

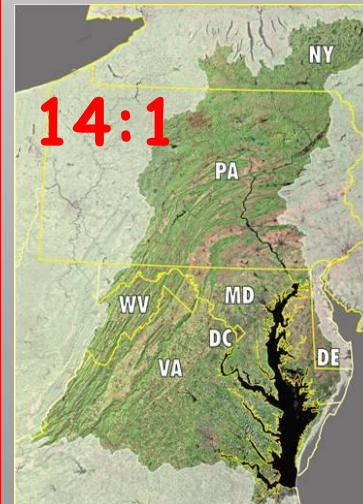
Case Studies within the Chesapeake Bay Estuarine System

Water Quality Trends Workshop

March, 2014



- 17 M people and rising
- Mixed land uses
- Shallow but seasonally stratified
- Estuary “flushes” slowly (4-6 mo)
- Many rivers connect land to Bay
- Various climate influences



Large Drainage Basin

Only 0.2 acres per person for dilution of wastes

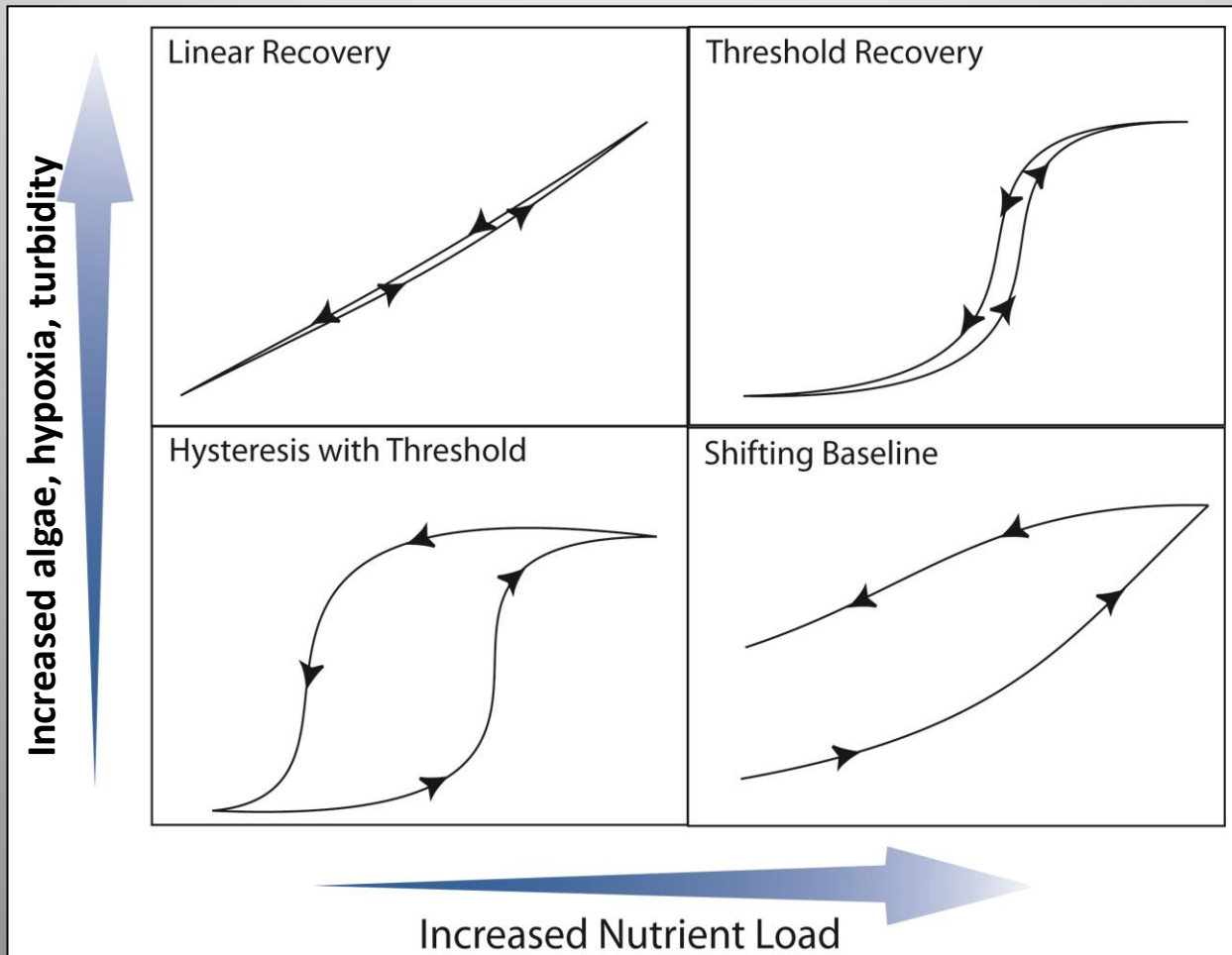
Walt Boynton and Friends
Center for Environmental
Science, Univ MD

Talk Outline

- This is tricky business...not all outcomes will be as expected
- Part way home in an URBAN estuary...and it's a local problem
- A system analysis of a small tidal creek...lags galore!
- Upper Patuxent SAV...delays and delays and then a threshold response
- A case for using Box Models for examining trends
- A super resurgence of SAV in the Upper Bay
- A few concluding comments and then Walter...go sit down!

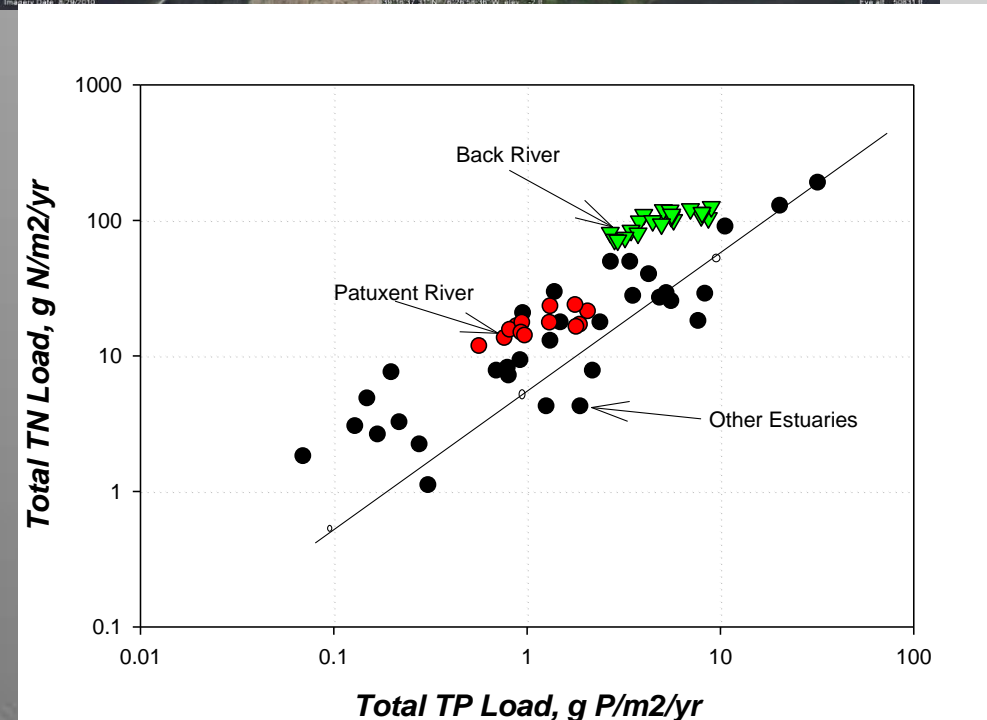
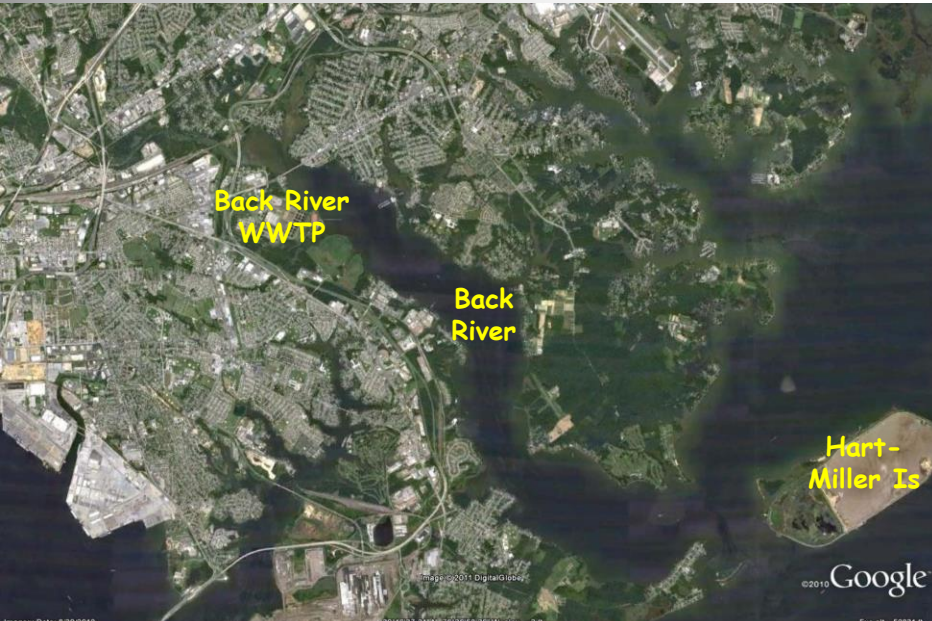
Ecosystem Responses to Nutrient Degradation and Remediation

we need to keep these things in mind



Back River Stats

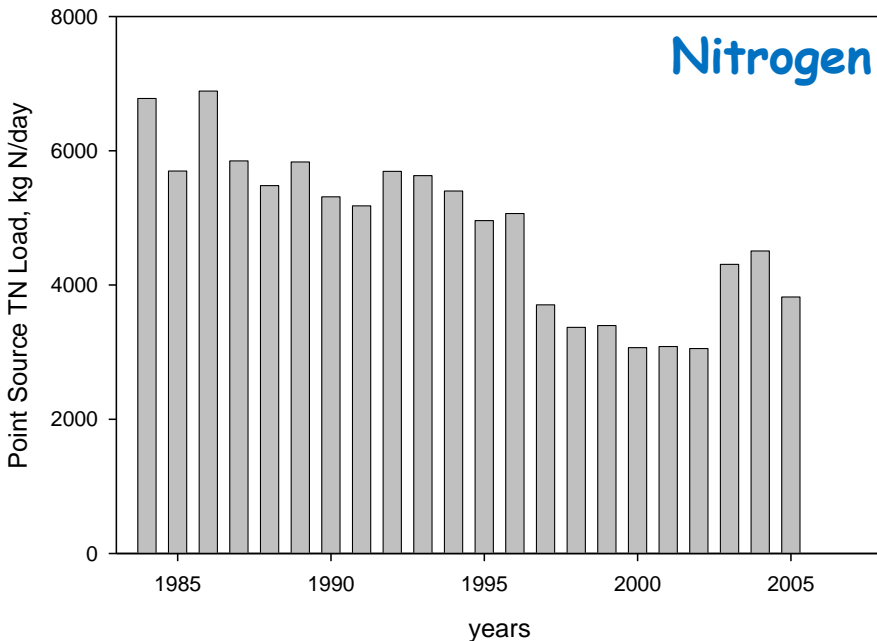
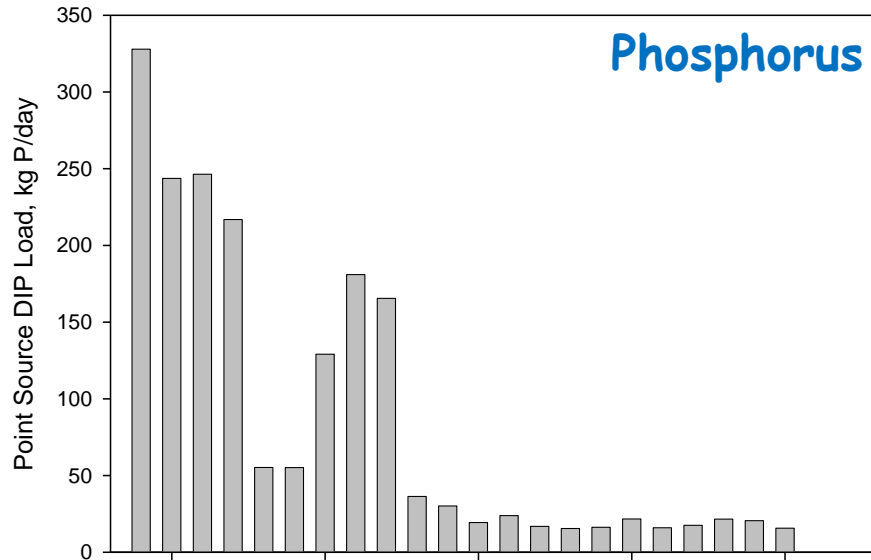
Pop density	5.3/acre	dense
Land use	80% urban	intense
Impervious	41%	high
Basin/estuary	5	low
Nitrogen loads	$\sim 100 \text{ g N m}^{-2} \text{ yr}^{-1}$	huge
SAV coverage	el zippo	none



- N and P loads very high compared to other estuaries
- Management efforts clear with N and P load reductions evident
- Corn fertilization rates = 140 lbs/acre/yr
- Back River fertilization = 900 lbs/acre/yr

Adapted from Boynton and Lee 2012

Back River WWTP Load Reductions



- *Good engineering works!*

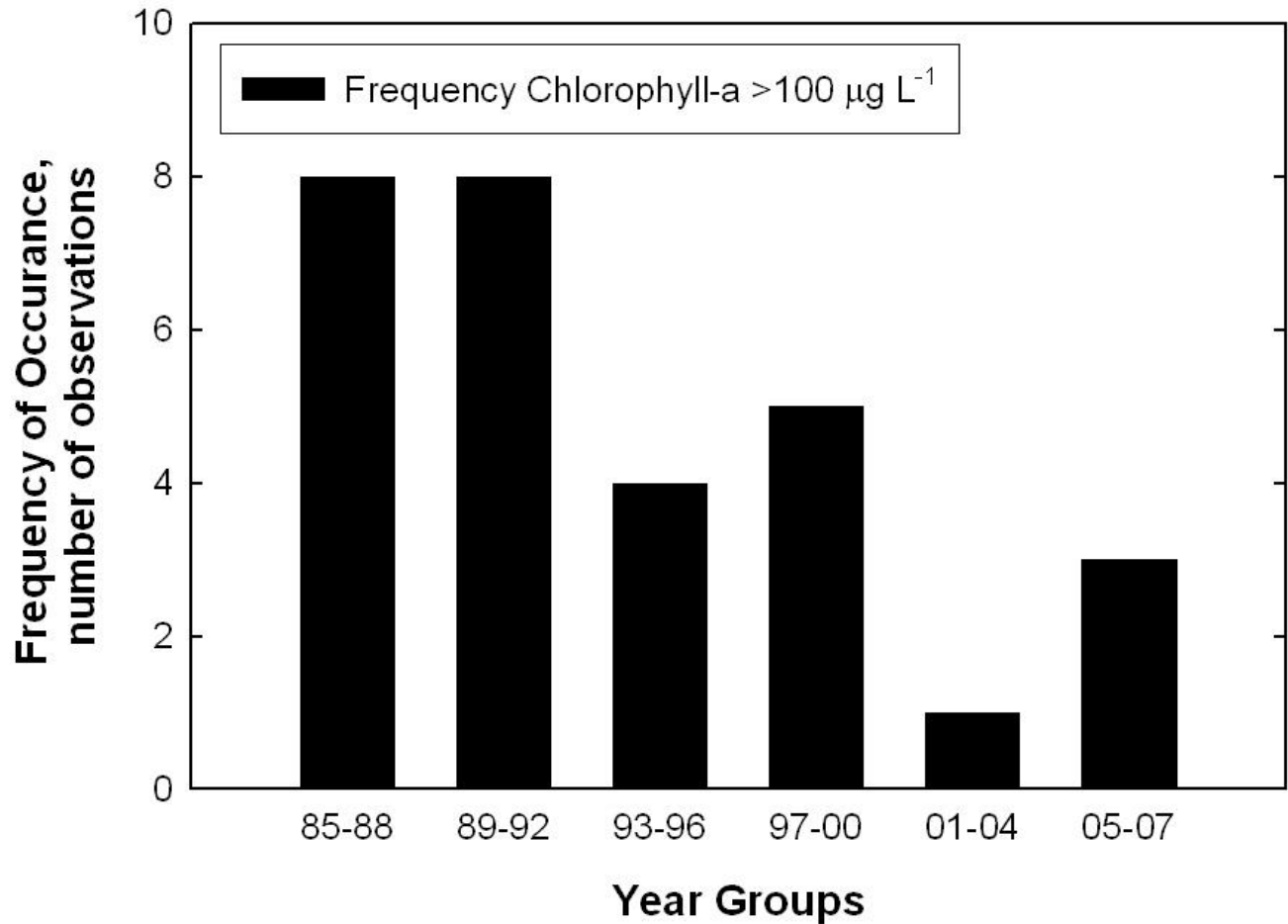
- **P loads dramatically reduced**

- **N loads substantially reduced**

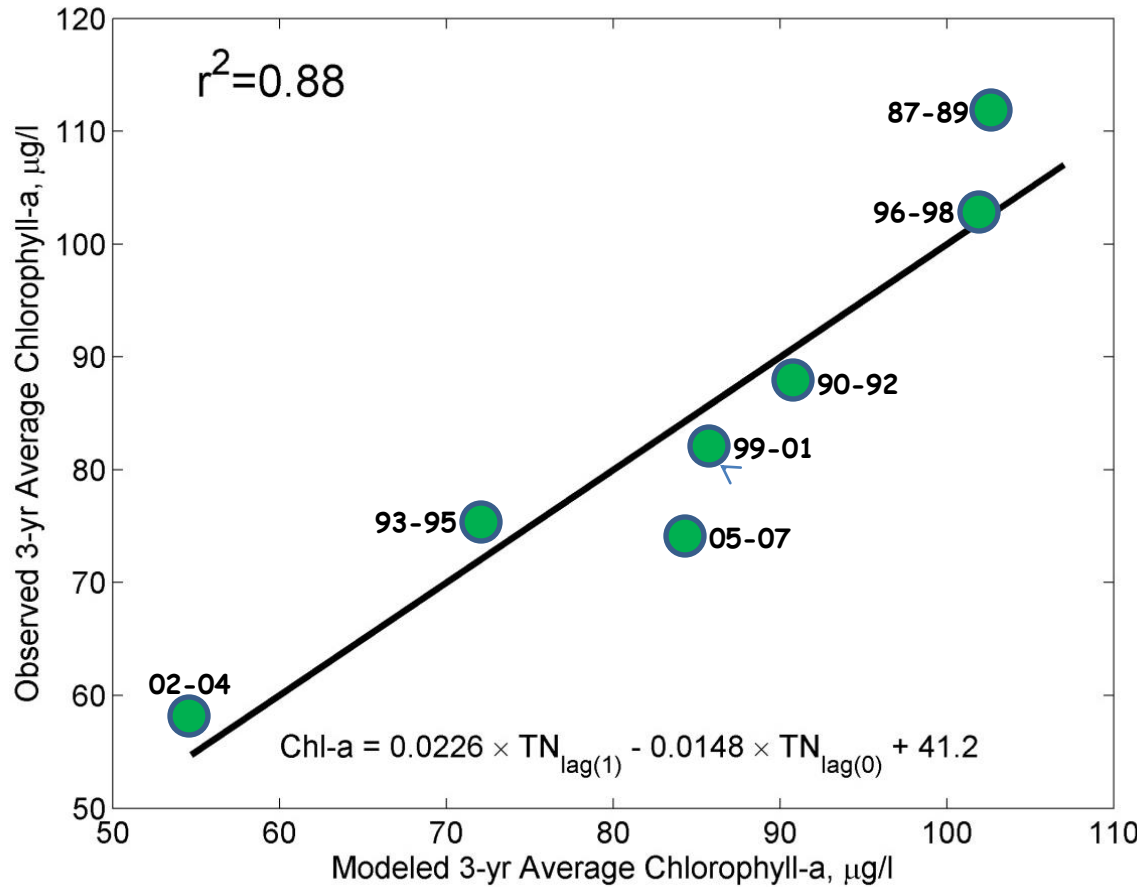
Severe Algal Blooms Decreasing

- Algal bloom frequency decreased after N load reductions

- When N loads increased again (05-07) rapid response in increased bloom frequency



Algal Bloom - Nutrient Relationships



Increasing Algal Blooms

- Strong relationship between NITROGEN loads and algal blooms
- Time lags between management action and response were important...there appears to be a nutrient memory (~3 years)
- Significant algal bloom reduction was achieved (~50%)

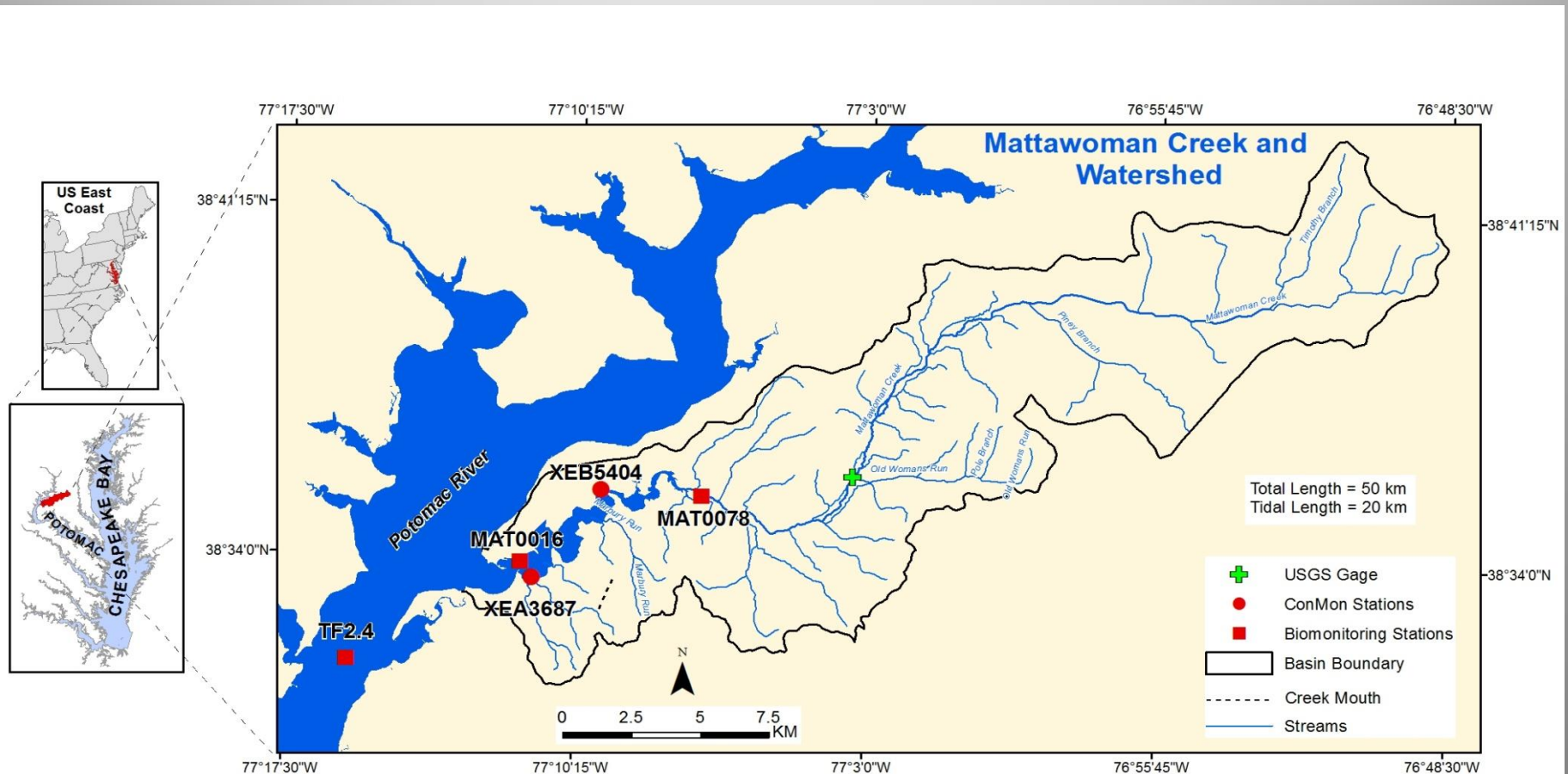
Two SAV Restoration Examples



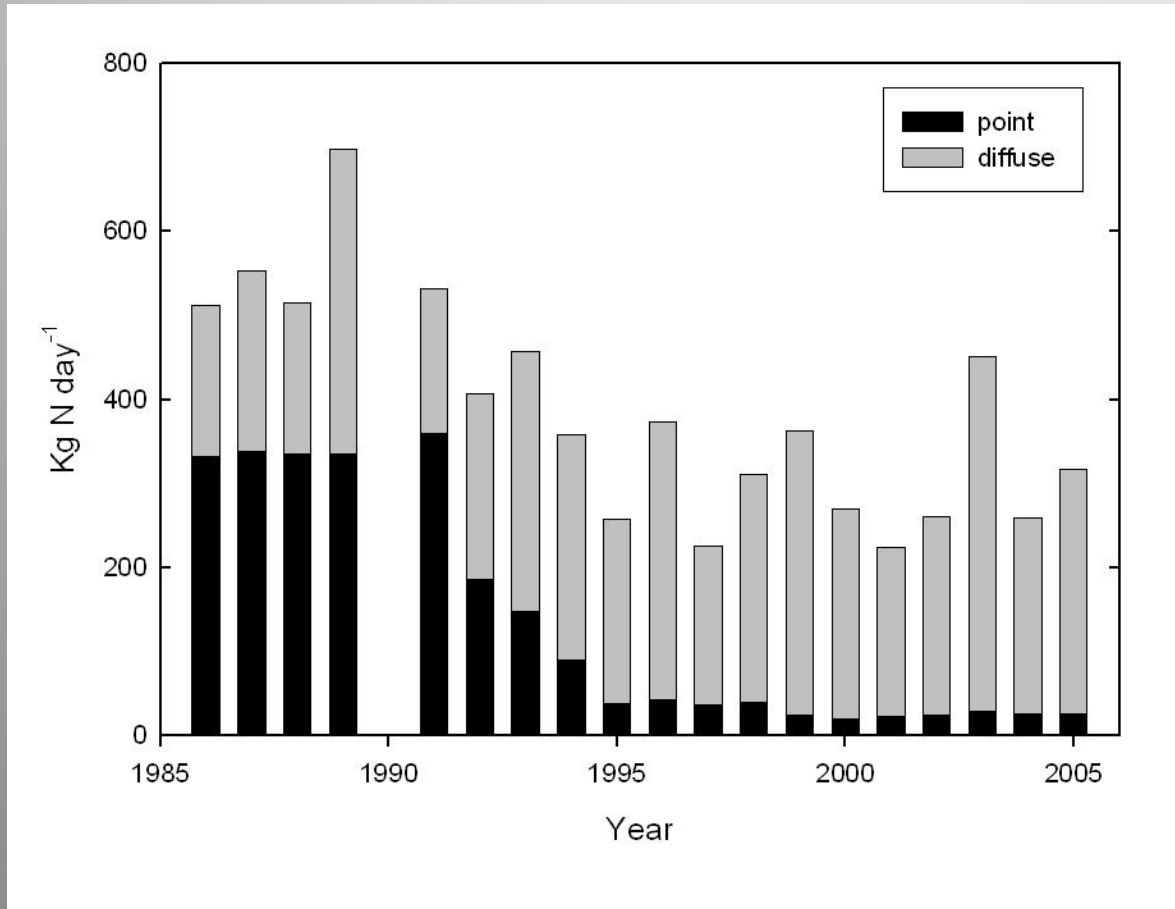
- Both involved natural re-invasion of SAV
- Both associated with WWTP upgrades
- Both have been persistent
- This is very good news!

MATTAWOMAN CREEK...UPPER POTOMAC TRIBUTARY

- Long history of being very eutrophic
- Major nutrient load reductions by ~1995
- Small tidal-freshwater tributary of the Potomac
- Large basin : estuary surface area ratio (~33)

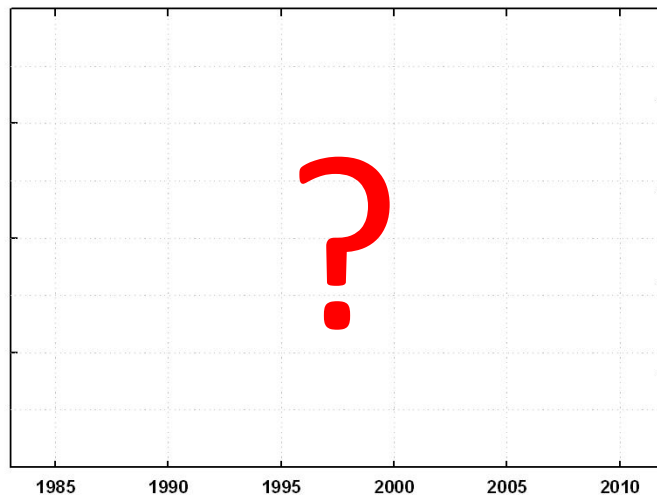


TIME-SERIES OF POINT AND DIFFUSE NITROGEN LOADS: 1986 - 2005



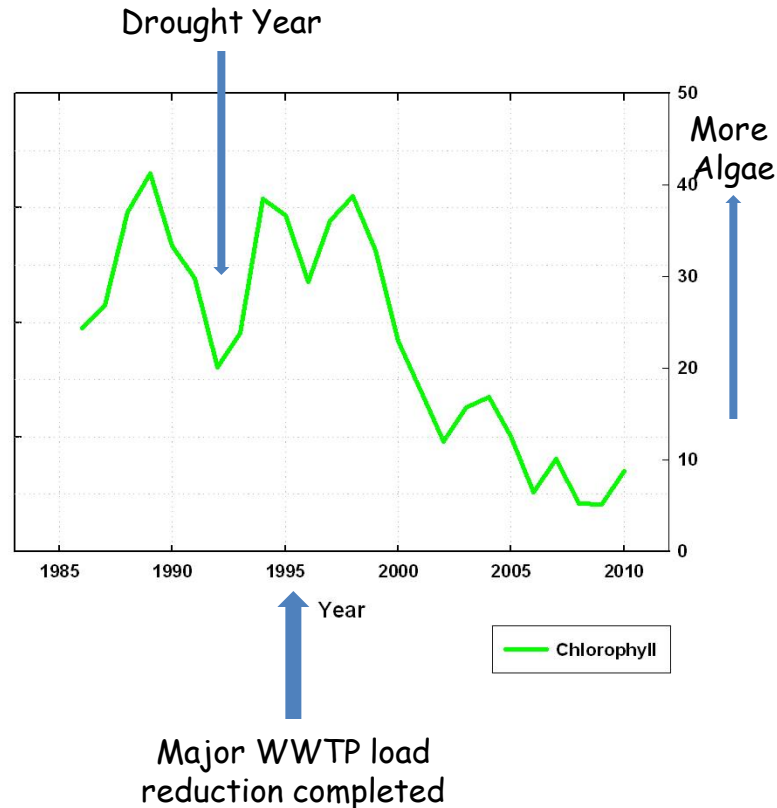
- Reductions related to point sources
- Diffuse loads weather dependent
- N-loads decreased from ~ 30 to $12 \text{ g N m}^{-2} \text{ yr}^{-1}$
- P-loads also decreased

WHAT WERE THE RESPONSES TO LOAD REDUCTIONS IN MATTAWOMAN CREEK?



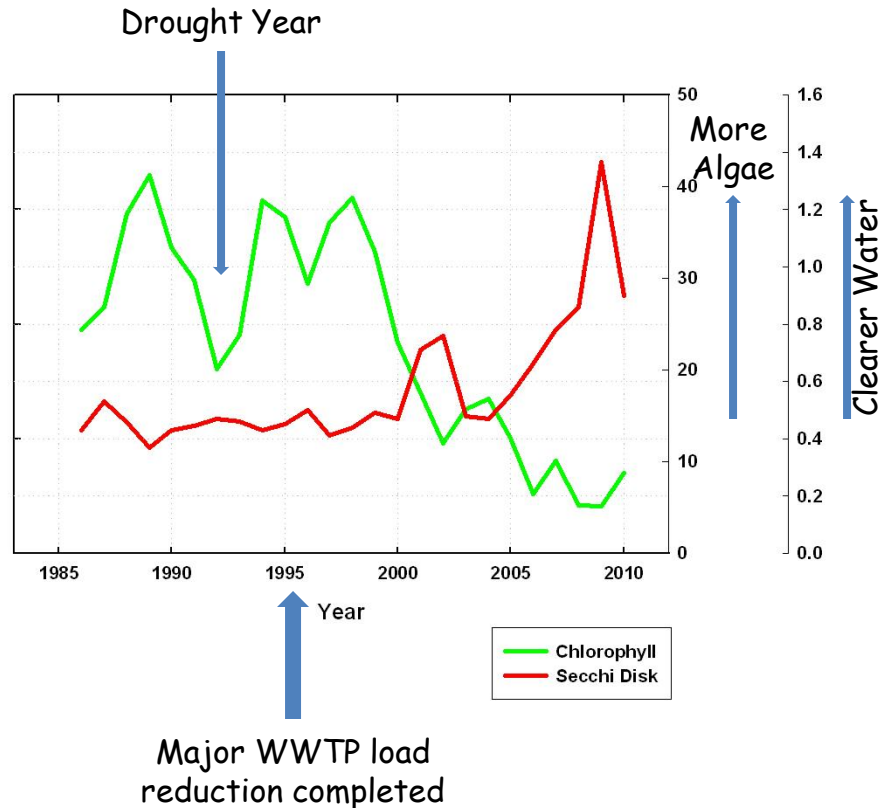
↑
Year
Major WWTP load
reduction completed

ALGAL BIOMASS DECREASED...WITH SUBSTANTIAL LAG TIME



- No clear response for about 4 years followed by sharp decline in Chloro-a
- After 2005 low levels of Chloro-a persisted
- Total lag time from completed load reduction to new condition ~ 10 years

WATER CLARITY INCREASED...ALSO WITH SUBSTANTIAL LAG TIME

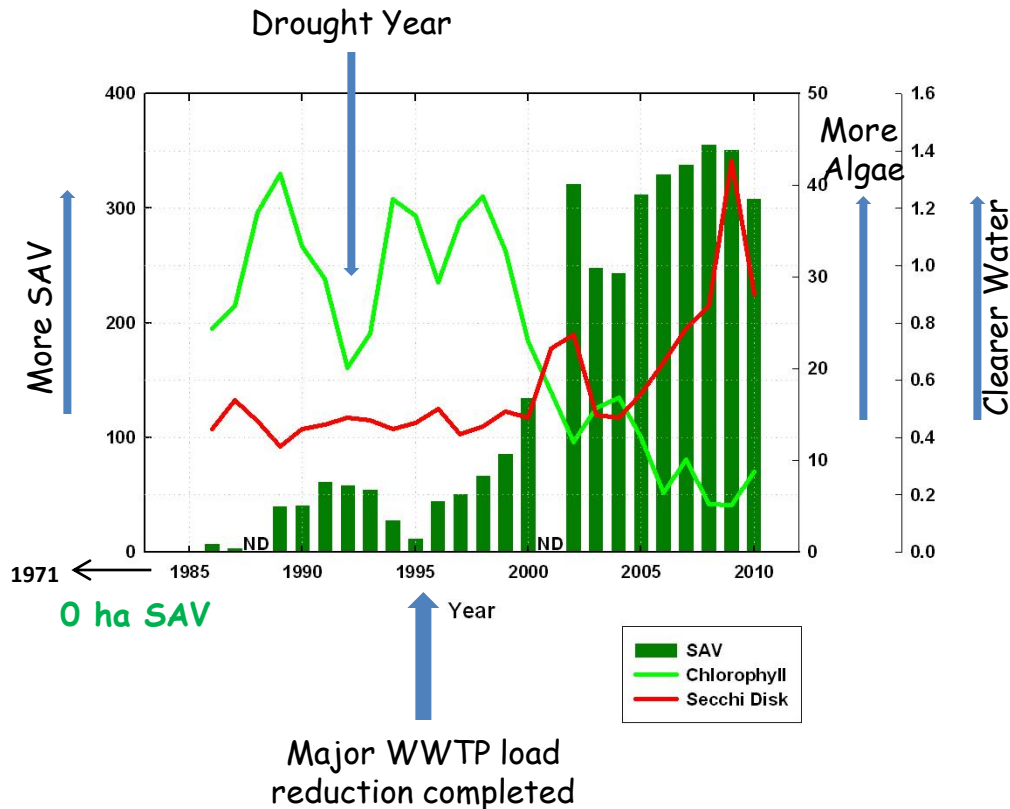


- No clear increase for about 8 years followed by sharp increase in clarity

- Water clarity and Chloro-a highly correlated in this and other shallow Chesapeake Bay systems

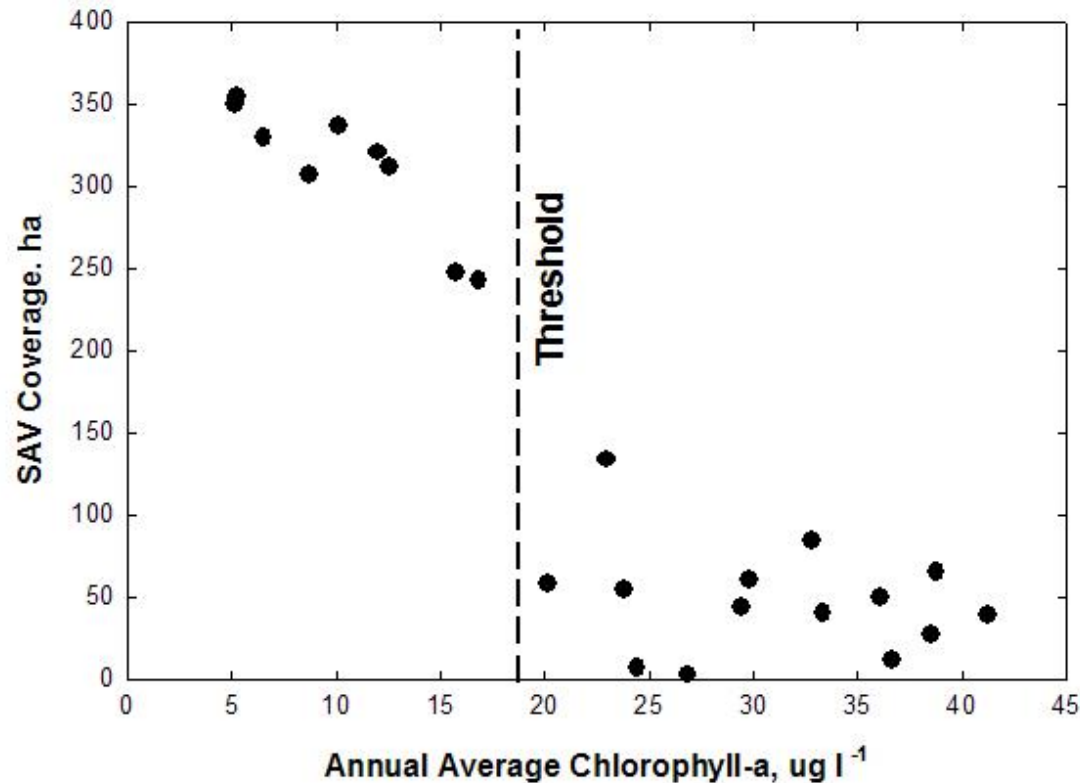
- Total lag time from completed load reduction to new condition ~ 13 years

SAV INCREASED...WITH SHORTER LAG TIME AND POSSIBLE THRESHOLD RESPONSE



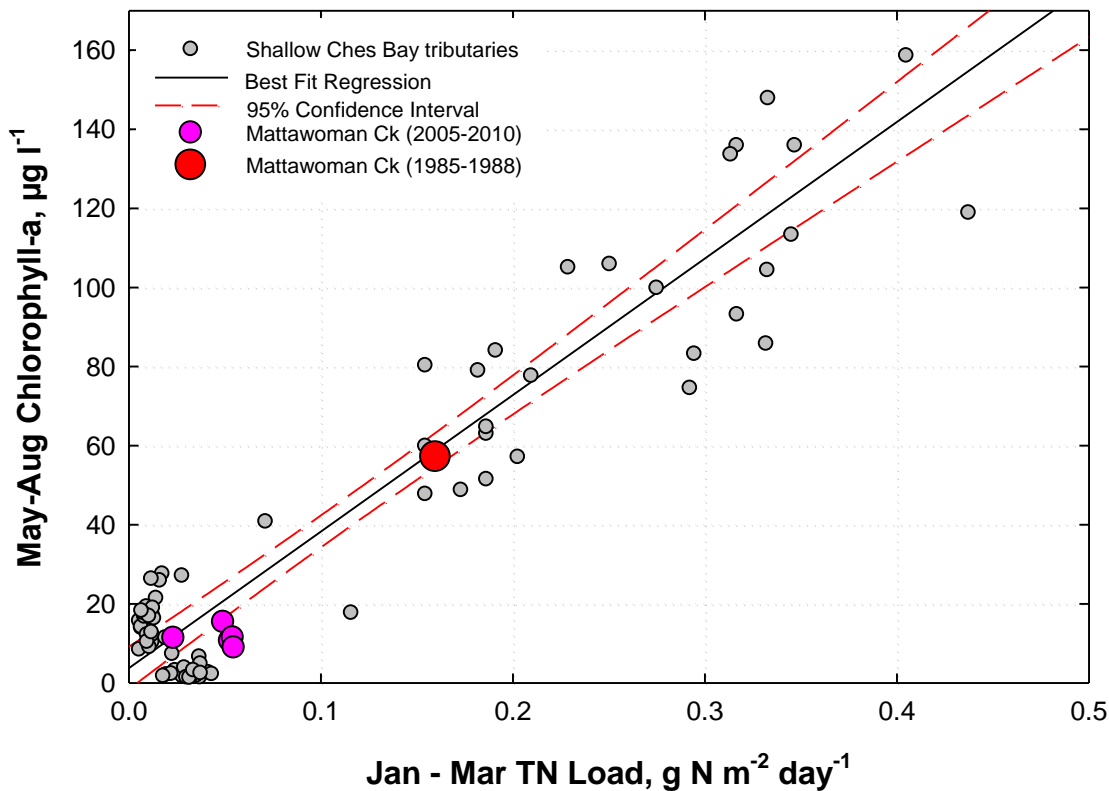
- Low levels of SAV were present prior to WWTP modifications
- Major expansion of SAV in 2002, a severe drought year
- SAV relatively stable post 2002; lag in SAV relatively short

POSSIBLE SAV THRESHOLD RELATED TO CHLOROPHYLL-A AND WATER CLARITY



- A large increase in SAV coverage (and density) associated with Chloro-a concentration < 18 ug L⁻¹
- SAV expansion in this creek occurred at N-loading rates only slightly higher than those observed in other coastal systems

Comparative Analysis: Mattawoman Creek and Other Shallow Chesapeake Tributaries



- Strong relationship between winter N load and summer Chlorophyll-a for many CB shallow systems
- Mattawoman Creek follows this pattern both before and after N load reduction

Patuxent River Estuary

Circa 1832



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

Water Quality and Habitat Conditions can be much improved in the Patuxent



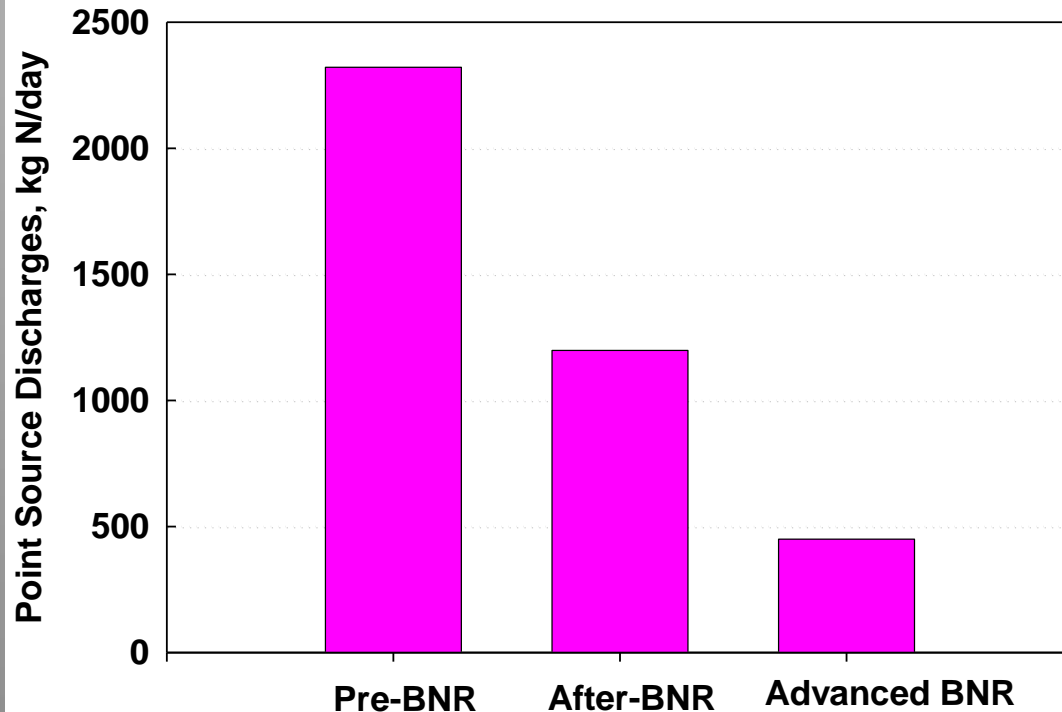
SAV in the Upper Patuxent River Estuary

- SAV gone by 1970 in upper estuary
- P removal at WWTP in 1986...no SAV response
- Seasonal N removal at WWTP 1992-1993
- Dramatic SAV response by 1994 and sustained to the present day
- Appears to be a response to N load reduction with **almost no lag time**

Major Reductions in WWTP Discharges of N and P in the Patuxent



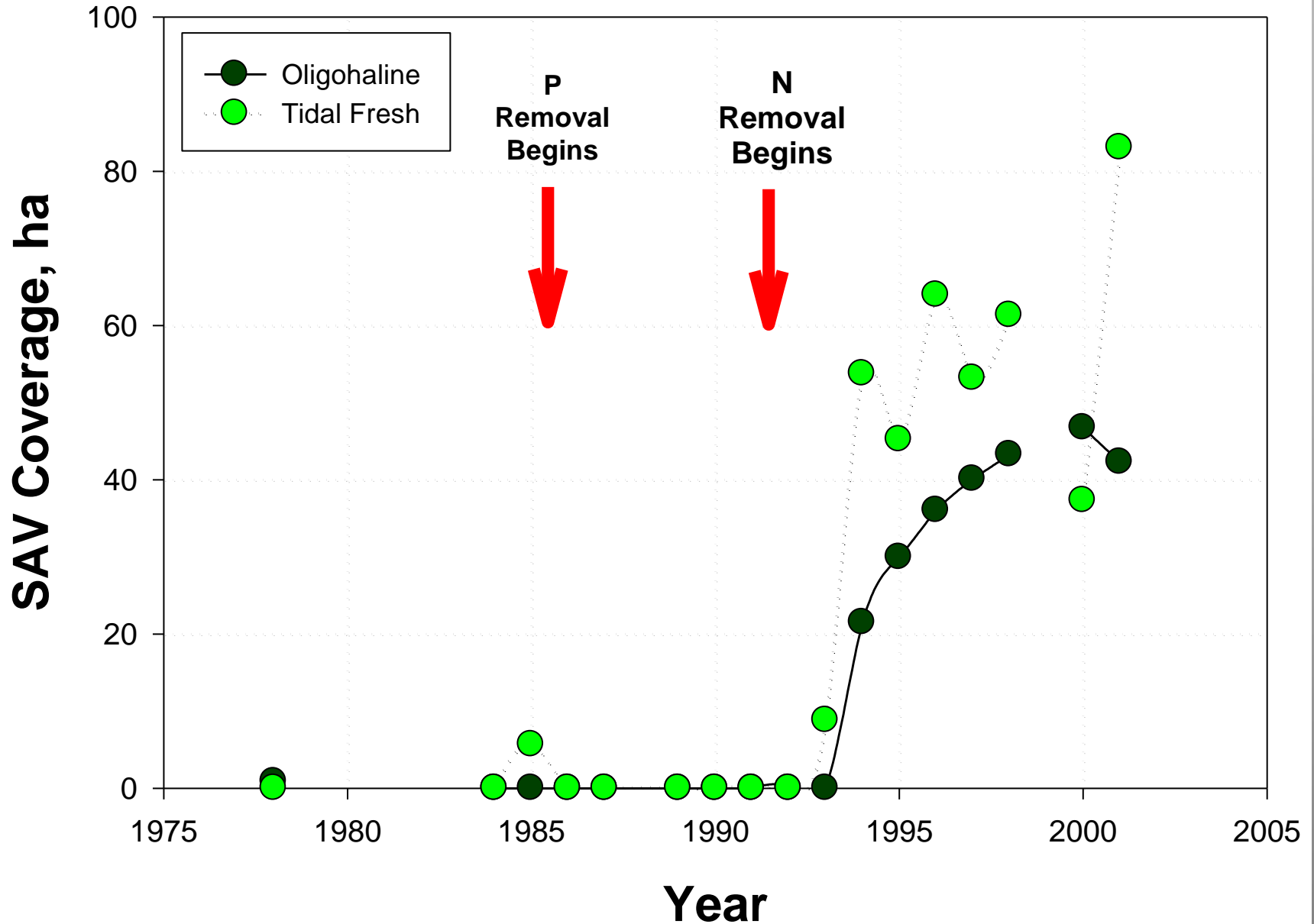
Wastewater Treatment in the Patuxent River Basin



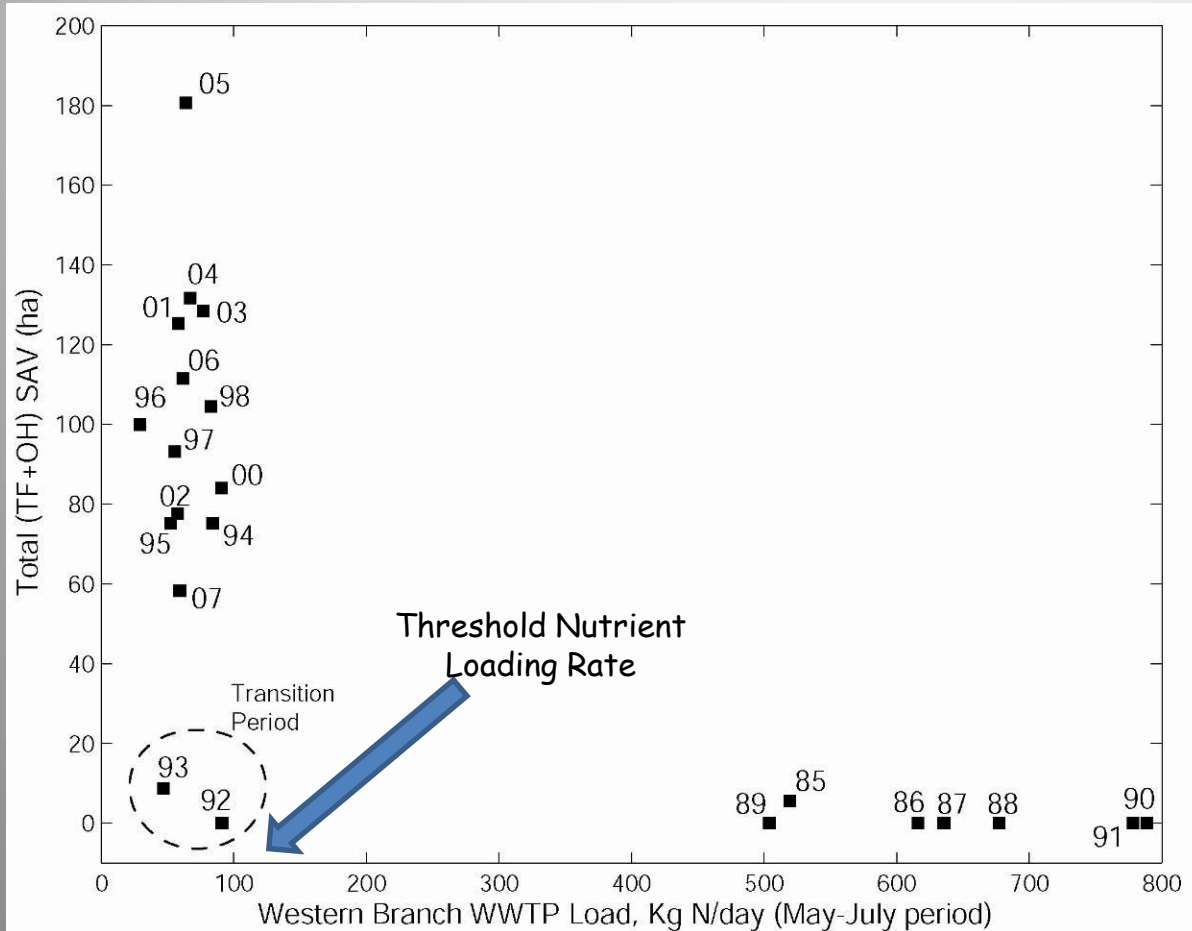
Patuxent WWTP Story

- 9 major WWTP in the basin
- Among the first to remove P
- N removal began 1992-93
- Plans call for further reductions by 2014
- When reductions completed, WWTP discharges will be a small part of the Patuxent nutrient problem

A rapid SAV response to BIG CHANGES in nutrient loads



A Threshold Response in the Upper Patuxent



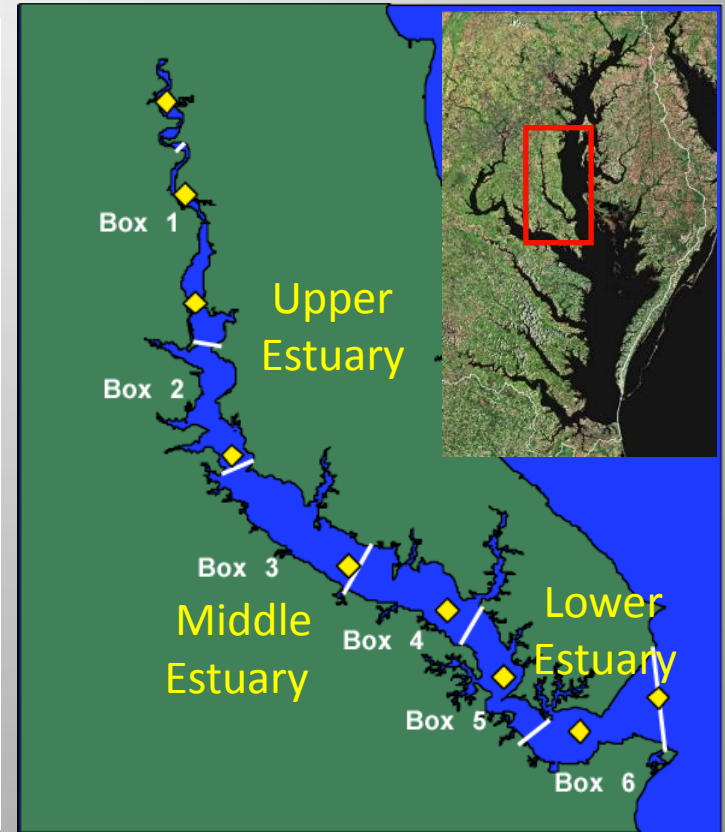
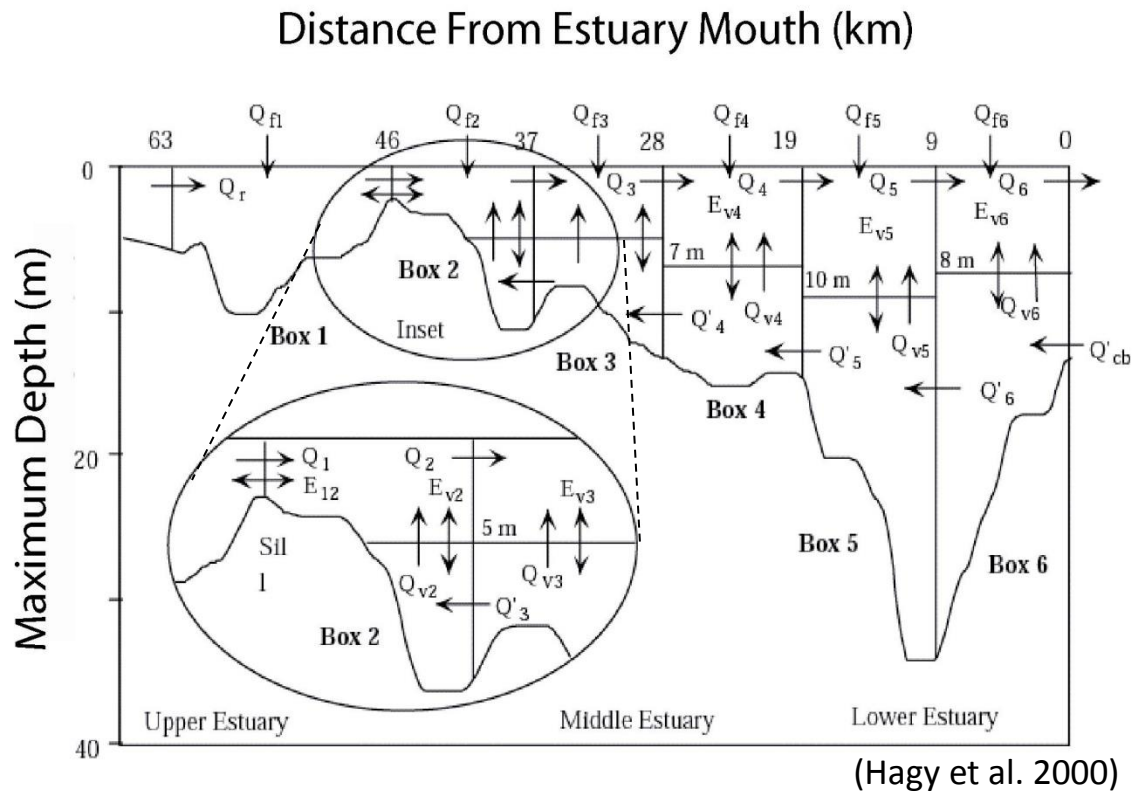
- No SAV at WWTP loads greater than ~100 kg N/day
- Very short transition period
- SAV exploded post 1993
- Post-1993 inter-annual variability not related to small variations in N load...mainly related to salinity



Nutrient Exchanges Between the Bay and Patuxent

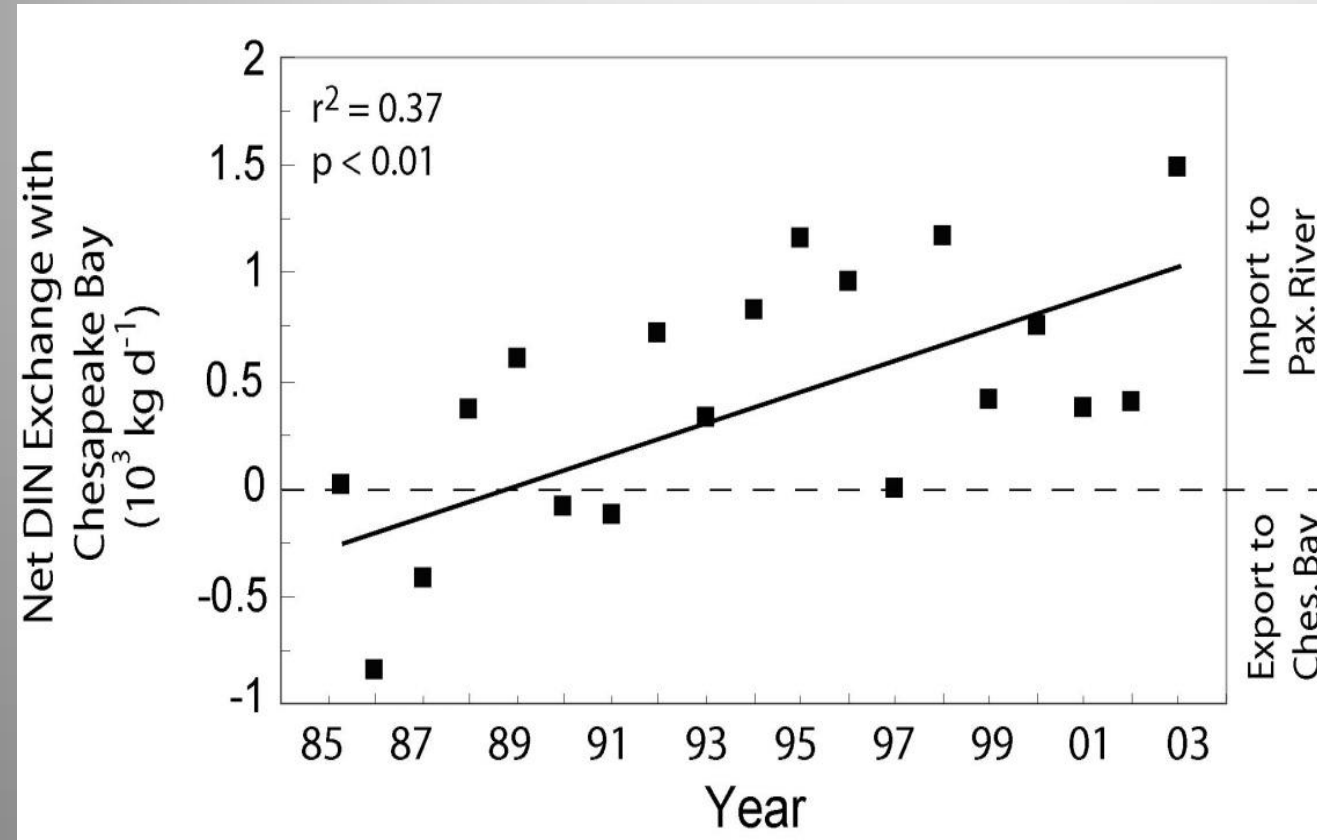
- Could the Bay influence water quality in the Patuxent and thereby off-set nutrient reductions by WWTPs?
- Flux estimates at the mouths of estuaries tough to accomplish
- Box Models use monitoring data and converts grab samples into rate estimates (e.g., flux at mouth)
- Running Box Models for multiple years can detect trends...this should be done for all tributaries

Patuxent Estuary Box Model Analysis



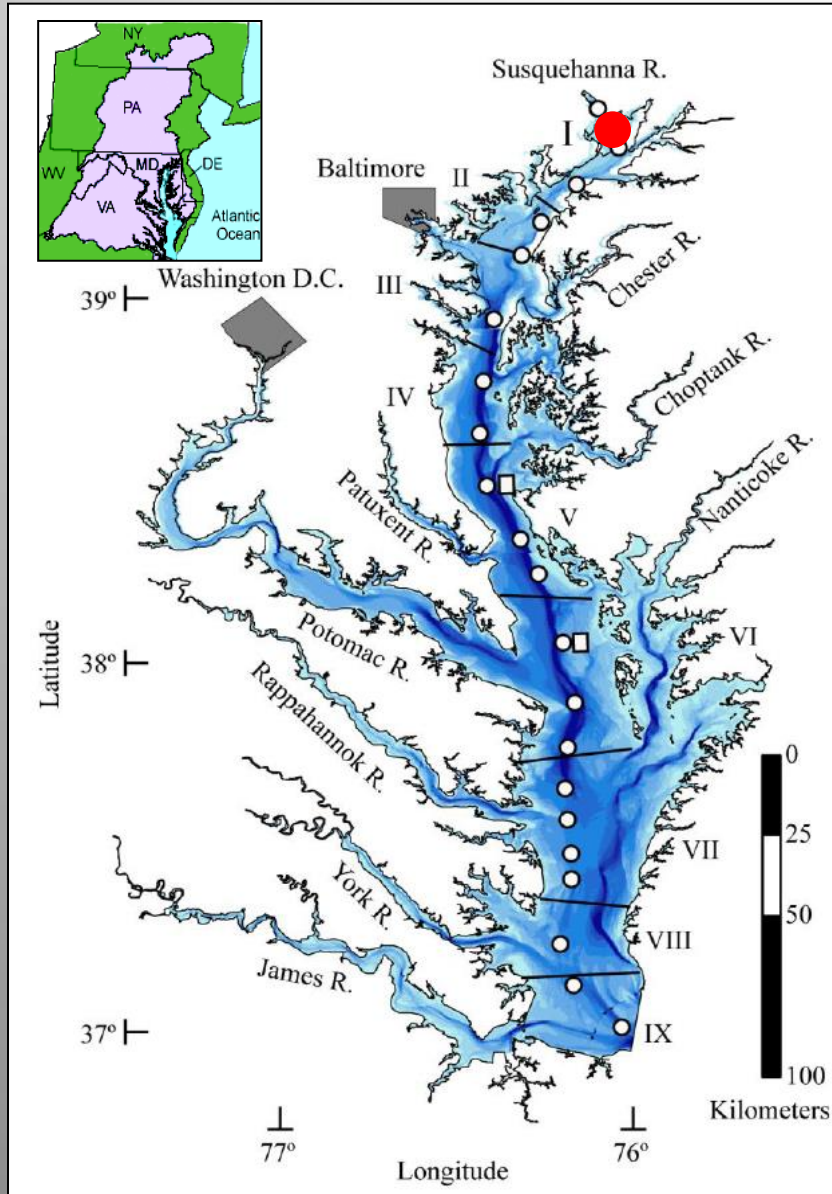
Use flow balance and salt balance equations for each box to compute unknown values for water flows (Q 's) and mixing rates (E 's), given salinities and FW inputs.

Increasing DIN Input from Bay to Patuxent...not a good trend



- A box model application using monitoring program data
- Suggests a trend of increasing Bay influence on Patuxent water quality
- A flux of $\sim 1000 \text{ kg N/day}$ represents about 15% of average daily TN load to the Patuxent system

Susquehanna Flats SAV at the Head of the Bay

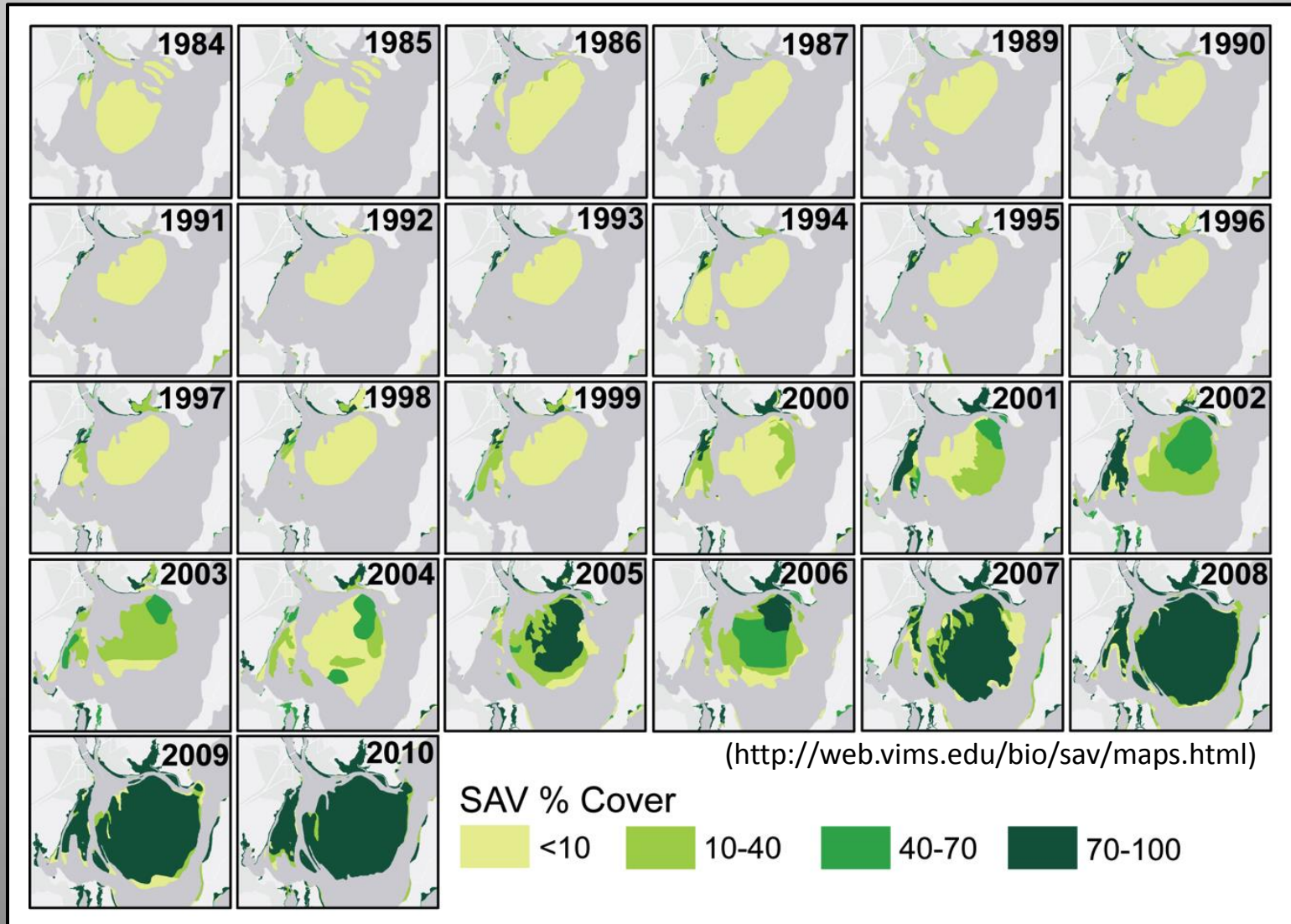


- Quite the unexpected piece of very good news

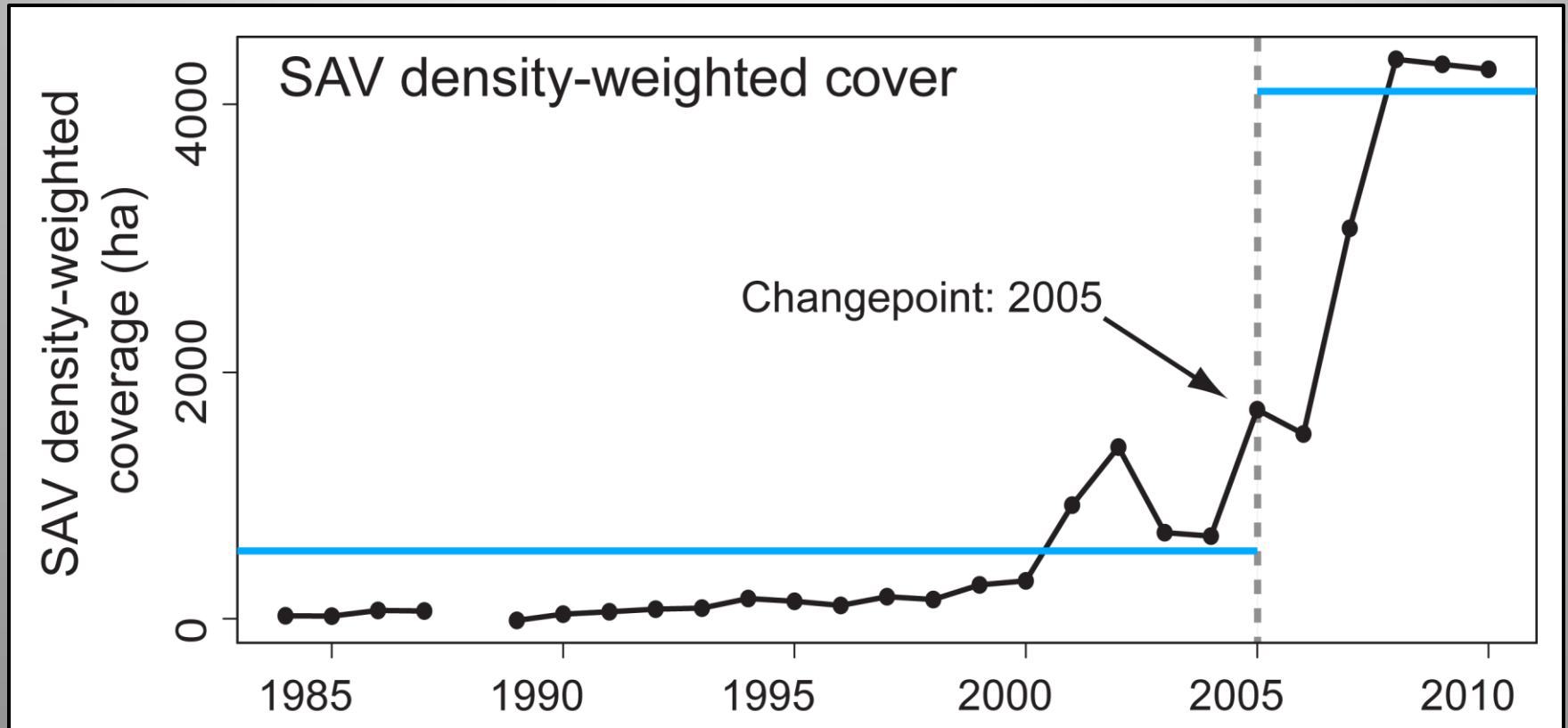
- A super-clear example of why long-term monitoring is so valuable for both trends and explanations

- This example also reminds us that once these habitats start to "get better" strong positive feedbacks can accelerate the restoration process

Time Series Maps of SAV Cover and Density

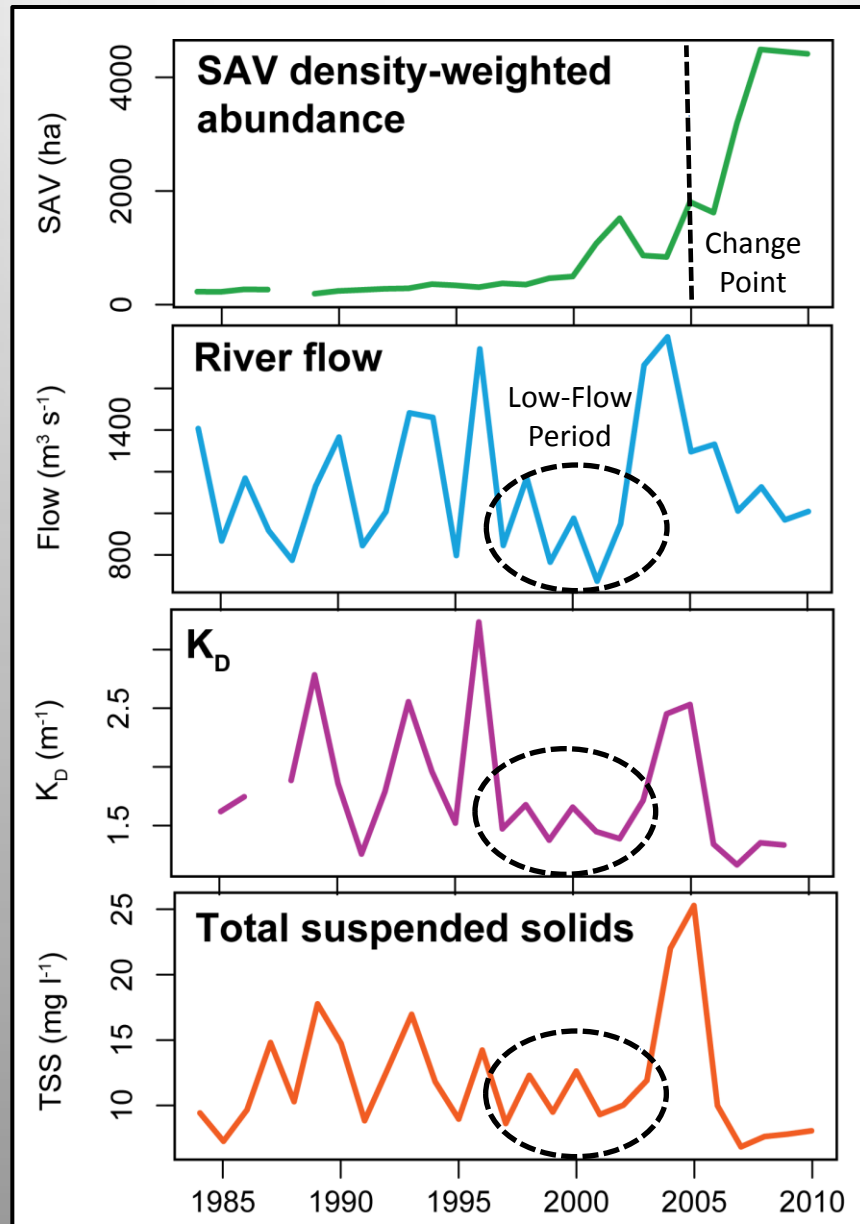


Change-Point in SAV Density-weighted Cover



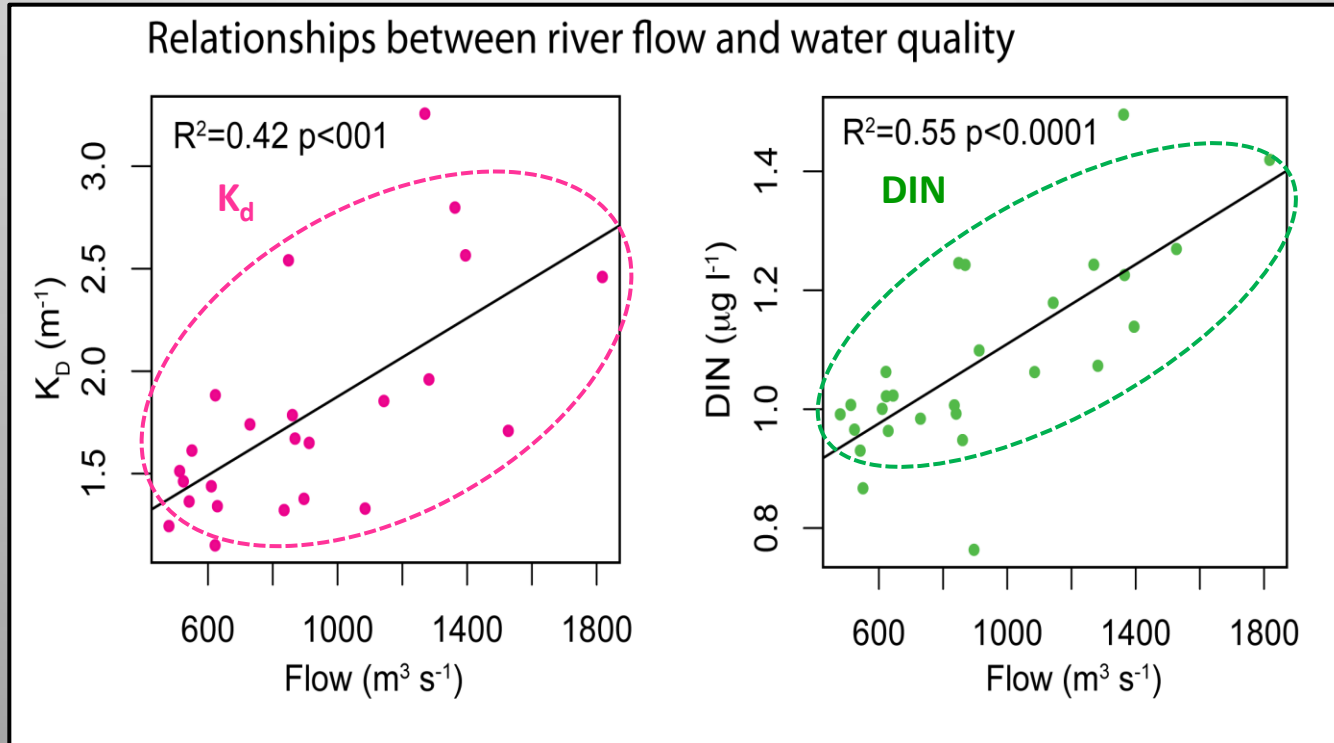
(Gurbisz & Kemp 2011)

River Flow & SAV Recovery: Drought Effects

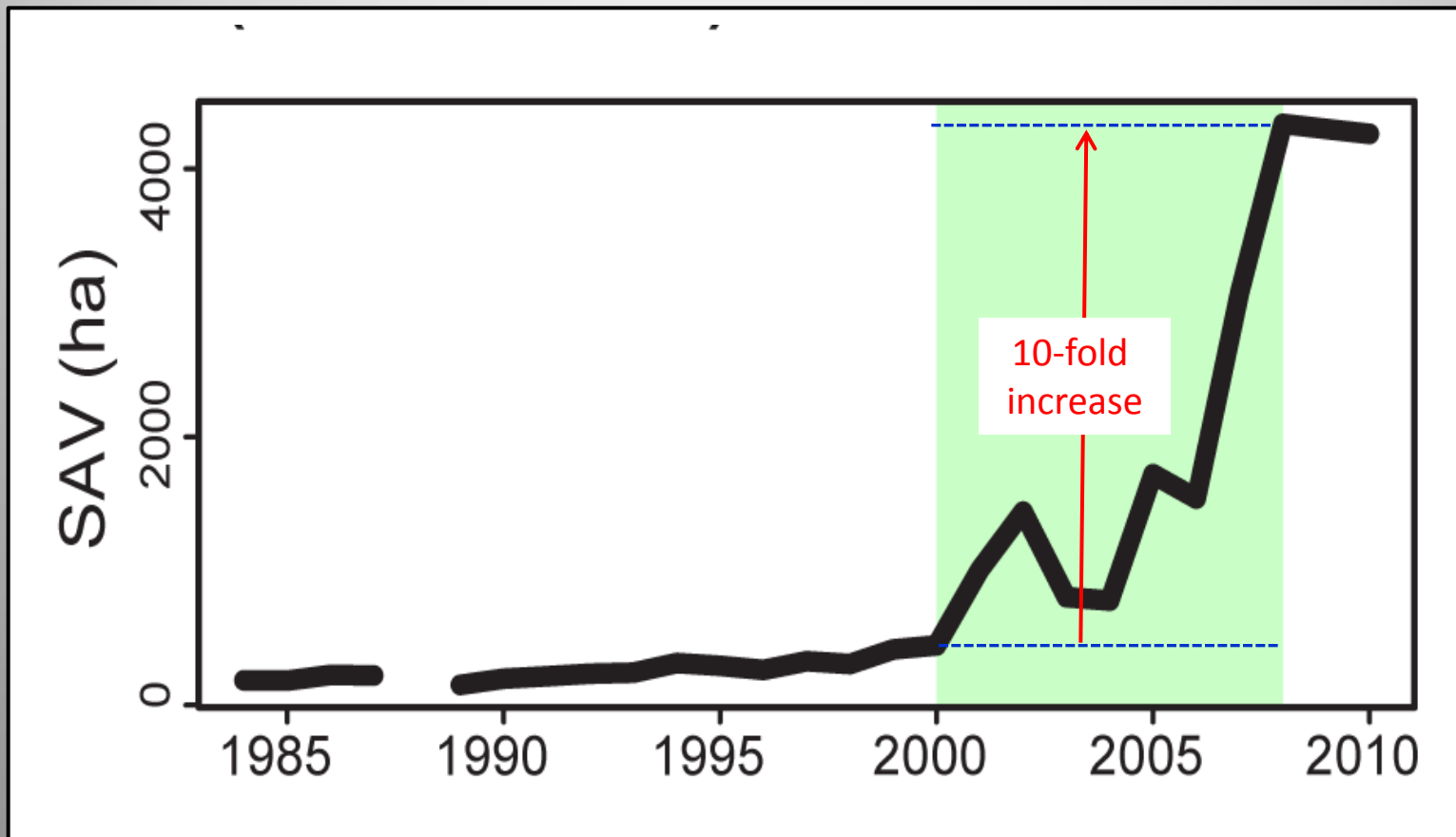


(Gurbisz & Kemp 2011)

Water Quality is Correlated with River Flow

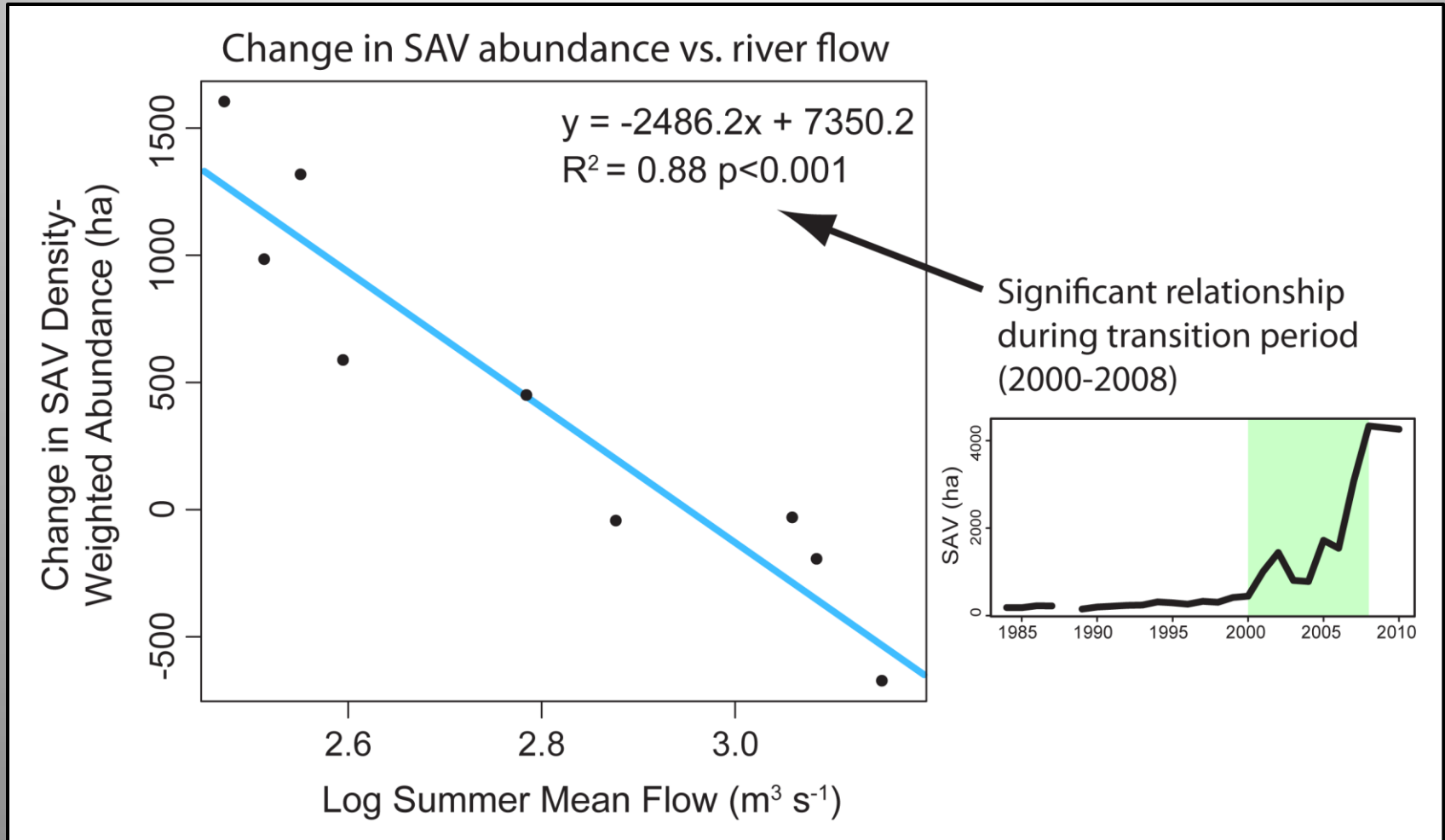


River Flow & SAV Recovery: Transition Period



(Gurbisz & Kemp 2011)

River Flow & SAV Recovery: Transition Period

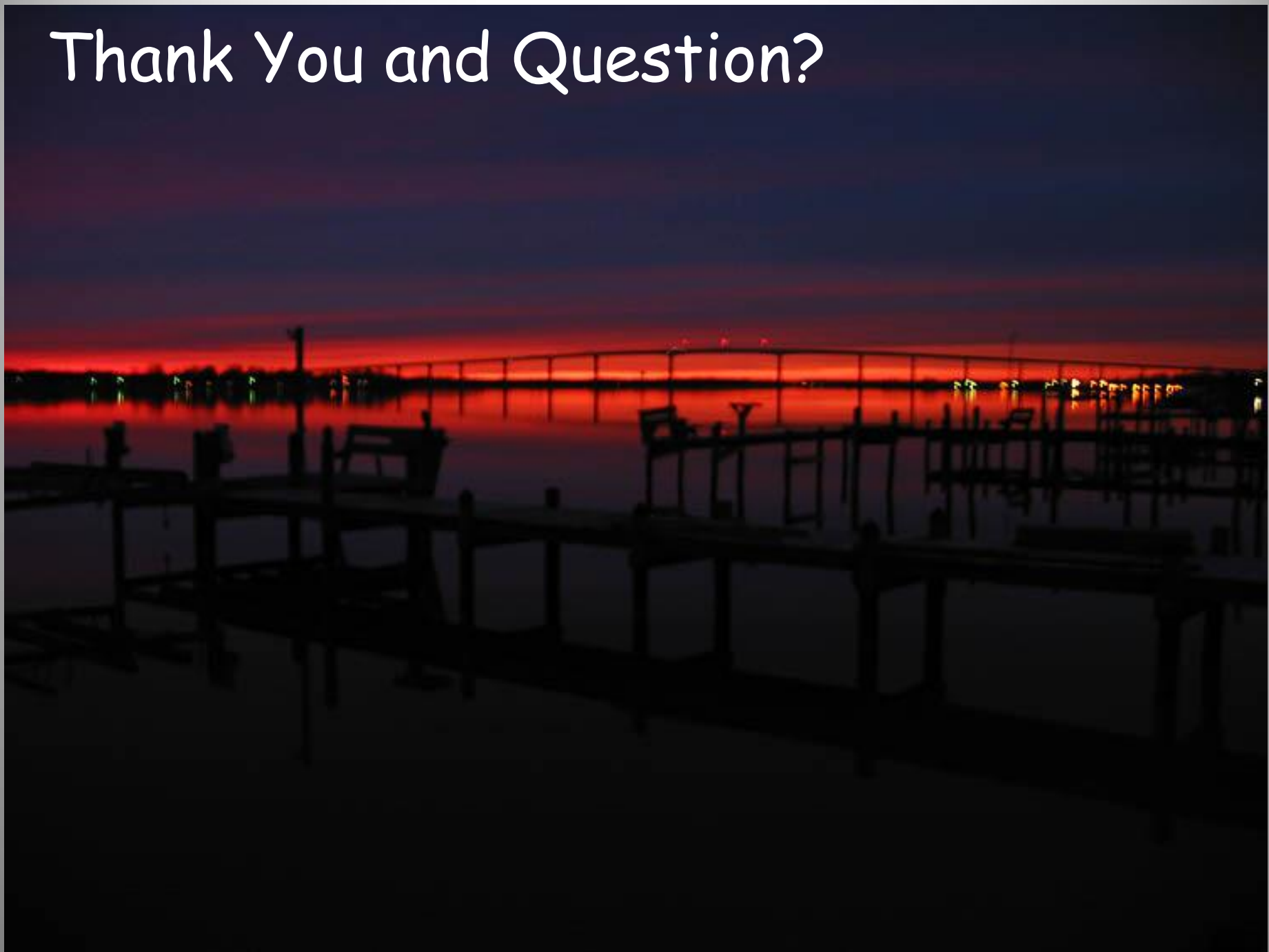


(Gurbisz & Kemp 2011)

Take-Home Points

- The basic model of nutrient enrichment and restoration is solid...stay with it! Weather, climate and Bay physics also play important roles
- Substantial reductions of N and P result in improved water quality and better habitat conditions...more examples are emerging. Positive feedbacks, when they kick in, will speed the restoration process.
- The pathways estuaries follow towards restoration often involve time delays (lags), abrupt changes (thresholds) and things not yet fully understood. Patience and persistence are very necessary
- Restoration trends (and hints of trends) have been observed in both small and large Chesapeake systems...very good signs!

Thank You and Question?



Tidal Water Trends and Explanations: Recent Useful News

Resurgence of SAV on Susquehanna Flats: Floods and droughts contributed to SAV loss and growth; underlying water quality trends also important; feedbacks evident. *Gurbisz and Kemp 2014*

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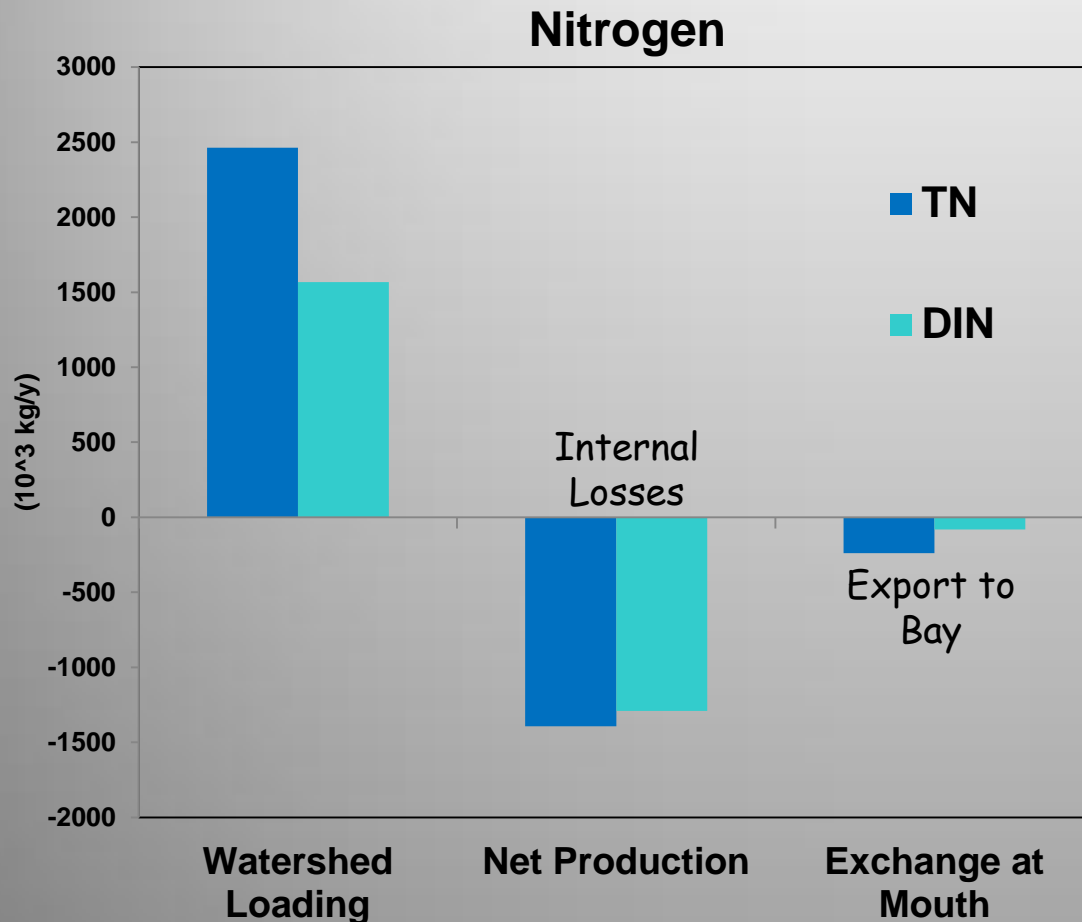
Concluding Comments

- Analysis of time series datasets provides a “window to the past”
- Time series as “synthesis research” analogous to comparative analysis
- Time series data for diverse “response” and “driver” variables
- Analysis to find trends, shifts, correlation, periodicity, and coherence
- SAV time series show dominant role of hydrology and interacting effects of water quality and climate

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- The basic model of nutrient enrichment and restoration is solid...stay with it!
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Is Back River Pollution a “Local” or Chesapeake Bay Issue...where does the enrichment come from?



A Simple Nutrient Budget

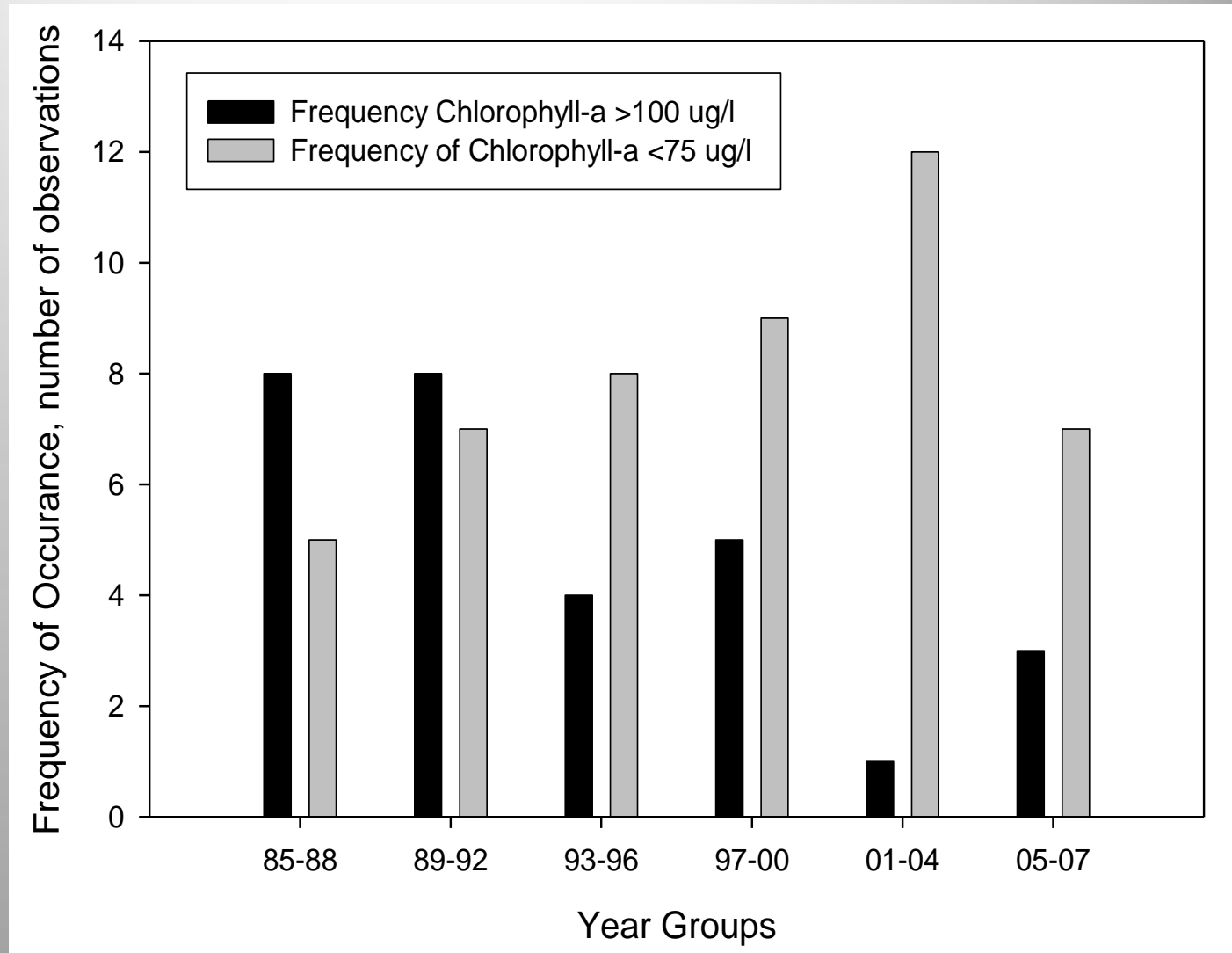
- Budget balances!
Inputs = Internal Losses + Exports
- Exports are **to** Chesapeake Bay
- The enrichment problem is **LOCAL**...don't blame the Bay for this pollution issue
- A good use of Box models!

Severe Algal Blooms Decreasing

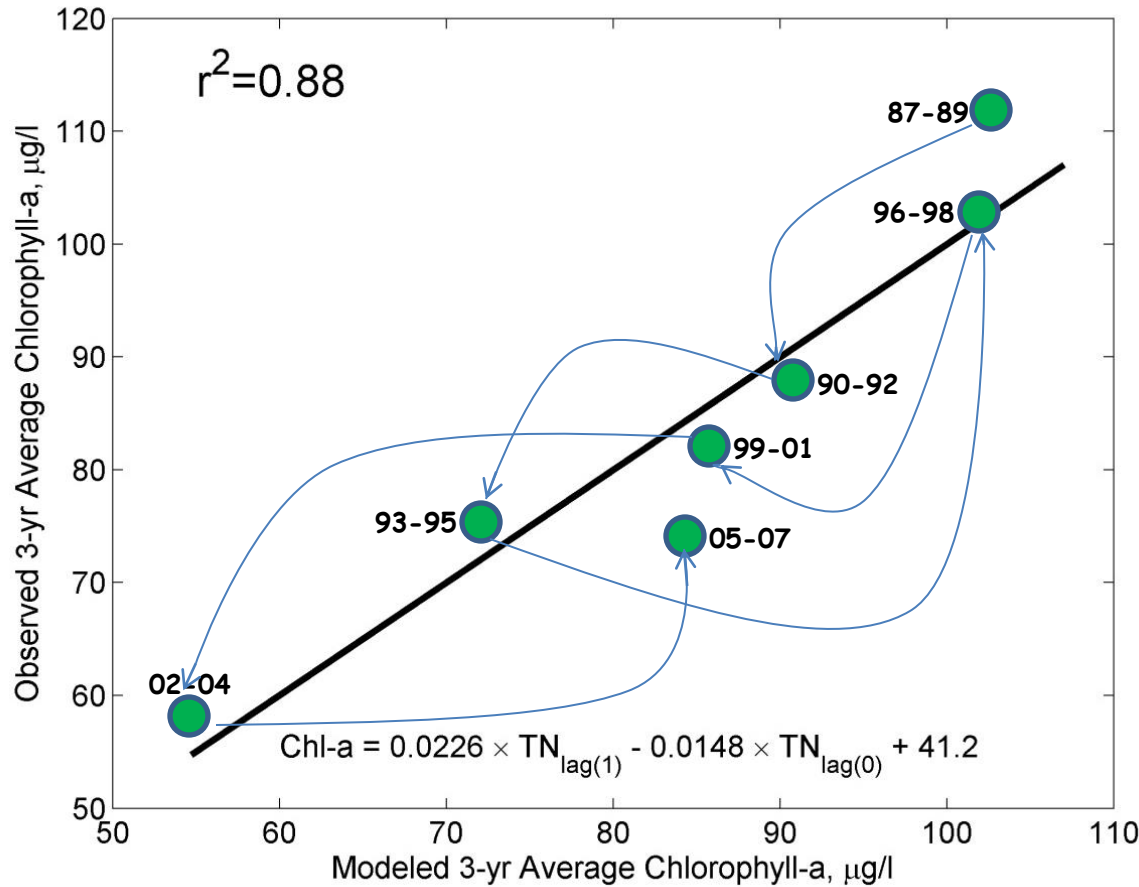
Re-Do this slide with just black bars and scale to 10 units in y-axis

- Algal bloom frequency decreased after N load reductions

- When N loads increased again (05-07) rapid response in increased bloom frequency



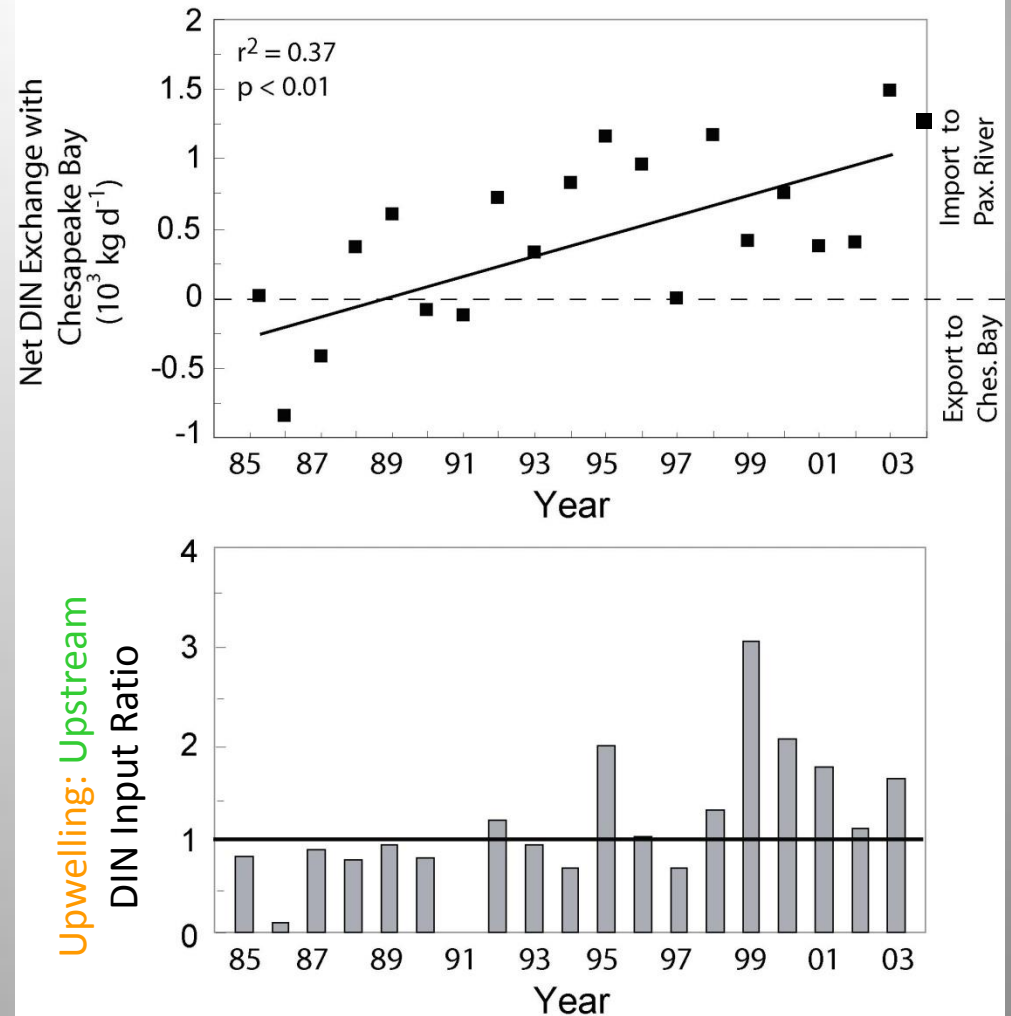
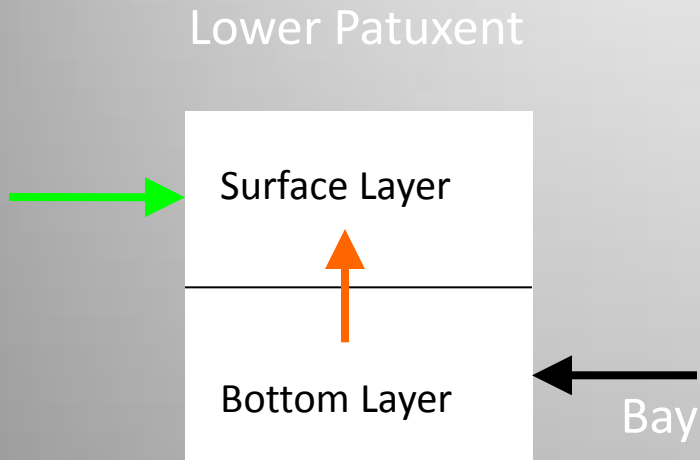
Algal Bloom - Nutrient Relationships



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- Significant algal bloom reduction was achieved (~50%)

Increasing DIN Input from Bay to Patuxent



- Upwelling a dominant DIN source to lower estuary surface layer