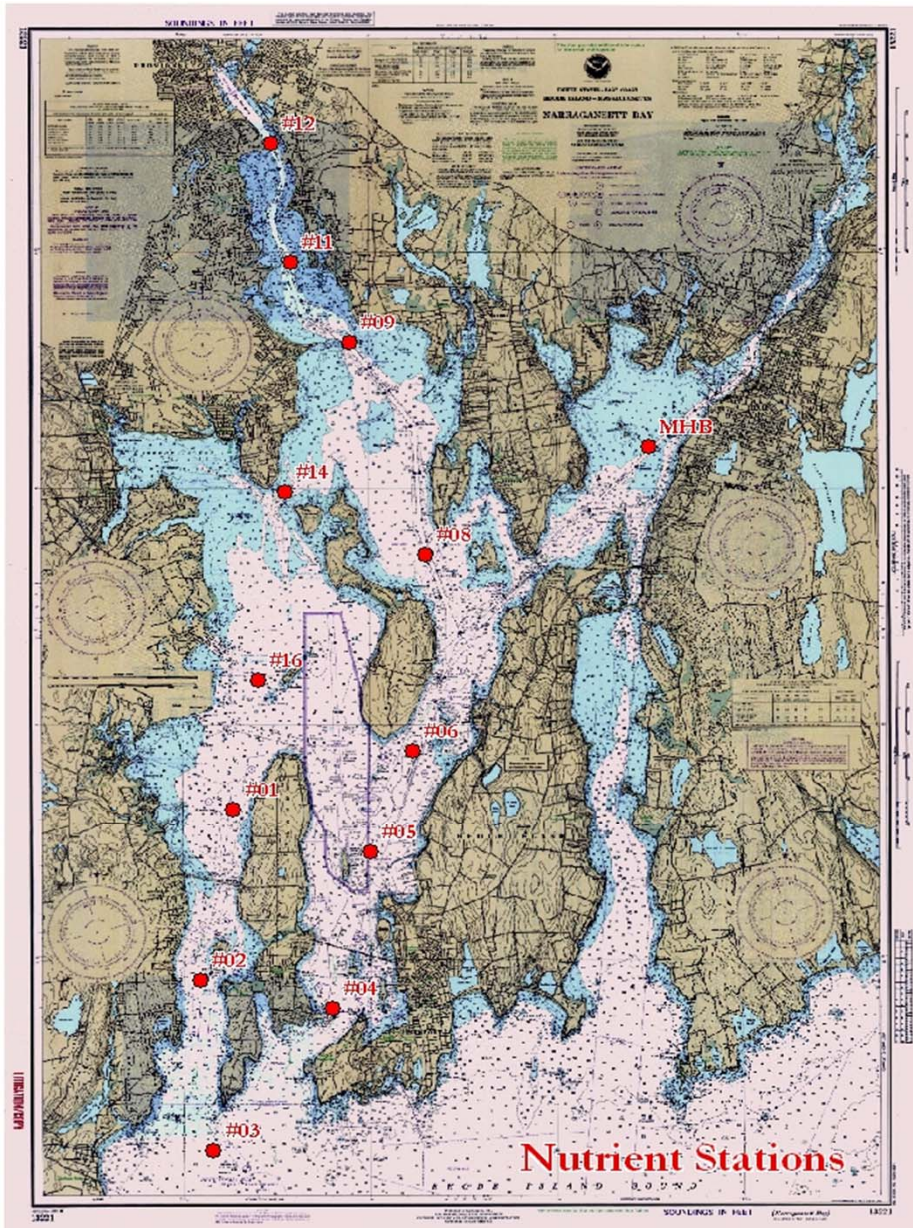


Nutrient Standing Stock Dynamics With Onset of Tertiary Treatment

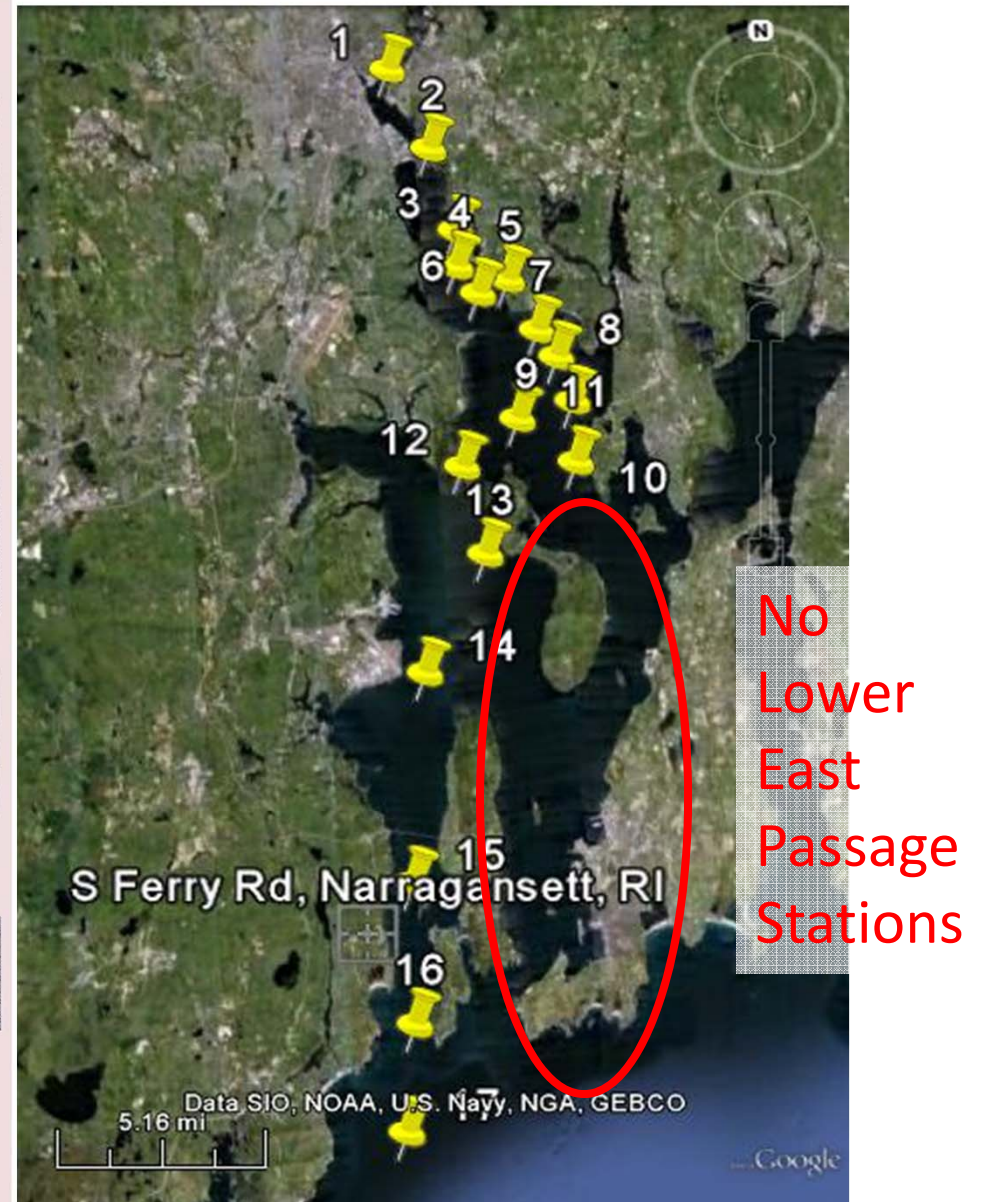
Jason Krumholz
Candace Oviatt

NBC Upper Bay Symposium 6/16/2011

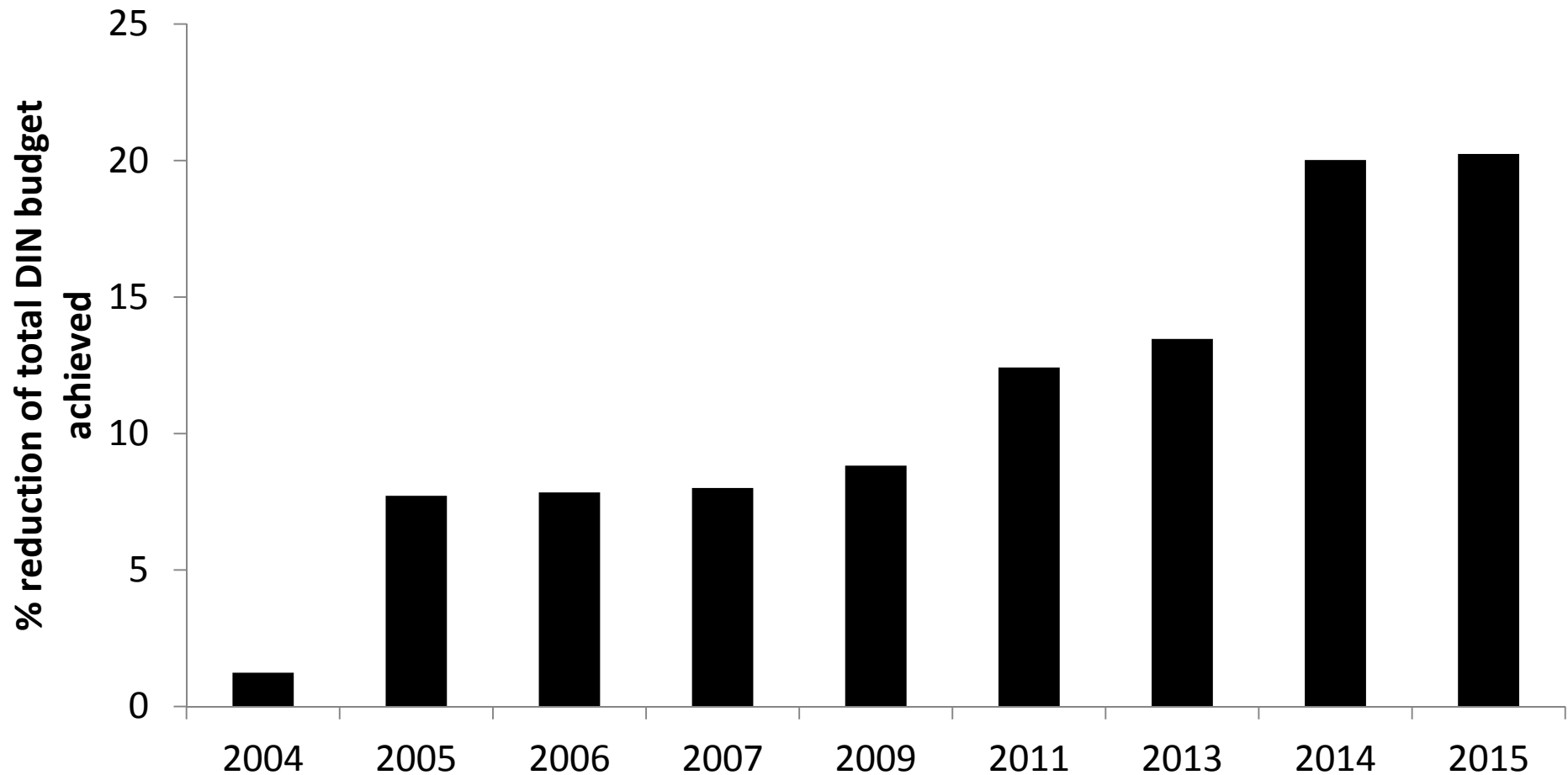
1998 & 2006-2009 Stations



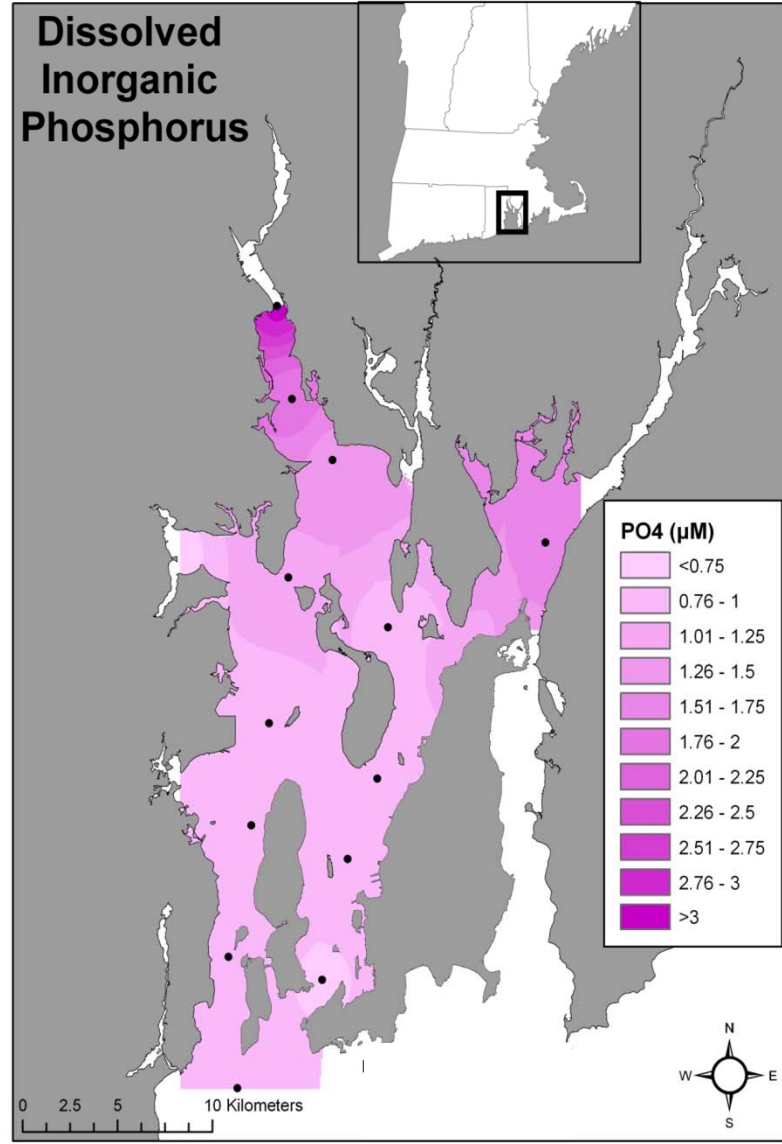
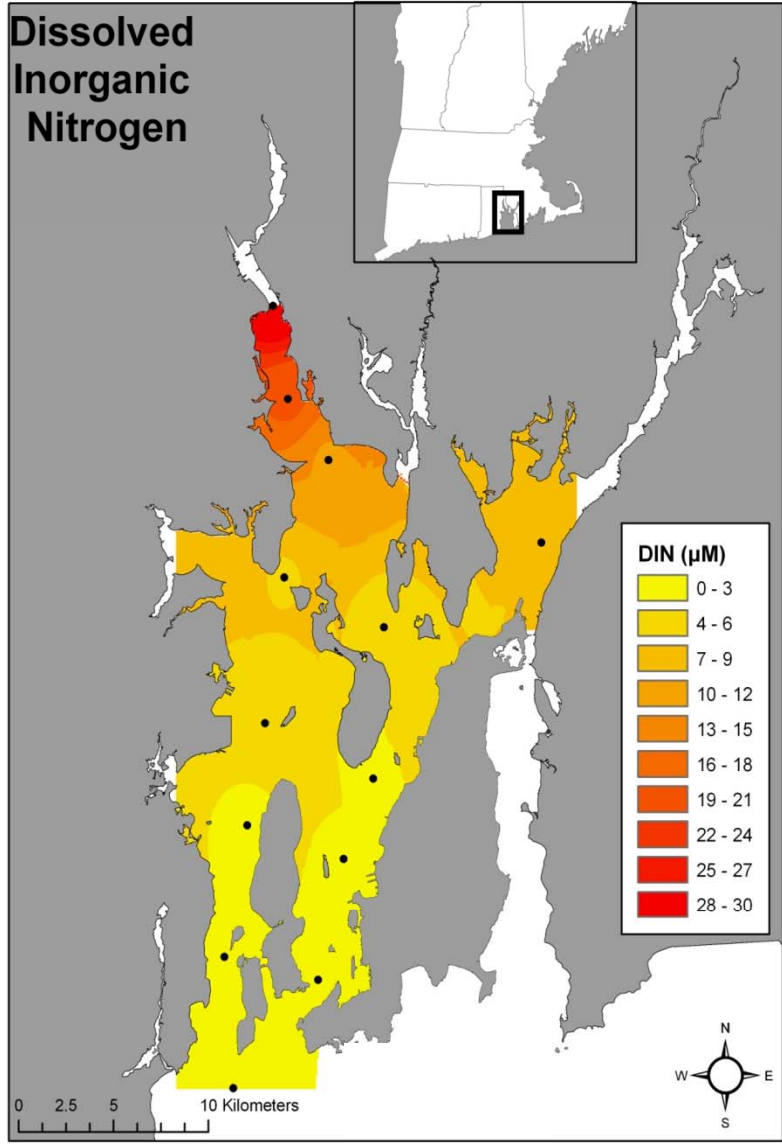
Oviatt 1980 Stations

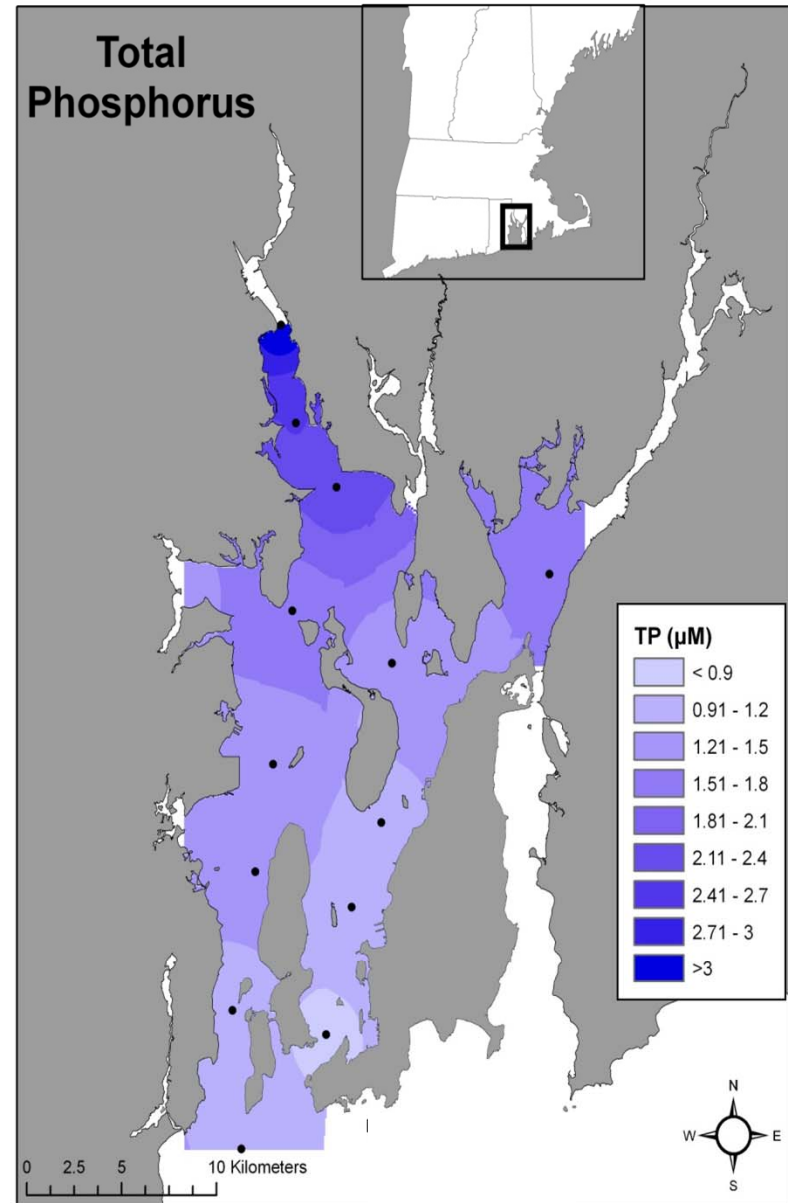
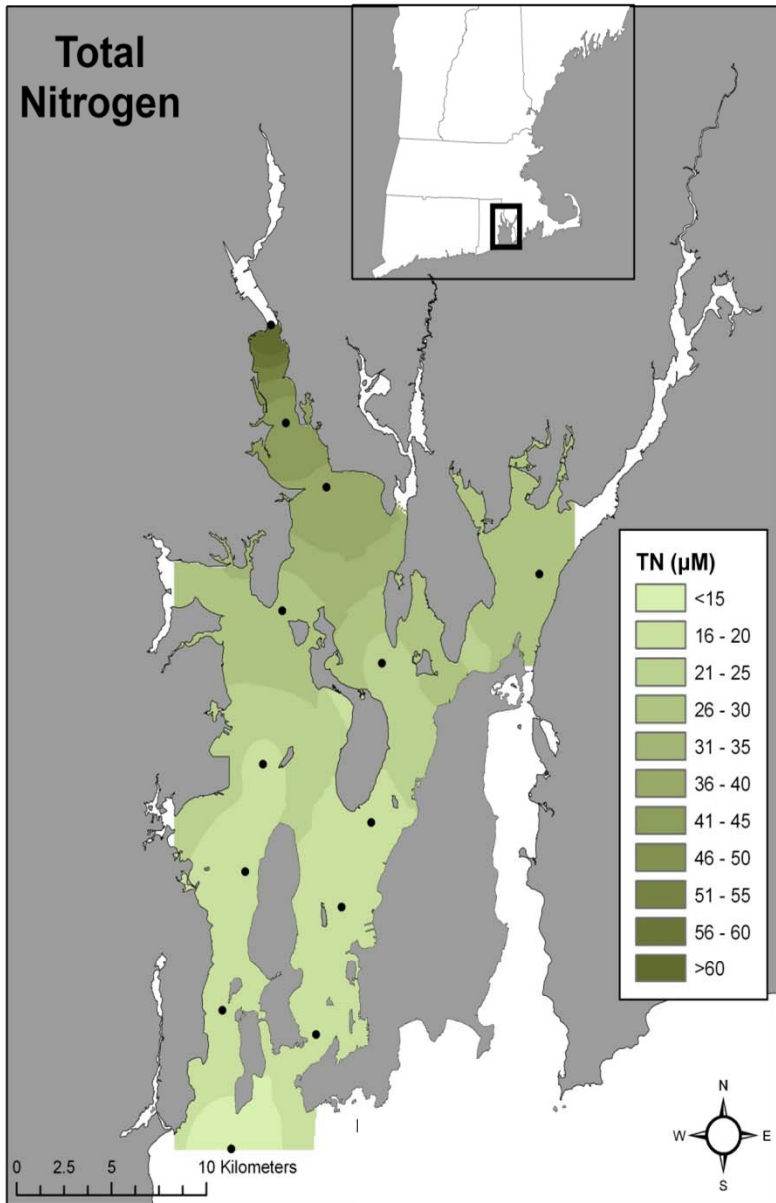


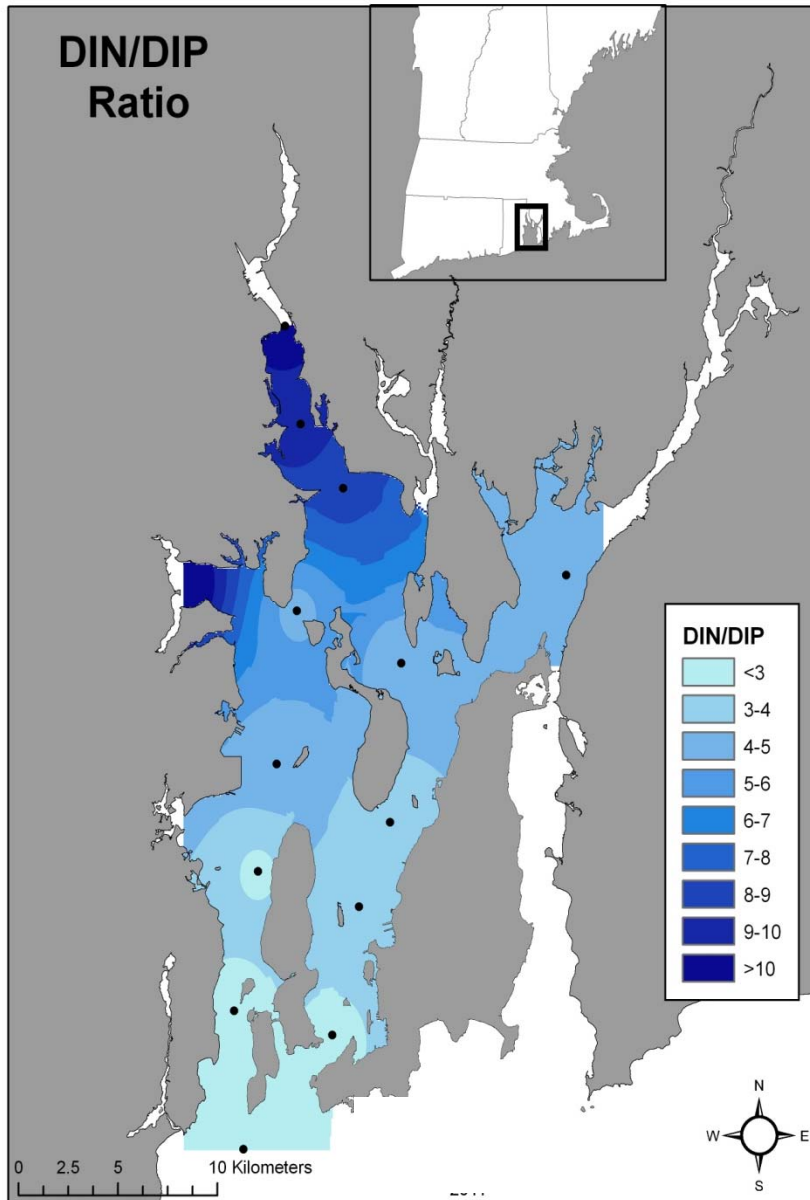
What is the Actual Load Reduction?



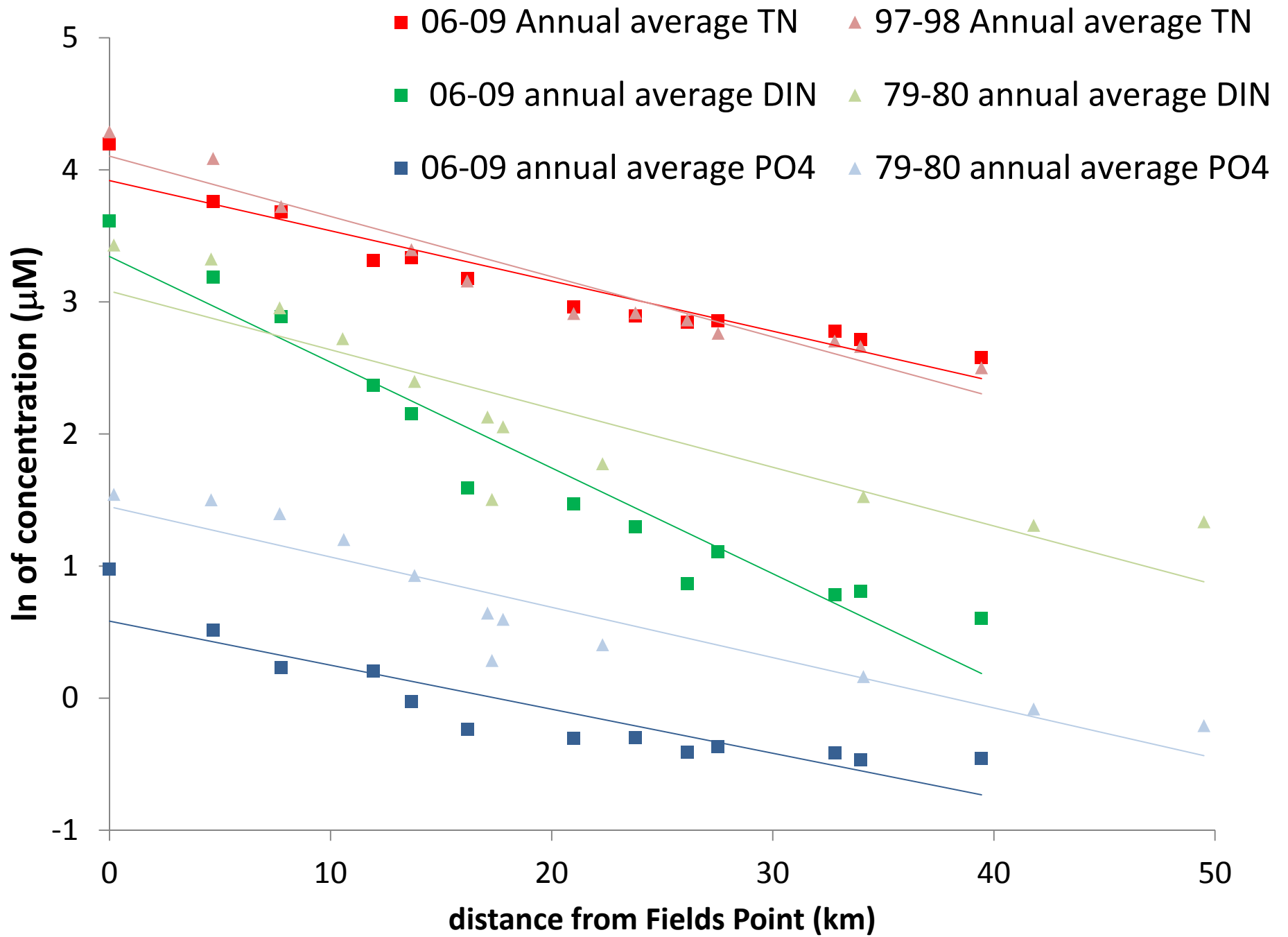
- 2004-2009 data based on loading data and previous mass balance (Nixon et al. 2008)
- 2011-2015 data based on loading estimates (Liberti, pers. Comm.) and monthly design flows (a conservative estimate)
- Reduction is almost entirely DIN



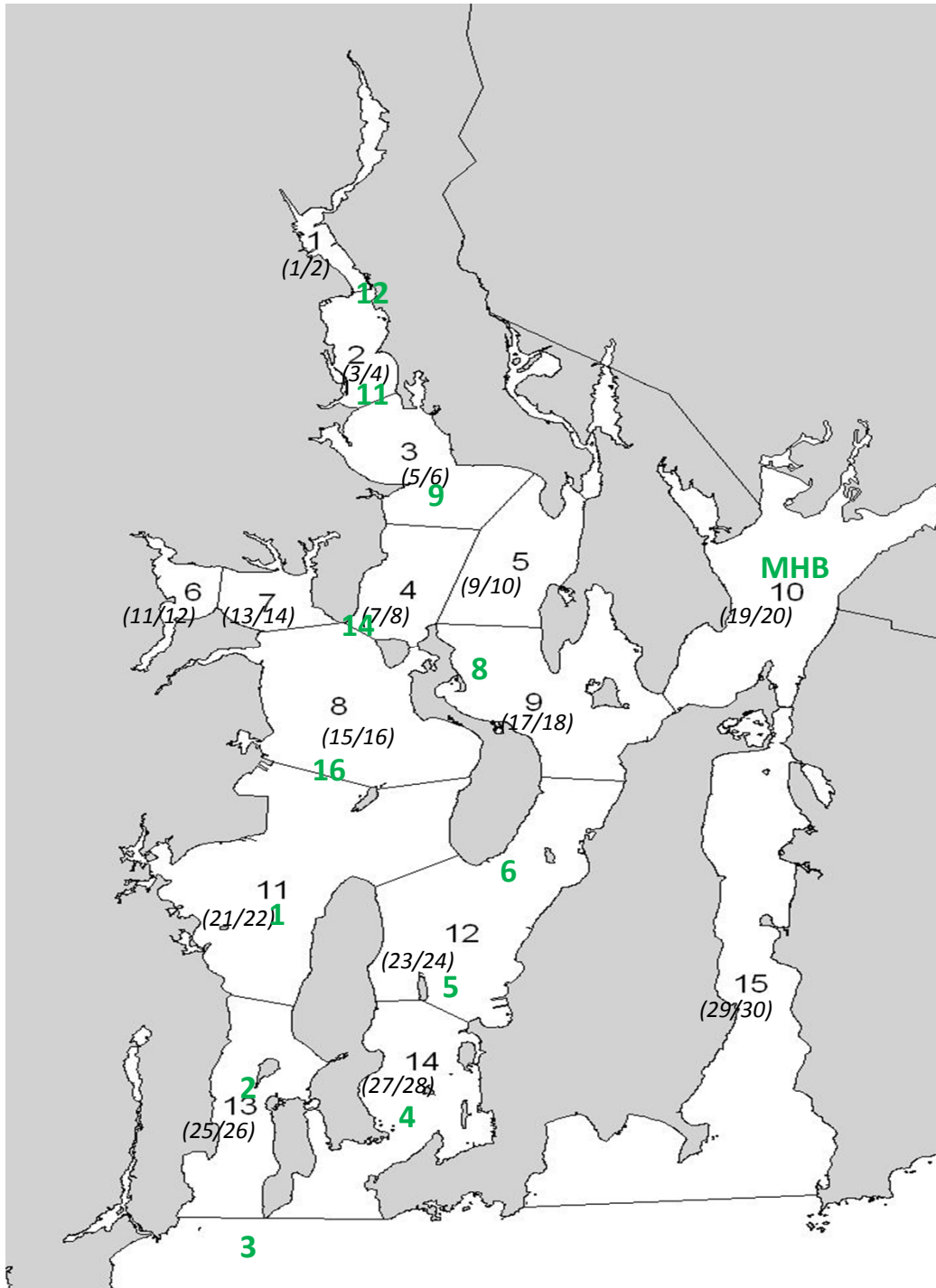




- DIN/DIP ratio <16:1 is traditionally viewed as a nitrogen limited system.
- On an annual average basis, Narragansett Bay remains nitrogen limited throughout, though this limitation is more severe in the mid and lower bay.
- On shorter time scales, some areas of the Upper Bay do show evidence of P limitation, which may become even more important as N inputs continue to drop.



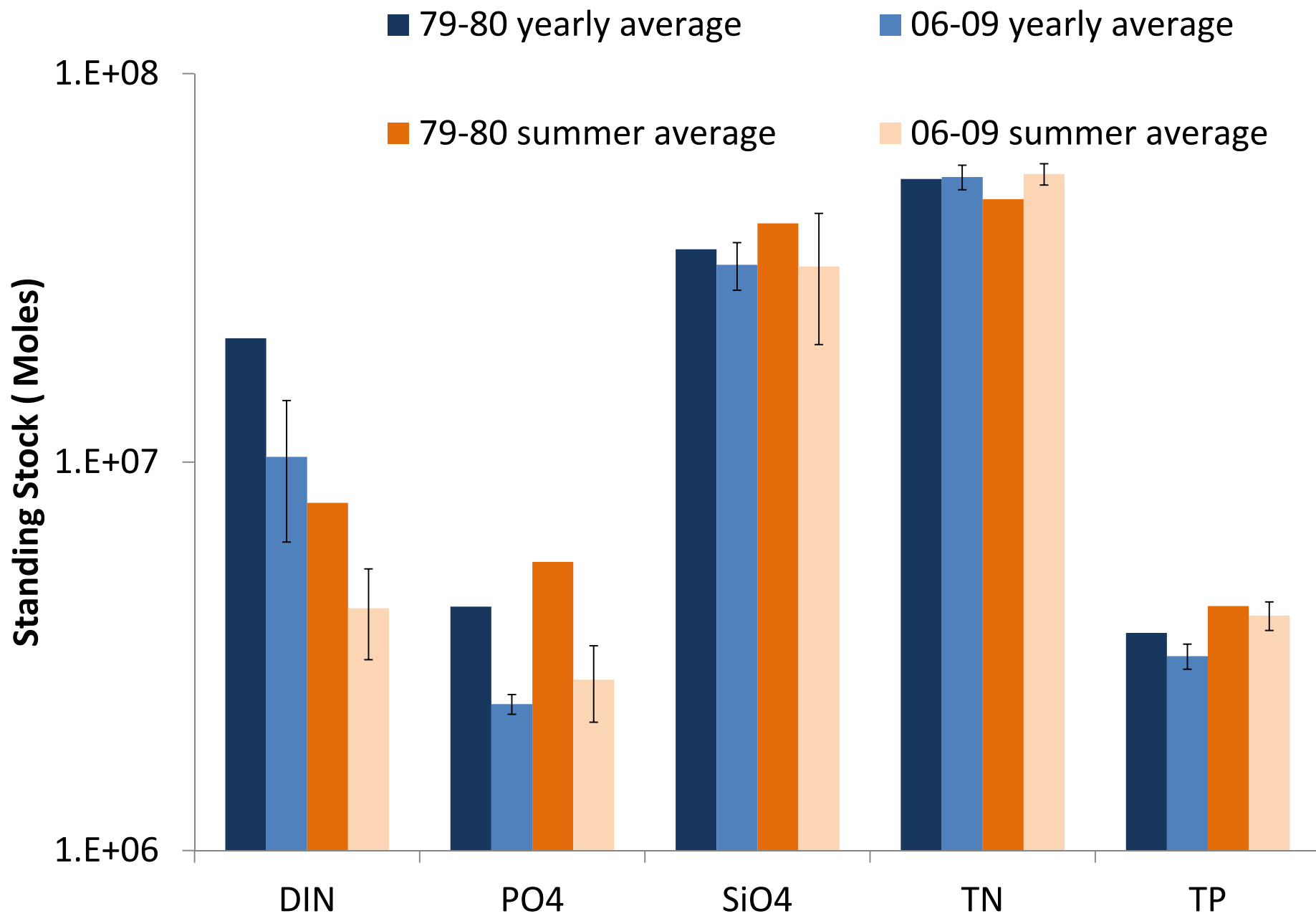
Lining Up the Stations with Volume Boxes from GEM Box Model (Kremer et al. 2010)



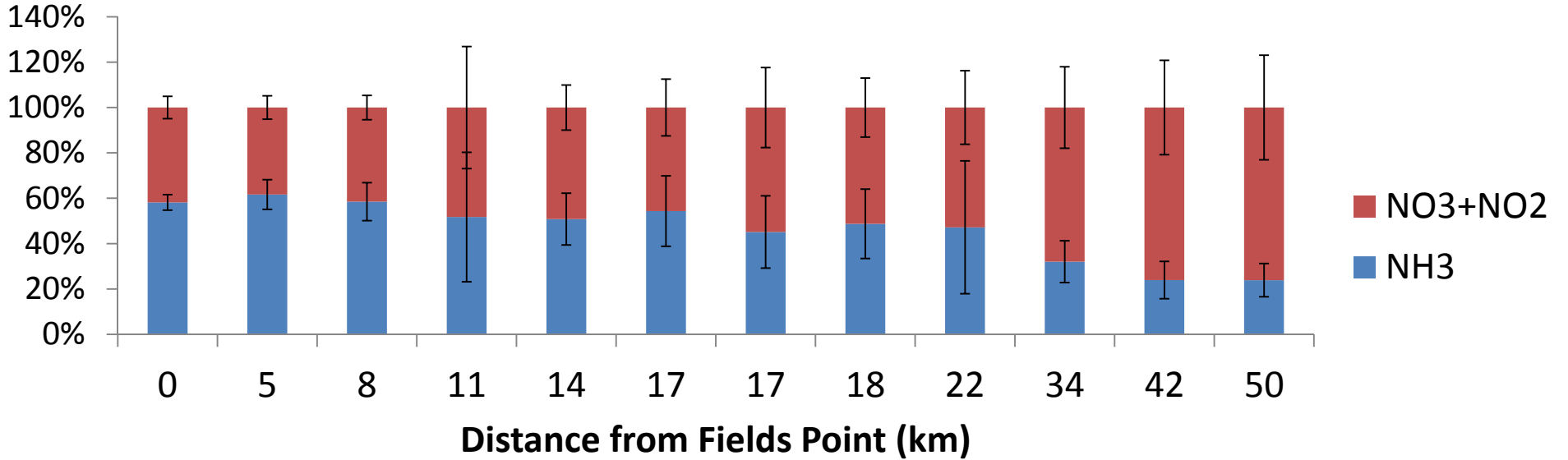
- Used Average of 9,14,8 for Box 5
- Averaged 5 and 6 for Box 12
- **Buoy data used for Greenwich Bay boxes (6 and 7)**
- **For 1979-80 data West passage data were used for stations 4,5,6. 2006-2009 data were used for Greenwich Bay and MHB**

- Multiplying by volume gives us the total 'standing stock' in the bay...

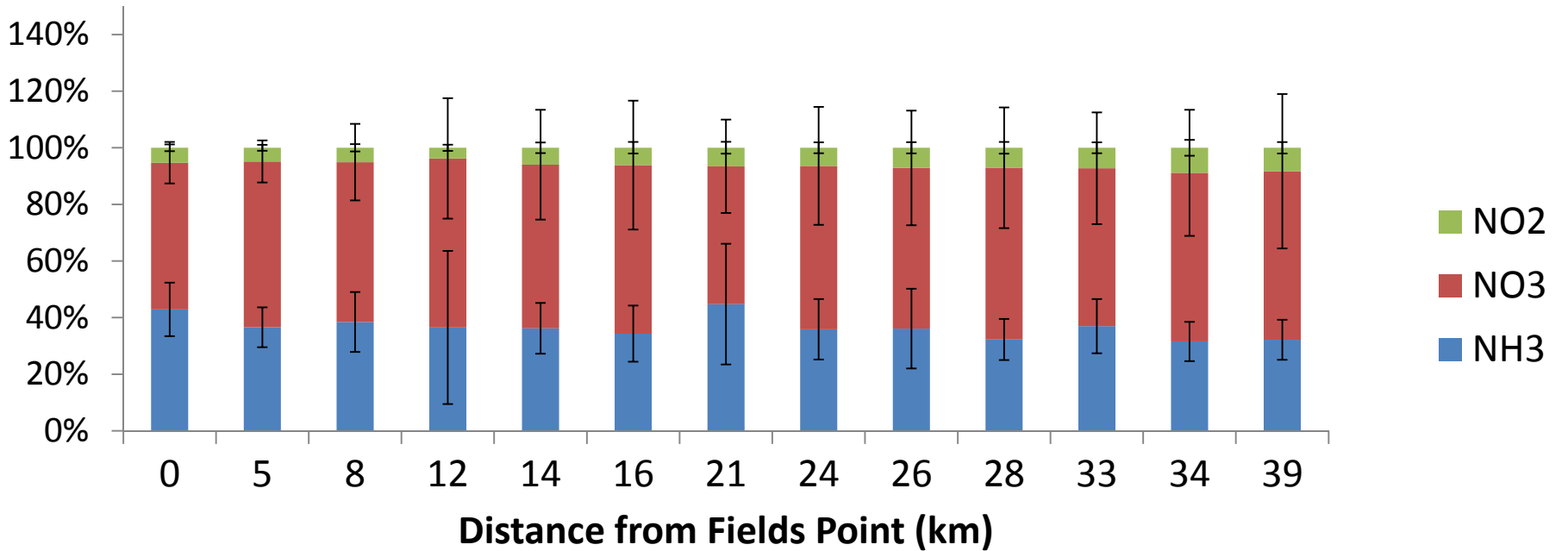
- **Future Work:** Bottom data may significantly improve resolution



Annual DIN breakdown 1979-1980



Annual DIN breakdown 2006-2010



The Short Short Version

- We do see a reduction in DIN roughly proportional to the reduction we might expect.
- We do not see a reduction in TN. However, we may lack resolution to detect the $\approx 7\%$ reduction which has occurred.
- The observed reduction does not appear to be greater in the summer.
- Phosphorus reduction appears to be much larger than would be expected from wastewater improvements alone.

Implications for Management

- Short and long term temporal variability in standing stocks relative to WWTF inputs is an important consideration.
- While there is a reduction in DIN, there is no apparent reduction in TN. DIP and TP show a similar pattern.
- Standing stocks of total nutrients are much less variable than inorganic nutrients.
- While DIN in the upper bay has not changed measurably, stocks in the lower bay have been significantly reduced, a possible indication that the lower bay is more nutrient limited.

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Nixon, S.W., Buckley, B.A., Granger, S.L., Harris, L.A., Oczkowski, A.J., Fulweiler, R.W., & Cole, L.W. (2008). Nitrogen and Phosphorus Inputs to Narragansett Bay: Past, Present, and Future. In B. Costa-Pierce, & A. Desbonnet, *Science for Ecosystem-based Management (pp. 101-175). New York: Springer.*

Kremer, J. N., J. M. P. Vaudrey, D. S. Ullman, D. L. Bergondo, N. LaSota, C. Kincaid, D. L. Codiga, and M. J. Brush. 2010. Simulating property exchange in estuarine ecosystem models at ecologically appropriate scales. *Ecological Modelling* **221:1080-1088.**