Learning Procedure

1. Preparation: If students do not have access to the Internet, download and copy:
    - Introductory essay on National Estuarine Research Reserves
    - Pages on Great Bay Reserve, New Hampshire: Site Description, Flora, Endangered Species, Tidal Range, and "Geology & Soil Types" (linked from http://www.nerrs.noaa.gov/GreatBay/Overview.html);
    - Project Profile and Final Report for the project "Eelgrass as an Indicator of Nutrient Over-Enrichment in Estuaries" (from the CICEET Project Explorer Web page, http://ciceet.unh.edu/searchprojects.html, click below the Project Explorer icon, then enter "Short" in the Coordinator box, select "Nutrient Enrichment" in the Issue box, select "Great Bay" in the NERR box, then press the Search button. "Early Detection of Nutrient Over-Enrichment Using Eelgrass Community Response" should appear in the Title box. Click on this title to display the Project Profile and a link to the Final Report (note that the Final Report is 59 pages long and approximately 5.5 Mb).
2. Briefly review the concept of estuaries.
    - You may want to have students review the tutorial in the "Estuaries Tutorial" http://oceanservice.noaa.gov/education/tutorial_estuaries/, and complete one version of the subject review.
    - Introduce the National Estuarine Research Reserve System, and tell students that they will be investigating one of these reserves and one of the many research projects that use these reserves as natural laboratories;
    - Provide each student or student group with a copy of the "Student Worksheet," as well as copies of the materials downloaded in Step 1 if students do not have access to the Internet.
3. Lead a discussion of students' answers to worksheet questions. The following points should be included:
    - Stewardship, research, and education are the three primary purposes for which National Estuarine Research Reserves are established.
    - The eight habitats found in the Great Bay Reserve include upland forest, upland field, salt marsh, mudflats, tidal creek, rocky intertidal, eelgrass beds, and channel bottom/subtidal.
    - The Great Bay Wildlife Refuge has the greatest diversity of habitats within the Great Bay NERR.
    - Spartina alterniflora and Spartina patens dominate saltmarsh habitats.
    - The Great Bay Reserve region is characterized as a transition zone between deciduous forest and coniferous forest.
    - The Great Bay Reserve estuary is critical to the wintering of the American bald eagle.
    - Tidal flow dominates over freshwater influence in the Great Bay Reserve estuary throughout most of the year.
    - Large outcrops of slate provide an important source of stable substrate for macroalgal attachment and contributes to the beaches in the Great Bay Reserve.
    - The Great Bay Reserve estuary is representative of a drowned river valley.
    - Marsh soils bordering streams within the Great Bay Reserve generally contain high amounts of organic matter and sulfur-containing minerals.
    - Man-made loading from coastal watersheds is the major cause of excessive nutrients in estuarine and coastal waters.
    - It is difficult to directly measure excessive nutrients in estuaries because they become diluted and dissipate through tidal and current action, as well as plant uptake.
    - Dr. Short used eelgrass, Zostera marina, as an indicator of nutrient over-enrichment.
    - In addition to Great Bay, Narragansett Bay (RI) and Waquoit Bay (MA) were used as research sites for Dr. Short's project.
    - Plant morphology and nutrient content of leaf tissue were used to create an early indicator of nutrient over-enrichment.

- Plant morphology and nutrient content were combined to provide a single measurement of early nutrient over-enrichment by calculating the ratio of leaf tissue nitrogen content to leaf mass. This ratio is called the Nutrient Pollution Indicator (NPI).
- Leaf mass is negatively related to leaf tissue nitrogen content; so, higher concentrations of nitrogen in leaf tissue correspond to a reduction in leaf mass. This is a good opportunity to distinguish between correlation and causality: This research shows that a reduction in leaf mass coincides with higher tissue nitrogen concentrations, but does not show that one response causes the other.
- Dr. Short's project developed an interactive CD-ROM to explain the step-by-step procedures for determining gradients of nutrient over-enrichment within estuaries; monitoring long-term changes in nutrient over-enrichment at specific sites; identifying sources of non-point nutrient pollution; and comparing the nutrient status of different estuaries.
- In samples from Waquoit Bay, leaf mass was highest in plants from down-estuary, while tissue nitrogen was highest in plants from up-estuary.
- Between April 1998 and April 2000, leaf nitrogen content in plants from Great Bay Estuary was highest during the spring.

The Bridge Connection

The Bridge is a growing collection online marine education resources. It provides educators with a convenient source of useful information on global, national, and regional marine science topics. Educators and scientists review sites selected for the Bridge to insure that they are accurate and current.

http://www.vims.edu/bridge - Click on "Ocean Science Topics" in the navigation menu to the left, then "Habitats," then "Coastal," then "Estuary."

The "Me" Connection

Have students write a brief essay describing three ways in which estuaries are personally important (e.g., recreation, fishing, source of seafood, protection from erosion caused by storms, etc.), and how they might directly benefit from the National Estuarine Research Reserve System.

Extensions

1. Have students select other NERRS estuaries or projects in the CICEET project database, and prepare brief reports about these systems or projects.
2. Visit http://oceanservice.noaa.gov/education/tutorial_estuaries/ and http://nerrs.noaa.gov/Education/Curriculum.html for more information and activities related to estuaries.