

NOTES re Social and Ecological Drivers of Nitrogen Loading and Coastal Hypoxia

Co-facilitators: Jeremy Rich, Seth Spielman, Heather Leslie, and Michael White
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Jeremy Rich provided an overview of coastal eutrophication and hypoxia, ecological effects, relevant dissolved oxygen data from Narragansett Bay, and a nitrogen budget for the Bay. Discussion ensued. We've tried to capture key questions/points below.

1. **OVERALL GOAL (PROPOSED):** To explore how land use and consumer decisions contribute to individual and municipal 'nitrogen footprints', and the opportunity for joint research
2. **APPROACH:** If the goal is to have an impact on policy, it's important to start with social rather than ecological problems, e.g. impacts on human well being and economies. Should our analysis focus on Narragansett Bay (NB) or also include other estuarine settings, e.g. Plum Island or Chesapeake Bay? The answer will depend on the scales of social, regulatory, oceanographic and ecological variation in the system(s) of interest. Ideally we would have both temporal and spatial comparisons across multiple estuaries. Alternatively, one could examine salt marshes only within NB and start to address some of these questions, maybe.
3. **SOCIAL DRIVERS AND RESPONSES:** In which contexts do consumption and stewardship patterns influence N loading, over and above sewage treatment? What behaviors contribute most to the nonpoint source components of N loading in the Bay, e.g. a person's nitrogen footprint? What would motivate different actors (institutions, individuals) to change behavior re N loading to the Bay? What policy choices contribute to N loading to the Bay and what are the levers to effect those? How will these policy choices impact N loading into the future?
4. **ECOLOGICAL RESPONSES:** Which ecological conditions are responsive to changes in human behavior? On what time and spatial scales? When nitrogen loading stops, what does the trajectory of recovery look like? The answers will likely be taxon-specific and involve hysteresis. For example: Impacts of nutrient pollution in intertidal areas include *Phragmites* invasion of salt marshes, which is stimulated by shoreline development → increased freshwater flow and N loading → top down control of consumers is turned on → salt marsh vegetation suppressed → *Phragmites* expands (see work by Silliman and Bertness). Once *Phragmites* is established, it's very hard to remove (and to return to the previous state).
5. **NEED FOR MORE DATA, CURRENT AND HISTORICAL:** What's the history of N loading and other pollution inputs and stressors to NB? Do local human/municipal actions translate into local or bay-wide impacts? There was some debate about the relative importance of various elements of the N budget in NB. There was an interesting discussion about how coastal marshes fit in.
6. **POTENTIAL NEXT STEPS:**
 - a. NB focused exploration of the variability in key social, regulatory, and ecological drivers, so as to address our OVERALL QUESTION and develop others.
 - b. NB focused investigation of the *Phragmites* invasion of salt marshes, with an explicit link with local resident and land use decisions
 - c. Cross site comparison of coupling between human activities and ecosystem health in the context of N loading.

- d. (an attempt at synthesis of a + c above) Understanding the coupling between highly dynamic coastal ecosystems and human behavior/policy at the local scale seems to be a major challenge. In terms of NB mgmt it is unclear to what extent the ecological impacts of human actions that result in N loading are felt locally (in the vicinity of the actor). For example, a localized phytoplankton bloom in Greenwich Bay may be driven more by Bay wide nutrient loading than human actions that result in N loading in the immediate vicinity. Several factors could lead to a breakdown in social-ecological coupling at the local scale. The sewage treatment system itself redistributes large volumes of nutrients from cities and towns, to locally concentrated discharge sites. These discharge sites are geographically removed from the human population responsible for nutrient loading. In addition, water column mixing and tidal flushing create diffuse boundaries, further redistributing nutrients in the Bay. For these reasons, the appropriate scale to examine social-ecological coupling in NB, from an ecosystems nutrient perspective, may be over the entire watershed. Clearly, NB is a highly coupled human-ecological system, but at what scales are most appropriate to explore this coupling? What social and ecological responses are most useful? This question may have important implications for policy and mgmt, and the scale of the coupling likely varies depending on the outcome of interest.