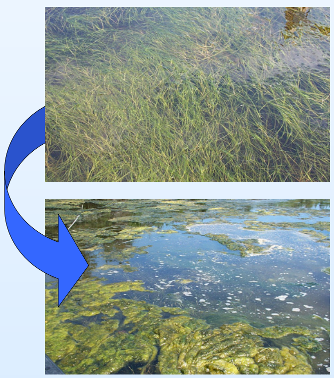
Effects of Nutrient Enrichment on Estuaries at Acadia National Park: Current Status and Future Projections

Hilary A. Neckles[1], Glenn R. Guntenspergen[1], Blaine S. Kopp[1], and Martha G. Nielsen[2]

[1]USGS Patuxent Wildlife Research Center, Augusta, ME; [2]USGS Maine District, Augusta, ME

PROBLEM

Estuaries throughout the northeast are threatened by nutrient enrichment associated with land clearing, fertilizer production and application, discharge of sewage and septic systems, and fossil fuel combustion. Excessive nutrient inputs lead to dense algal growth, decreased oxygen availability in sediments and bottom waters, loss of submerged vascular plants, and reduced habitat value for fish and wildlife. At Acadia National Park, nutrient loading to coastal systems is one of the most significant resource management challenges. Park estuaries are threatened by rapidly increasing residential development outside the Park boundary. Protecting estuarine resources from continued nutrient inputs requires the ability to predict responses to potential increases in nutrient loading resulting from changing land-use patterns and to detect early changes in estuarine status.



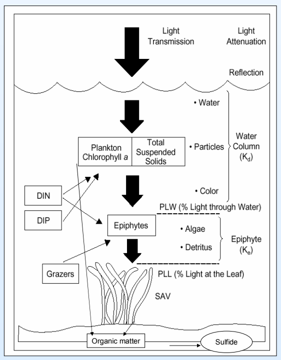
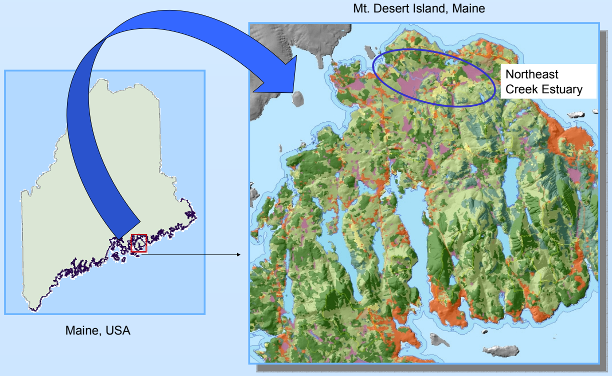


Diagram Source: Batiuk et al., 2000, Ches. Bay Program

STUDY AREA

Northeast Creek estuary lies on the northern margin of Mt. Desert Island, Maine. The estuary is 4.2 km long and drains a watershed of approximately 2600 ha. Although much of the estuary is within the boundaries of Acadia National Park, most of the watershed is not. The most rapid residential development on Mt. Desert Island is occurring in the watershed of Northeast Creek estuary. The average water depth is about 1 m, with a deeper central channel surrounded by broad shoals less than 0.5 m in depth. The shallow open water zone of the estuary is vegetated with the submerged macrophyte *Ruppia maritima* (widgeon grass) along most of its length, and the estuary and fringing wetland provide valuable habitat for a host of fish and wildlife species. Conversion of surrounding forest land to housing threatens the estuary with nutrient enrichment and ultimate decline in habitat value.



GOALS AND OBJECTIVES

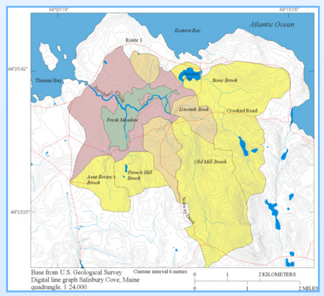
The overall aim of this project is to develop tools for predicting long-term response of Acadia's estuaries to nutrient enrichment. We have used an interdisciplinary approach integrated across a variety of spatial and temporal scales to link land use, nutrient loading, and ecological response within Northeast Creek Estuary. From 1999 – 2003 we addressed the following specific objectives:

- Determine the magnitudes of nutrient loading to the Northeast Creek system from surface water, ground water, tidal, and atmospheric sources
- Measure landscape characteristics within the watershed and relate them to nutrient flux
- Use *in situ* enrichment experiments to determine critical thresholds of nutrient loading that result in changes in estuarine structure and function
- Develop a decision support system relating land use patterns to estuarine responses

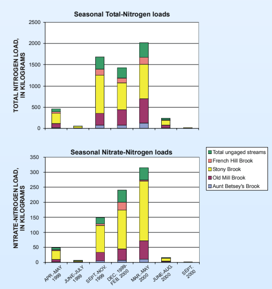
APPROACH

MEASURE NITROGEN LOAD TO NORTHEAST CREEK

We estimated nitrogen loads to the estuary through continuous streamflow and monthly water-quality measurements in major tributaries over 18 months and evaluations of atmospheric and groundwater contributions.



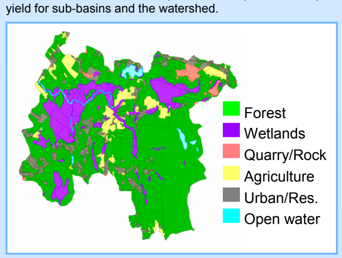
Northeast Creek Estuary Watershed Basins. Yellow= surface-water tributary basin with measured streamflow/ water quality data; Beige=Surface-water tributary basin without measured streamflow/water-quality data; Pink= basin area not contributing channelized surface-water flow (ground-water area); Green=wetland area.



Seasonal nitrogen loads by tributary to Northeast Creek Estuary, April 1999 to September 2000. Surface-water nitrogen loads are strongly correlated with streamflow, which drops dramatically in the summer.

RELATE LAND USE TO NITROGEN FLUX

Spatial information on watershed physical characteristics (e.g. bedrock geology, soils, topography), plant community types, and land use were integrated in a Geographic Information System. Nitrogen export coefficients for various land-use types were then derived based on measured nitrogen yields from areas of different land-use/land-cover patterns, comparison with published values, and calibration with total measured yield for sub-basins and the watershed.

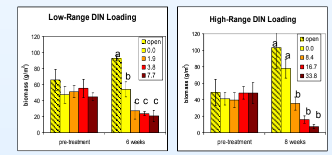


Land-Use Type	Export Coefficient (kg N ha^{-1} yr^{-1})
Agriculture	3.1↔6.5
Forest	0.9↔1.0
Open Water	0
Quarry/Gravel pit	0
Suburban/Residential	8.0↔8.1
Wetland	-1.0↔-0.4

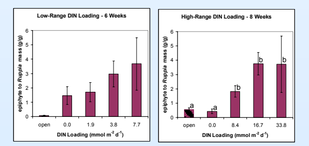
Land use types and parcels within Northeast Creek watershed.

QUANTIFY ESTUARINE RESPONSE TO NITROGEN LOAD

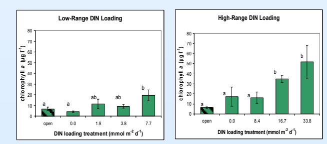
In-situ experimental chambers were used to quantify estuarine ecosystem responses to nitrogen input. Nutrient load treatments were selected to span current conditions and the range of inputs for estuaries in the northeastern U.S. Responses of all major autotrophic groups (*Ruppia maritima*, epiphytic algae, phytoplankton, and macroalgae) were measured throughout the course of two growing seasons to determine the level of nutrient load that causes major changes in estuarine structure and function. Physical/chemical characteristics (light attenuation, dissolved oxygen concentration, soil organic matter) were also measured in response to treatment. Algae showed clear increases in density with N-inputs and *Ruppia* showed a corresponding decline in biomass. Critical thresholds causing significant increases in suspended chlorophyll concentrations and epiphyte loads were below 8 mmol DIN m^{-2} d^{-1}. *Ruppia* biomass decreased at relatively low nitrogen loading (2 mmol DIN m^{-2} d^{-1}).



Ruppia biomass response to experimental N additions



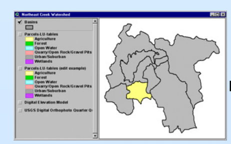
Epiphyte response to experimental N additions



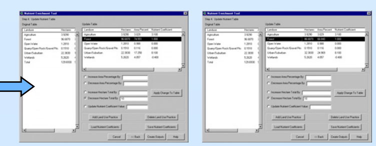
Average summertime chlorophyll-a response

DEVELOP A DECISION SUPPORT SYSTEM LINKING CHANGES IN LAND USE TO ESTUARINE RESPONSE

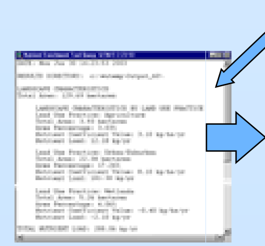
We have integrated data on land-use/land-cover, nitrogen load, and ecosystem response in a decision support system that can be used to evaluate the impacts of changes in landscape characteristics on the estuary.



Users can select sub-basins,



make hypothetical changes to the character of the area (e.g. shown here as a 10-ha conversion from forest to urban/suburban cover),



and generate a new nutrient load associated withhypothetical changes in land use.

	Watershed Yield of TN Kg ha^{-1} yr^{-1}	DIN Loading To Estuary mmol m^{-2} d^{-1}
At Current N loading: **Healthy**	1.7	1.5
Development to HALF of current residential zoning allowance: **Symptoms of Eutrophication**	3.3	2.9
Residential build-out to FULL extent of current zoning: **Degraded**	5.1	4.5

The predicted nutrient load is then linked to experimentally-based thresholds of estuarine response to predict the status of the ecosystem under changing patterns of land-use.