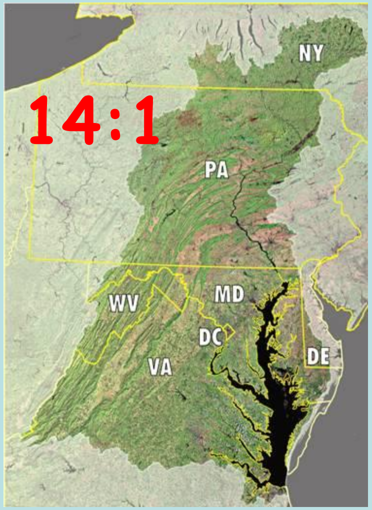
NUTRIENTS: The Good, the Bad and the TMDL

Chesapeake Bay Commission

September 2015

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



Large Drainage Basin

Only 0.2 acres per person for dilution of wastes

Walt Boynton and many Colleagues

Center for Environmental Science, Univ MD

Topics for Today

- Some definitions concerning nutrients
- How nutrients influence Bay ecology
- It's complicated…lots of interactions
- The TMDL…a nutrient diet for the Bay
- A few success stories
- All this in 30 minutes…so let's get going!

Some Definitions: Nutrient Ecology 101

Eutrophication: An increase in plant production (mainly algae) based on excessive nutrient inputs…creates "dead zones", turbid water and loss of SAV

Nutrients: Mainly NITROGEN and PHOSPHORUS.
Many different kinds of N and P…some biological active…some not
Ammonium (NH_4) and Nitrate (NO_3) can be used directly by plants
Dissolved Phosphate (PO_4) can be used directly by plants
Other forms of N and P must be "re-mineralized" before plant use

Sediments: Mainly very small INORGANIC particles…dirt suspended in the water.
Chesapeake sediments are rich in iron and that plays a role in P dynamics

Denitrification: A biological process (microbes do it) that removes nitrogen from the water and transforms it to nitrogen gas which is released to the atmosphere

Thresholds: A "sudden and large" response to a relatively small change in some controlling variable (e.g., just a bit more N and the "dead zone" increases a lot)

Lag Times: A delay in ecological response to an increase or decrease of a controlling variable (e.g., nutrients reduced but no water quality improvement for several years)

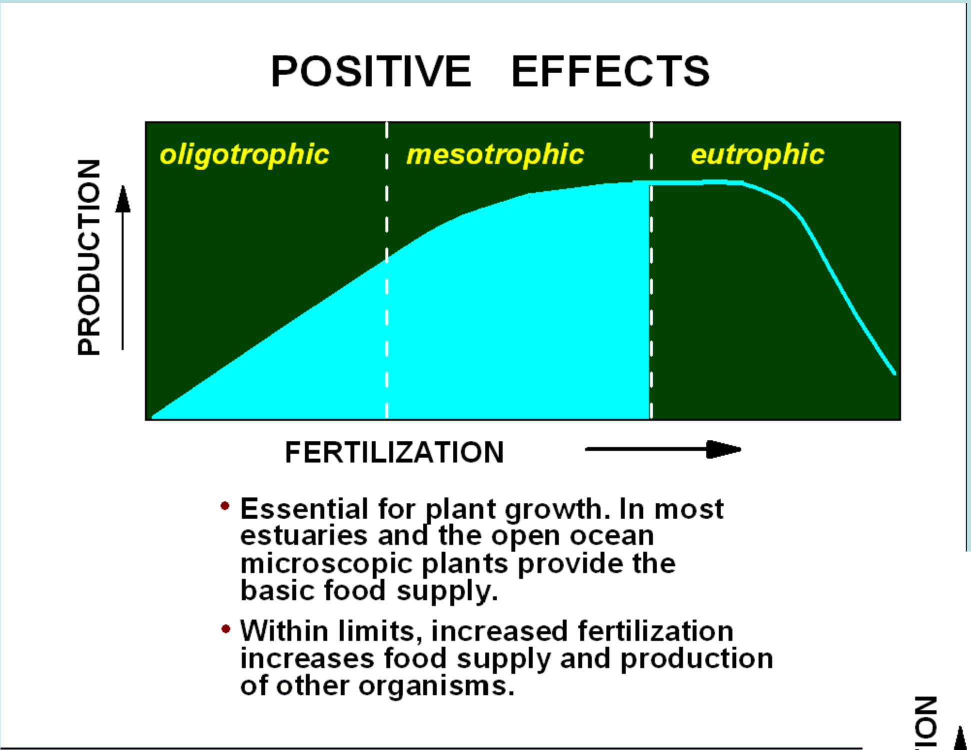
Major Nutrient Sources

Urban/Suburban Run-off

Summary

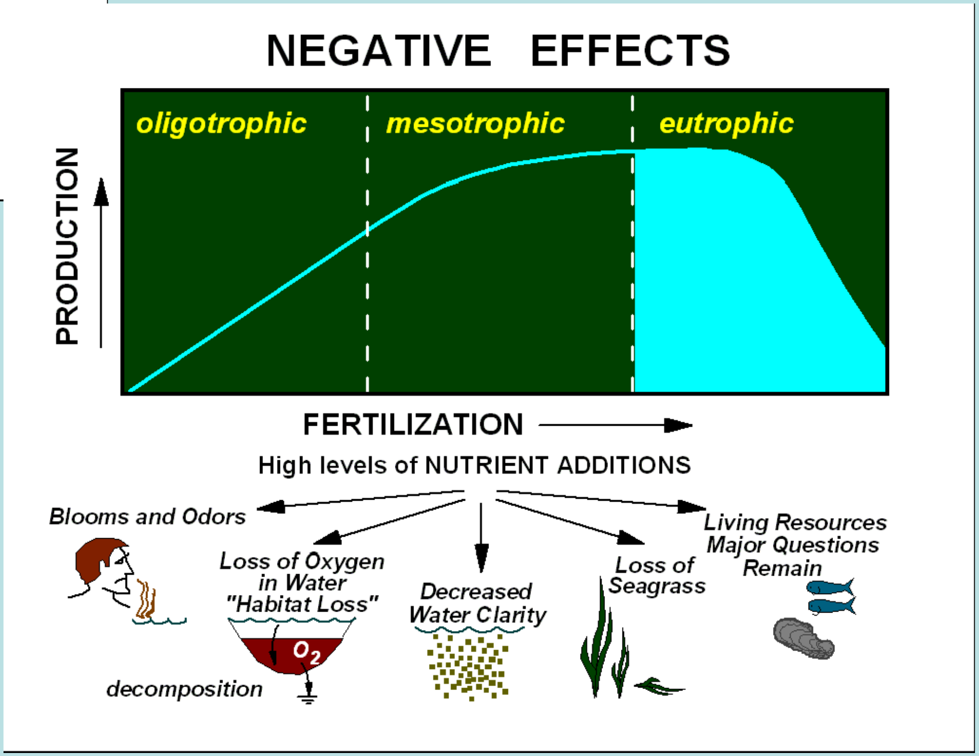
- All have increased during last 50 yrs
- Importance varies widely with location
- Most reductions with point sources

A simple conceptual model

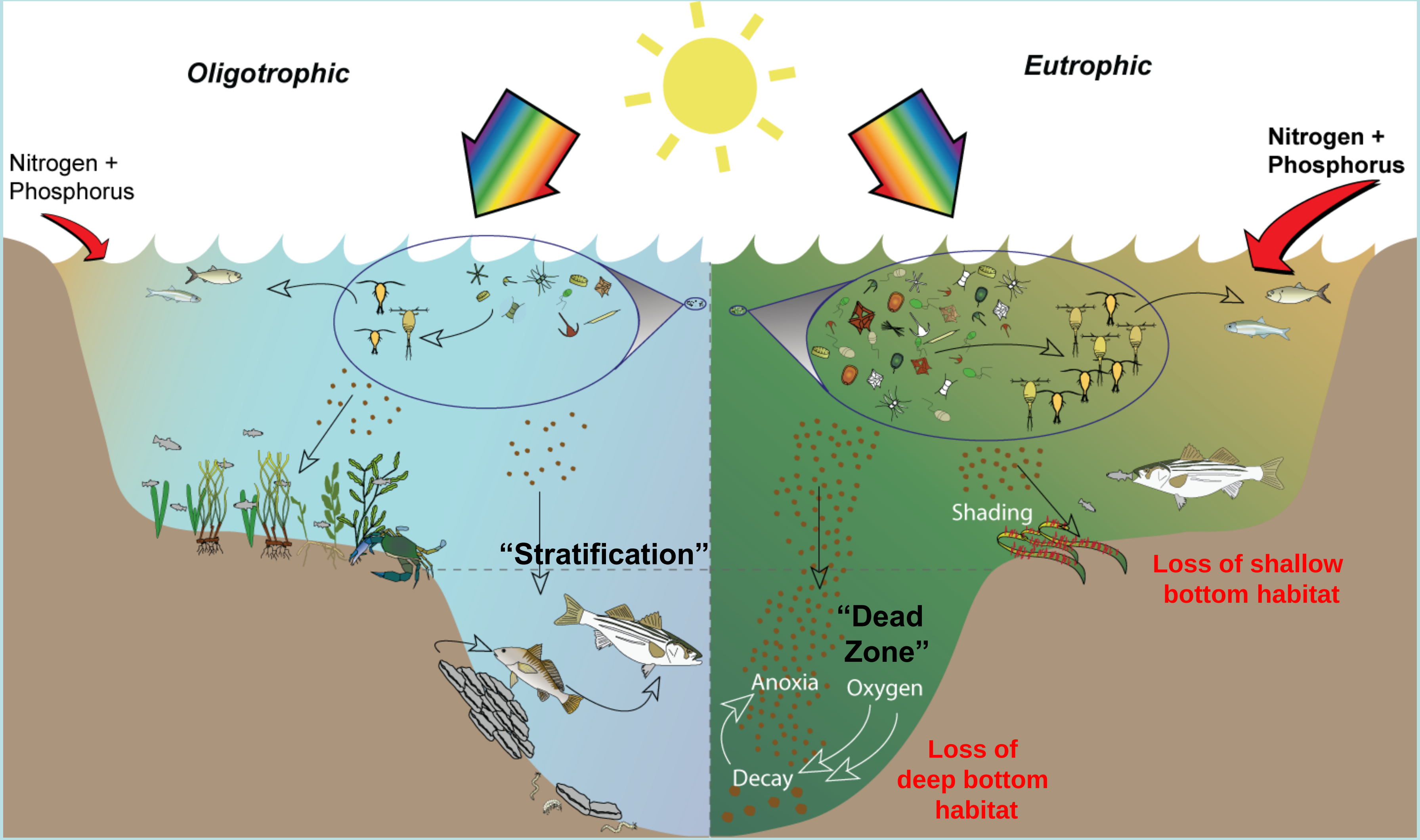


- Essential for plant and animal growth
- Within limits, increased fertilization increases production

- Beyond a certain level, additional fertilization has numerous negative effects
- A key management question concerns "what is the optimum level?"

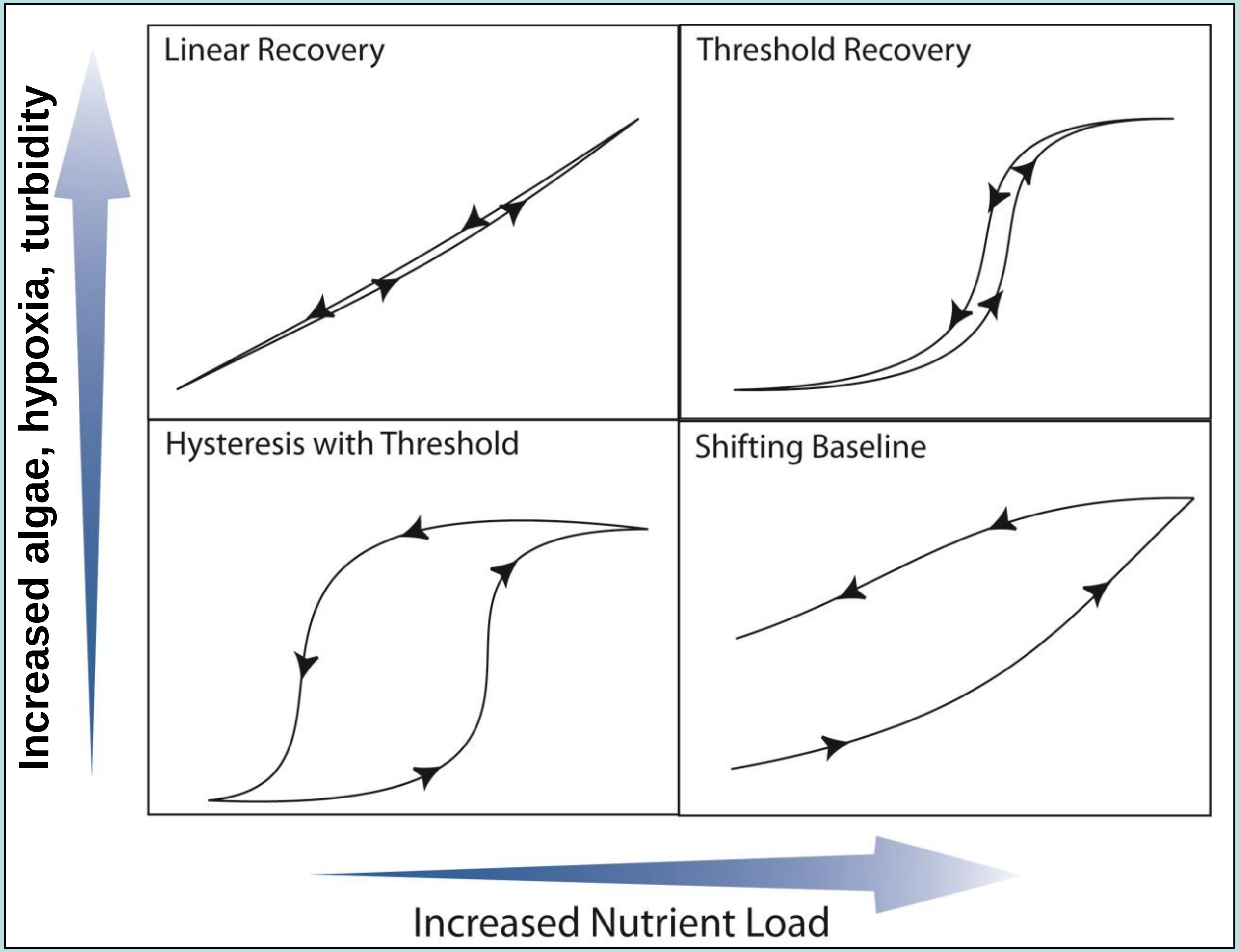


Basic Nutrient Enrichment Effects: Estuarine Ecosystems



Ecosystem Responses to Nutrient Degradation and Remediation

we need to keep these things in mind

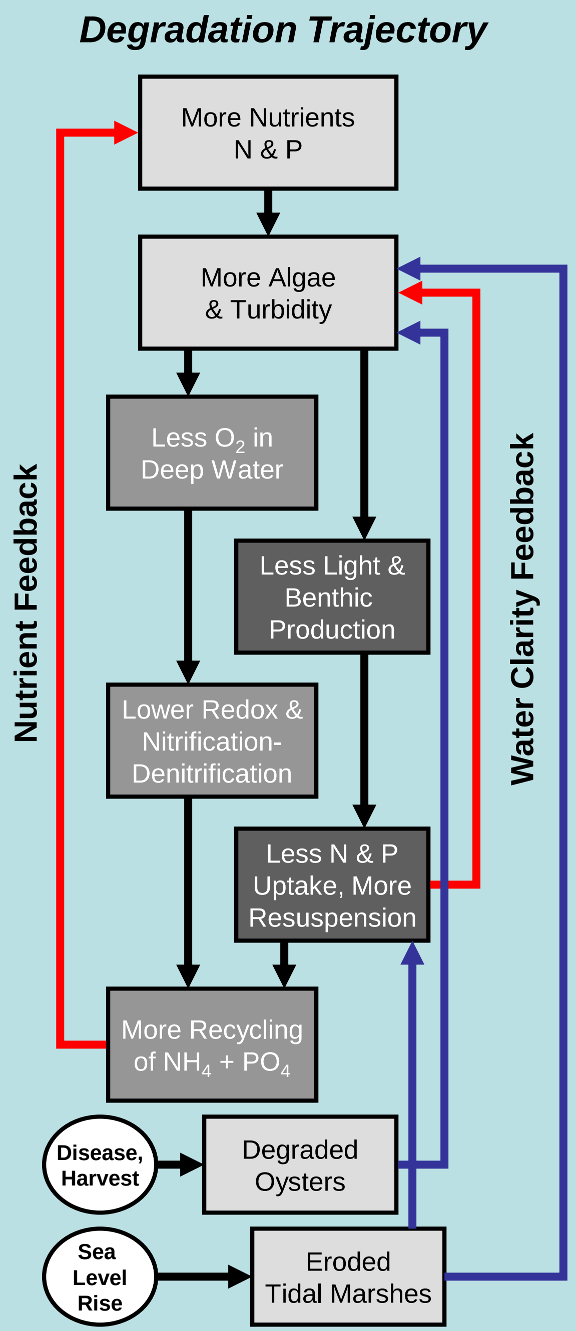


Degradation Trajectories…

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

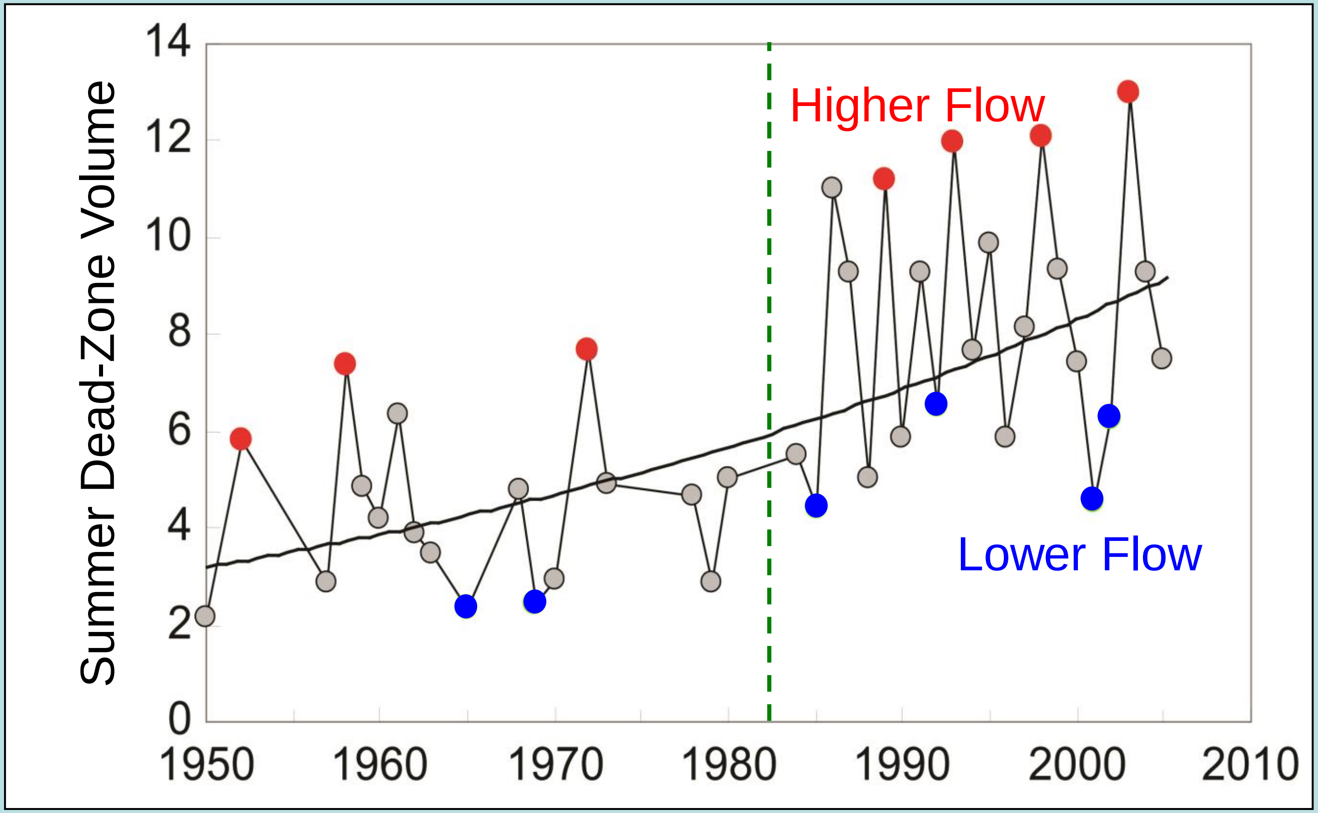
(Kemp et al. 2005)



One thing we are collectively sure of…

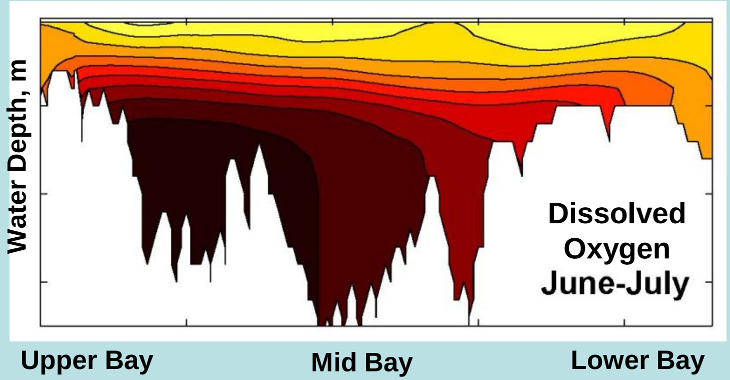
there is plenty of room for additional degradation if nutrient inputs increase

Trends in Bay Hypoxia…size of "dead zone"

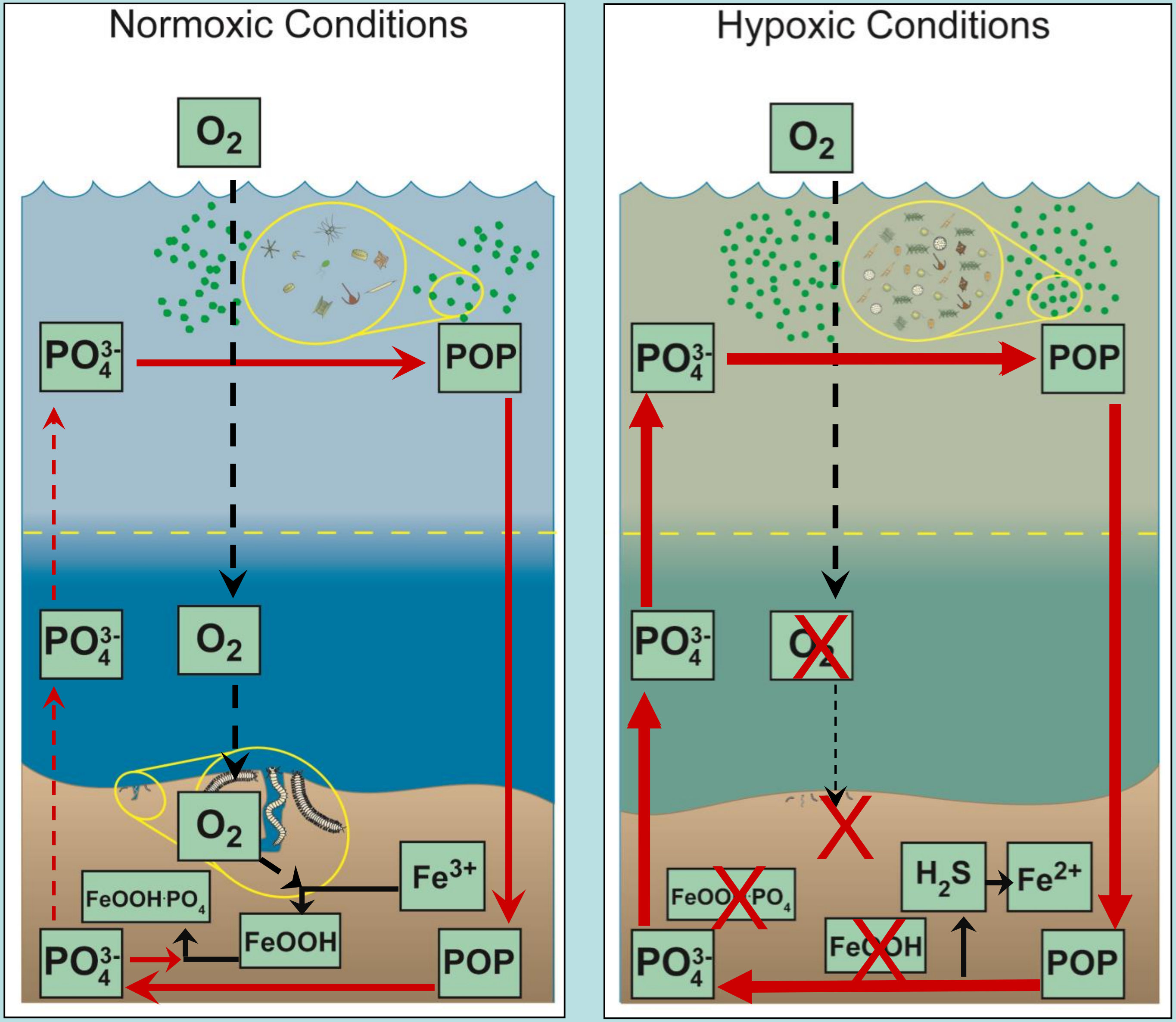


- Hypoxia highly variable between years
- More hypoxia during wet years
- Until recently generally increasing over time
- Current indications of reduced hypoxia in late summer…a sign of restoration progress

Average Summer DO Conditions

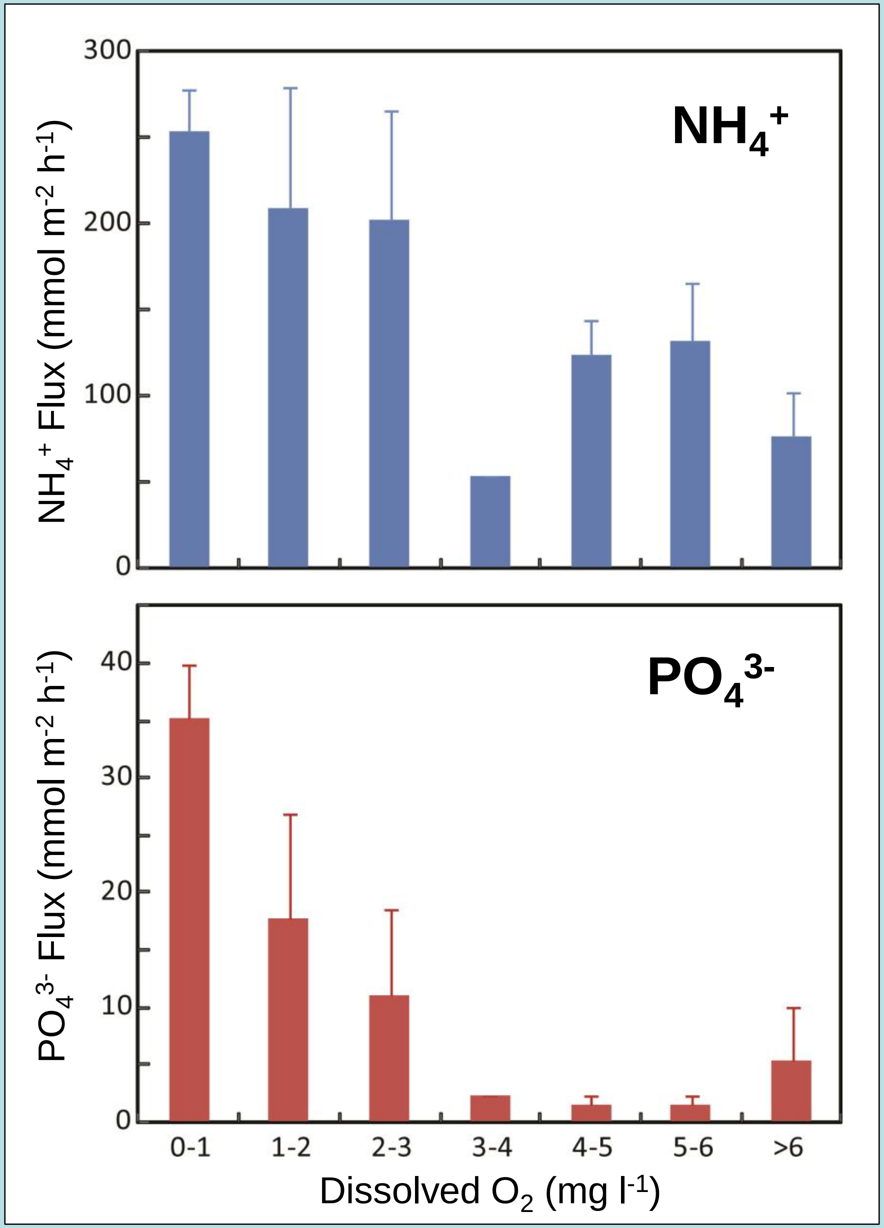


DO Interactions with Phosphorus Cycle: strong feedbacks



J. Testa, pers. comm.

Sediment Releases of N & P vs. Bottom DO



- Both N and P sediment releases decrease as bottom water DO increases
- Sediment P flux is particularly sensitive to DO conditions

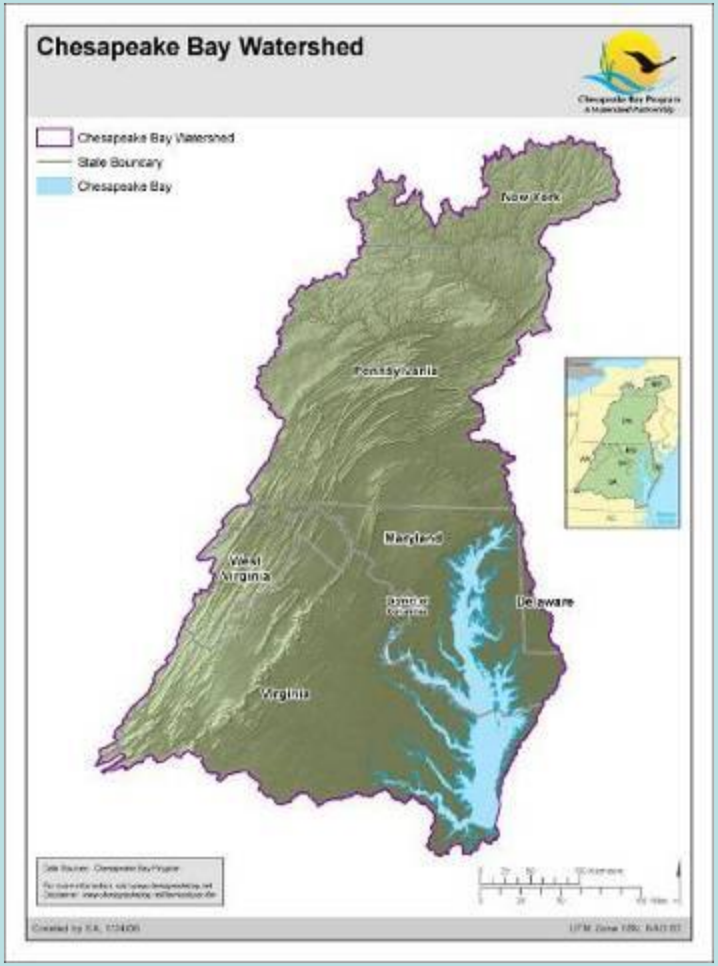
J. Testa, pers. comm.

The Chesapeake Bay TMDL

- EPA sets basin-State nutrient and sediment targets to meet clean water standards.

- <u>Caps</u> on nitrogen, phosphorus and sediment loads for all 6 Bay watershed States and DC

- With the State-basin targets the States set load caps for point and non-point sources



Chesapeake Bay TMDL

- Bay TMDL is the most comprehensive roadmap for restoration we have ever had for Chesapeake Bay.
- Addresses all sectors and major sources of nutrient and sediment pollution.
- Designed with rigorous accountability measures to ensure that all pollution controls needed to restore Bay are in place by 2025, with 60 percent by 2017.
- Restoration activities will protect and enhance the economic value of the Bay and rivers, and be a driver for local economies.

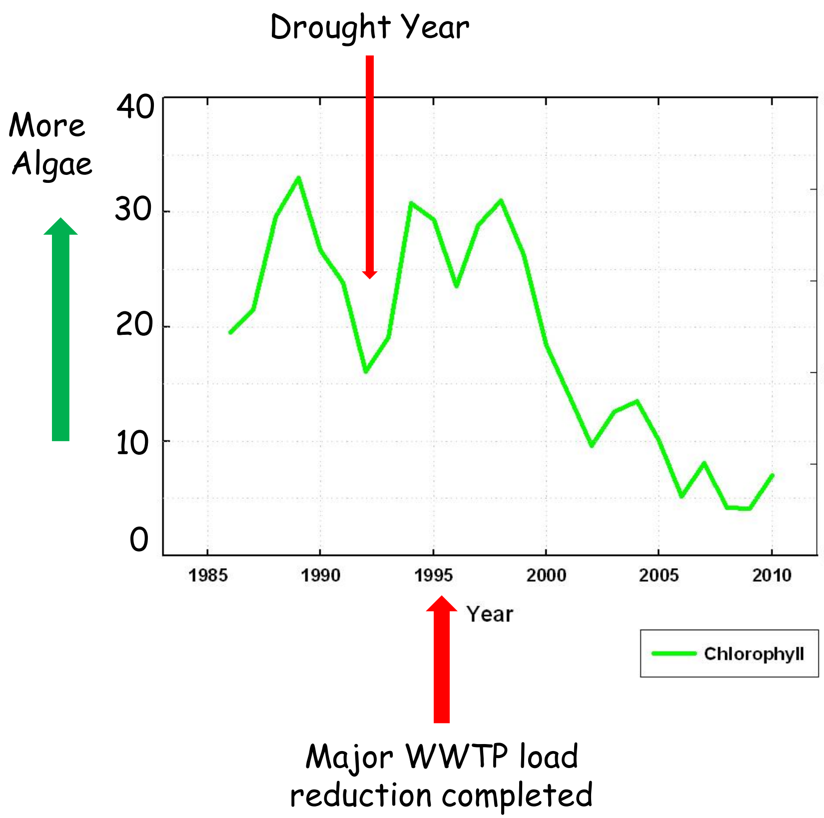
- Responds to court orders and legal settlements.
- Authorized under Clean Water Act
- Chesapeake 2000 Agreement by 2010
- Cornerstone of Executive Order

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

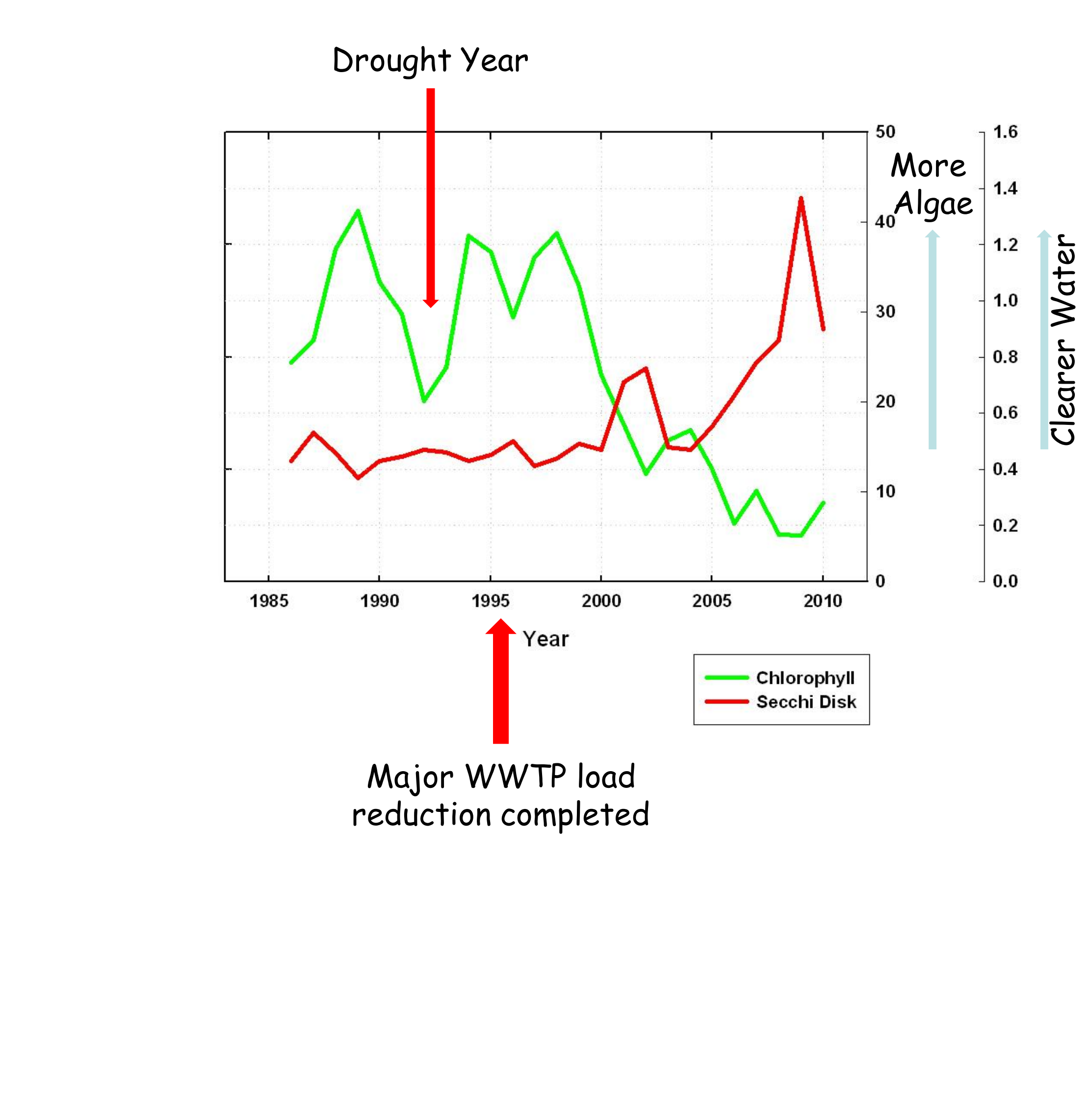
Photo from Elena Gilroy

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

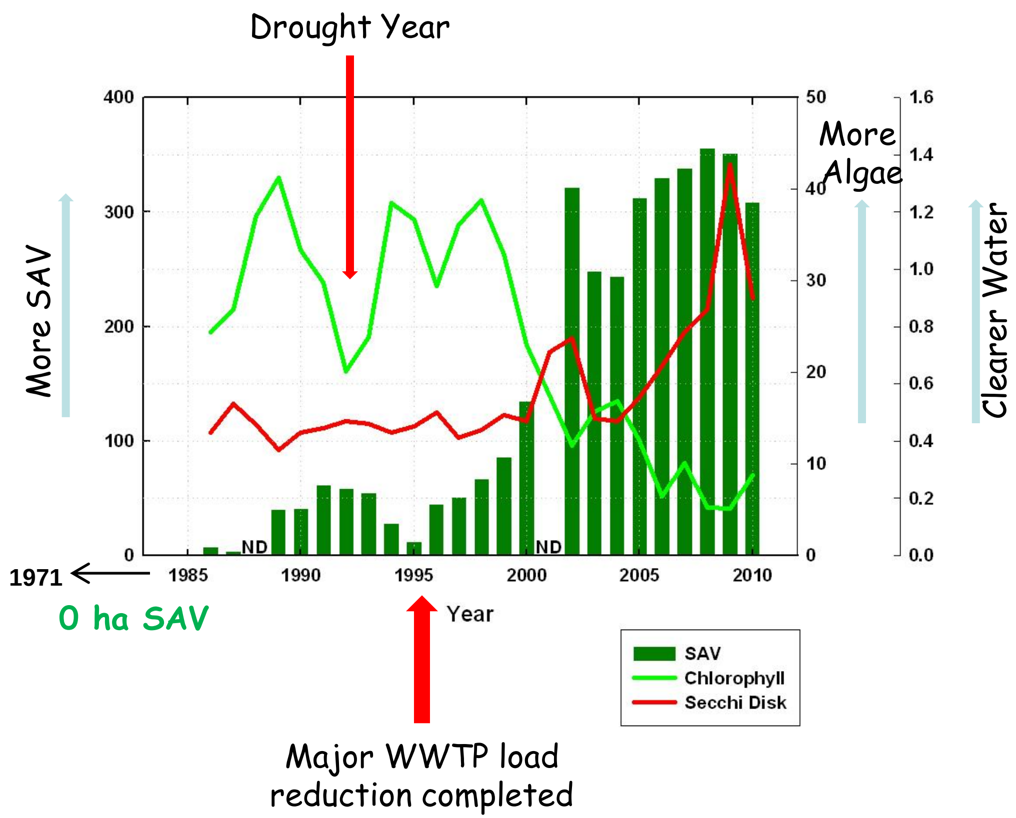
Water Clarity Increased…also with a Lag Time



- No clear increase for about 8 years followed by sharp increase in clarity

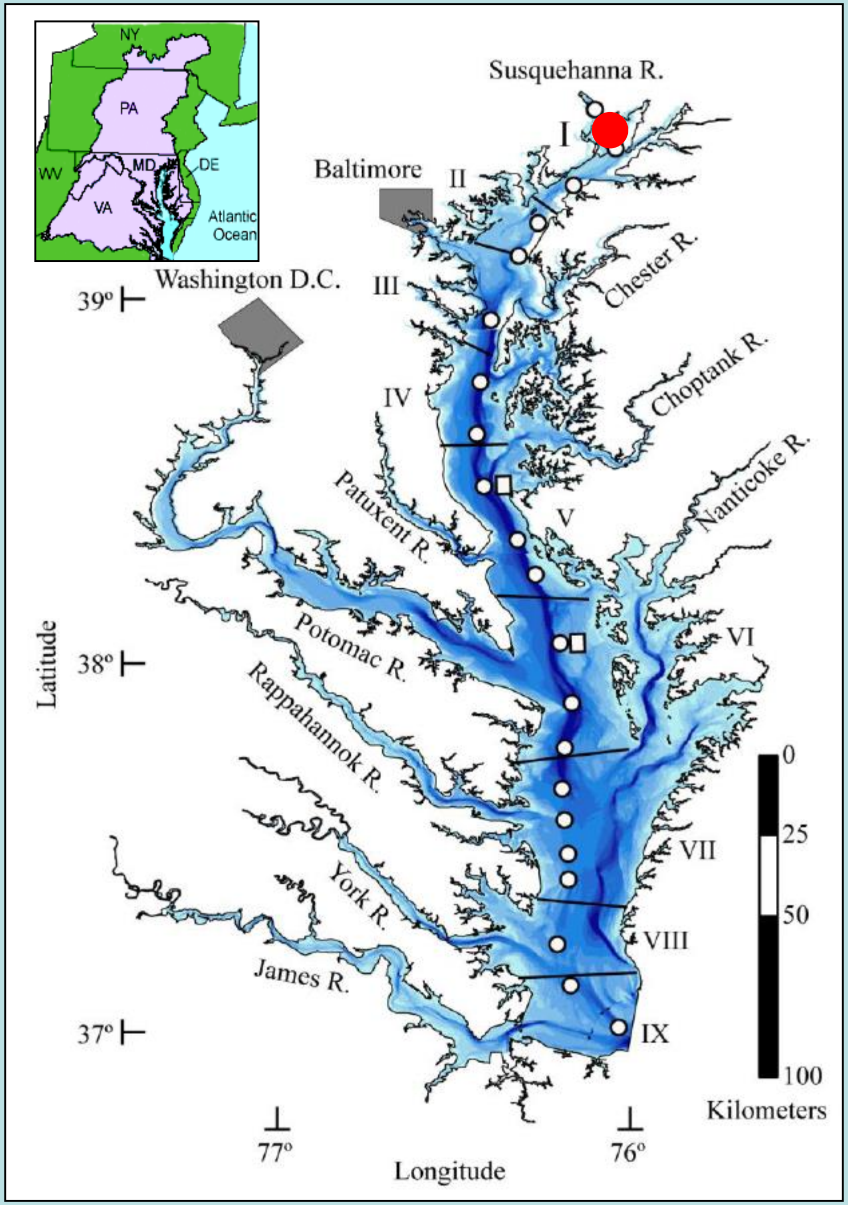
- Water clarity and algae highly correlated shallow Chesapeake Bay systems

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

Susquehanna Flats SAV at the Head of the Bay



- An unexpected piece of very good news
- A clear example of why long-term monitoring is so valuable for both trends and explanations
- This example also reminds us that once these habitats start to " get better" strong positive feedbacks can accelerate the restoration process

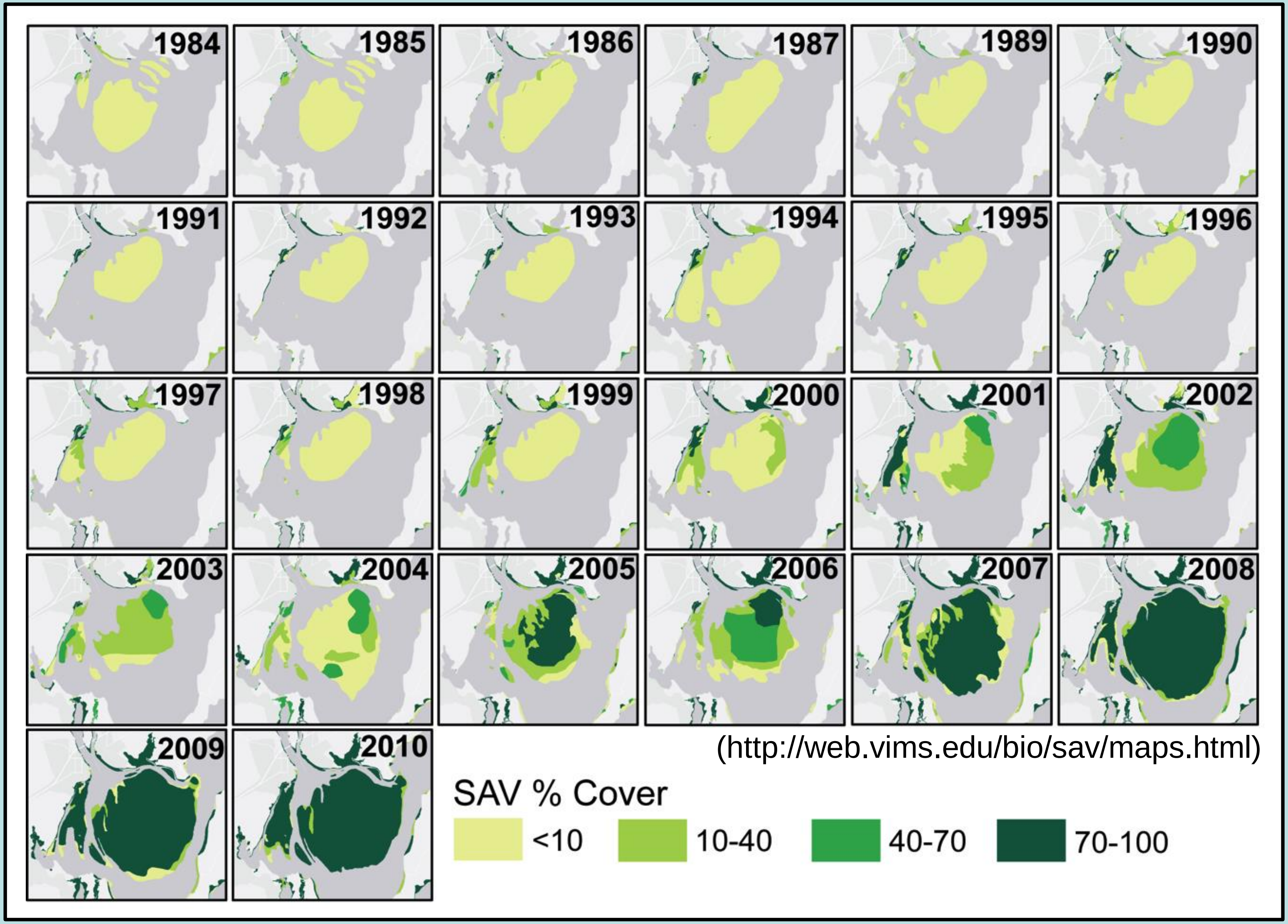
Adapted from Gurbisz and Kemp 2014

Now…this is a SAV bed!

- Huge expanse ~ 20 square miles (13,000 acres)
- Clear water
- Resilient to major storms; recovery from major storm = several years (not decades!)

C. Gurbisz, UMCES

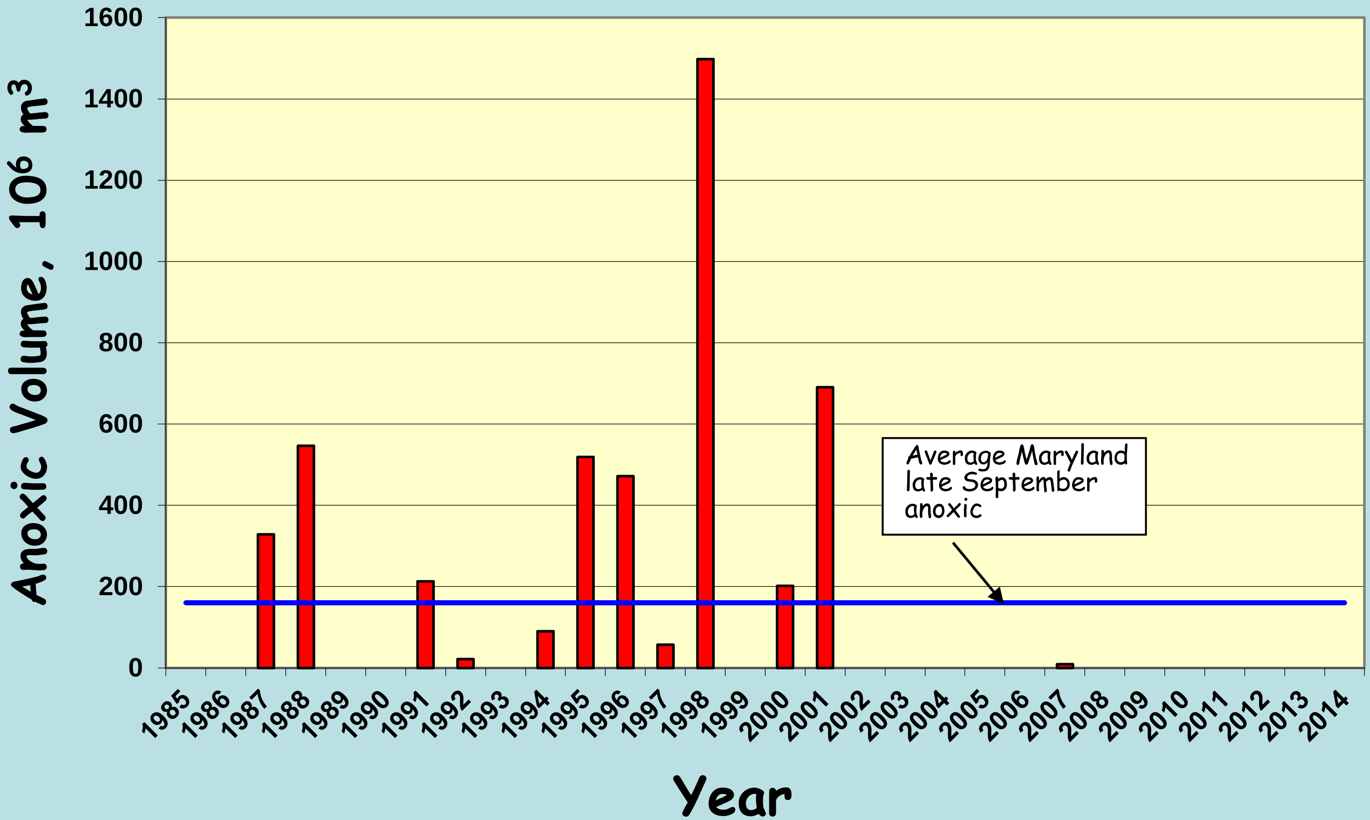
Maps of SAV Cover and Density:
Susquehanna Flats (1984 – 2010)



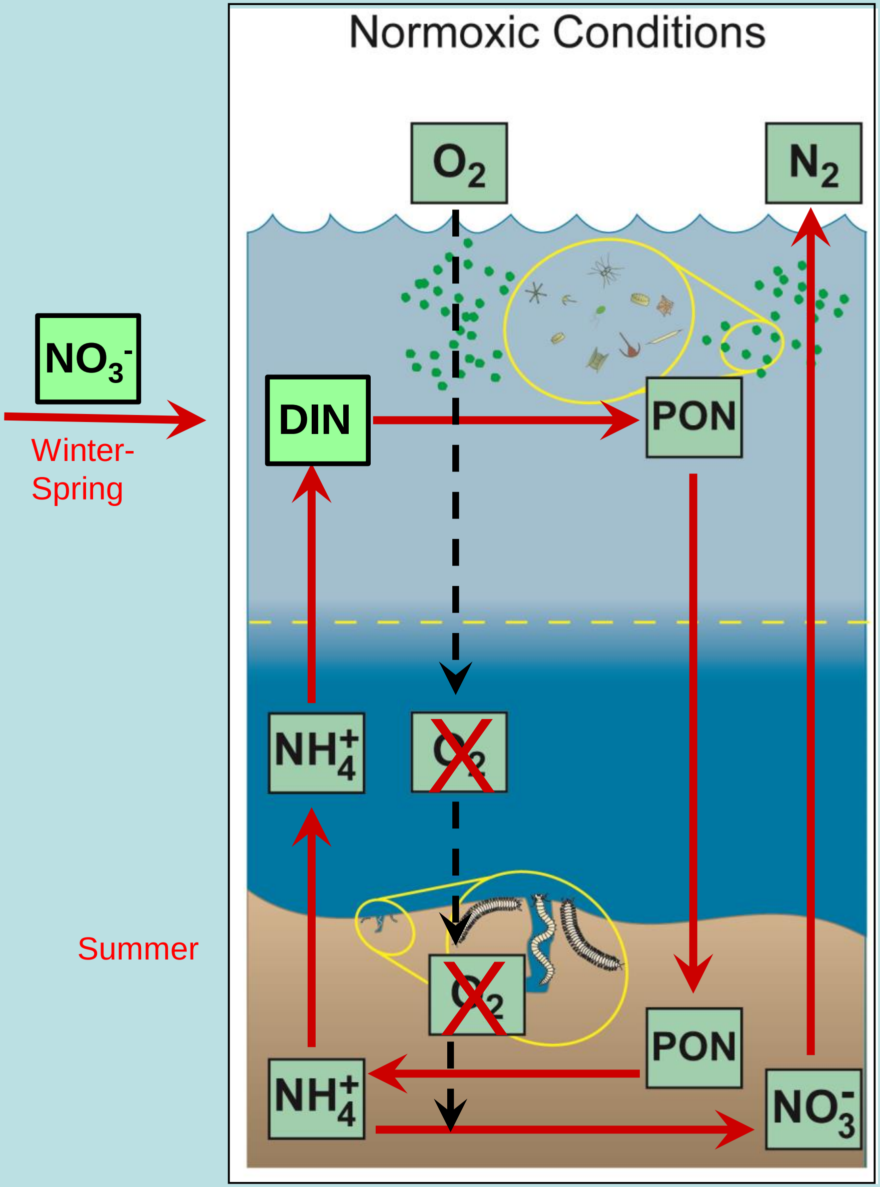
(Gurbisz & Kemp 2011)

MD Bay Anoxia: September Data

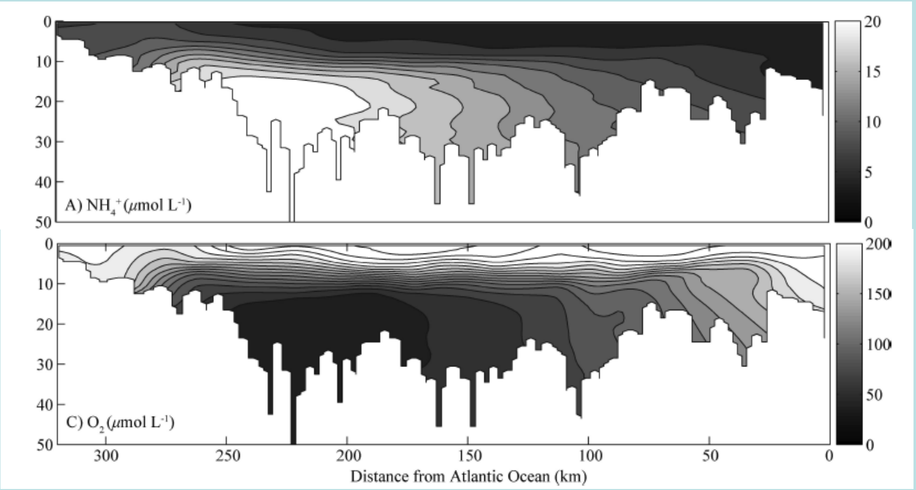
(0 - 0.2 mg/L)

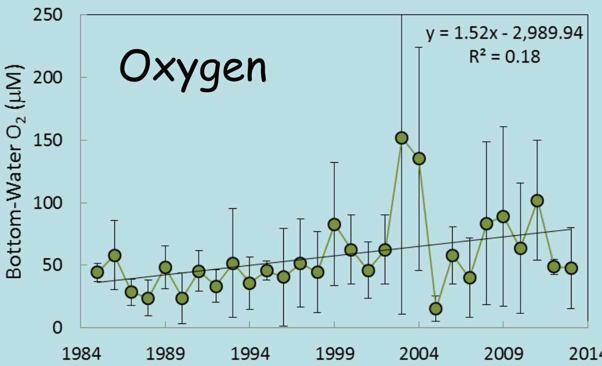


Conceptual Model of O_2 Interactions with N-Cycle

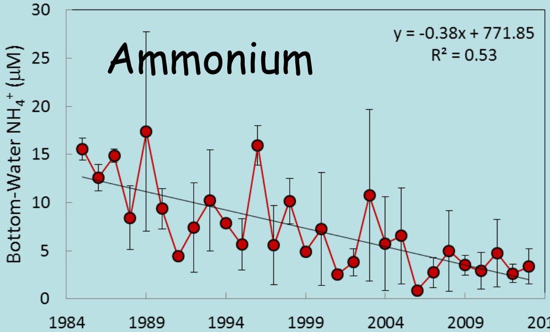


Earlier Summer Conditions





Recent Late-Summer Conditions
Mid-Bay



Take-Home Points

- Basic ideas of enrichment and restoration are scientifically solid
- The Duel Nutrient reduction strategy is sound…both P and N play powerful roles in Bay water and habitat quality
- 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
- Restoration trends (and hints of trends) have been observed in both small and large Chesapeake systems…very good signs!