Delaware Sea Grant Project:
Forecasting the Response of Delmarva Lagoons to Changing Landuse and Climate: Alternative Stable States and Recovery Trajectories (R/ECO-7) (Regional Project)

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Project Summary

Problem Statement. Coastal lagoons like those along the Delmarva peninsula play a critical role in processing of land-derived nutrients on their transit from watershed to coastal ocean (McGlathery et al. 2001; Anderson et al. 2003). However, these systems are vulnerable to rapid changes in population, land use, and associated nitrogen (N) loads, along with potential increases in sea level and water temperatures associated with global climate change. As a response to these impacts, lagoons frequently exhibit a shift in the dominant autotroph and nature of nutrient processing that may ultimately affect water quality, restoration of seagrasses and other important habitat for living resources, as well as the ability to support clam aquaculture, which is prevalent along the Eastern Shore (Condon 2005).

Increasing nutrient loads would likely shift autotrophic dominance from benthic microalgae (BMA) and eelgrass to nuisance blooms of phytoplankton and macroalgae (Valiela et al. 1997), although this dominance has been difficult to predict in cross-system comparisons (Nixon et al. 2001). Consequences of macroalgal blooms include shading of BMA and eelgrass and release of nutrients during decomposition events in mid-summer, enabling increased phytoplankton production. Reduced light penetration will reduce the ability of BMA to sequester nutrients and reduce survival of eelgrass, which has been resurging in the southern VA lagoons. Concomitant increases in sea level will also reduce light to benthic autotrophs, and temperature increases should further favor phytoplankton and macroalgae due to a relatively low temperature optimum for eelgrass (e.g. Bintz et al. 2003).

While reducing nutrient loads is frequently heralded as a prudent restoration measure, it is uncertain how coastal lagoons will respond to reductions due to the potential for non-linear recovery trajectories and hysteresis, in part due to long-term accumulation of watershed-derived nutrients in sediments and groundwater (Kemp and Goldman, in prep). In light of the myriad of stressors to lagoonal communities and our current inability to predict changes in stable states and recovery trajectories, the purpose of the proposed work is to conduct a combined field and integrative modeling study focused on the following areas of emphasis from the RFP: (1) Land Use Decisions and Water Quality Impacts, (2) Changing Shorelines (as related to landuse change), and (3) Climate Change (as related to sea level rise and increased temperatures).

Objectives:

- Model watershed N loading along the Delmarva under current and future landuse.
- Model lagoon response to changing N loads, water depths, and temperatures with a focus on (1) changes in autotrophic dominance, (2) changes in N retention and cycling, (3) recovery trajectories under reduced loading, and (4) carrying capacity for clam aquaculture.
- Measure *in situ* system metabolism, autotrophic and sediment metabolism, sediment nutrient fluxes, and hydrodynamic fluxes to calibrate the model.
- Experimentally assess the role of nutrients stored in lagoon sediments in delaying recovery.

Methods. *Field studies:* We will identify sentinel lagoons in DE, MD, and VA that reflect a range of N loading and autotrophic dominance. Current target lagoons are Rehoboth Bay (high load, macroalgal dominance), Chincoteague Bay (moderate load, eelgrass dominance), and Hog Island Bay (low load, mixed BMA and macroalgal dominance). In Year 1 we will visit mid-lagoon sites three times between May and September. Water and sediment cores along with macralgae and eelgrass will be collected and incubated in a light gradient box at VIMS to generate production-irradiance (PI) curves. These PI curves will be combined with hourly irradiance and light attenuation to scale up to areal rates of production and respiration by each component and the entire system. Additional cores taken at each site will be used to measure nutrient fluxes in a controlled environmental chamber. During each visit a small portable autonomous underwater vehicle (AUV) will be used for measurements of hydrodynamics (current profile), water quality (dissolved oxygen, chl-a, turbidity), and seabed composition and morphology (side-scan sonar, swath bathymetry, video camera) (Skarke and Trembanis 2008). The AUV surveys will provide a spatial domain to compliment Eulerian point measurements and provide data for model calibration (Griffiths and Trembanis, 2007).

In Year 2 we will assess the potential for nutrients accumulated in sediments to support continued production in the absence of watershed loading (i.e. hysteresis). Cores will be collected at each site and returned to VIMS for incubation in our environmental chamber at constant summer temperatures (e.g. 25°C). Half of the cores will be incubated on a diel light cycle and the other half in complete darkness. Inorganic and organic nutrient fluxes will be measured initially and at regular intervals throughout the experiment. AUV surveys will be conducted at dawn and dusk along system tracklines to assess diel and spatial patterns of production and respiration (Patterson and Trembanis 2008).

Watershed modeling: We have successfully applied a nitrogen-loading model to Gargathy Bay on the VA Eastern Shore (Poleto and Brush 2007) using an existing model developed for Waquoit Bay, MA (Valiela et al. 1997) and adapted for Delmarva systems in a study of Chincoteague Bay (Cole 2005). The model combines atmospheric deposition with landuse distribution, agricultural fertilizer application, and population size to compute long-term N load. Model predictions for Gargathy Bay were calibrated to measurements of load by Stanhope (2003). We are currently collaborating with colleagues at the University of Virginia to apply this model throughout the VA Eastern Shore, using measured loads by Stanhope in 13 other watersheds for calibration. In Year 1, this model will be incorporated in a Geographic Information System (GIS), applied throughout our Delmarva study systems, and calibrated to existing measures of load prior to running scenarios of changing landuse and population size.

Lagoon modeling: In Years 1-2, we will combine our novel shallow water ecosystem model including N, phytoplankton, macroalgae, oxygen, and hard clams (Brush and Nixon, in review), which is undergoing expansion to include BMA for a separate project, with our novel eelgrass model (Harris 2006). The integrated lagoon model will be driven with our modeled N loads and calibrated to the extensive monitoring data available across the states (DE Department of Natural Resources and Environmental Control, MD Department of Natural Resources, National Park Service, and VA Coast Reserve Long-Term Ecological Research program) and our measurements of production, respiration, sediment-water nutrient fluxes, and residence time (computed from AUV current measurements). Once calibrated, the models will be run forward under various scenarios of landuse change, sea level rise, and temperature to predict responses of these systems with respect to autotrophic dominance, N cycling, and ability to support clam aquaculture. The models will then be run with decreasing nutrient loads to predict any non-linear recovery trajectories – especially due to sediment-bound nutrients and lag times in groundwater inputs – and the potential to restore eelgrass habitat to these systems.