Small watershed and subestuary studies link drivers and management practices to system responses

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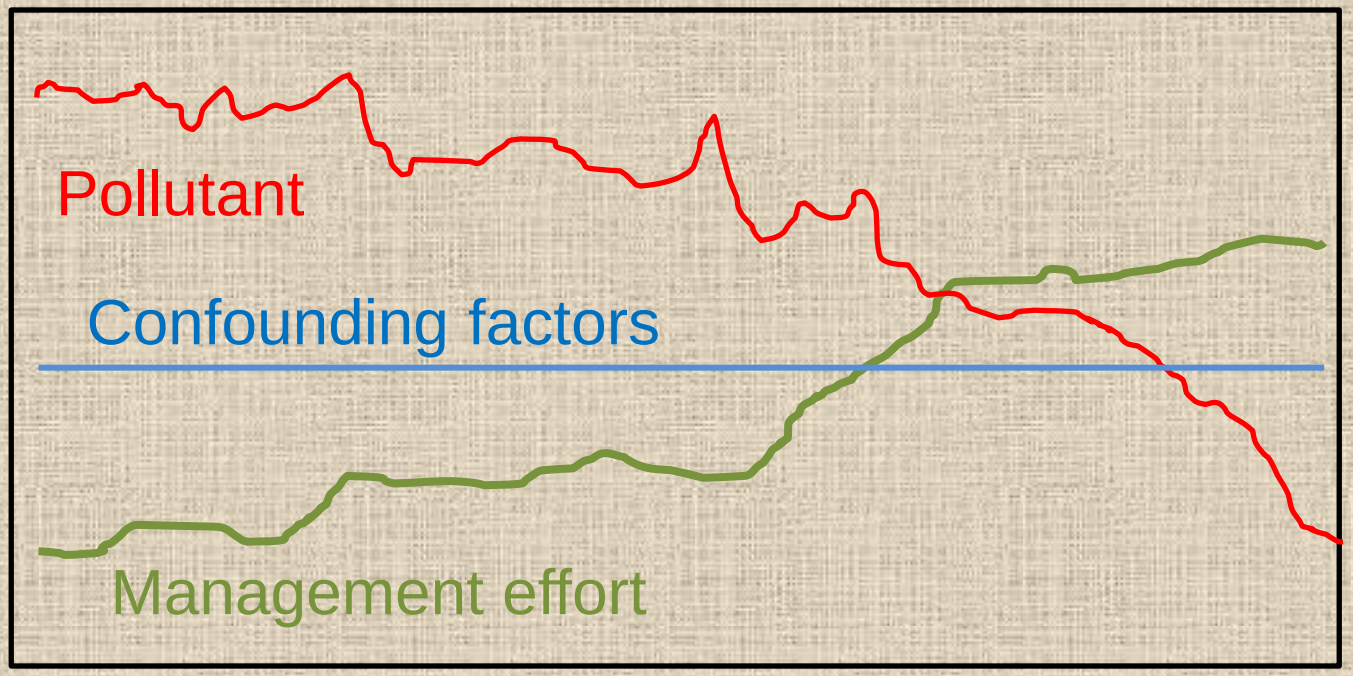
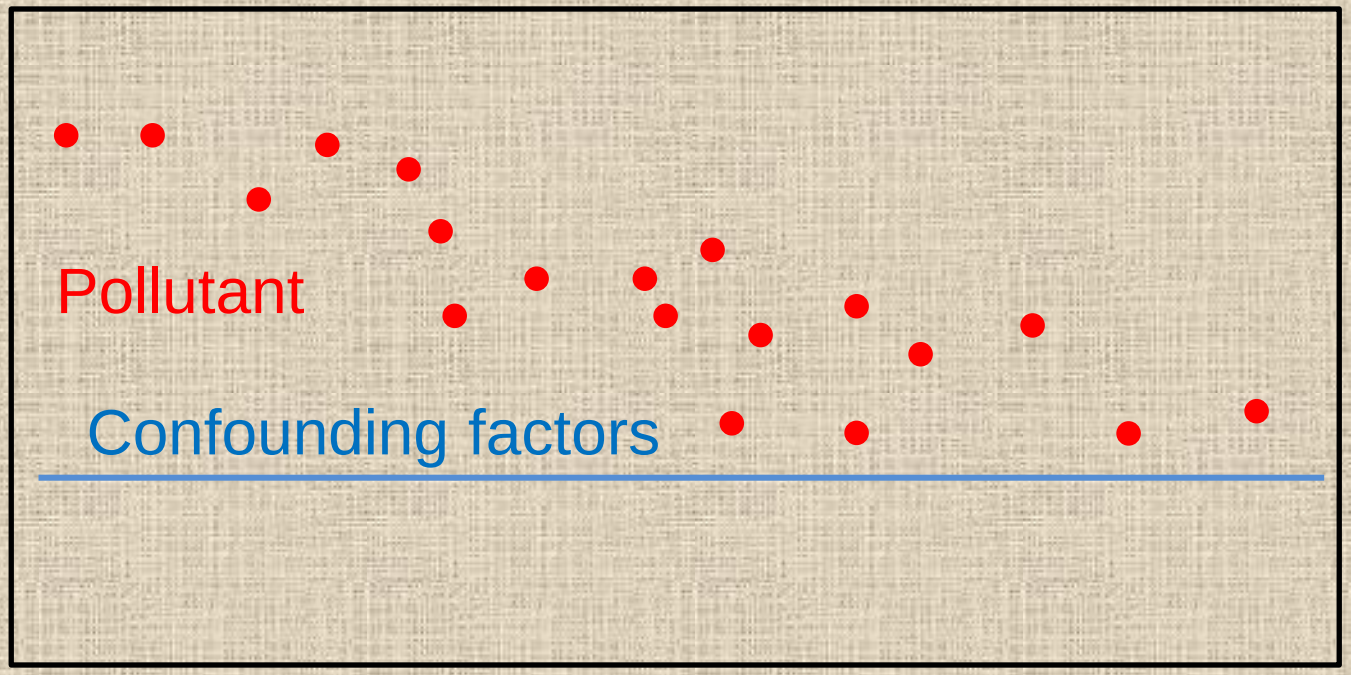
AN HONORS UNIVERSITY IN MARYLAND

Connecting water quality to management



- Gold standard, but patience is required
- Adaptive management needs early feedback

Another approach



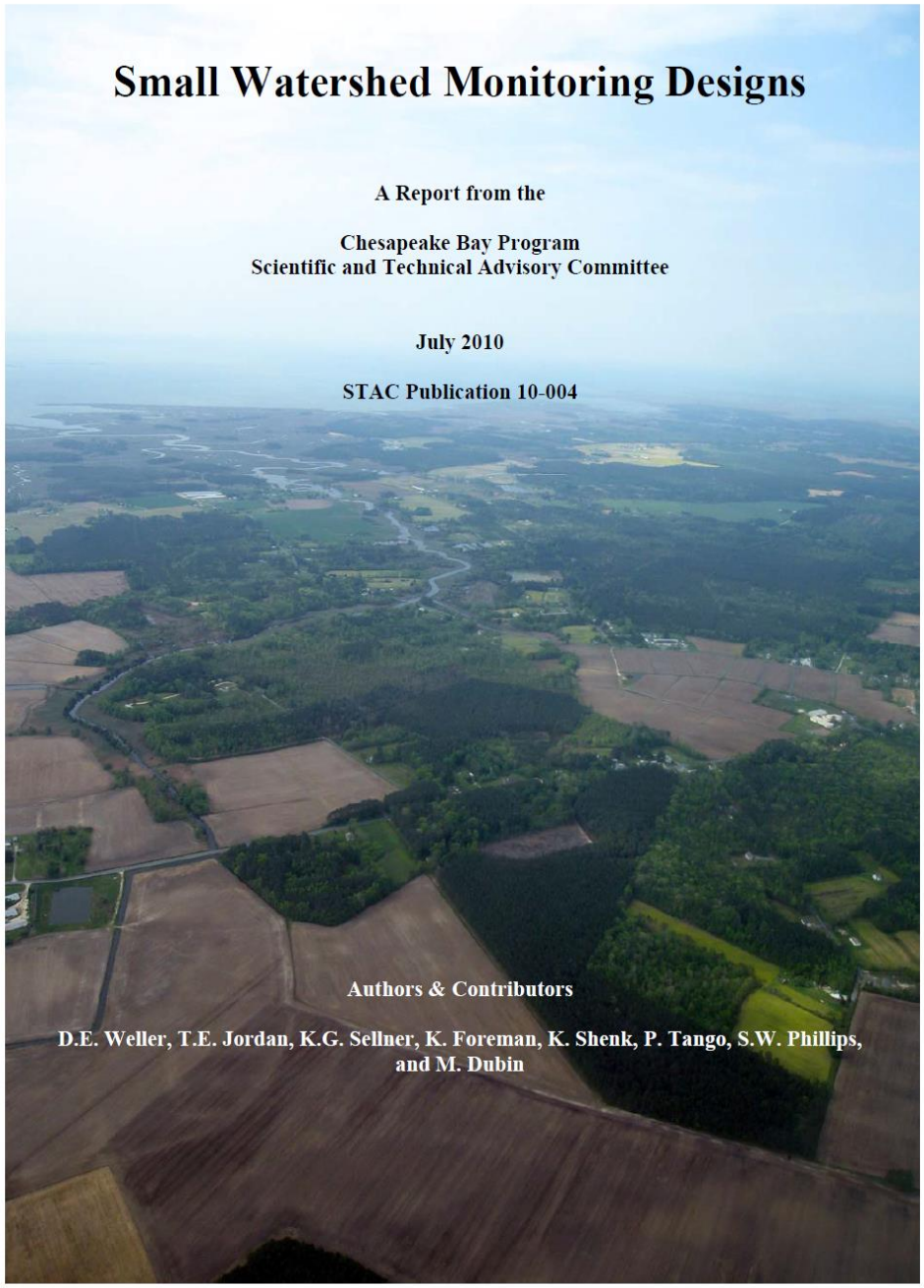
Management effort

One site through time

Different sites

- Can provide quicker feedback

Small Watershed Monitoring Designs



A Report from the

Chesapeake Bay Program
Scientific and Technical Advisory Committee

July 2010

STAC Publication 10-004

Authors & Contributors

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Favorite recommendations

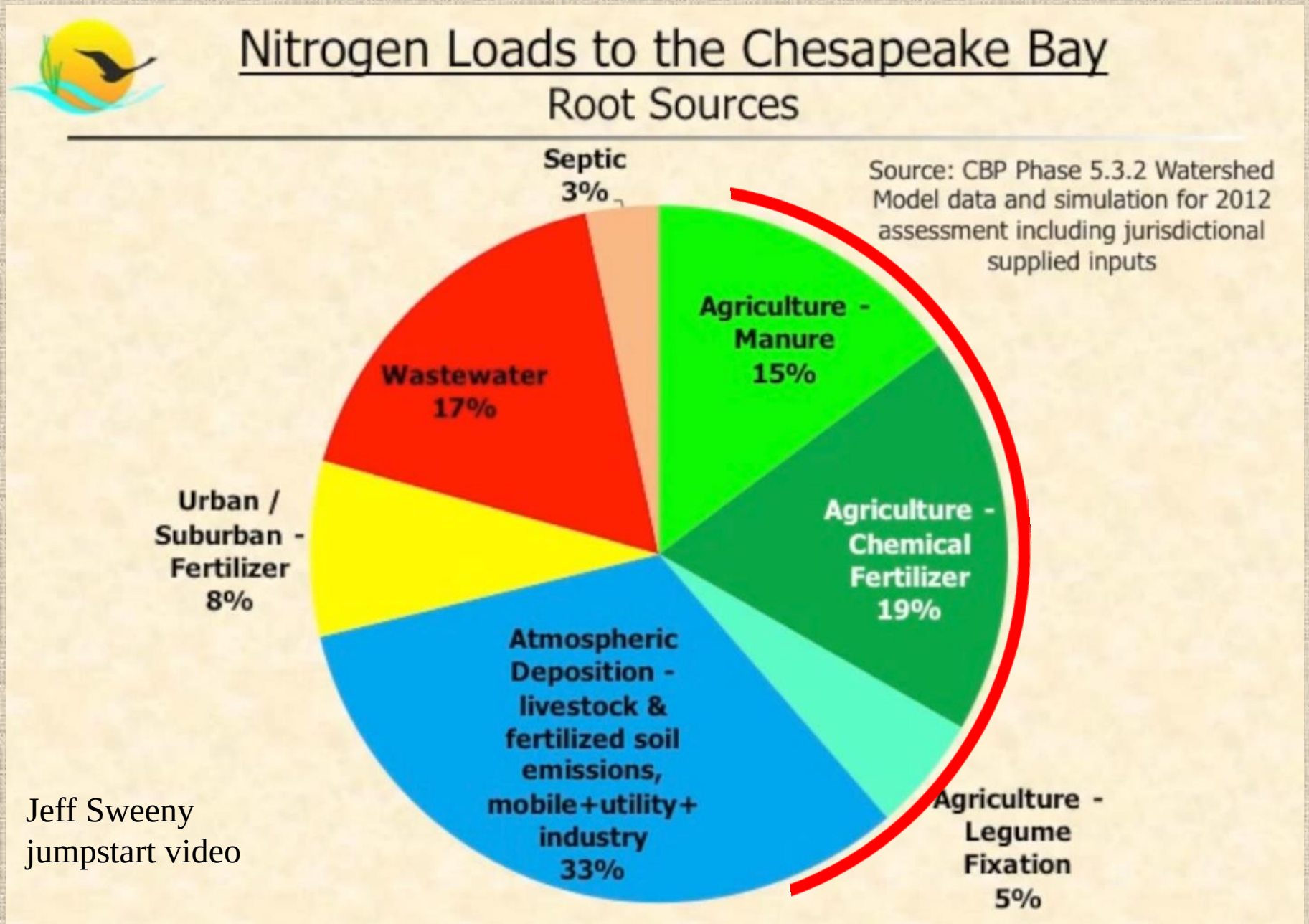
- Study lots of small watersheds with contrasting patterns
- Include many watersheds with high ag & high BMPs
- Use space-for-time analysis as well as time series
- Use easy-to-measure water quality responses
- Assemble data on BMPs and weather, crops, fertilizer, & animals
- Measuring water quality is the easy part
- Tracking BMPs & drivers is the hard part

Weller et al. 2010. STAC 10-004

Two examples from SERC research

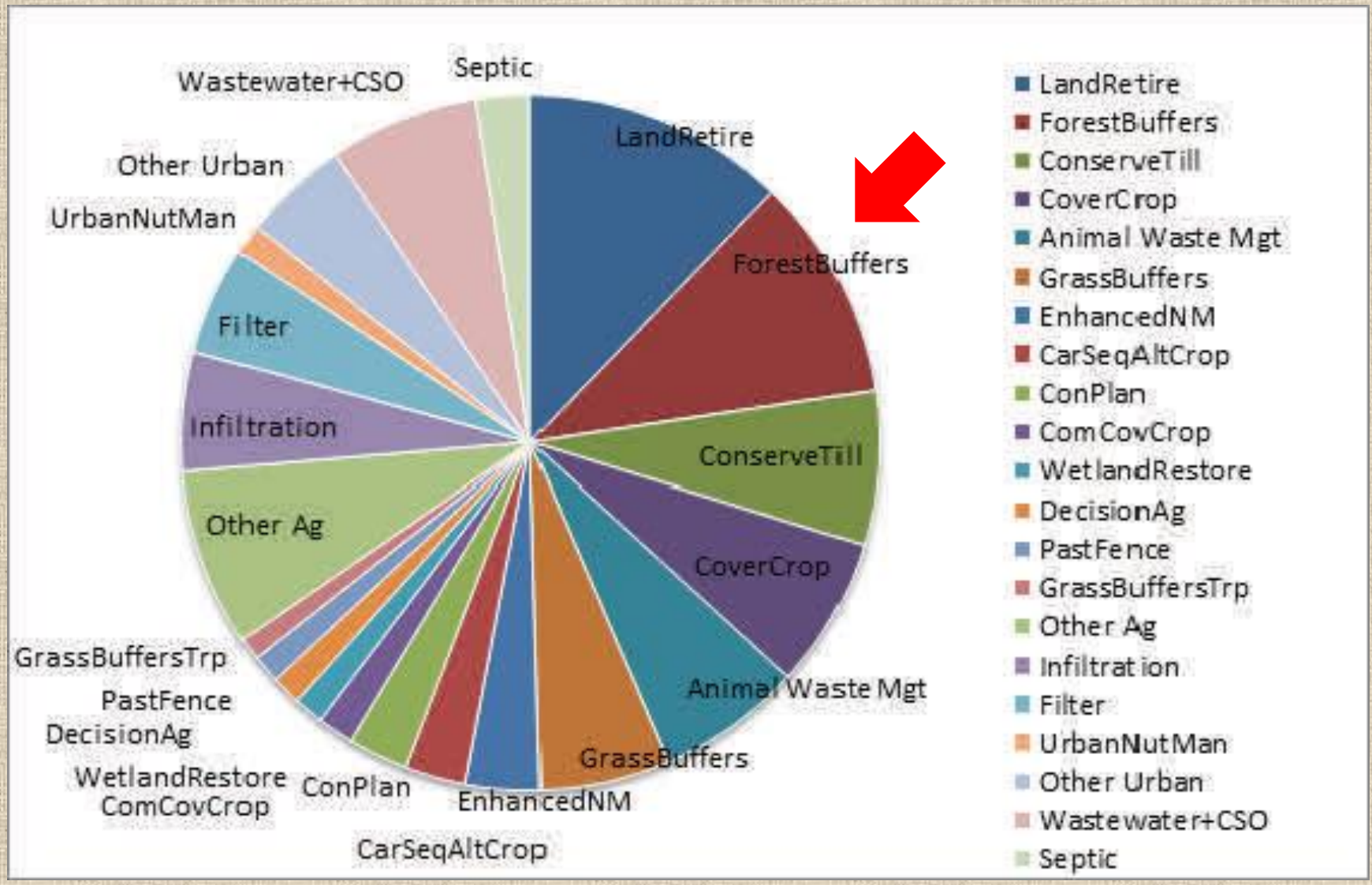
Small watershed studies quantify Bay-wide cropland nitrate removal by riparian buffers

Cropland--number 1 land use N source



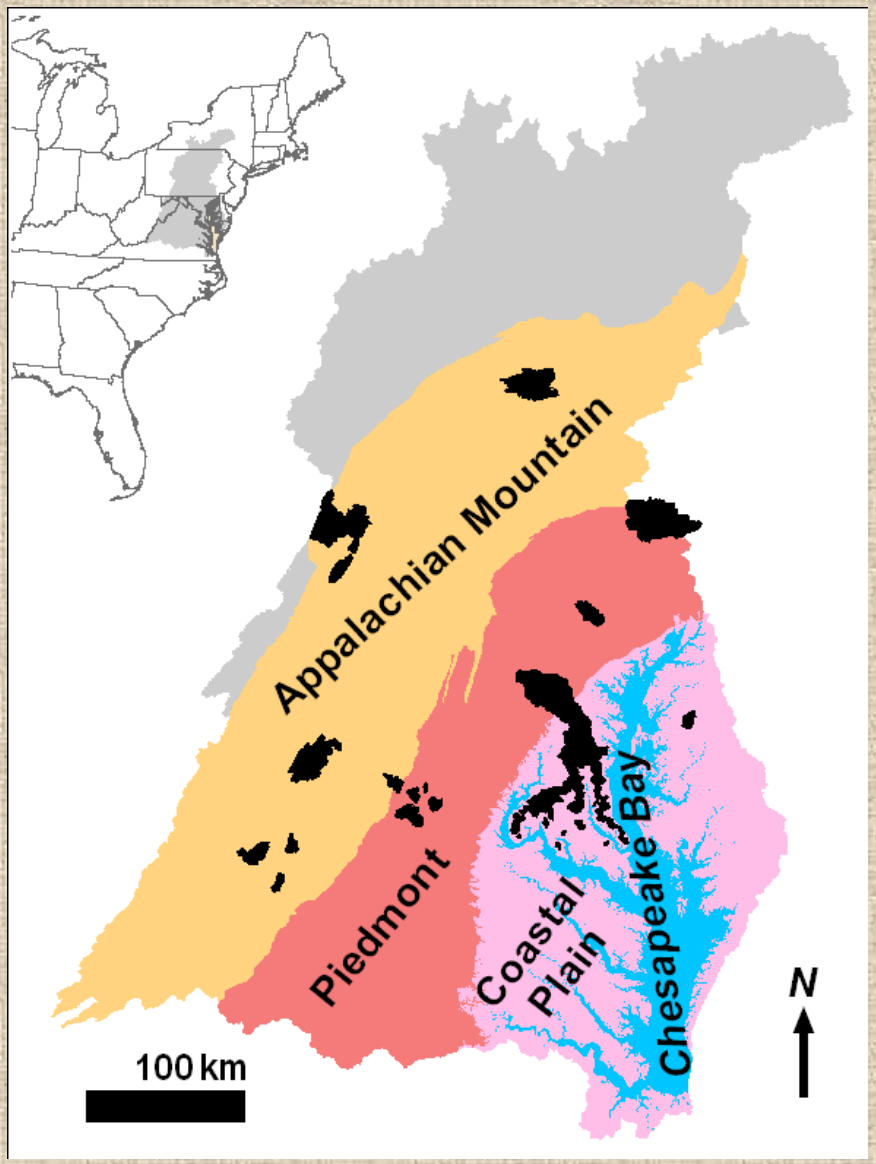
Jeff Sweeny jumpstart video

Number 2 WIP BMP 1985-2025



CBP Forestry Workgroup. 2014 report. *Buffering the Bay*

SERC watershed study

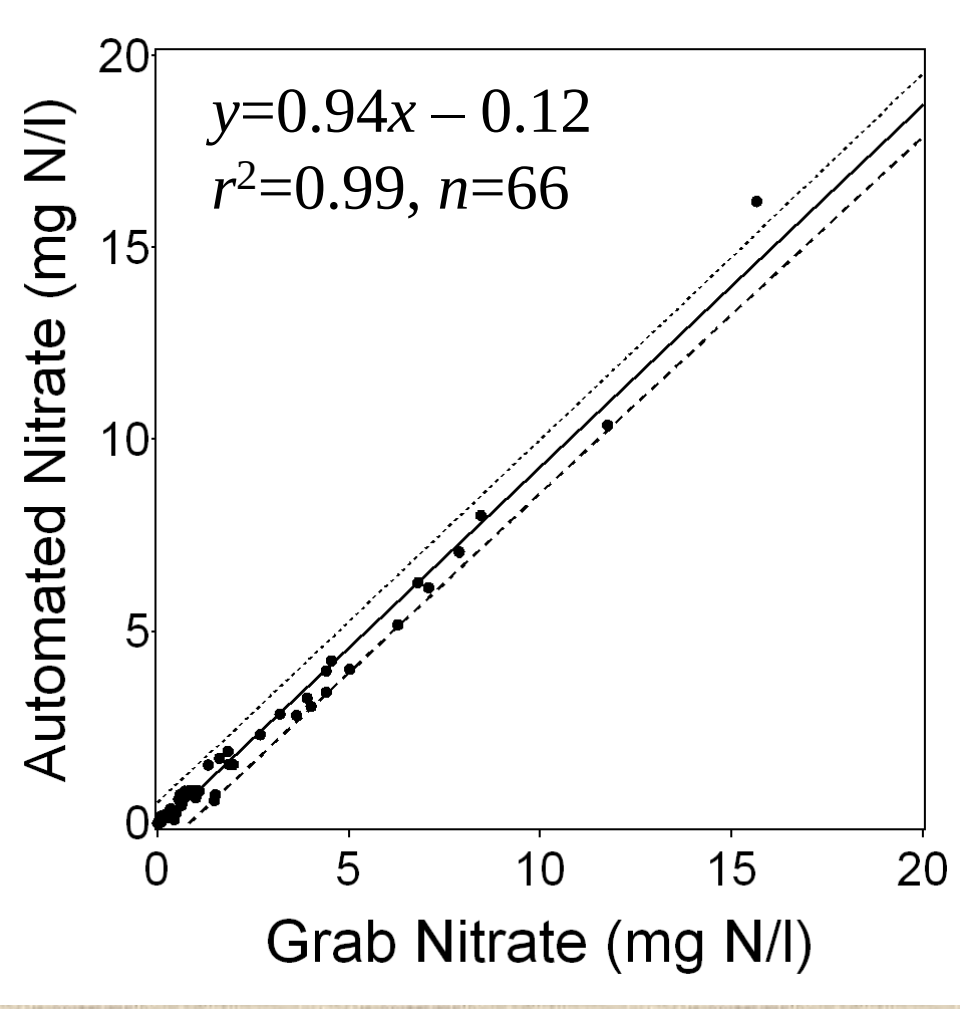


Sampling design

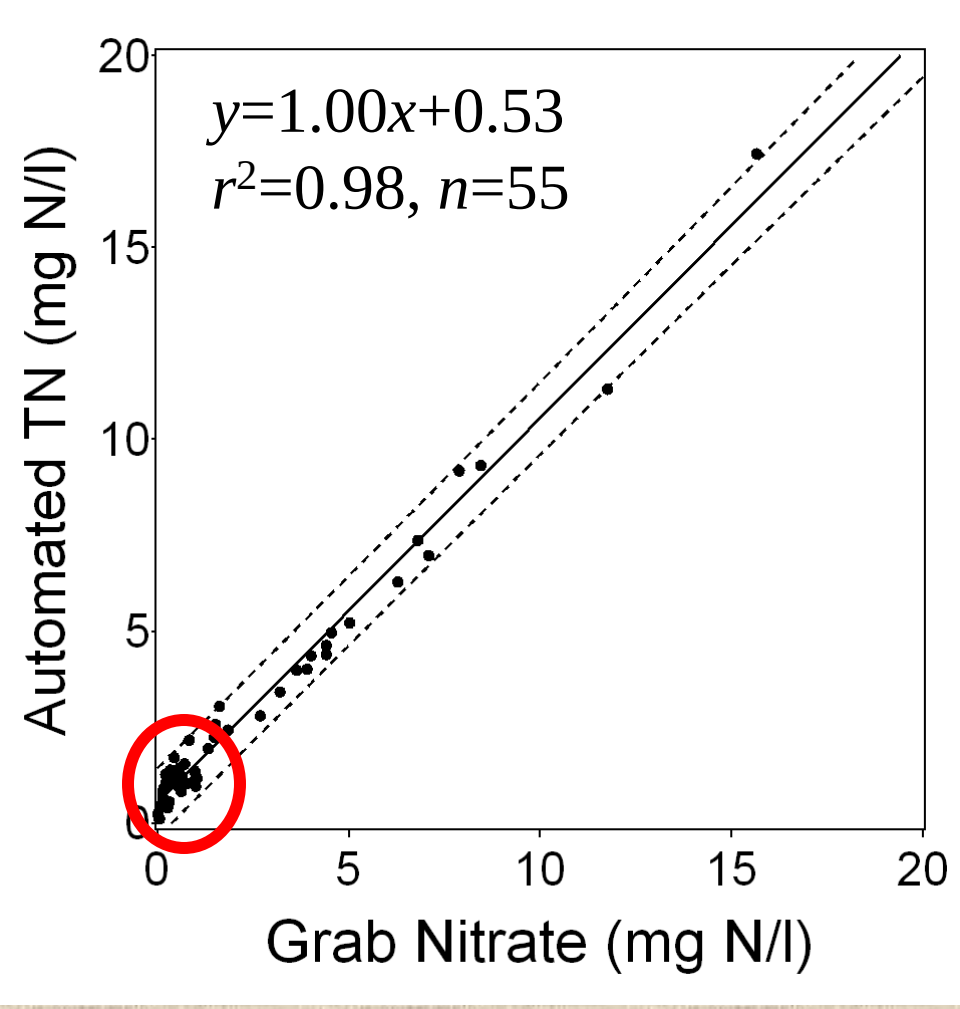
- 321 watersheds
- 12 clusters
- 3 physiographic provinces
- mostly rural watersheds
- measured baseflow nitrate concentration

Liu et al. 2000 *JAWRA* 36:1349-1366

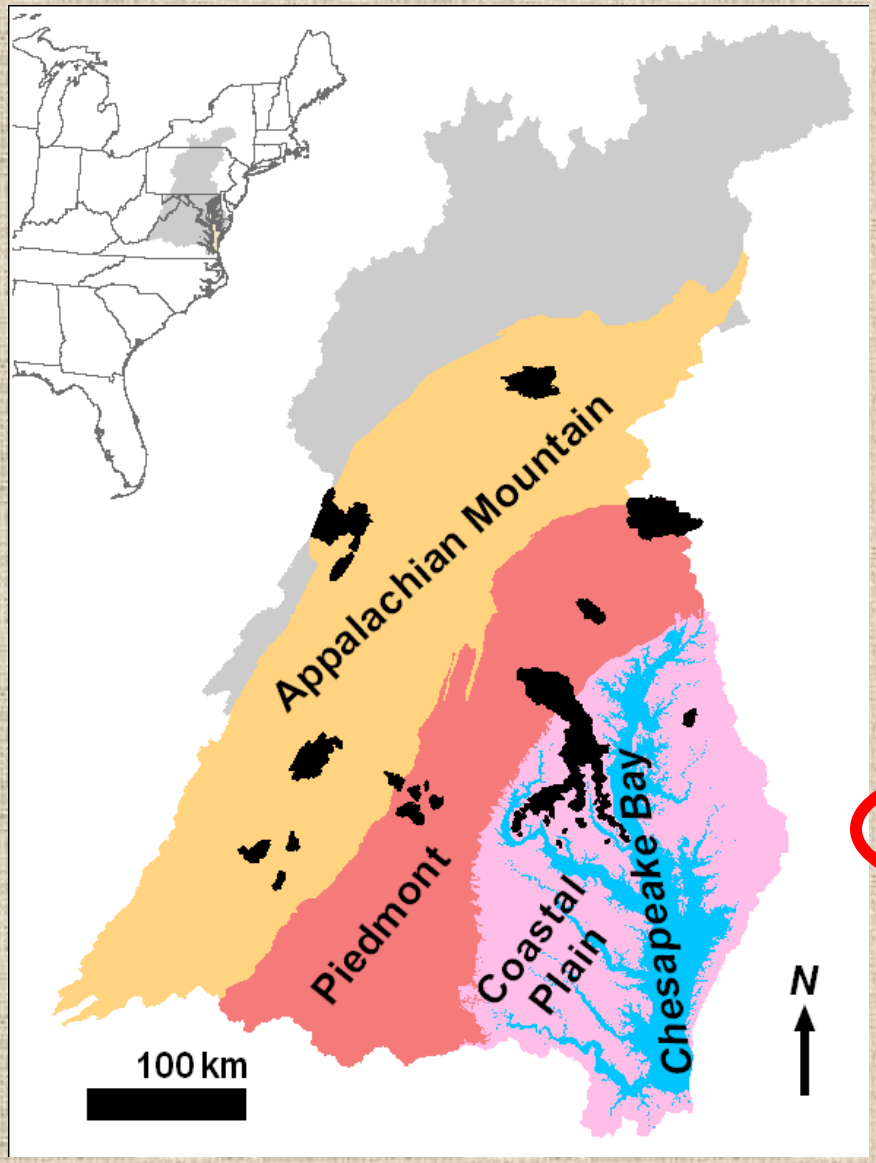
Baseflow nitrate was a great indicator of flow-weighted annual average nitrate . . .



. . . and total-N concentration



Spatial data and analysis



Spatial data

- National Land Cover Dataset 1990 (30 m pixels)
  - Cropland
  - Forest/wetland (buffers)
- 1:24K topography (DEM)
- 1:24K stream maps

Flow path metrics

- Buffer gaps *below cropland* distinguish buffered and unbuffered cropland

Baker et al. 2006 *Land. Ecol.* 21:1327-1345

Bare bones of the statistical approach

- Resolved buffered from unbuffered cropland

$$\mathrm{NO}_3 = \beta_0 + \beta_c C + \beta_u C_u$$

- Fit separate βs for 3 physiographic provinces

- Used information theory to compare models with & without buffers

Weller et al. 2011 *Ecol*. Applic. 21:1679–1695

Buffer effect demonstrated!

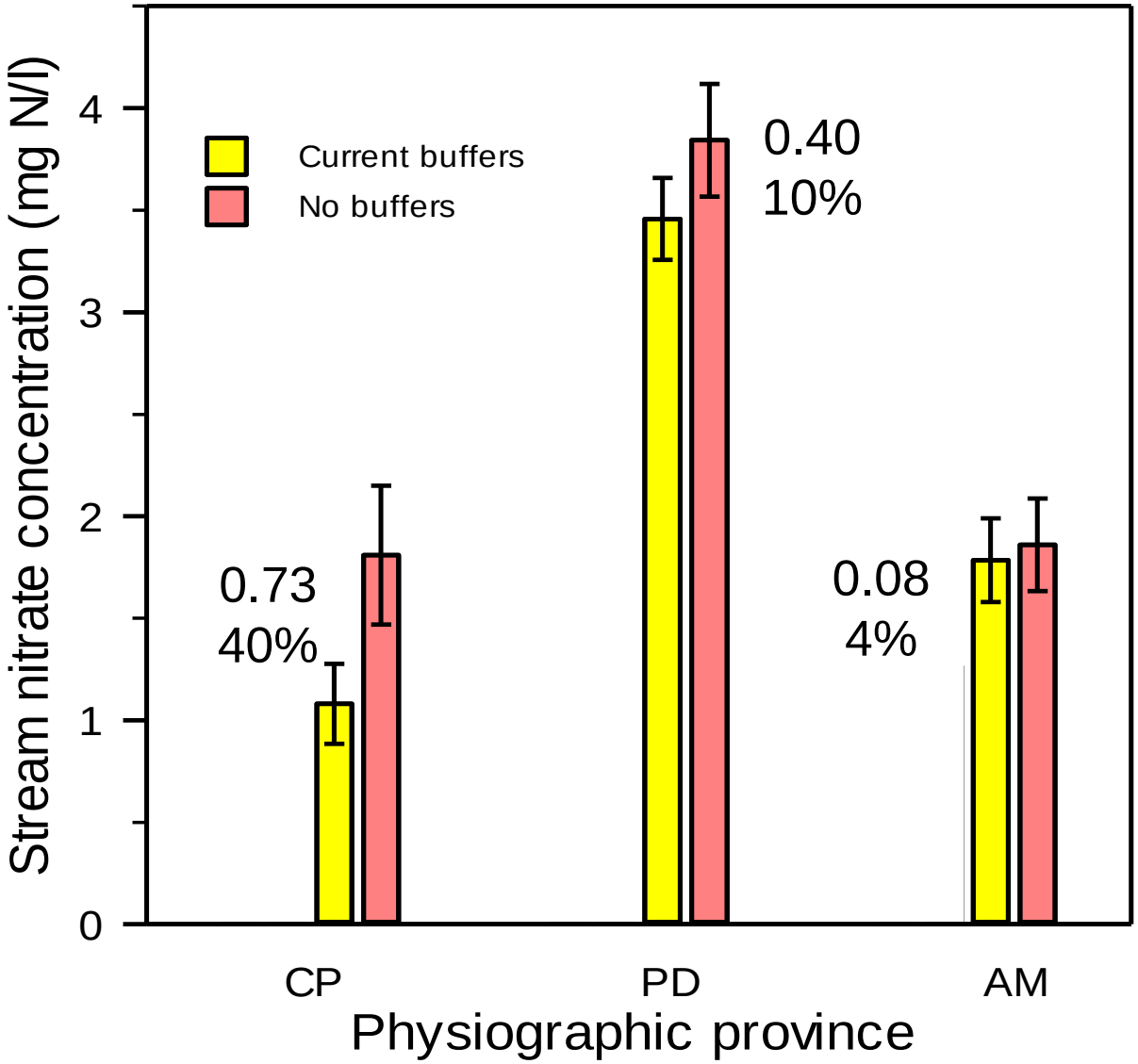
- Δ_{AIC}=18 (buffer model lower)

Support for weaker model	
0-2	Substantial
4-7	Considerably less
>10	Essentially none

- Akaike weight (probability) of buffer model = 0.9999
- ~7000 times more likely than no buffer model)

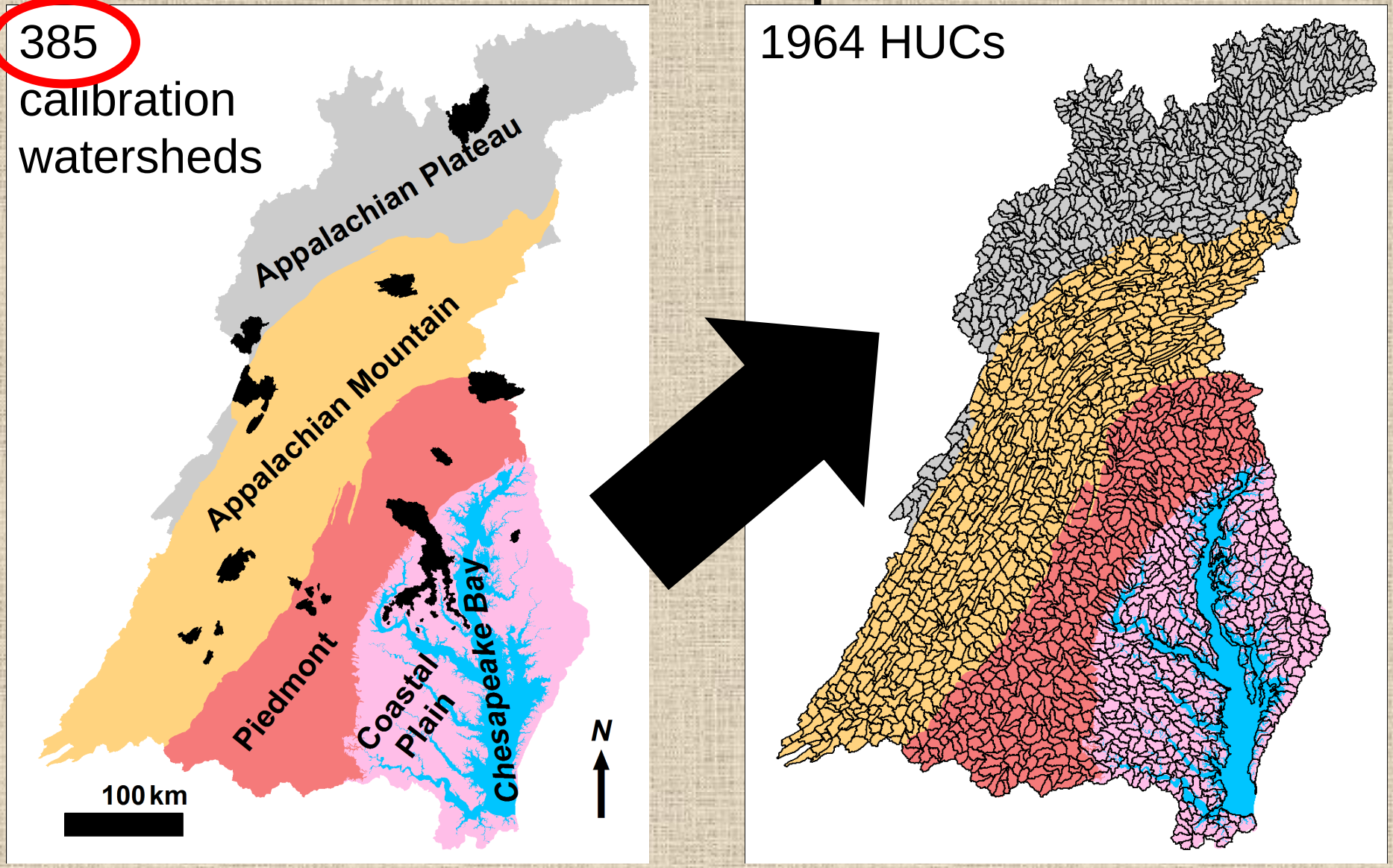
Weller et al. 2011 *Ecol. Applic*. 23:1679-1695

Buffer effect quantified!

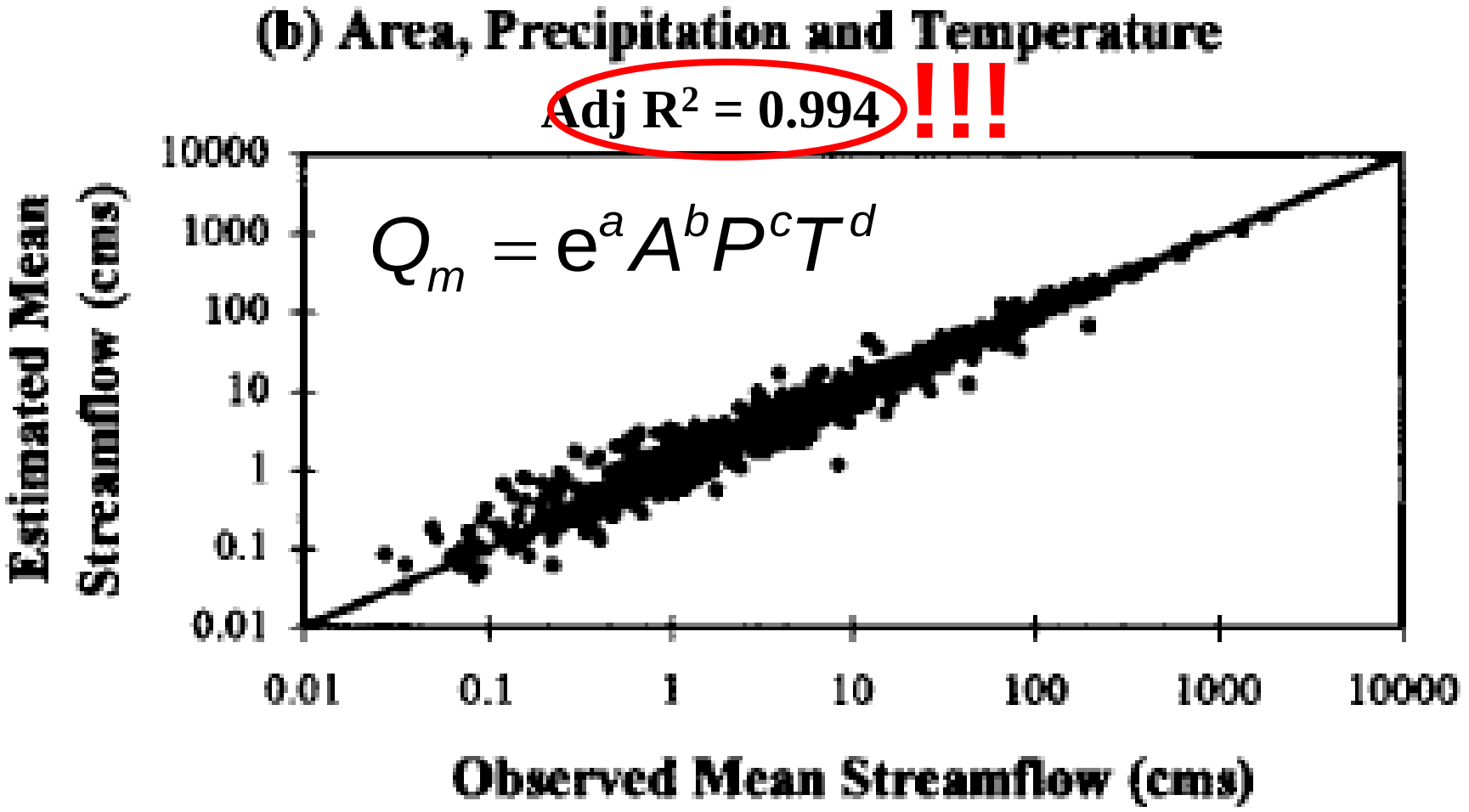


Weller et al. 2011 *Ecol. Applic.* 23:1679-1695

Extrapolating to predict watershed-wide effects on cropland nitrate



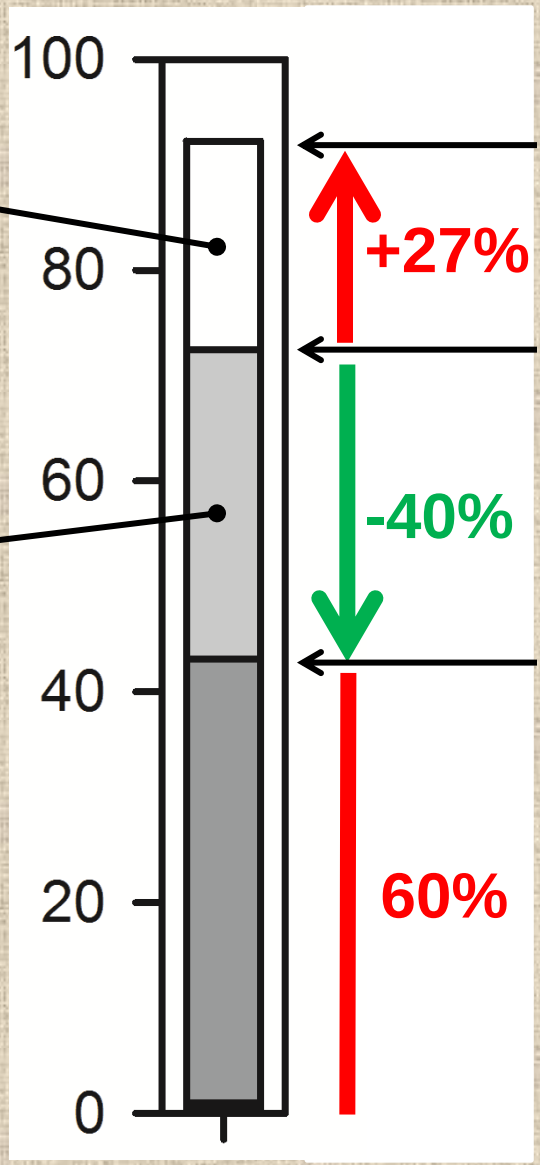
Mean annual stream flow model



Vogel et al. 1999 *J. Irrig. Drainage Engin*. 125:148-157

Daly et al. 2002. *Climate Research* 22:99-113 (PRISM 1971-2000)

Bay-wide buffer effects on nitrate load *to streams* (Gg N/yr)



removal by existing buffers

possible removal in restored buffer gaps (an upper limit)

must address with other practices

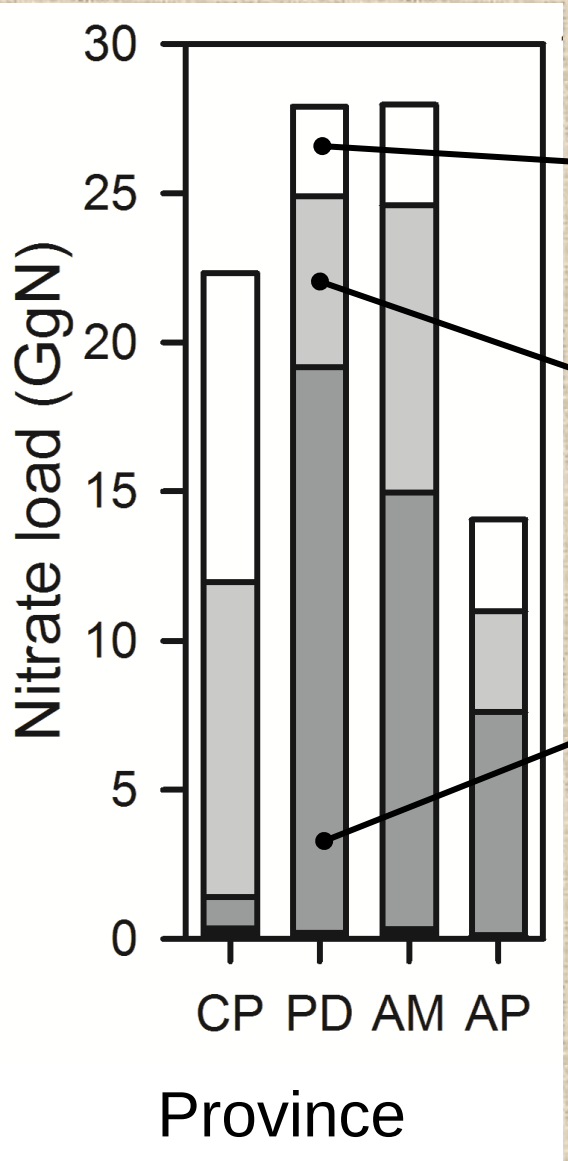
with no buffers

cropland stream nitrate load with existing buffers

with crop buffer gaps restored

1 Gg
2.2 million lbs
1100 tons

Differences among provinces

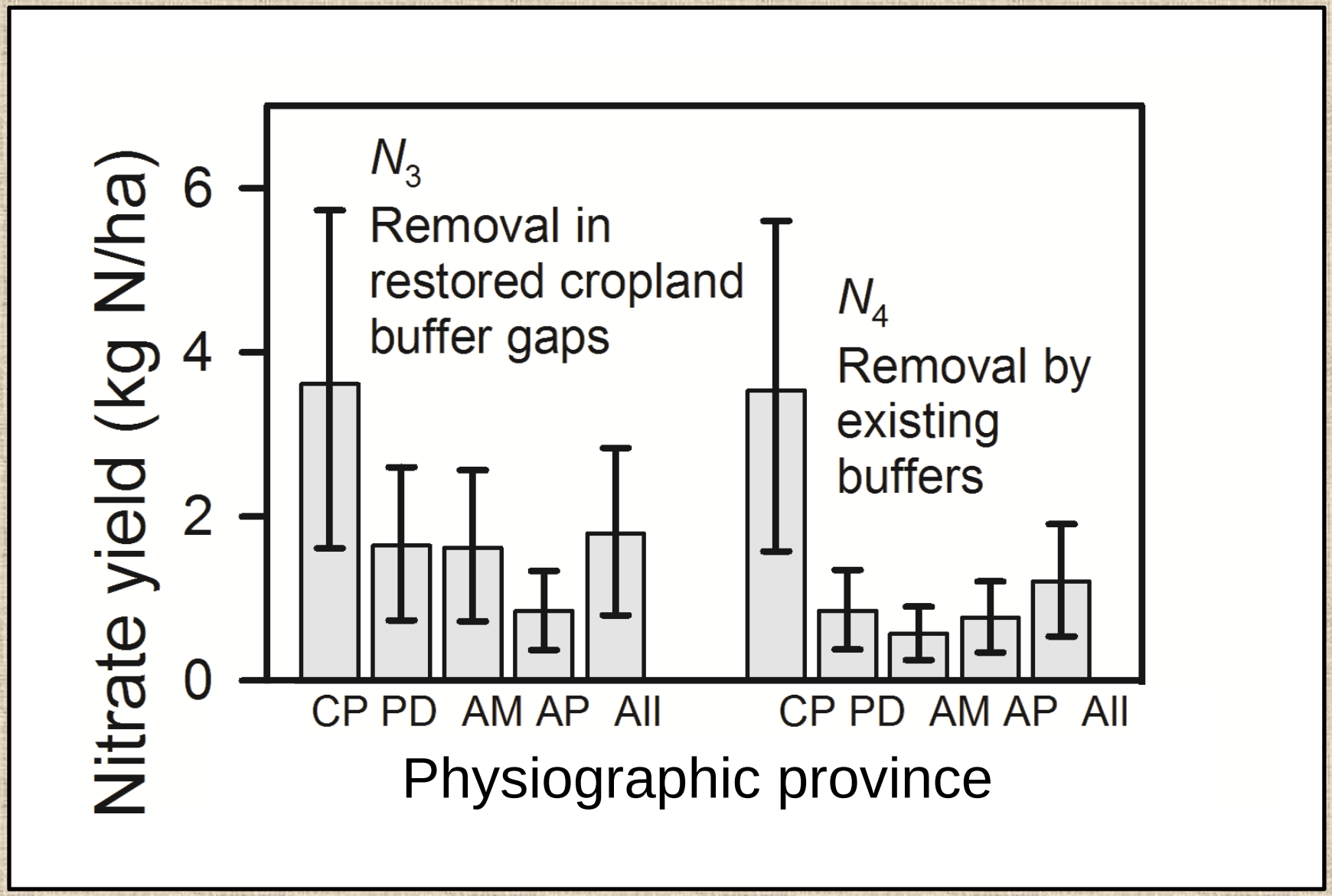


removal by existing buffers

possible removal in restored buffer gaps (an upper limit)

must address with other practices

Analysis provides confidence limits



Summary – first example

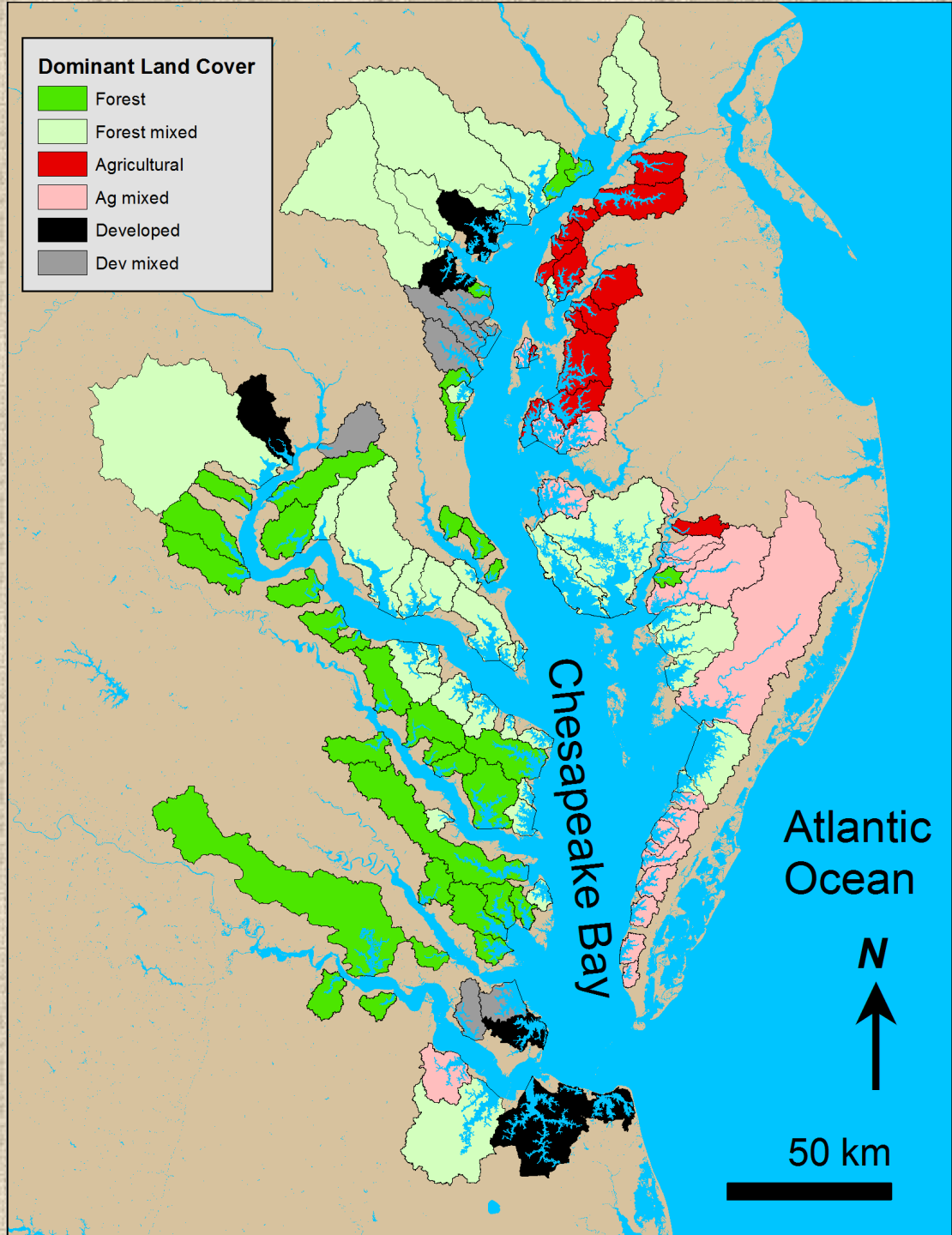
- Good news
  - Related a source (cropland) and management practice (buffers) to water quality
  - Accounted for environmental setting
  - Demonstrated buffer effect
  - Quantified buffer effect
  - Extrapolated to whole Bay watershed
- Bad news
  - Not the buffers the CBP tracks as a BMP
  - Need higher resolution land cover and buffer BMP locations

Example 2 -- subestuary studies document effects of land cover and shoreline armoring on SAV abundance

- Important habitat and ecosystem component
- Integrating indicator of water quality
- Water quality standard

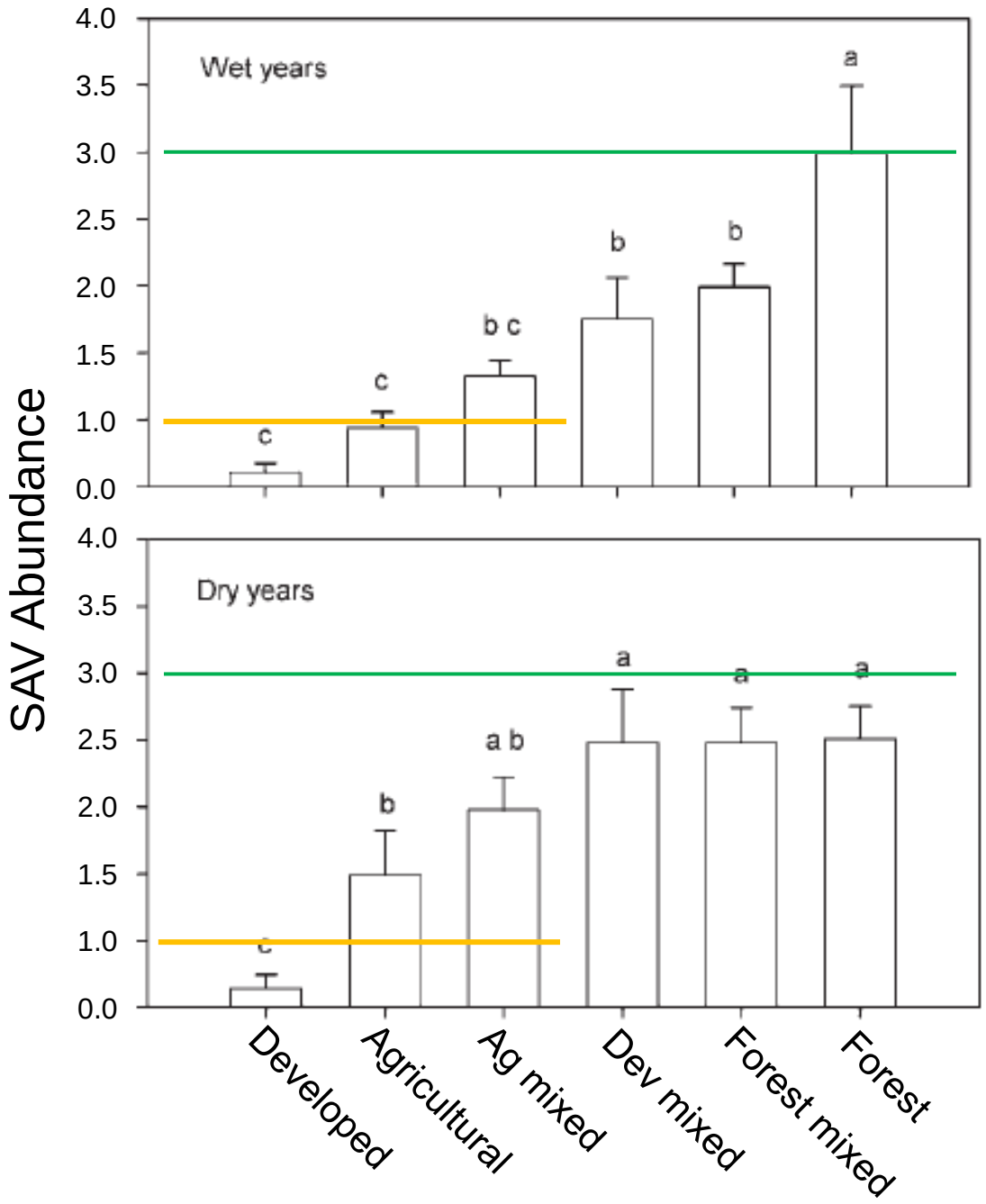
~100 study subestuaries

- Shallow hot spots
- Contrasting local watersheds (*a priori* categories)
- Replicates



Interacting effects of land cover and weather

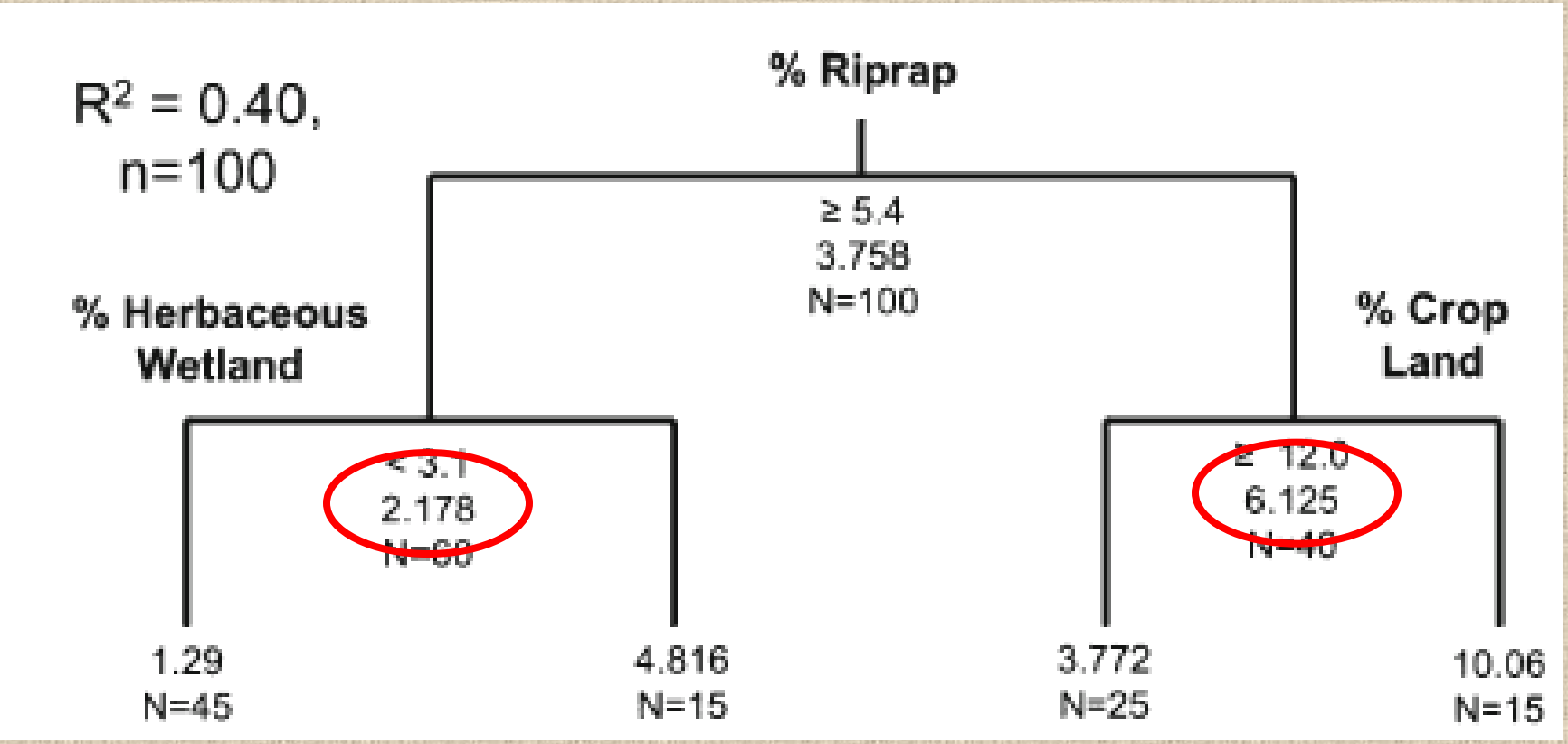
- SAV area normalized to habitat area & density weighted
- RM ANOVA
- Dev always low
- Ag better in dry years
- Forest better in wet years



Li et al. 2007. Estuaries & Coasts 30:840-854

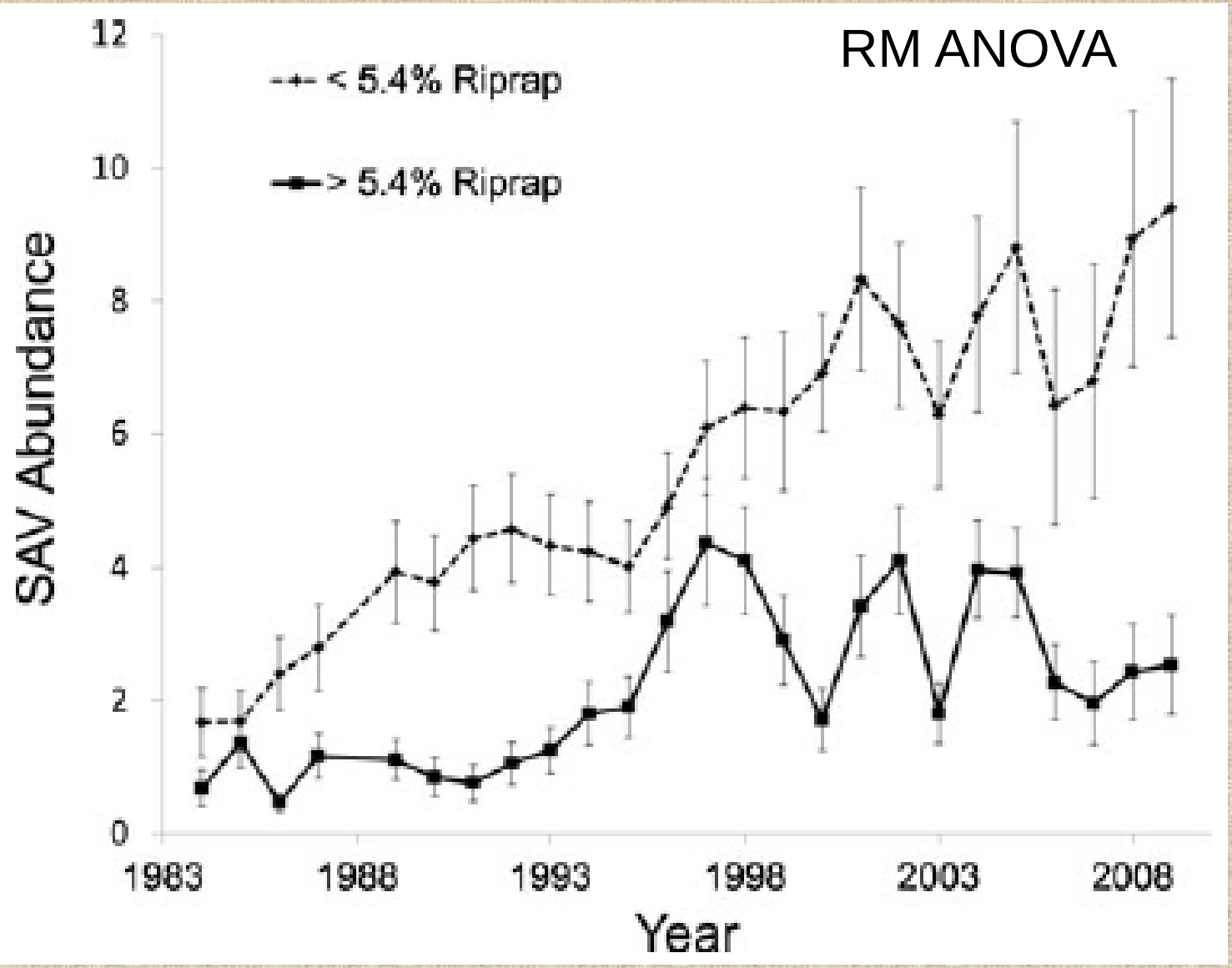
Shoreline armoring predicts abundance

CART analysis of normalized abundance vs. watershed and estuary characteristics



Patrick et al. 2014. Estuaries & Coasts (Early view)

Recovery trends differ with armoring



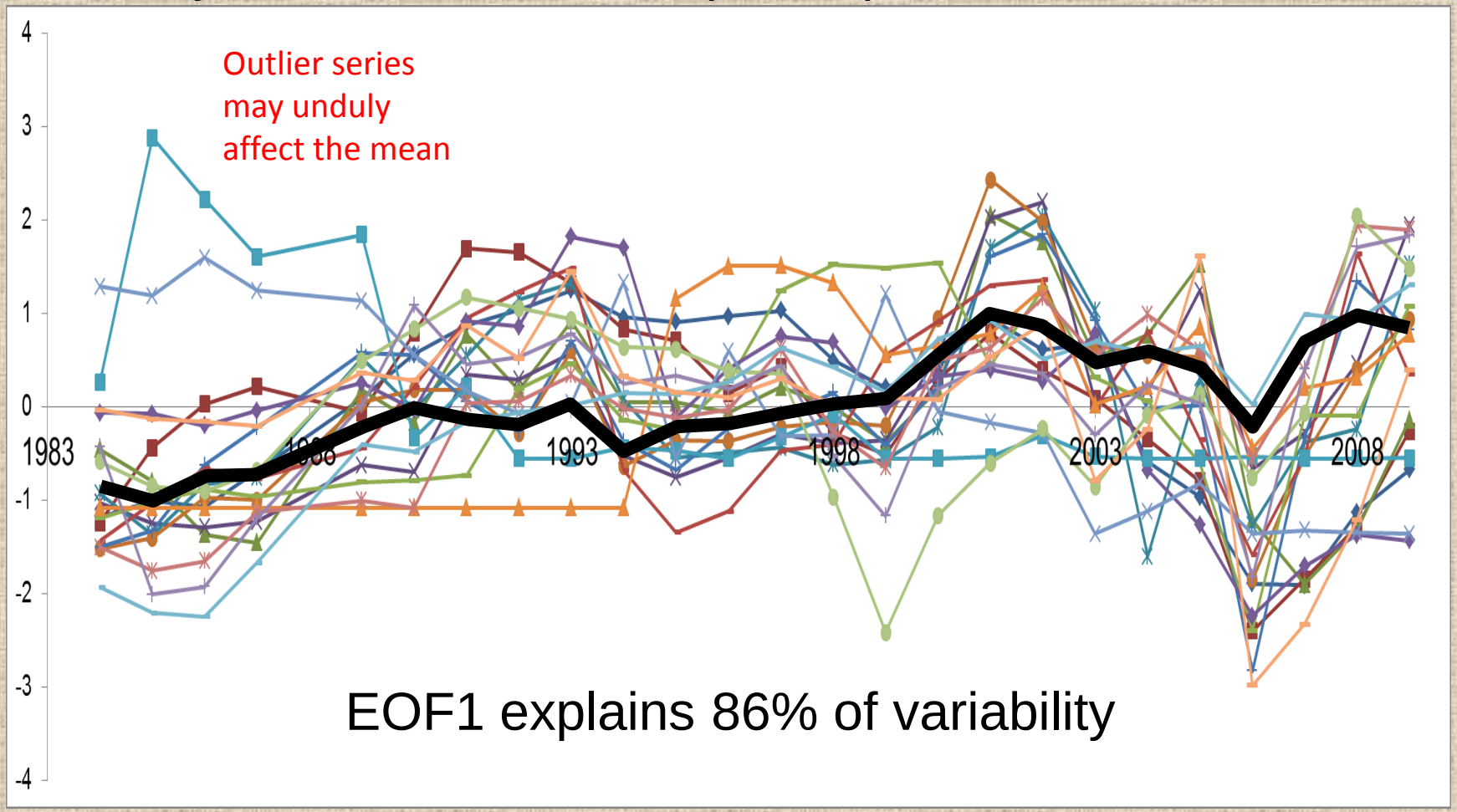
Patrick et al. 2014. Estuaries & Coasts (Early view)

Time series analysis of SAV abundance

Empirical Orthogonal Function Analysis

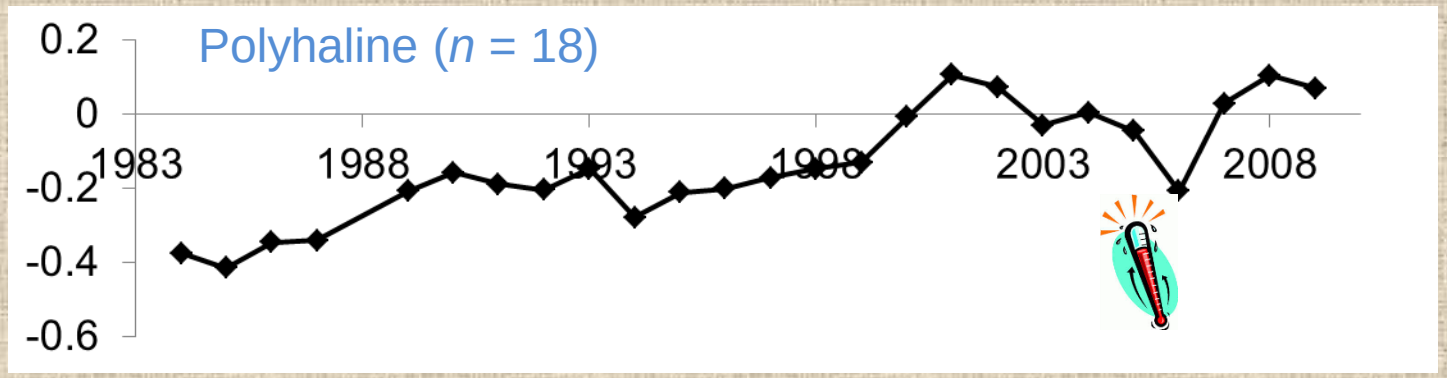
Reduces the dimensionality of a set of time series (like PCA)

Polyhaline subestuaries (n = 18) 1983-2009

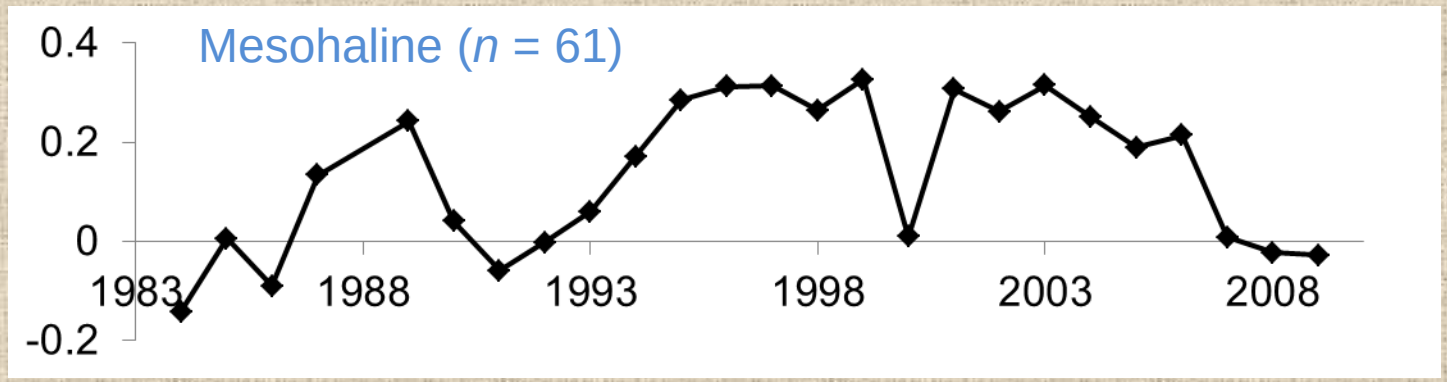


Patrick & Weller. In prep.

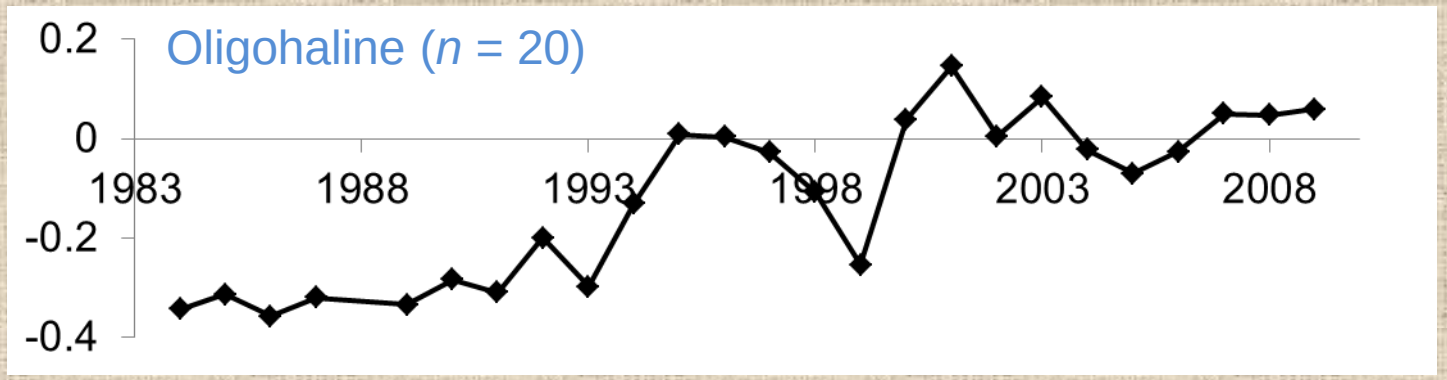
EOF results



86%



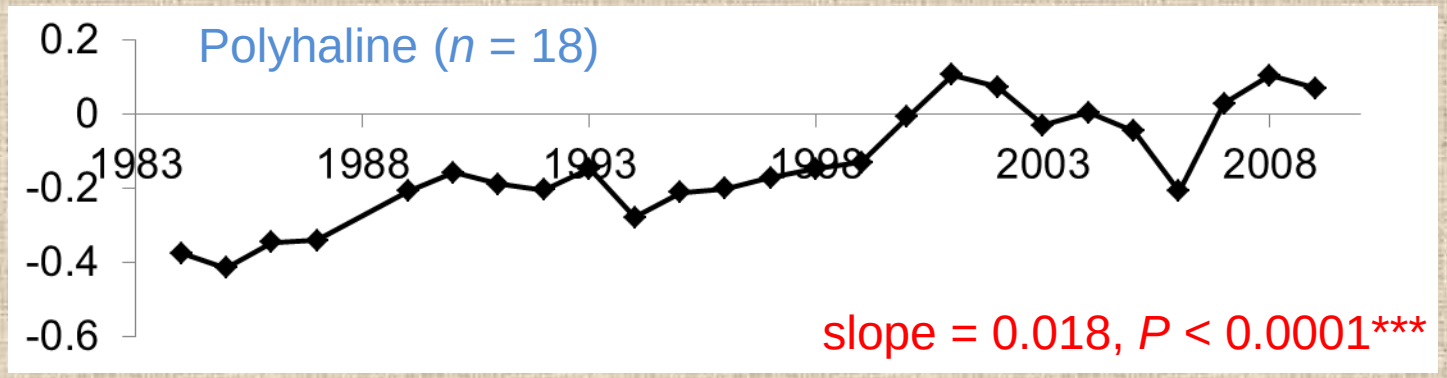
57%

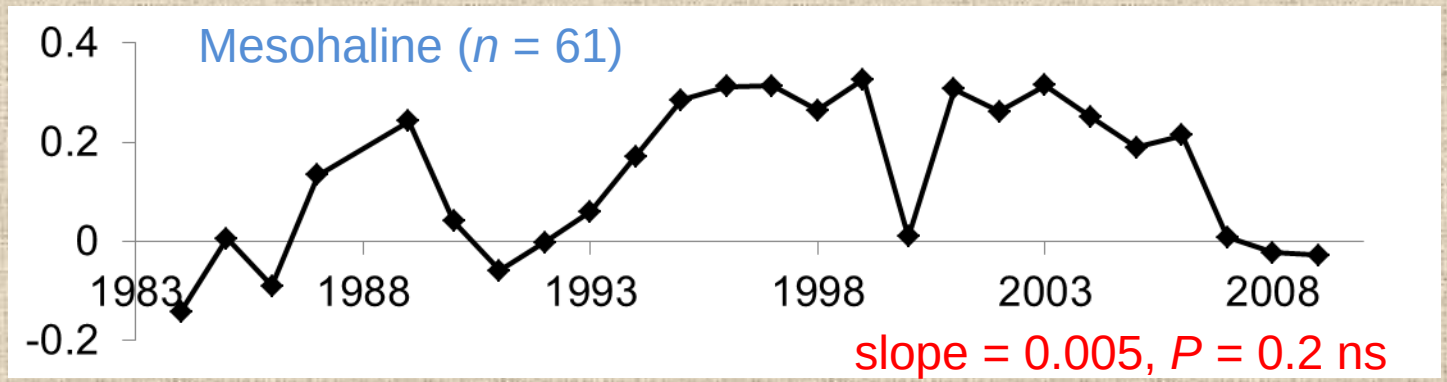


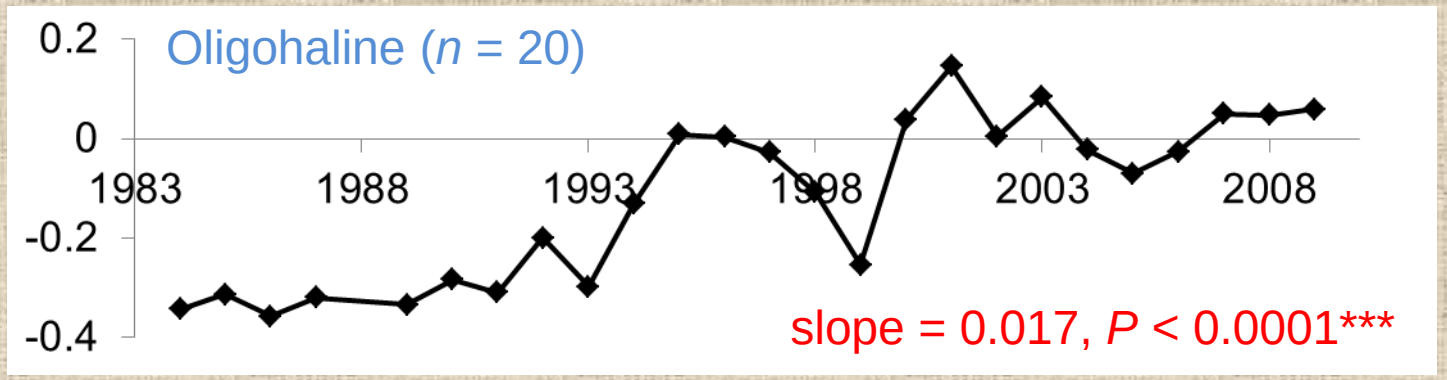
49%

Patrick & Weller. In prep.

Kendall trend tests

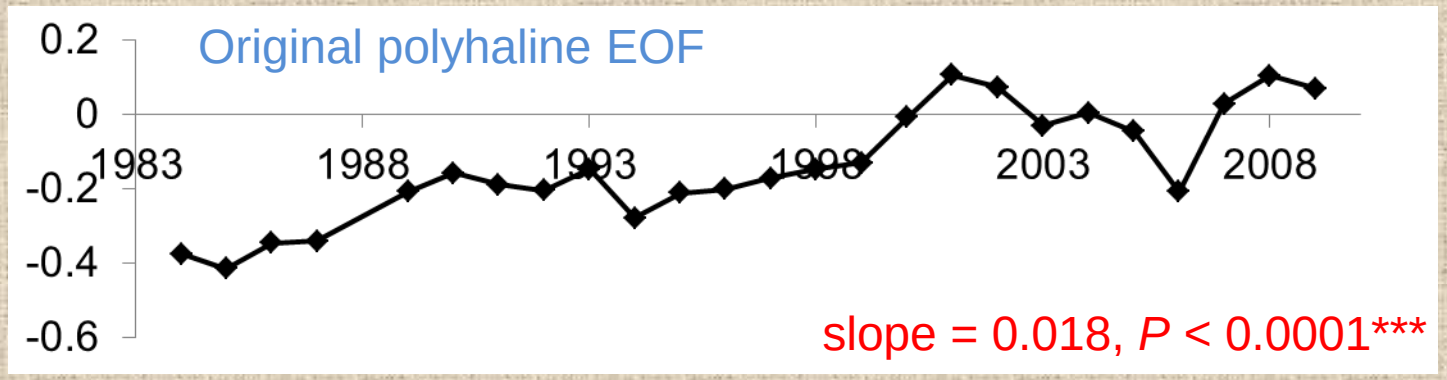


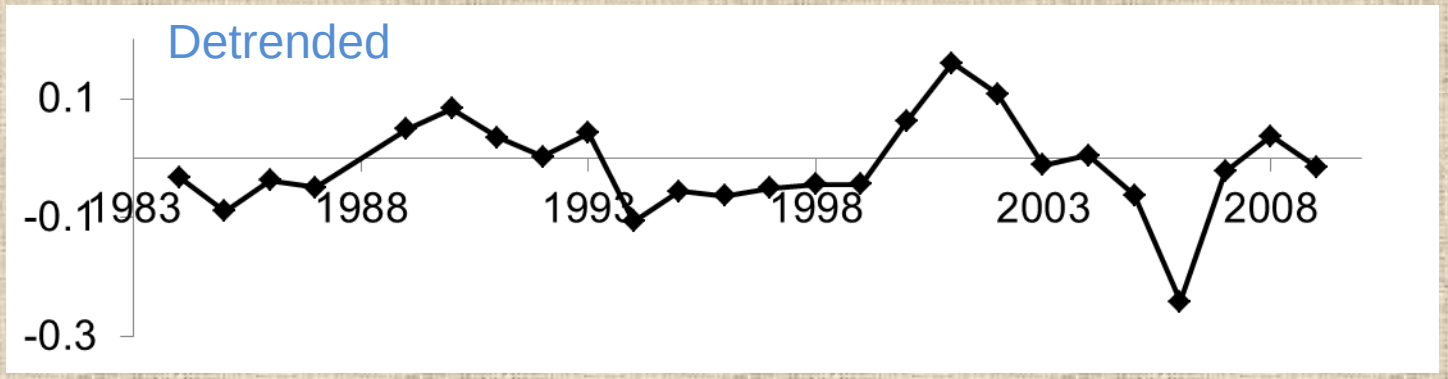




Patrick & Weller. In prep.

Detrending for cross correlation analysis with water quality

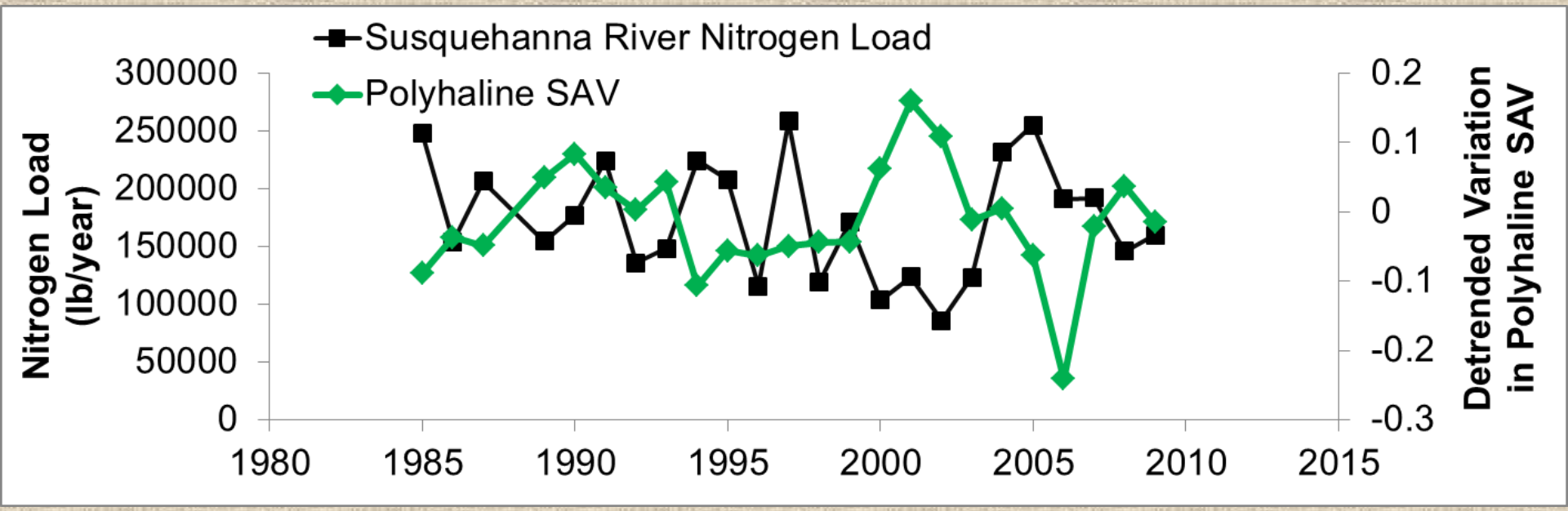




Patrick & Weller. In prep.

Significant cross correlates of interannual variability

	Same year	Last year	Two years ago
Susquehanna River N load	ns	-0.46	-0.44
March chlorophyll *a*	ns	-0.45	



Significant correlates differ among salinity zones

Patrick & Weller. In prep.

Summary – SAV example

- Good news
  - Documented effects of natural factor (precipitation) and human stressors (land use, shoreline armoring) on SAV response
  - Considered environmental setting (salinity)
  - Illustrated (yet another) time series method
    - Identified trends
    - Cross correlated year-to-year variations
- Bad news
  - Didn’t document effects of BMPs
  - Need data on living shoreline installations

Take me home

- Study lots of small systems
- Maximize contrast in important factors
- Compare to stressor or management gradient for early feedback

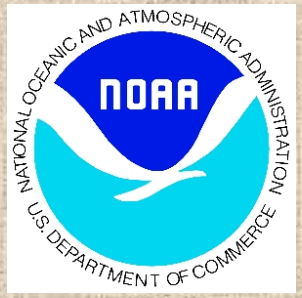
Recent sponsors

Atlantic Slope Consortium

EPA Estuarine & Great Lakes Indicators Program

EPA Watershed Classification Program

The Cooperative Institute for Coastal and Estuarine Environmental Technology



NOAA Coastal Oceans Program