Coupling of Carbon, Nitrogen, Silica and Phosphorus Cycles in Coastal Ecosystems: Climate Effects and Trophic Implications

W. M. Kemp, W. Boynton, J. Testa

University of Maryland Center for Environmental Science

National Science Foundation OPUS

(Opportunities for Promoting Understanding through Synthesis)

Proposed Research Plan

Motivating Research Questions

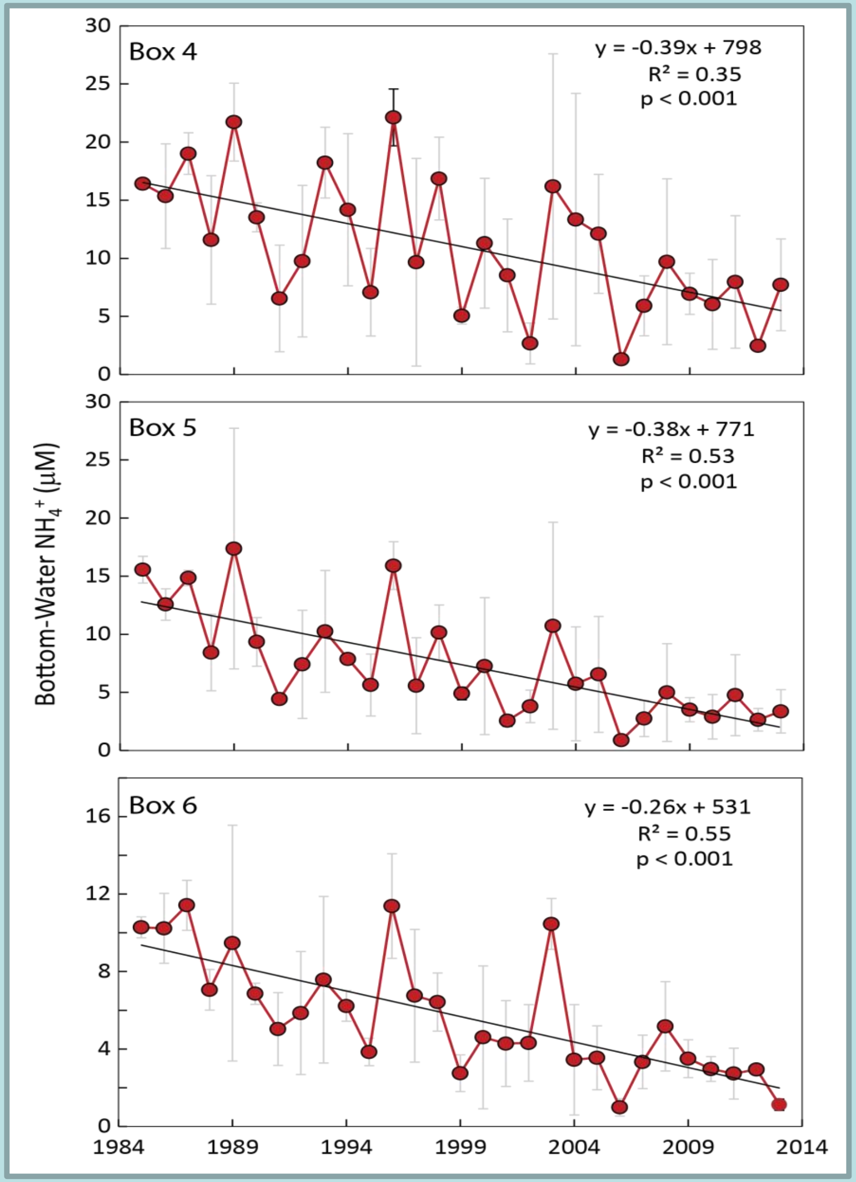
- How do C, O, N, Si, P fluxes (and flux ratios) vary spatially along the land-sea salinity gradients and temporally across seasonal cycles? Do these follow patterns of algal nutrient limitation?
- How do these fluxes and ratios vary over decadal scales in response to changes in external drivers (river flow, temperature, winds, storm events, nutrient loading)?
- How do these fluxes and ratios vary among different estuaries in relation to differences in internal physical properties (size, water depth, stratification, flushing rate)?

Approach and Methods

- Time-series data analyses
- Comparative analysis among Bay tributaries
- Statistical modeling
- Box-modeling to estimate rates from concentrations

Research Activities: Time-series data analyses

e.g., Long-Term Bay Trends for Lower-Layer NH_4 in Late Summer

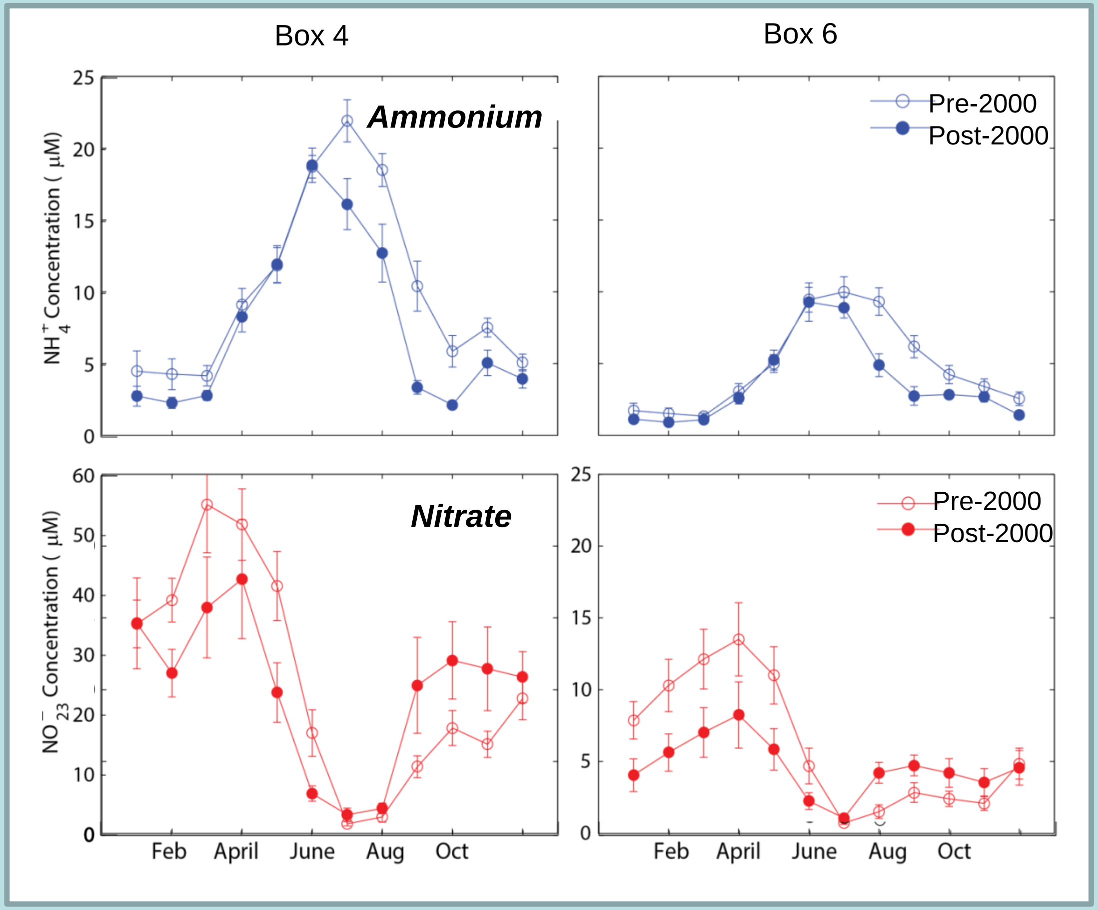


- Significant trends over 3 decades
- NH_4 late-summer mean values
- NH_4 is main nitrogen metabolite of organic decomposition
- Bottom-layer pools in hypoxic region of Bay

What drives this NH_4 trend?

Why has nobody noticed it?

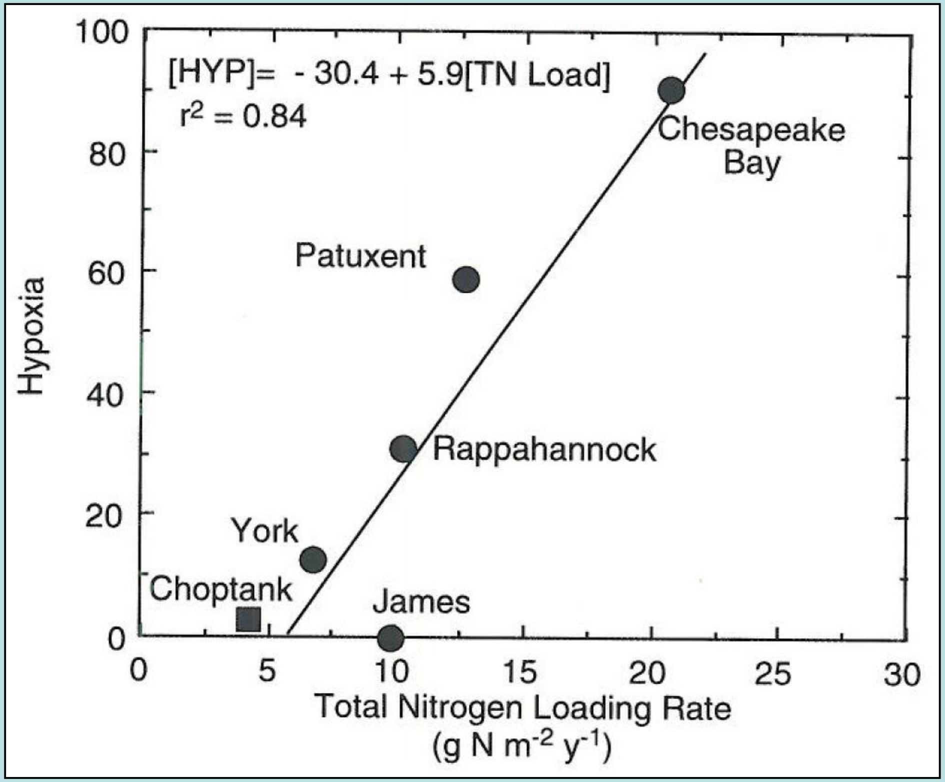
Seasonal Cycles of NH_4 & NO_3 in Pre- and Post-2000

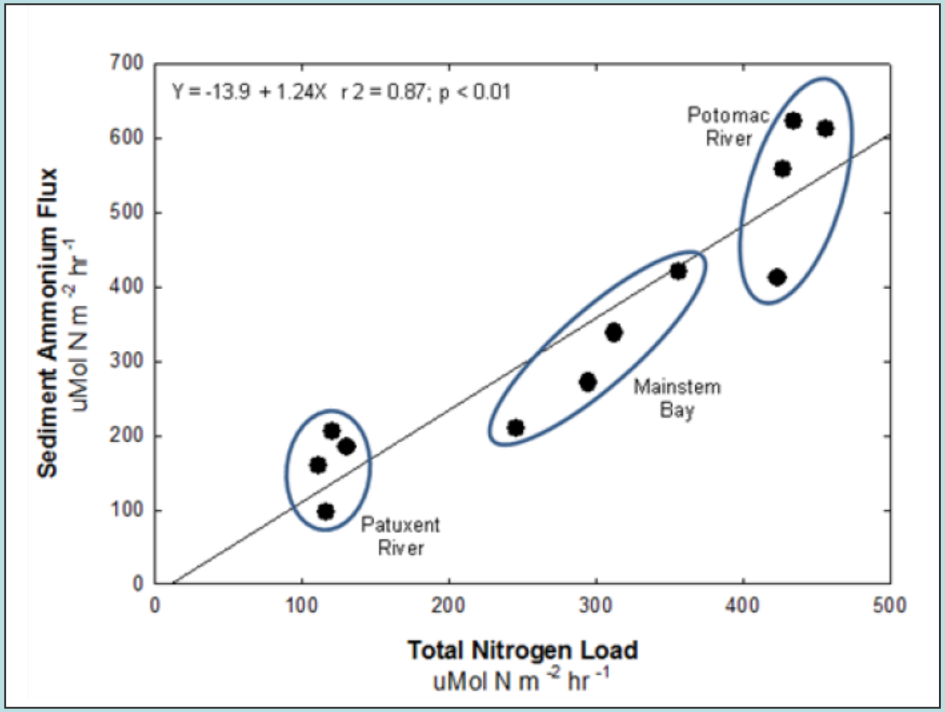


- NH_4 levels lower in recent 15 yr compared to previous 15 yr
- NH_4 differences are greater in late summer to early fall
- NO_3 values are lower in winter-spring and higher in summer-fall
- NO_3 differences are greater in upper Bay end of hypoxic region

How do net production rates for NH_4 & NO_3 compare?

Research Activities: Comparative analysis among Bay tributaries



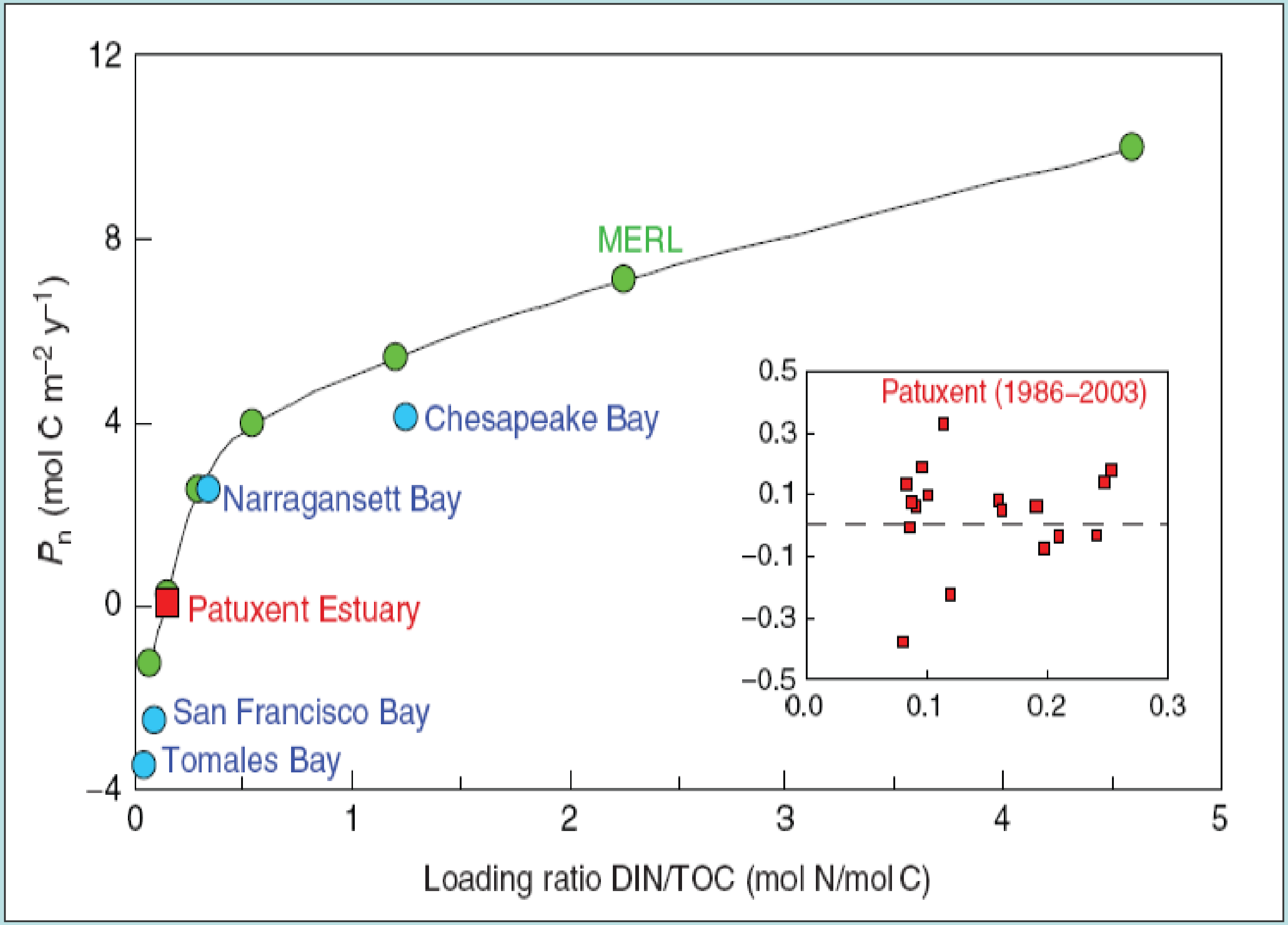


- Hypoxia versus Areal N-Load by Trib

- Summer Sediment-Water NH_4 flux vs. Spring N-loading in Subsystems in Chesapeake Bay.

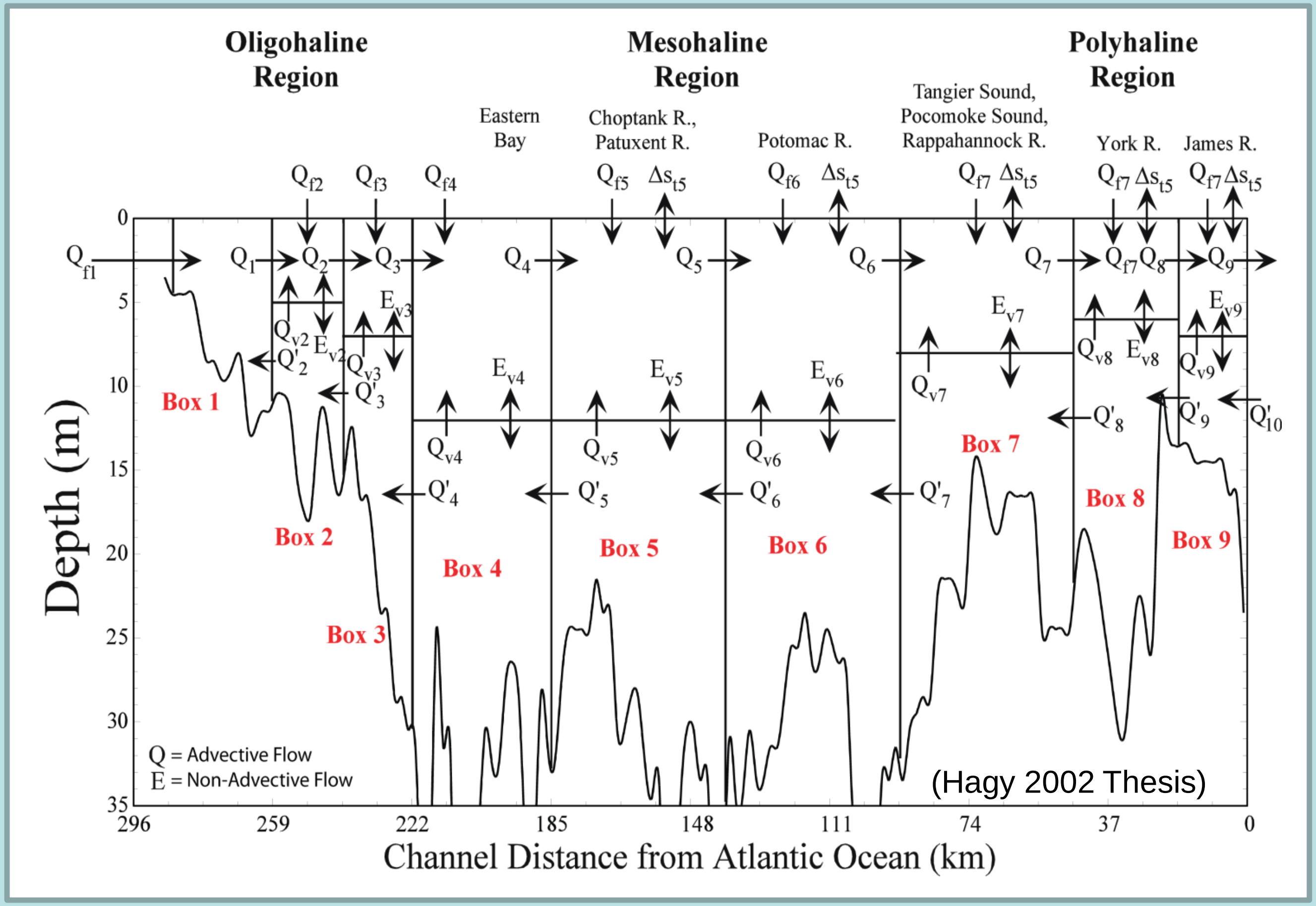
What can we learn about Bay nutrient and oxygen cycling by looking “cross-tributary”?

Comparative Analysis of Estuarine Net Ecosystem Production vs. Loading Ratio of DIN:TOC



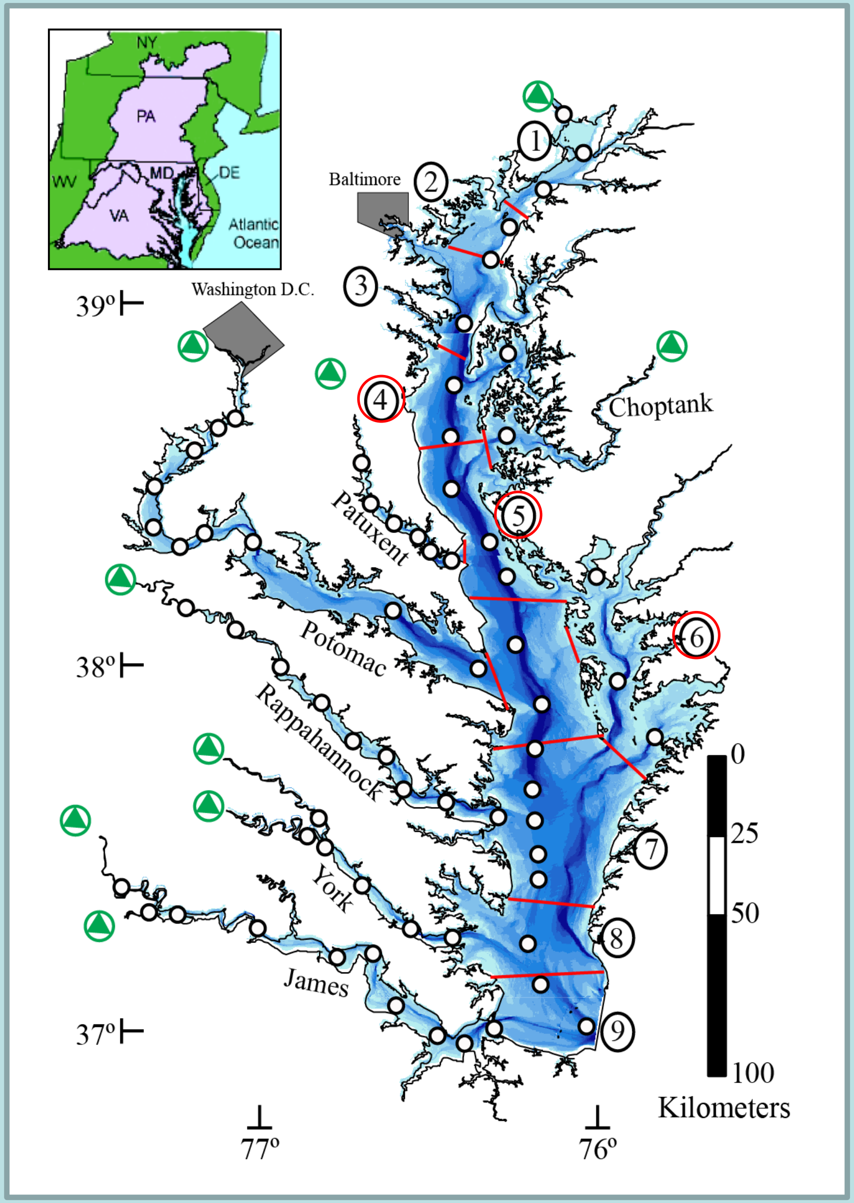
NEP follows apparent hyperbolic function with DIN/TOC loading ratio, and apparent substantial interannual variations in NEP (Kemp & Testa 2011)

Research Activities: Box-Modeling: A Tool for Calculating and Analyzing Fluxes



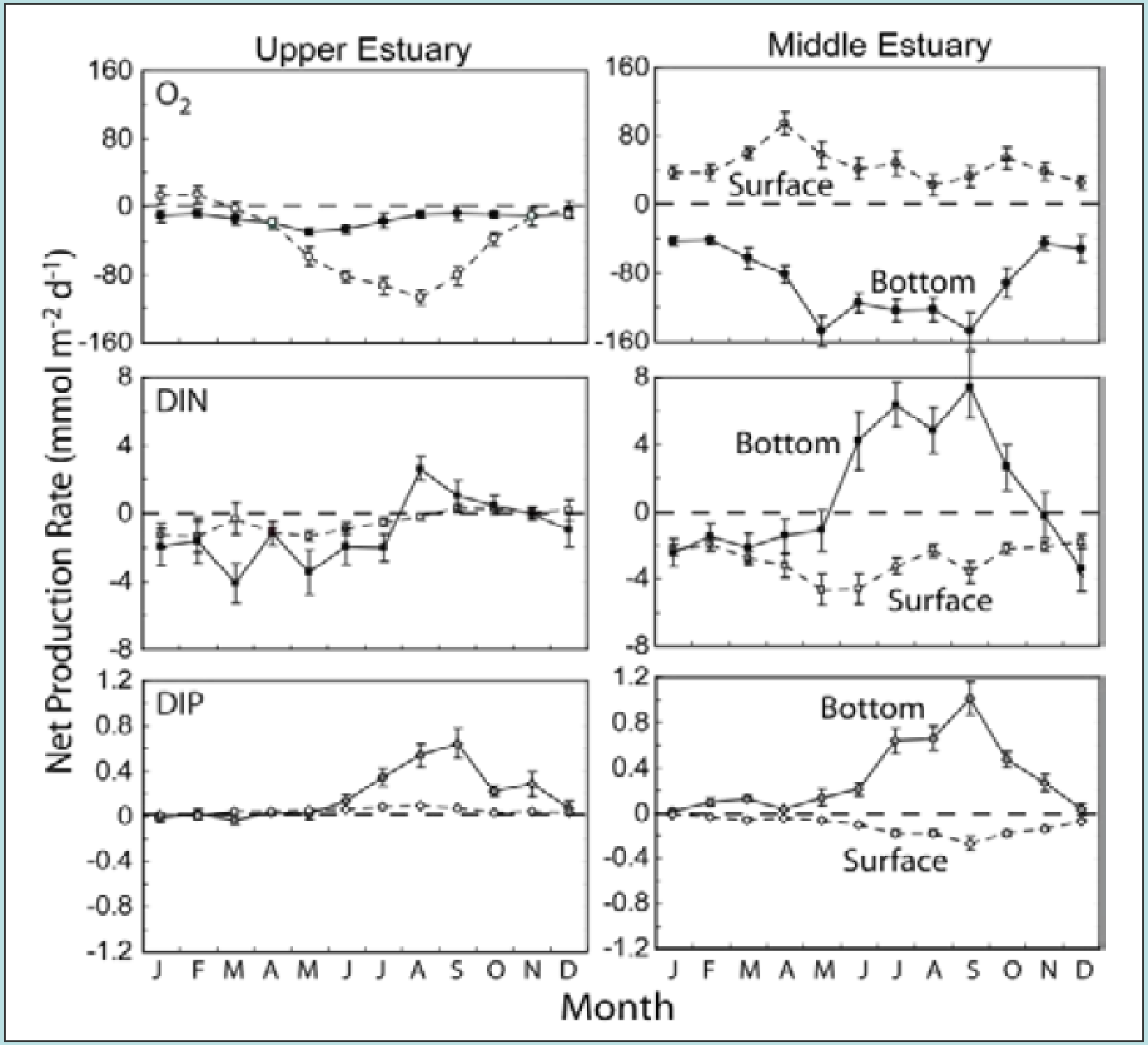
- Box-model uses salt- and water-balance equations to compute net fluxes
- Box-model computes rates from WQ concentrations and hydrologic flows
- Note that net transport is seaward in surface-layer & landward in bottom-layer

Box Modeling the Bay and the Tribs

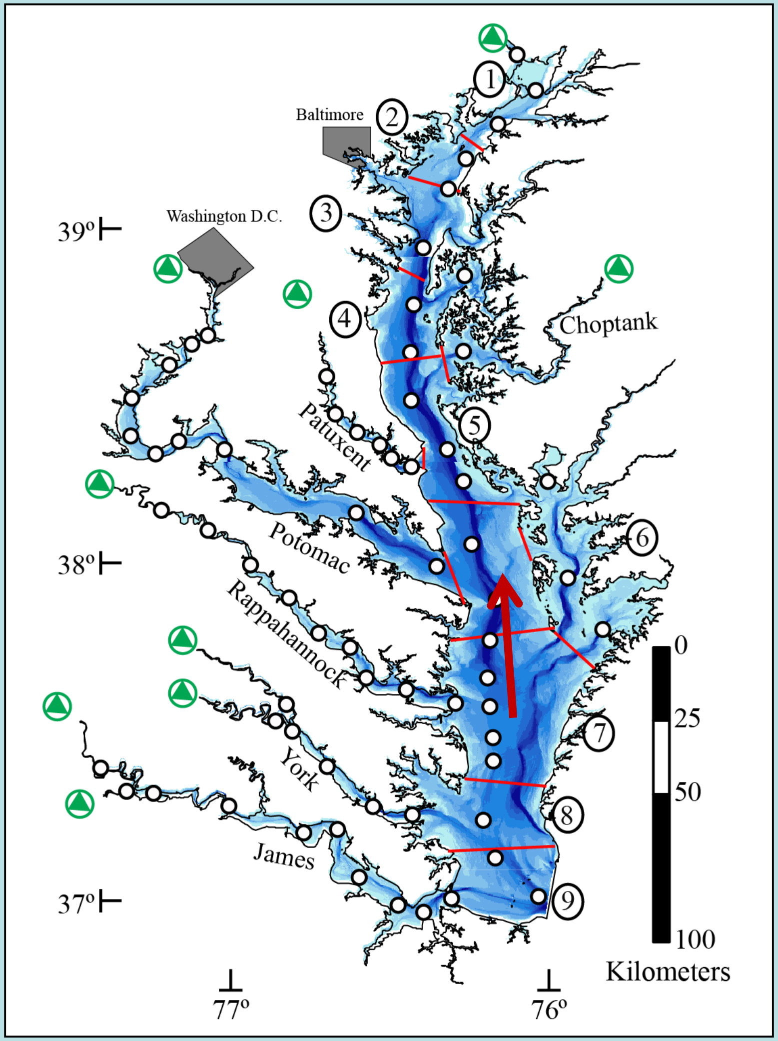


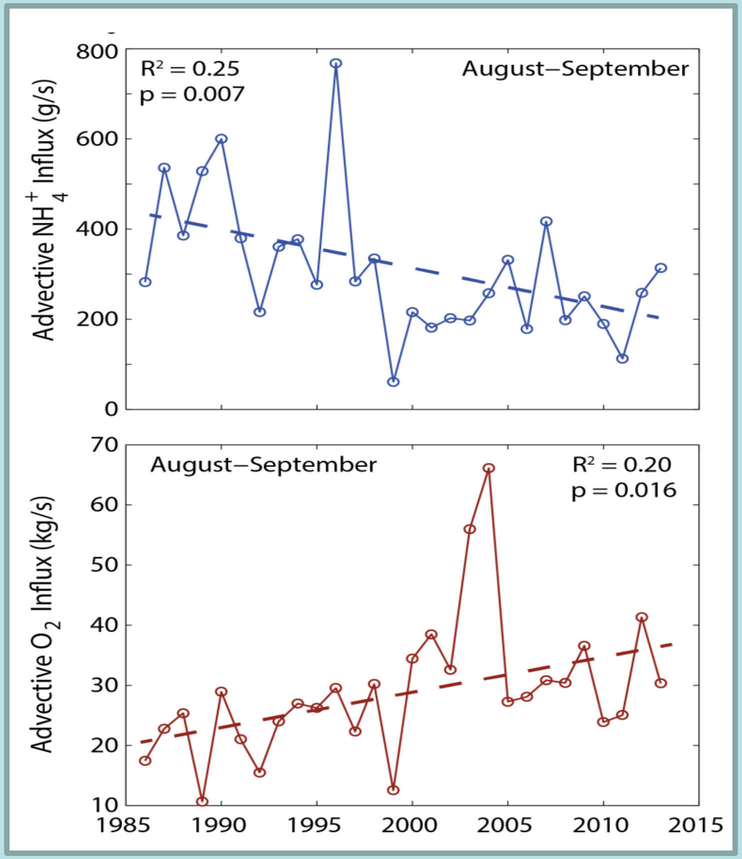
- Box Model for Mainstem (red lines)
- Patuxent Box Model Updated (from Hagy et al. 2000, Testa and Kemp 2008)
- Choptank Box Model from Boynton et al. 2014
- To-Do: Potomac, Rapp, York, James

Patuxent Estuary has Revealed Key Aspects of Biogeochemistry, Nutrient Transport, and Remediation Response



Box-Model Computed O_2 & NH_4 Landward Transport from Lower to Upper Bay in Late Summer





- Reduced transport of NH_4 and Elevated O_2 Transport from lower to mid estuary linked to long-term improvements in late summer

Research Activities: Relative Influence of Watershed Load to Bay-Tributary Exchange

Key Motivation:

(1) Can we discern local influences from “remote” influence received from seaward exchanges with the mainstem?

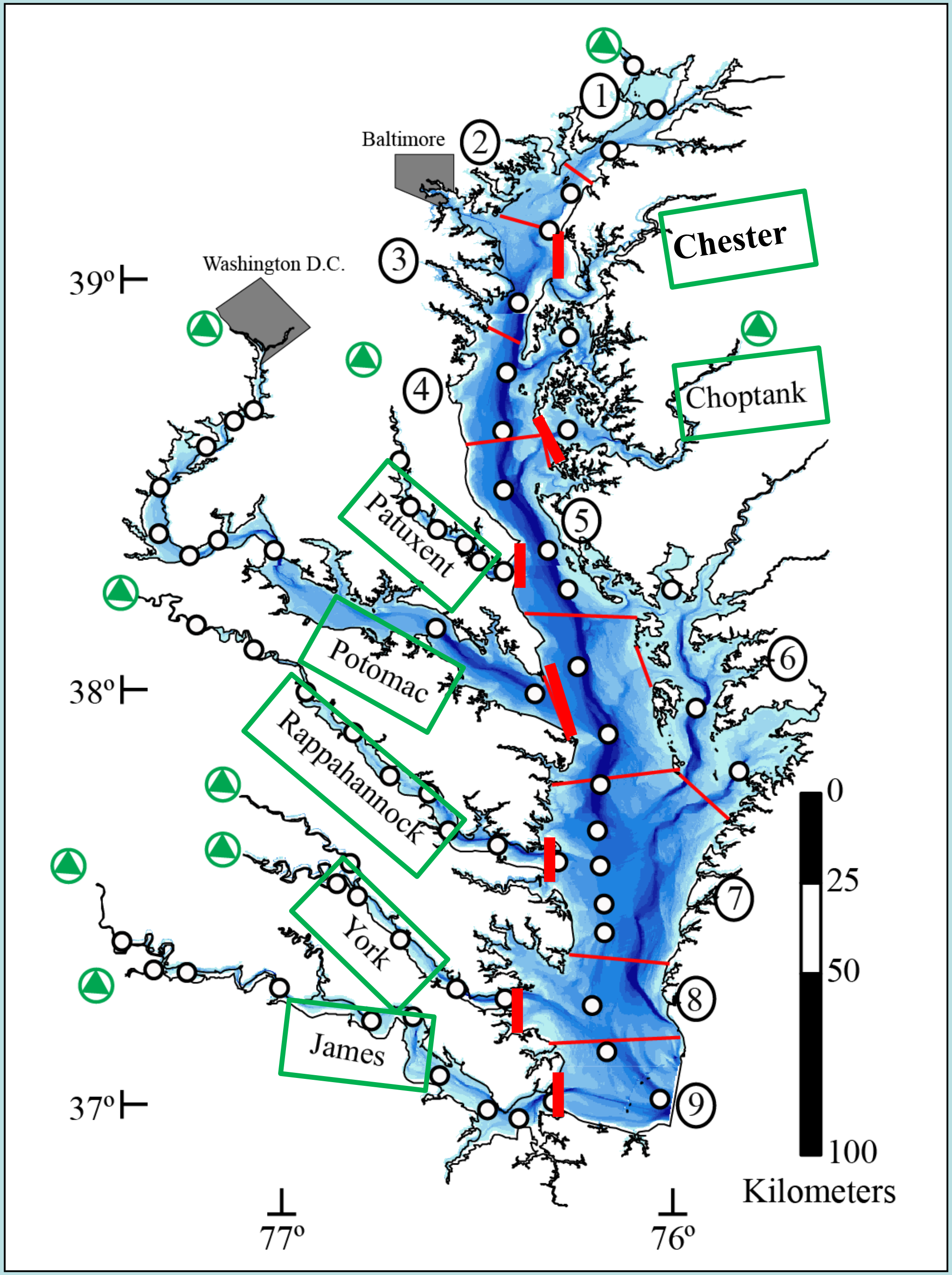
(2) What is role of small watersheds in TMDL-based criteria exceedance in mainstem?

Long-Term Changes in Water Quality and Productivity in the Patuxent River Estuary: 1985 to 2003

Jeremy M. Testa • W. Michael Kemp •
Walter R. Boynton • James D. Hagy III

Internal versus external drivers of periodic hypoxia in a coastal plain tributary estuary: the York River, Virginia

Samuel J. Lake*, Mark J. Brush, Iris C. Anderson, Howard I. Kator



Approach

(1) Compare WQSTM-computed exchanges of nutrients between the tributary and the mainstem with measured and modeled watershed loads

(2) Develop relationships between in-tributary properties (e.g., chl-a) and relative role of seaward exchange

(3) Compare box-model exchanges with WQSTM-computed fluxes

(4) Consider tributary properties that control sensitivity to Bay-derived fluxes

(5) Effort has just begun – results in January

Chesapeake Bay and Tributary Physical Features and Biogeochemical Data Availability

Table 2. Chesapeake Bay and tributary physical features and biogeochemical data availability

Sites Size*	Site	Physical & Chemical Features					Rate Processes#			Other**
		FW Flow $m^3 sec^{-1}$	Basin km^2	Estuary km^2	Depth m	N-Load $g N m^{-2} yr^{-1}$	Plankton Production	Plankton Respiration	Benthic C,N,P flux	Water Quality
Large	Ches Bay (1)	2500	70000	5820	9	12	10 ('85-'09)	3-11 ('88-'93)	6 ('86-'02)	39 ('85-'12)
	Potomac (1)	350	30000	1210	5.9	32	4 ('85-'09)	6-20 ('02-'11)	10 ('86-'11)	10 ('85-'12)
Medium	Patuxent (3)	28	2400	137	4.8	17	4 ('85-'09)	5 ('78-'82)	9 ('86-'05)	12 ('85-'12)
	Choptank (2)	21	1800	361	3.7	8	2 ('85-'09)	no data	2 ('86-'92)	4 ('85-'12)
	York (1)	31	6890	215	4.3	13	4 ('85-'09)	4 ('06-'08)	12 ('78-'96)	18 ('85-'12)
	Rappah (2)	47	7250	392	4.5	12	3 ('85-'09)	no data	no data	25 ('85-'12)
Small	Patapsco (3)	19	1640	101	4.6	47	1 ('85-'09)	no data	5 ('90s)	3 ('85-'12)
	Corsica (2)	1.2	102	5.4	1.9	22	3 ('03-'12)	3 ('03-'12)	5 ('05-'07)	5 ('03-'12)

* **Sites:** Numbers in parentheses (1, 2, or 3) indicate basins that have mixed, agricultural and urban watersheds, respectively.

Rate Processes: Given are number stations (years) with rates in upper, middle, lower zones of main Bay (NSF- PROTEUS and NSF-TIES) and in Patuxent River (NSF-SNAPI). Other rates supported by MD-DNR, MD-DoE, NOAA, and US Army CoE.

** **Water Quality:** Given are number of stations (and years). All NSF Programs made water quality measurements. Additional measurements are available from the Chesapeake Bay Bio-monitoring Program (www.chesapeakebay.net).