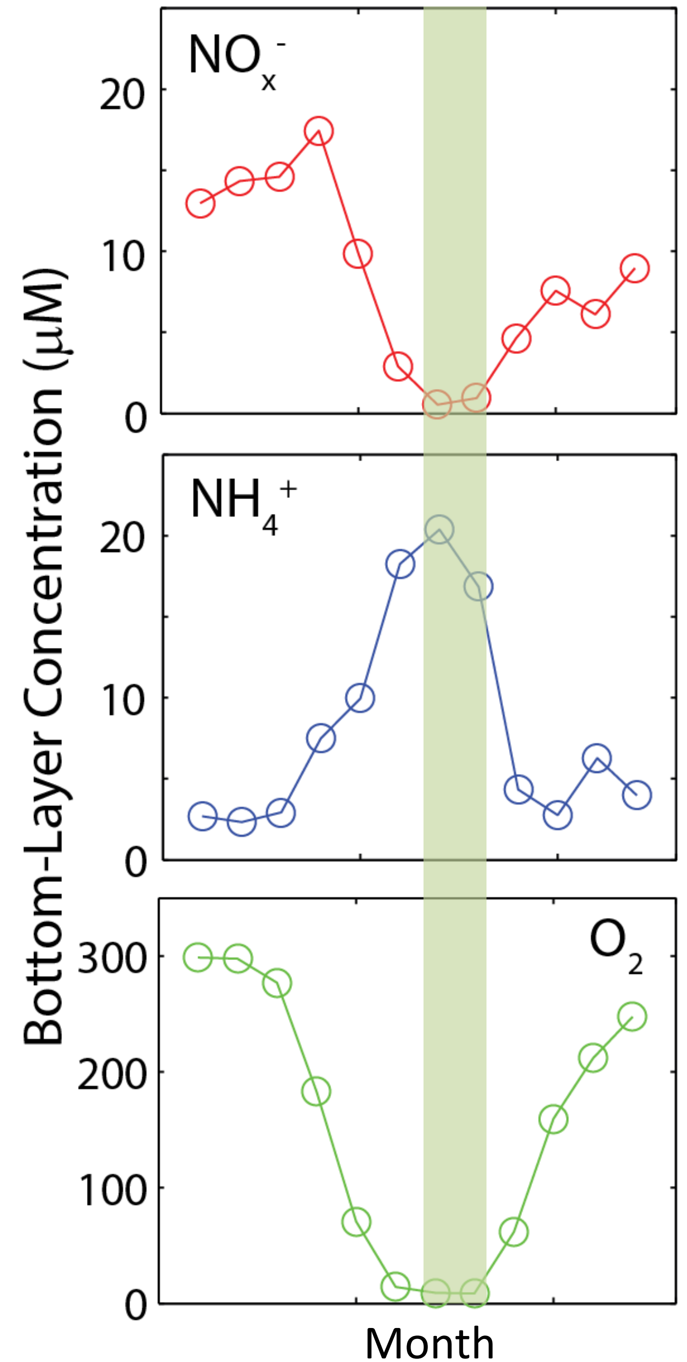
- Likewise, water clarity is better in the bed than up-stream of the bed
- Such "feedbacks" help the Bay "get better"…and it's free!





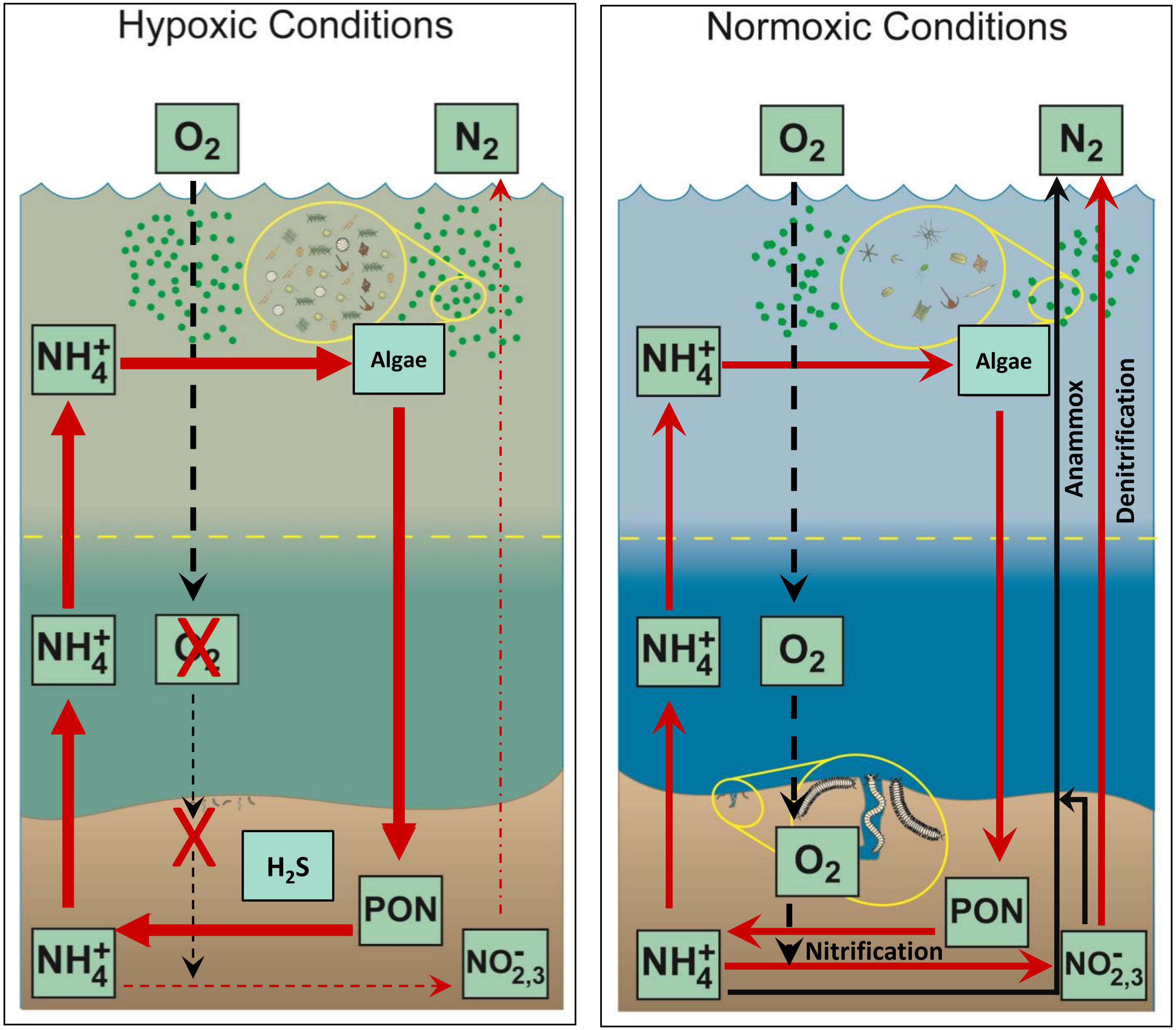
Tipping Points and Hypoxia



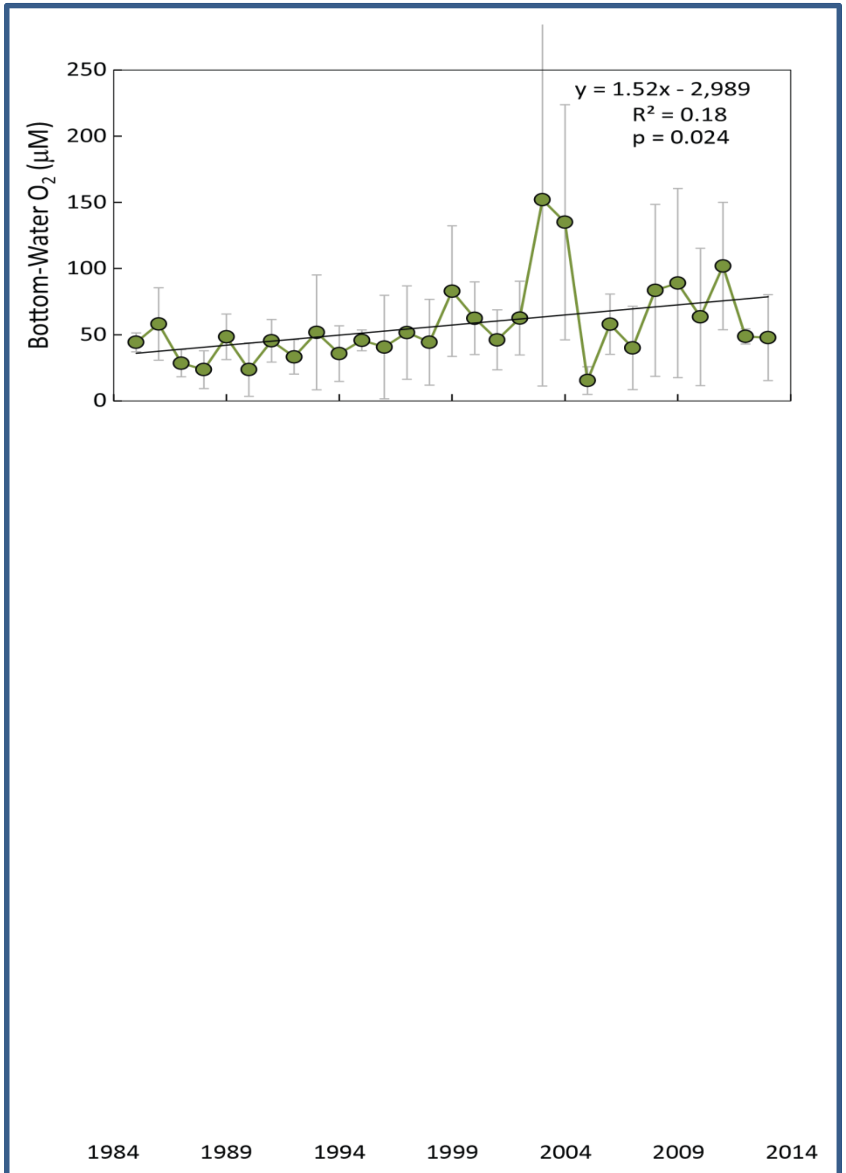


Hypoxia Occurs at Roughly The Same Time Each Year…..and it controls the availability of nitrogen

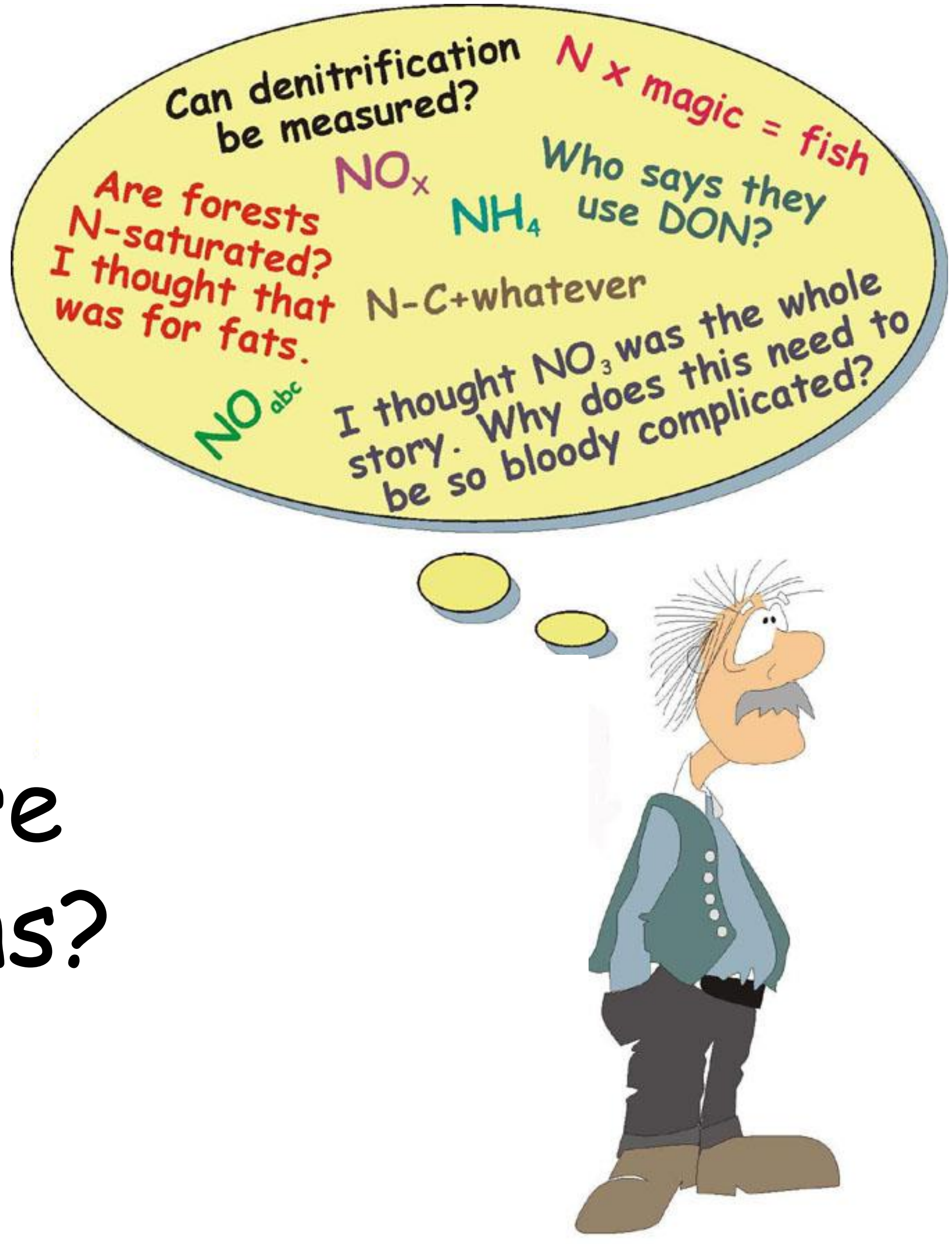
Tipping Points: Oxygen Interactions with Nitrogen



Long-Term Bay Trends for O_2, NH_4, & NO_3 in Late Summer



- Significant trends over 3 decades
- Late-summer mean values
- Increasing **dissolved oxygen**
- Decreasing **ammonium**
- Increasing **nitrate**
- Hypoxic region of Bay is becoming less hypoxic…an important sign of recovery

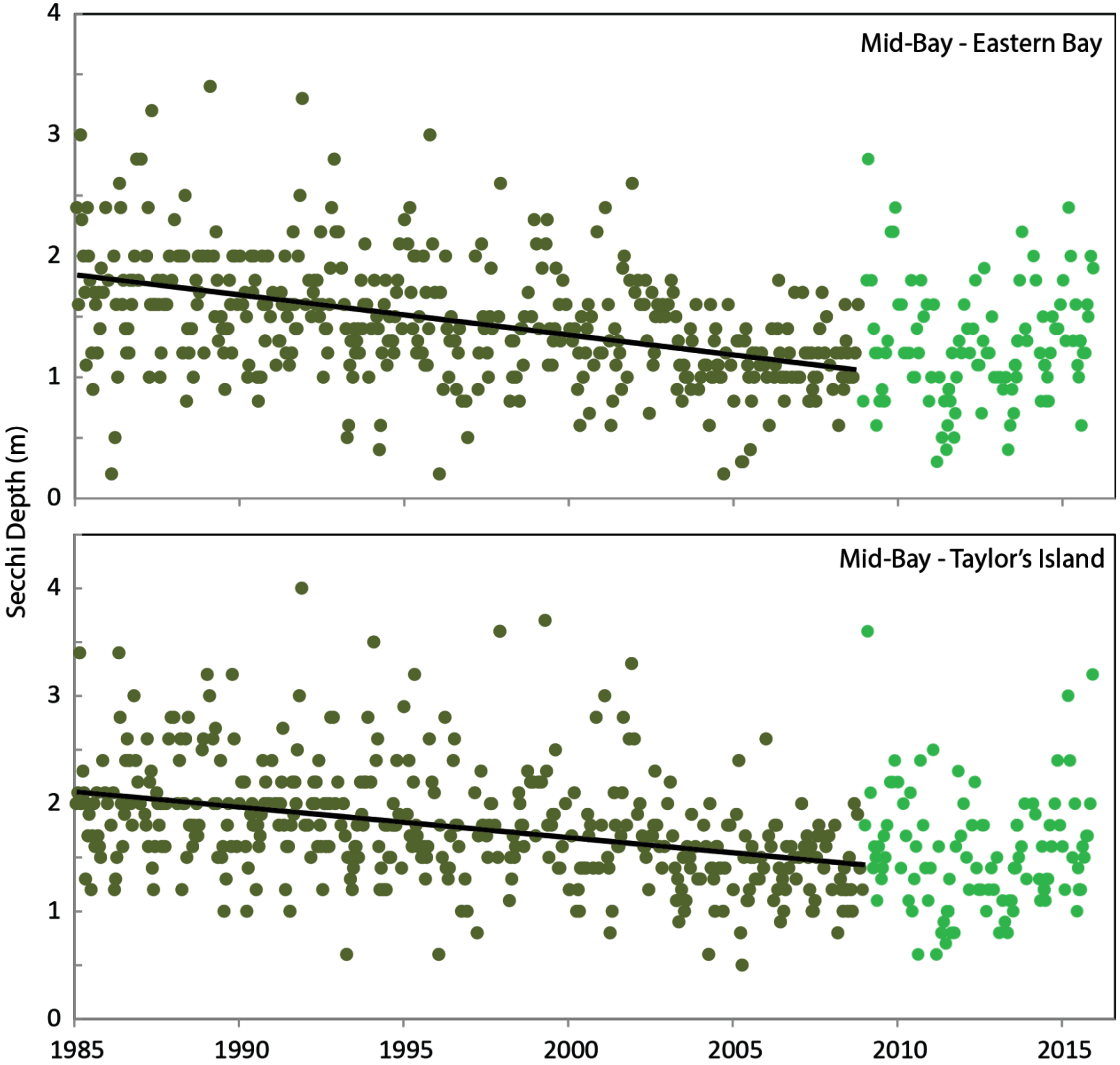


Any more questions?

What are the Challenges?

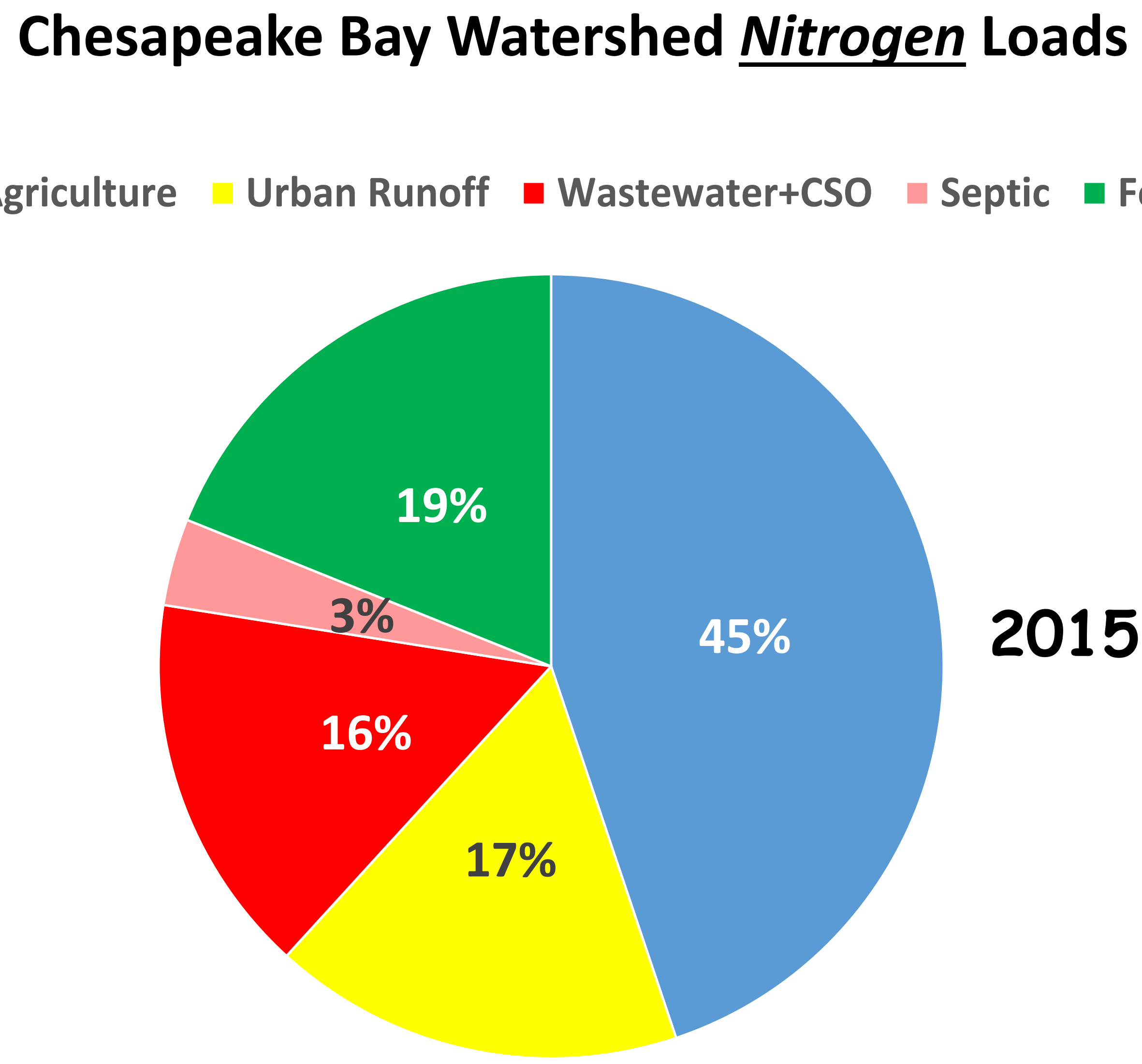
(1) Water Clarity
(2) Keep Reducing Nutrient Inputs!
(3) Climate Change
(4) Maintain Monitoring and Analysis

Challenge #1: Water clarity



- Secchi Depth measure the light available for SAV – but it is also an index of nutrient and sediment loading problems

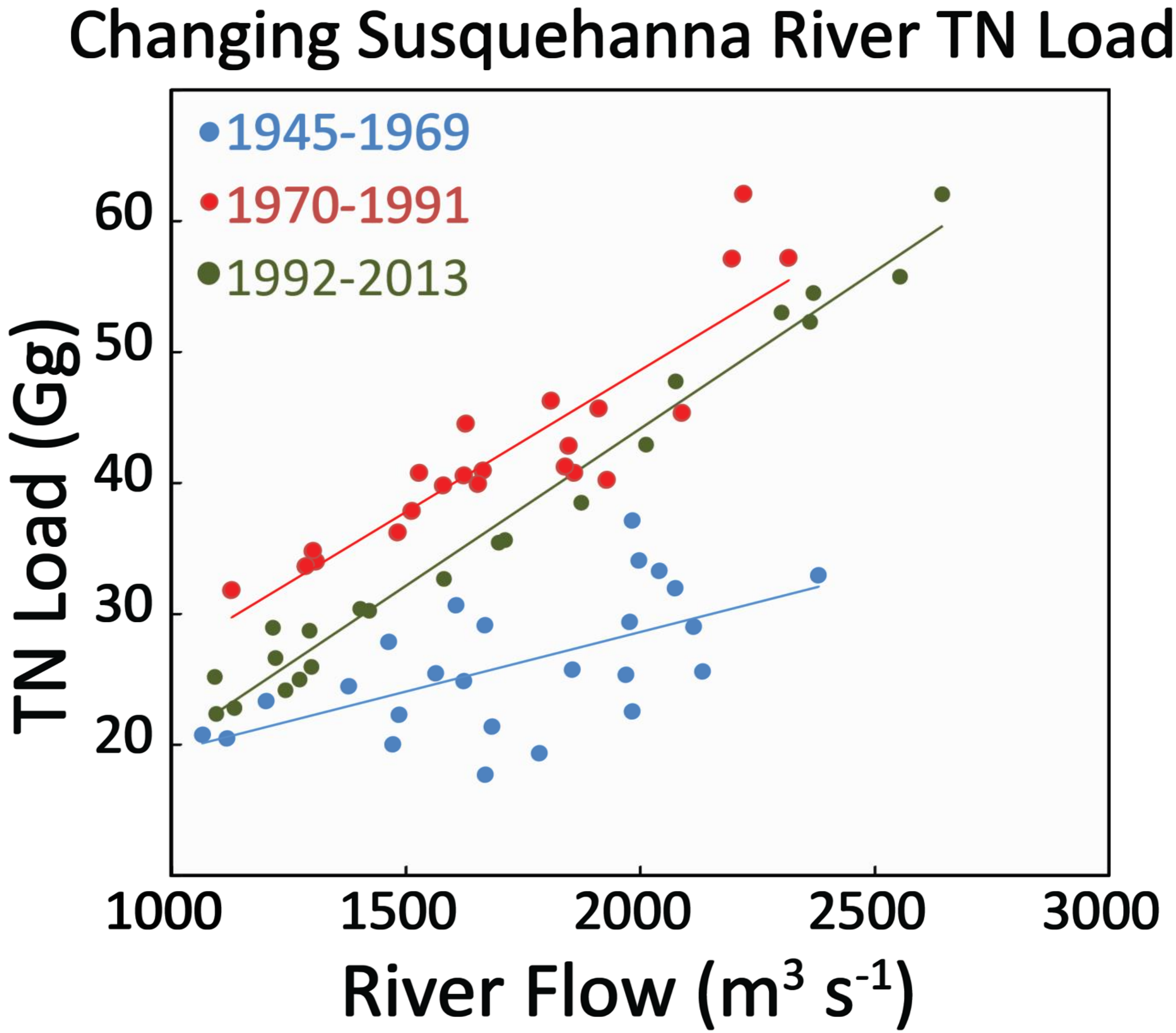
Challenge #2: Keep Reducing Nutrient Inputs!



Source: Chesapeake Bay Program

Water Year	Annual-Mean Streamflow to Bay	Flow Classification	Relative Magnitude of Streamflow
2017 (current)	--	--	
2016	71600	Normal	
2015	63500	Below Normal	
2014	81300	Normal	
2013	76000	Normal	
2012	80000	Normal	
2011	113000	Above Normal	
2010	79900	Normal	
2009	63400	Below Normal	
2008	74300	Normal	
2007	79500	Normal	
2006	77500	Normal	
2005	87600	Normal	
2004	118000	Above Normal	
2003	119000	Above Normal	
2002	45400	Below Normal	
2001	52600	Below Normal	
2000	70600	Normal	
1999	45600	Below Normal	
1998	106000	Above Normal	
1997	89800	Above Normal	
1996	115000	Above Normal	
1995	59900	Below Normal	
1994	107000	Above Normal	
1993	101000	Above Normal	
1992	60400	Below Normal	
1991	84000	Normal	
1990	75600	Normal	
1989	76400	Normal	
1988	59300	Below Normal	
1987	78100	Normal	
1986	78100	Normal	
1985	56800	Below Normal	
1984	108000	Above Normal	
1983	75900	Normal	
1982	75100	Normal	
1981	49200	Below Normal	
1980	86000	Normal	

Source: USGS (http://md.water.usgs.gov/waterdata/chesinflow/wy/)

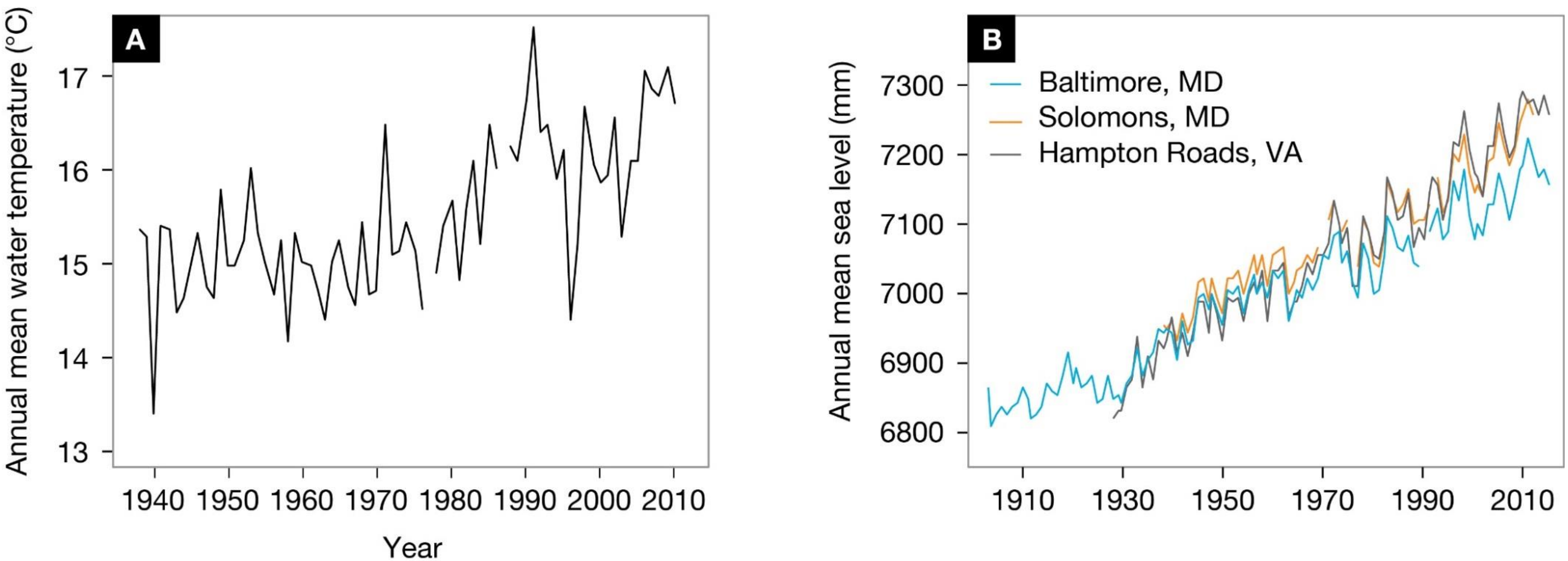

Changing Susquehanna River TN Load
1945-1969
1970-1991
1992-2013
TN Load (Gg)
60
50
40
30
20
1000
1500
2000
2500
3000
River Flow (m3 s-1)

Challenge #3: Climate Change

Temperature and sea level rise both clearly observed

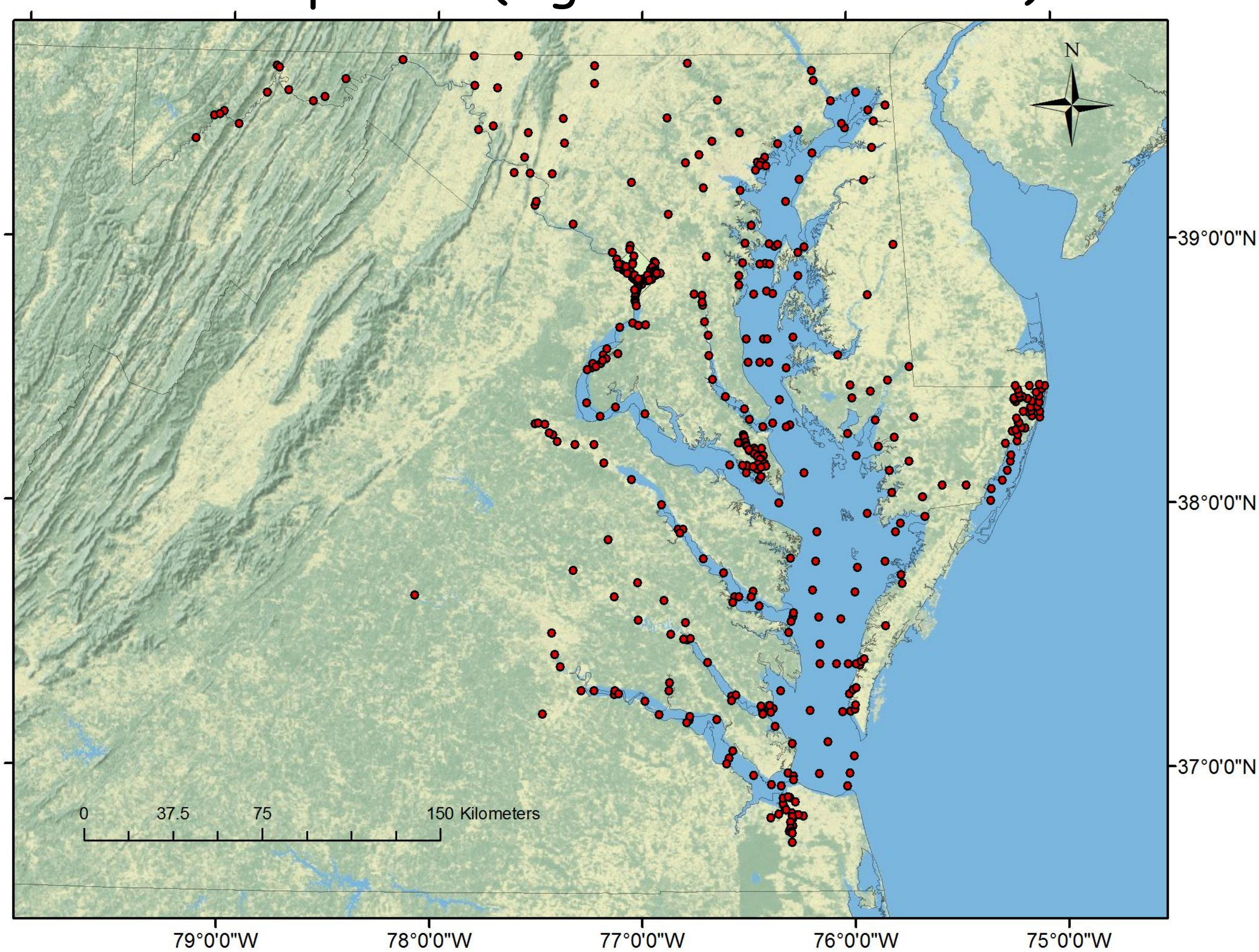
- Temperature increases will influence hypoxia, plants and animal function and distribution and other processes as well

- Sea level rise will also have multiple effects including shoreline and tidal marsh erosion



Orth et al., in review

Challenge #4: Monitoring and Analysis
Keep core going; be adaptive; utilize new technologies when proven (e.g. nutrient sensors)



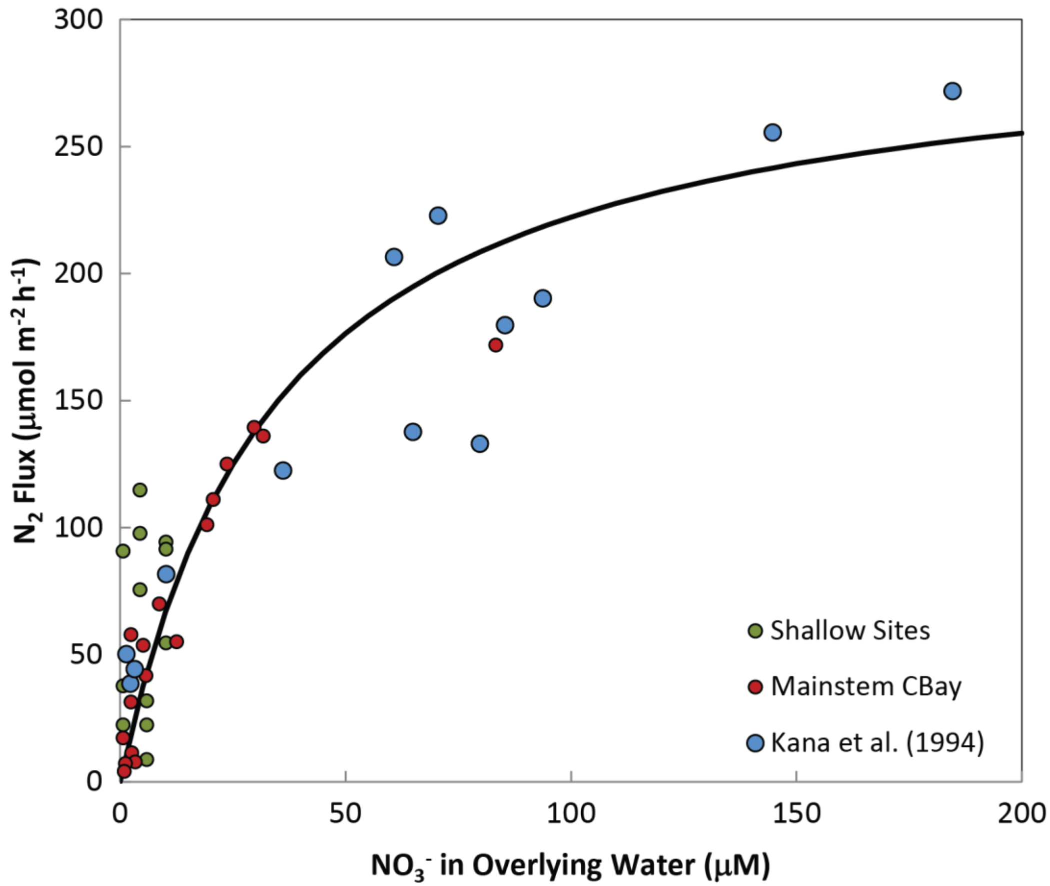
Chesapeake Bay Program water quality monitoring sites (Cole 2011).
These sites represent a compromise between SCIENCE, MANAGEMENT AND POLITICS.

Take-Home Points

- Basic ideas of enrichment and restoration are scientifically solid
- Substantial reductions of N and P result in improved water quality and better habitat conditions…the Bay is RESPONSIVE to load changes
- The pathways estuaries follow during degradation and restoration often involve time delays (lags), abrupt changes (thresholds) and other things not yet known or fully understood – or predictable!
- Restoration trends (and hints of trends) have been observed in both small and large Chesapeake systems…very good signs!
- Climate change and variability, continued and adaptive monitoring and analysis, control of diffuse sources all major challenges

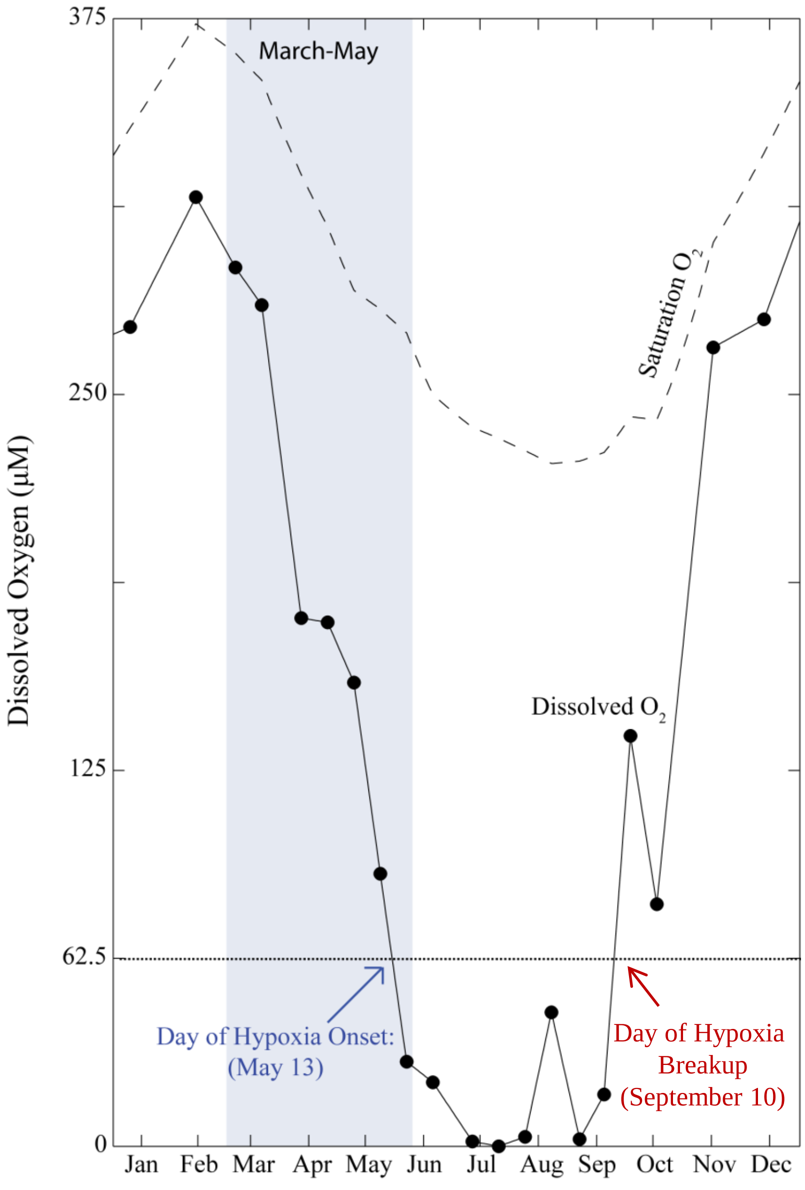
Extra Slides

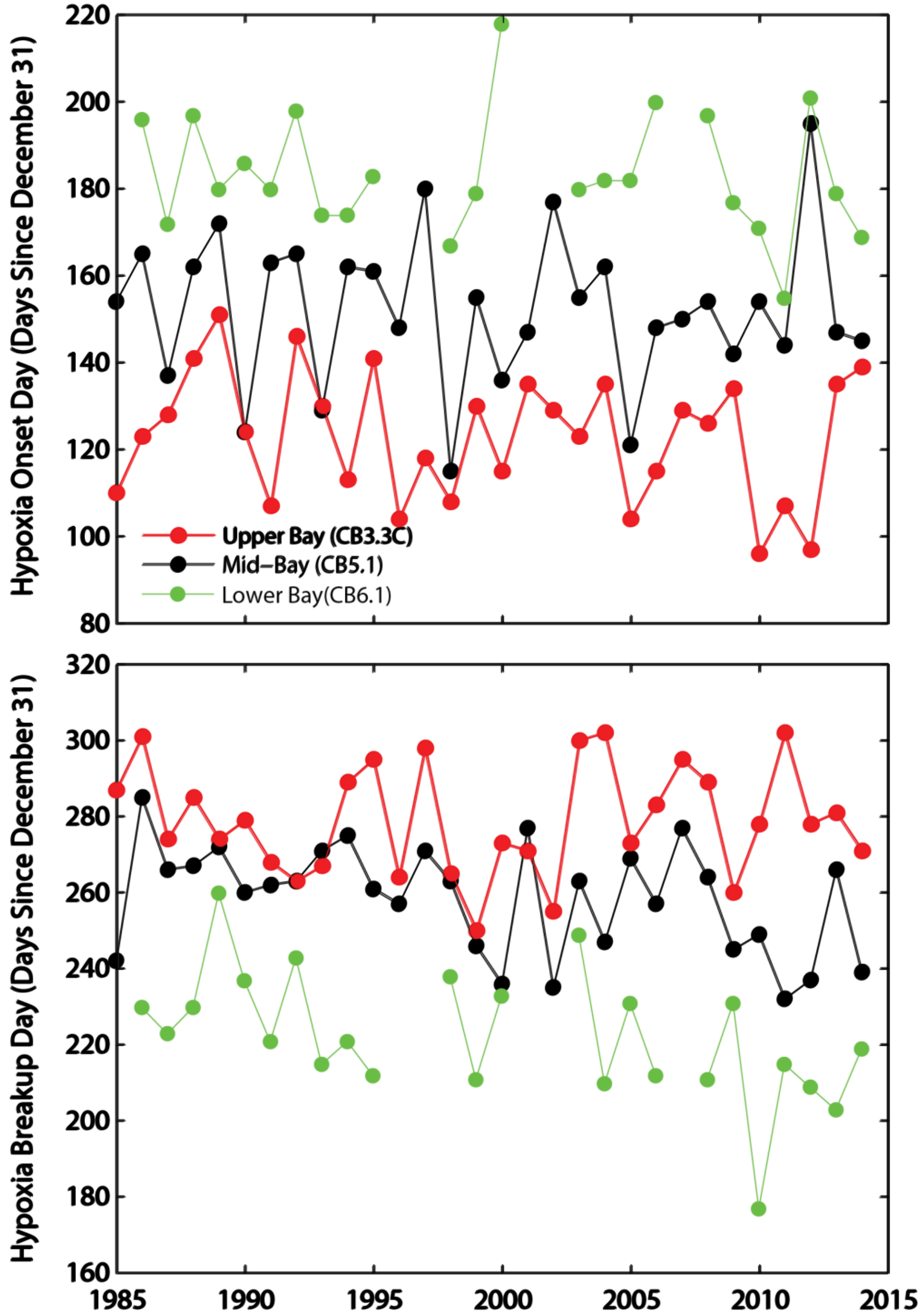
View of the Conowingo Dam on the Susquehanna River in the aftermath of Tropical Storm Lee taken Sept. 12, 2011. Discharge at time of the photo was 220,000 cubic feet per second. Peak discharge for the flood was 778,000 cubic feet per second at 4 a.m.on Sept. 9, 2011. Photo by Wendy McPherson, U.S. Geological Survey.



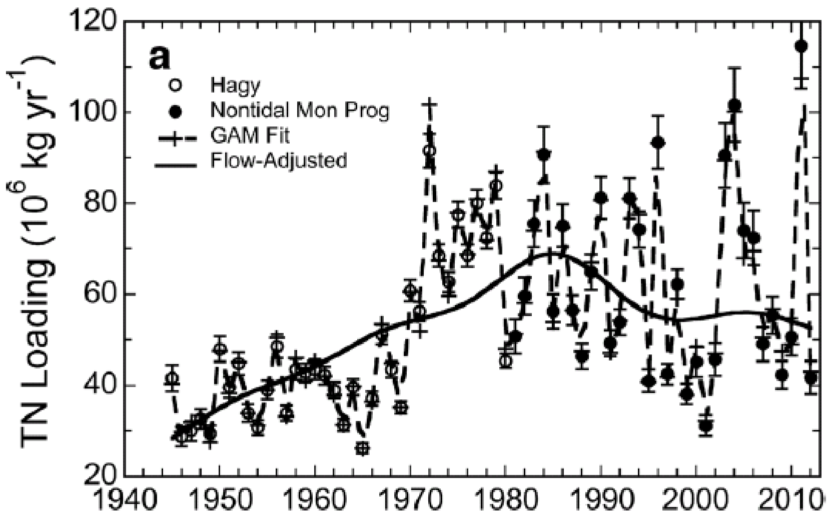
300
250
200
150
100
50
0
0
50
100
150
200
N_2 Flux (µmol m^{-2} h^{-1})
NO_3^- in Overlying Water (µM)
Shallow Sites
Mainstem CBay
Kana et al. (1994)

Hypoxia Timing

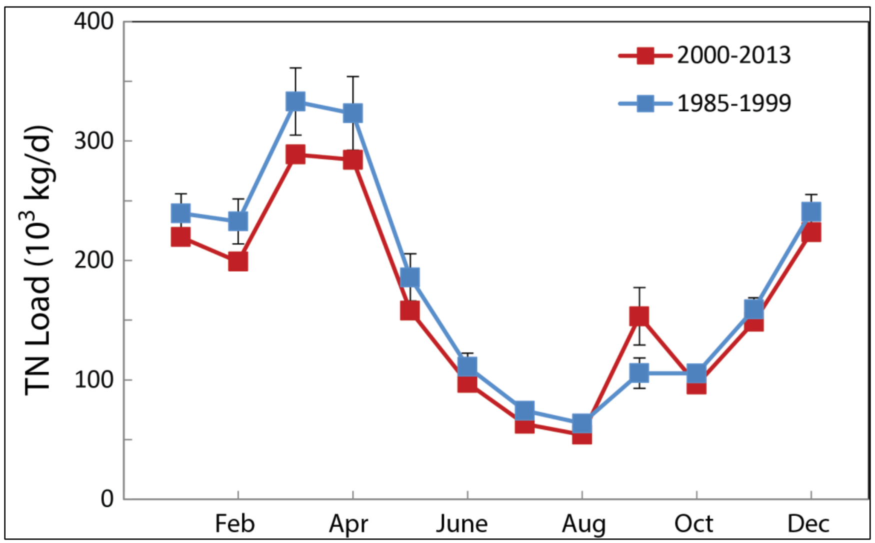




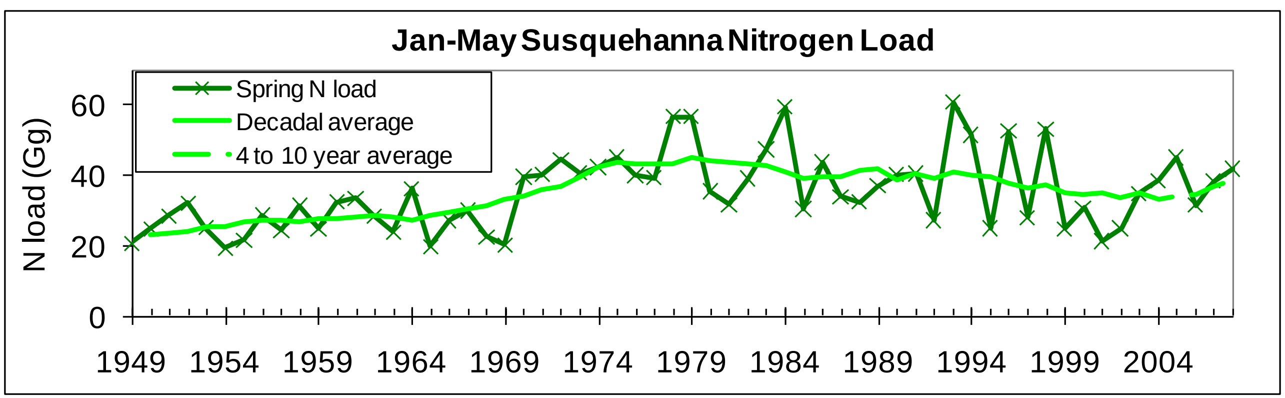
Modest Declines in Susquehanna N Load



Annual Loads - Harding et al. (2015)



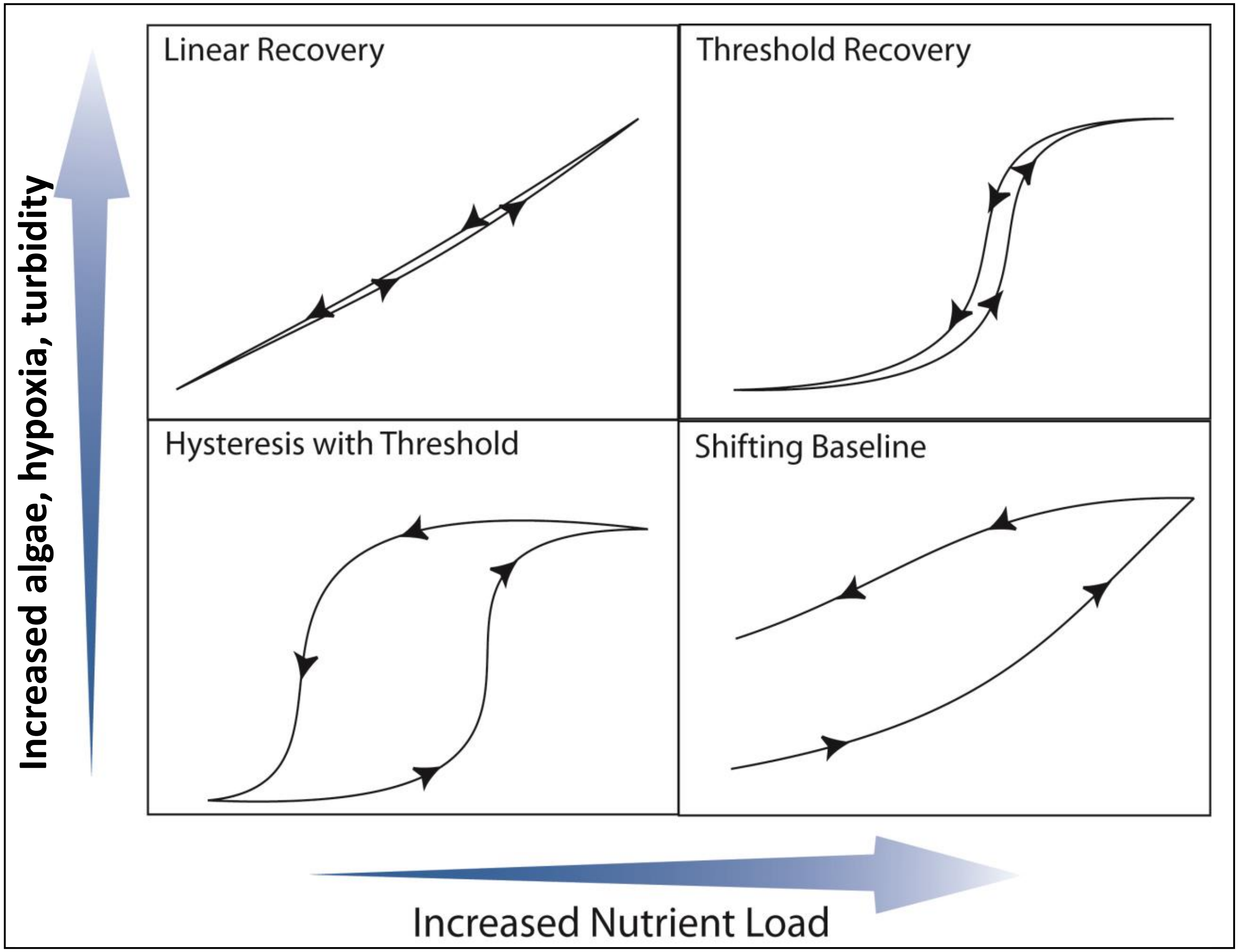
Testa (unpublished) using USGS data



Murphy et al. (2011)

Ecosystem Responses to Nutrient Degradation and Remediation

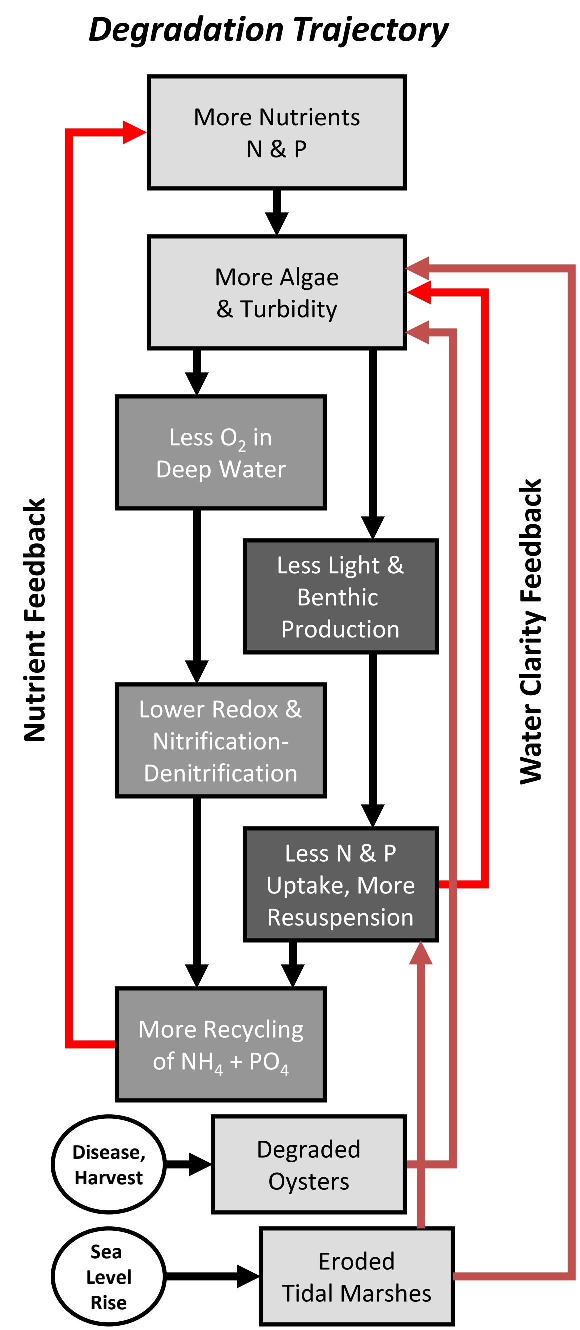
we need to keep these things in mind



Degradation Trajectories…

where things are not so simple

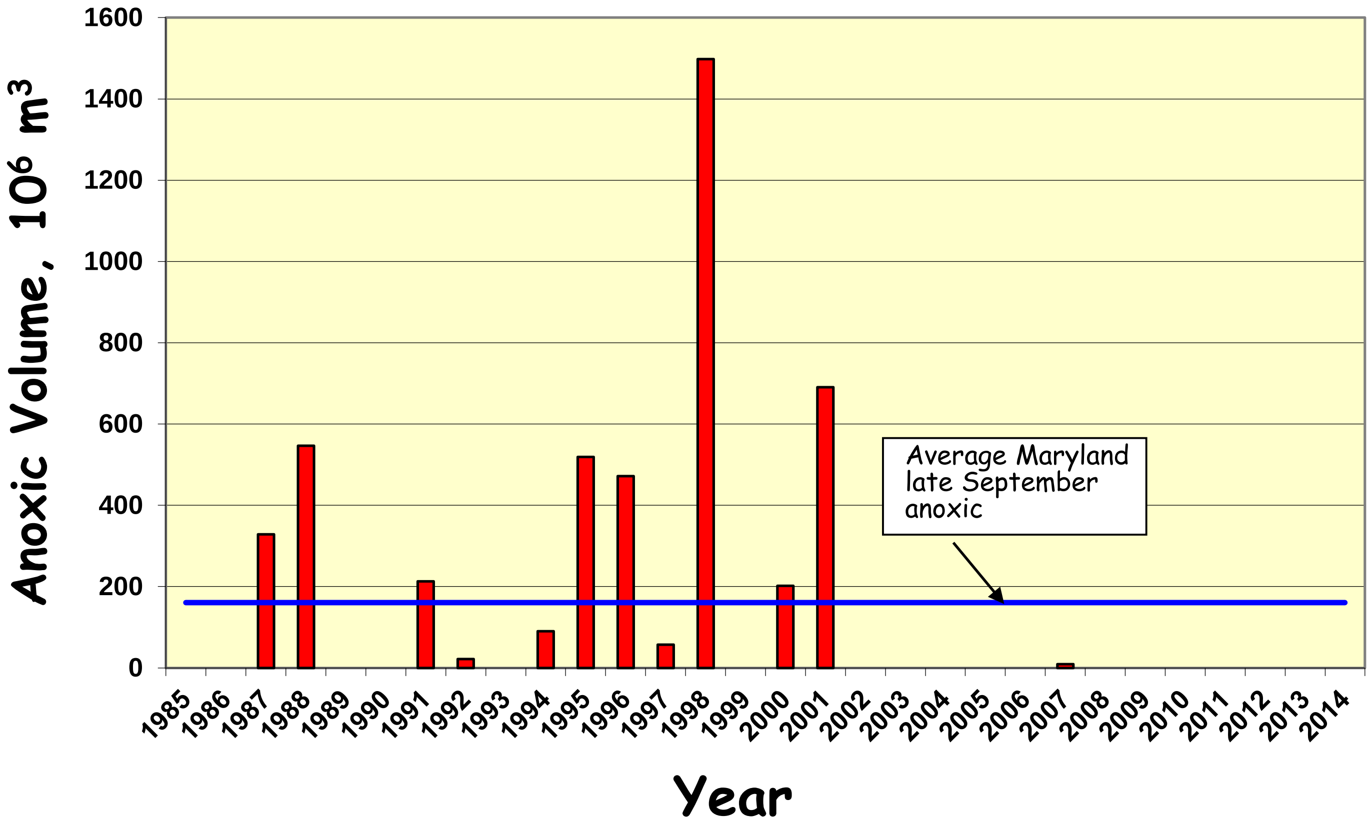
- Positive & negative feedbacks
- N & P inputs affect hypoxia & light
- Hypoxia leads to more nutrients, more algae, & more hypoxia
- Turbidity leads to less SAV causing more turbidity, less SAV
- Loss of oysters & marshes tend to reinforce these feedbacks



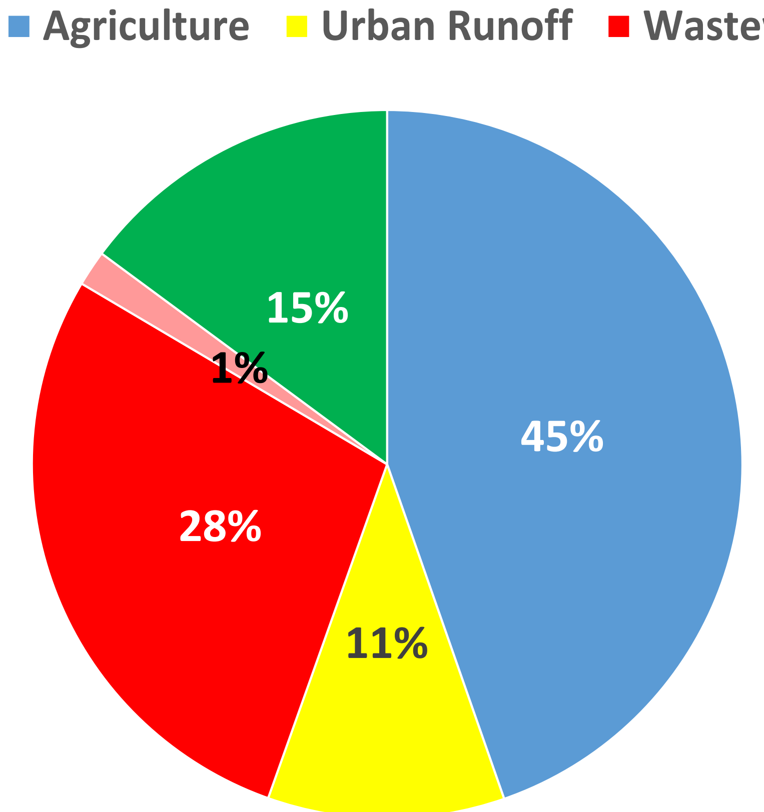
(Kemp et al. 2005)

MD Bay Anoxia: September Data

(0 - 0.2 mg/L)



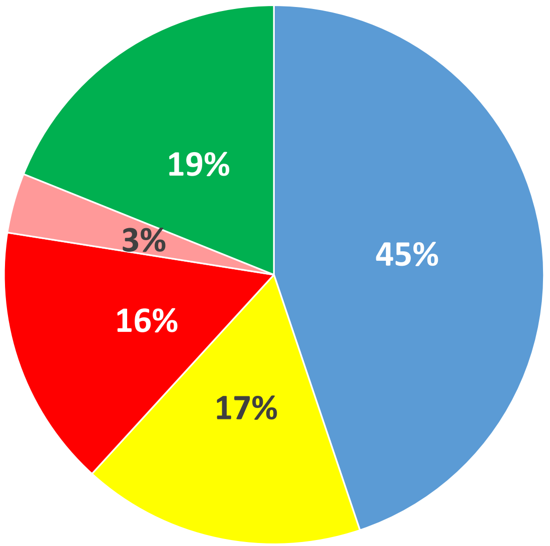
Chesapeake Bay Watershed Nitrogen Loads



1985

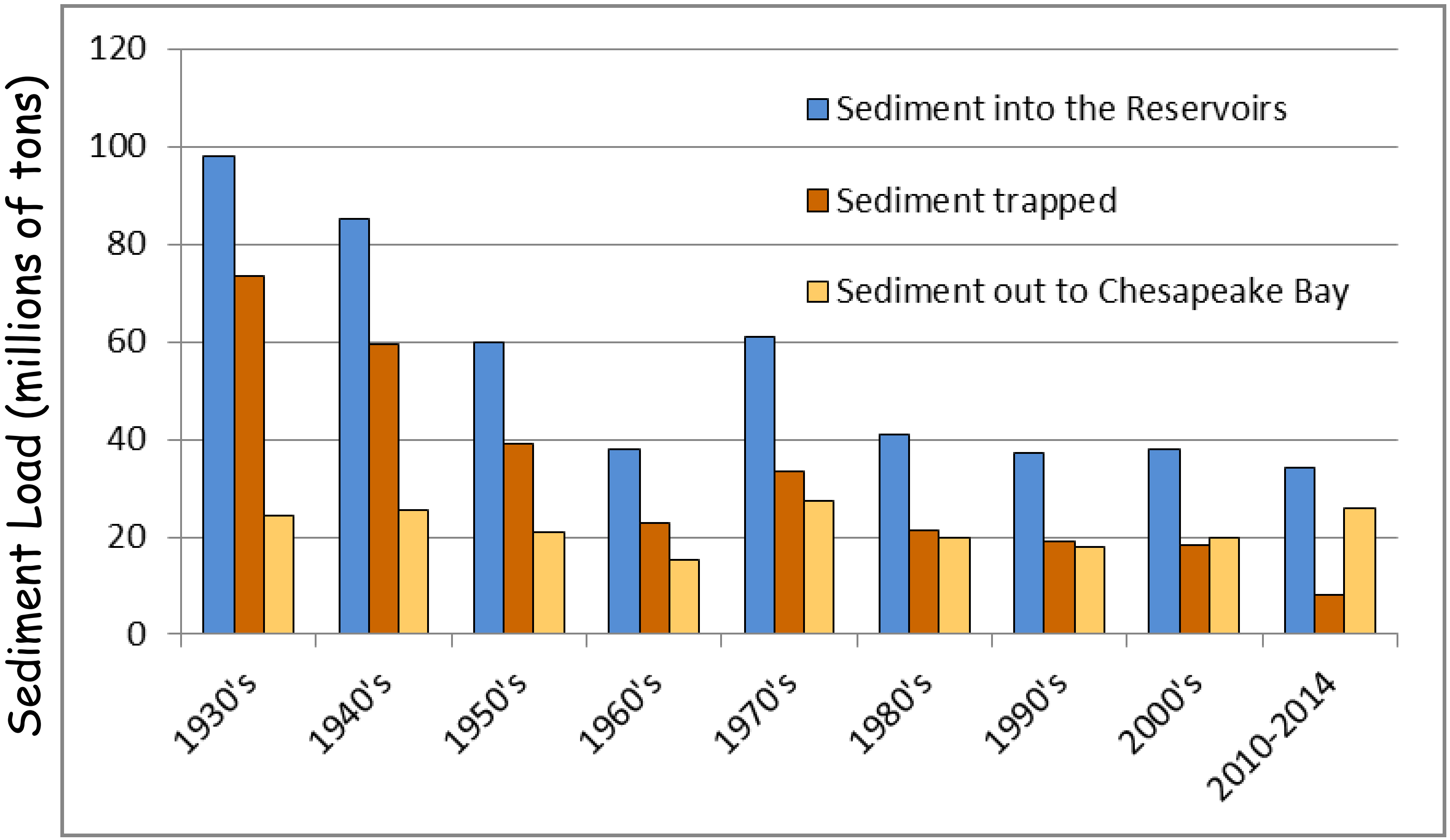
Where did the Nitrogen reductions come from?

Agriculture	39%
Wastewater	59%
Forest	2%



2015

Trapping Significantly Decreased over Last Century: Now Considered to be in Dynamic Equilibrium



Source: Langland 2016

Trend of average Nitrate (NO_3) and Ammonia (NH_3) deposition concentrations across the Bay watershed