Estuaries 101 Curriculum

Earth, Life and Physical Science Modules

Teacher's Guide

A Curriculum for Grade Levels 9-12

The Estuaries 101 Curriculum was produced for the National Oceanic & Atmospheric Administration (NOAA) and the National Estuarine Research Reserve System (NERR) by TERC.

To download the Estuaries 101 Curriculum and access other supporting materials, visit http://www.estuaries.gov

Teacher's Guide

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Foreword

Everyone loves the ocean, and most people know the ocean through their experiences at the shore, often in an estuary. A sunbather on a barrier beach, the captain of a cargo vessel maneuvering to offload freight in a seaport harbor, an artist painting a scenic salt marsh, shellfishers probing a mud flat, a family in a coastal city strolling along the waterfront, and a couple of kids out for a day sail in a protected coastal bay all depend on estuaries for their activities, yet few can even define the word if asked. Furthermore, human activities such as filling wetlands, armoring the shoreline, and discharging wastewater have seriously impacted the integrity of coastal ecosystems. When asked in a survey about the health of coastal waters, over a quarter of the public reported that they do not know enough about these areas to give an opinion (Belden et al., 1999). Though the public is aware of ocean and coastal resources, detailed knowledge of environmental science, ocean and coastal science, and the ocean's connection to humans' well-being is lacking (NEETF, 2005 and Belden et al., 1999). People need to know what estuaries are, how they are related to terrestrial and ocean systems, what important services they provide for humans, and how to restore and protect them.

In response to this challenge, we, in NOAA's National Estuarine Research Reserve System (NERRS), recognized an opportunity to build a national program that would help advance ocean and estuarine literacy, building on and integrating educational and scientific resources across the full NERRS system. Instead of a collection of locally-developed activities, we have worked to create a comprehensive national program, for use by all the NERRS education coordinators, as well as, students and teachers throughout the US. This integrated program was conceived and planned by all NERRS educators and built to meet the best pedagogical designs. Envisioned ultimately as a full K–12 set of activities, development begun with a high school set of modules that we called "Estuaries 101".

It is thus our pleasure to introduce the Estuaries 101 Curriculum. Focusing on estuaries, the curriculum modules feature hands-on learning, experiments, field work and data explorations. The curriculum consists of four modules, Life Science, Earth Science & Physical Science each using estuaries as the context for developing content knowledge and skills relevant to that domain, and a Chesapeake Bay Module which integrates and deepens the focus on estuarine concepts in a local context.

The Estuaries 101 Curriculum is comprised of four two-three week modules on estuaries. Designed for 9th–12th grade classrooms – with the flexibility to adapt to higher or lower grades – it covers key National Science Education Standards for Physical Science (Transfer of Energy and Properties, Changes in Matter), Earth Science (Structure of the Earth System), and Life Science (Interdependence of Organisms, Matter, Energy, and Organization in Living Systems).

While this version of the Estuaries 101 Curriculum, for grade level 9-12, is now available for distribution, we wish to remind all educators that curriculum design and review is a continuous, cyclic process. We wish to have a product that is truly effective for educators to implement in their classrooms. But to do so, we will evaluate it's effectiveness and continue to invite educators to provide us with feedback.

Many thanks go to all who have contributed to the development of the Estuaries 101 Curriculum: teachers, principals, parents, employer representatives, TERC staff, and to a very talented group of NERRS education coordinators. TERC, an educational nonprofit with over 40 years of experience in science, math, technology, and engineering education, was the main partner in drafting and developing all the activities that form part of the Estuaries 101 Curriculum.

Our next steps? Building on this framework to offer our young people the most effective and meaningful teaching possible that will enable them in the future to make sound informed decisions about our estuaries and coasts.

Purpose & Goal

With the many threats that our nation's oceans face, it is time for a new era of ocean literacy and enhanced efforts to prepare today's children to be tomorrow's ocean stewards. Estuaries are an ideal topic to excite students about studying the ocean because of the strong personal connections people have with estuaries—from treasured recreation experiences, scenic views during transits, to making a living on the water. Advancing estuarine, coastal, and ocean literacy is a priority of NOAA's National Estuarine Research Reserve System (NERRS). It is our expectation that, through the Estuaries 101 Curriculum, students and teachers will gain an understanding of the great importance of estuaries and the intricate connections it has with the ocean and climate systems.

The goal of Estuaries 101 is for students and teachers throughout the nation to become more ocean literate through increasing their knowledge of coastal and estuarine science and how estuaries affect their daily lives. To achieve this increased literacy, teachers will use this estuaries.gov site to access the modules and activities for grades 9-12 and an online interface to real-time and archived estuarine monitoring data (from NERRS' System Wide Monitoring Program). Use of the Estuaries 101 Curriculum will be encouraged and supported through professional development trainings hosted at 27 Reserves and at professional meetings across the nation.

Using the Estuaries 101 curriculum, teachers will be able to teach their students about Earth System Science using coastal and ocean data. Through this curriculum—which includes interactive investigations, field studies, and data analysis—teachers and students will learn that estuaries provide shelter, spawning grounds, and food for many species, that they act as buffers to improve water quality, reduce the effects of floodwaters, and prevent erosion, and that coastal areas provide value to humans in the form of recreation, scientific knowledge, aesthetics, commercial and recreational fishing, and transportation (Thayer et al., 2003).

Why teach about estuaries?

Estuaries offer a wonderfully rich context for science education and inter-disciplinary learning. Estuaries are dynamic environments with a daily flux of ocean flows mingling with river water, creating a remarkably diverse range of life and ecosystems. As a result, they offer learners a convergence of such fields as Earth systems science, biology, chemistry, geography, geology and marine science. For example, students develop math skills through detailed measurements, modeling phenomena such as growth and cyclical variation, and analyzing data to make comparisons across multiple estuaries. They develop language skills as they read and write about estuary-related topics and communicate their explorations and findings with other students and scientists. Since estuaries have also played a significant role in human settlement, exploration and development, students gain new eyes on human history, geography and culture.

Most estuarine concepts and skills are part of the national and state science standards. Although "estuaries" per se may not appear prominently in many state standards, the underlying science concepts embodied in estuaries have broad connections throughout the standards. For example, most state science education standards refer to understanding "Earth as a system", with interwoven cycles and processes relating to land, air and water. Estuaries provide engaging and accessible examples of these processes at work. Estuaries also integrate key concepts in biology (e.g. habitat adaptations), chemistry (e.g. salinity analysis) and physics (e.g. wave motions). Furthermore, most state standards call for inquiry-based learning through hands-on experiments, direct observations and active use of data - all of which occur as students engage with estuaries.

In addition, while learning interdisciplinary skills using estuaries, students gain an appreciation for the importance of estuaries in their lives and learn how their behavior impacts coastal ecosystems. We believe that it is of utmost importance to prepare tomorrow's leaders to make sound decisions about the environment and the nation's oceans and coasts. Students must understand the crucial connection between estuaries, coastal, and upland areas, and the effects of a growing population.

Components of the Curriculum

About Estuaries 101

Recognizing the incredible power of estuaries to provide a rich environment for learning, exploration, and discovery, NOAA and TERC developed *Estuaries 101*—a series of three Modules: Life Science, Earth Science, and Physical Science—addressing different aspects of the estuary environment. You can do any or all of the Modules, which consist of a series of activities and a final assessment.

* The activities in the Estuaries 101 Modules have been field tested and found to be very engaging and popular with both teachers and students.

* They are inquiry-based, conveying both content knowledge and scientific thinking and problem solving skills.

* They are aligned with the National Science Education Standards and to some State Standards. Please check the estuaries.gov site to find new alignments to other State Standards.

* They are also based upon core principles and concepts identified by the National Estuarine Research Reserve System (NERRS) educators—key principles and concepts about estuaries that students need to master in order to become estuarine literate.

* They are grounded in specific estuaries within the NERR system, though you should feel free to adapt the activities for an estuary near your school or ones in parts of the world appropriate to your classroom and curriculum. (See the *About the Modules* section of this guide and each activity for specifics.)

* A number of the activities make use of Google Earth as a means of providing context to the students' investigations and offering virtual field experiences. A support guide on using Google Earth as part of the Estuaries 101 curriculum is available online and details related to exploring specific estuaries are included in the activities that use Google Earth. (See *Using Google Earth to Explore Estuaries*, available on the estuaries.gov site, and each activity.)

* And the activities all follow the same basic structure:

- Teacher Guide, including an introduction and overview, learning goals and standards-matching, background information, materials and preparations, procedures, assessments, and extensions
- Teacher Answer Key
- Student Reading(s)
- Student Sheet(s)
- Student Data Sheet(s)

Finally, each Module concludes with an assessment piece, designed for use after completion of all the activities within that Module. These assessments, which overarch all the activities within a Module, provide a means for both grading, as appropriate, and checking in with student advances in understanding. Also, within each activity, there are opportunities for formative assessment.

About the Modules

Each Module tells the estuary story through one of three perspectives—through Earth, life, or physical science. With theses emphases on specific domains, each Module will appeal to different teachers, to be used together or separately.

Earth Science Module

Students investigate landforms and features associated with estuaries, tides and salinity in estuaries, watersheds and their relationship to the dynamic changes that occur in estuaries due to drainage and runoff, and how hurricanes can affect estuaries.

- ✦ Activity 1: Observing Estuaries: A Landform and Feature Scavenger Hunt
- ✦ Activity 2: Salinity and Tides in York River
- ✦ Activity 3: Estuary and Watershed
- ✦ Activity 4: Extreme Weather and Estuaries
- ✦ Final Earth Science Module Assessment

Life Science Module

Students investigate the range of conditions that selected animal and plant species need to survive in an estuary, model estuaries, consider algae blooms in estuaries, study how nutrients cycle through an estuary, suggest recommendations for reducing nutrient inputs to estuary waters, and investigate the incredible biodiversity that exists in estuarine environments.

- ✦ Activity 1: Survival in the Estuary
- ✦ Activity 2: Nutrients in an Estuary
- ✦ Activity 3: Biodiversity in an Estuary
- ✦ Final Life Science Module Assessment

Physical Science

Students investigate water quality parameters to study the nature of, and the cyclical changes inherent in, the chemistry of estuarine water, learn about dissolved oxygen and its effects on life, with a focus on the chemistry, model a pollution spill that occurred at Bangs Lake (a tidal lake within the Grand Bay NERR), and study the actual spill and how it changed water quality parameters in the estuary.

- ✦ Activity 1: Chemistry in an Estuary
- ✦ Activity 2: Dissolved Oxygen in the Estuary
- ✦ Activity 3: Human Impacts on Estuaries: A Terrible Spill in Grand Bay
- ✦ Final Physical Science Assessment

Curriculum Map—Earth Science Module

Enduring Understanding	Activities	Learning Objectives
Estuaries are unique, dynamic transition zones, between the watershed and the world ocean system. Earth processes create and determine the physical features of estuaries.	**Activity 1 — Observing Estuaries** Students investigate landforms and features associated with estuaries. They begin by taking a journey down a river to an estuary system where the river empties into the Gulf of Mexico near Weeks Bay NERR to investigate how landforms differ between uplands and riverine/ estuarine environments. Student teams then use Google Earth and other resources to engage in a scavenger hunt to locate and identify landforms and features of estuaries.	**Students will be able to:** • Describe differences between upland non-estuarine and estuarine landforms and features. • Visually identify and describe various landforms and features associated with estuarine environments, including salt marshes, barrier beaches, peninsulas, headlands, spits, mud flats, fjords, deltas, coves, harbors, sounds, and others.
Earth processes, characteristics of the watershed, and the physical features of the estuary affect patterns of mixing of fresh and salt water in an estuary.	**Activity 2 — Salinity and Tides in York River** Students observe time-lapse models of tides and salinity distribution in the York River, part of the Chesapeake Bay, VA NERR. They learn how salinity changes with an incoming and outgoing tide, observing the dynamics of the salt wedge at various sites along the river. They make predictions about the salinity changes at each site based upon their observations of the animation. They then use salinity data from monitoring stations along the river to see changes during a typical day, and they describe the patterns of each salinity graph and compare the graphs.	**Students will be able to:** • Analyze different forms of data and synthesize information to develop a hypothesis. • Explain how tides and the geology of the estuary affect water circulation in an estuary. • Describe daily patterns of salinity changes in the estuary.
Estuaries are part of watershed systems. The characteristics of the watershed determine some of the characteristics of the estuary.	**Activity 3 — Estuary and Watershed** Students investigate the nature of watersheds and their relationship to the dynamic changes that occur in estuaries due to drainage and runoff. They begin by examining the San Francisco Bay Estuarine Research Reserve and tracing the extent of its watershed using Google Earth. Then they identify possible sources of pollution and contamination along the major rivers that feed into the bay. Students also examine water quality data in the San Pablo region of the estuary and identify changes that occur due to a storm event.	**Students will be able to:** • Identify the processes in the watershed that affect conditions in the estuary and explain some specific examples. • Apply their understanding of changes in the watershed and the resulting effects on the estuary to explain real-life situations regarding land use and weather in watersheds. • Understand how water quality factors are affected by natural and man-made sources of pollution and contamination.
Coastal processes and interactions within the ocean system play an important role in estuarine dynamics.	**Activity 4 — Extreme Weather and Estuaries** Students investigate how hurricanes can affect NERRS estuaries. Students begin by studying the North Carolina NERR in the Cape Fear area with Google Earth and predict which areas of the reserve might be more vulnerable to the onslaught of high winds, heavy rain and storm surge than others. Then students monitor and interpret the changes in water quality factors day by day as a severe storm approaches, strikes the estuary, and then dissipates.	**Students will be able to:** • Describe the features and landforms associated with a coastal estuary. • Predict how major storm events affect NERRS reserves in the United States. • Investigate and interpret changes in water quality in an estuary due to a severe weather event. • Determine the relationship between the characteristics of an extreme weather event (heavy wind, torrential rains and storm surge) and the subsequent change in water quality over time.

Parts of the Activity	Estuary	Science Concepts	Assessment
• What is an Estuary? • A trip down the Alabama River • Estuary Landforms and Features—Scavanger Hunt	Weeks Bay NERR, Alabama	Watersheds, coastal geography, coastal circulation, coastal processes, tides	Discuss the following: • How do the terrain and types of landforms change as you travel down a river toward a source of salt water? • Which of the landforms and features on your scavenger hunt list were fairly common? • Which landforms were not present at all? Have students sketch an imaginary estuary system on a piece of paper. Direct them to draw and label as many landforms and features on their diagram as possible. Collect and evaluate them for accuracy, clarity, and the number of landforms correctly identified.
• Tides in Chesapeake Bay • Salinity as York River Flows into the Bay • Interaction of Tides and River Flow	Chesapeake Bay, VA NERR	The water cycle, salinity and density, tides, ocean currents and circulation, coastal processes	1. Discuss the following: • How do the changes at each monitoring station compare with changes at those same areas in the animation? • Name several factors that determine why salinity changes are different depending on your location within the estuary. 2. Ask small groups to use their handouts to answer this question. Collect this assignment and use it as a final assessment. *Imagine that an intense rainstorm dumps 3 inches of rain over the entire Chesapeake Bay region. Predict how the salinity would change at all four stations in the bay for a period of 24 hours after the storm ends. Supply a graph and an explanation of what you might expect to see at each station.*
• Exploring the San Francisco Watershed • What's Upstream Comes Downstream • Water Quality at the Mouth of the Watershed • *Optional*: Mapping Your Local Watershed	San Francisco Bay NERR, California	Watersheds, water cycle, runoff, biogeochemical cycles, water pollution	1. Discuss the following: • How do agricultural areas, industrial sites, landfills, and sewage treatment plants affect water quality in a watershed? • Explain how an estuary can act as a filtration system for runoff in a watershed. 2. Supply students with a road map of the eastern U.S. and project a satellite image of the Chesapeake Bay watershed. Ask students to identify major urban areas around Chesapeake Bay and major rivers that drain the watershed. Ask students to predict where they would expect areas in the most danger of contamination and pollution if a major storm event such as a hurricane struck the region.
• Investigating an Estuary • Which NERRS are Affected by Hurricanes? • Impact of Extreme Weather on an Estuary	North Carolina NERR	Water cycle, climate change, sea level rise, ocean currents, coastal processes, food webs	Discuss the following with students: • What were the effects of a major storm event in the North Carolina NERR? • What caused the change in each of the four abiotic parameters studied in this activity? • Why is there a difference in the time it takes for the different parameters to return to normal? • What effects do you think the storm might have had on different plants and animals in the estuary?

Curriculum Map—Life Science Module

Enduring Understanding	Activities	Learning Objectives
Estuaries have unique communities that are adapted to variable, dynamic environment in these transition zones between watersheds and the ocean.	**Activity 1 — Survival in an Estuary** Students investigate the range of conditions that selected animal and plant species need to survive in an estuary. They examine data for abiotic factors that affect life in estuaries—salinity, dissolved oxygen, temperature, and pH. Students use archived data (trend analysis graphs) and real-time conditions at Elkhorn Slough to predict whether a particular animal or plant species could survive in an estuary.	**Students will be able to:** • Describe three types of estuarine environments. • Describe the particular environmental conditions necessary for organisms to survive in an estuary. • List four principal abiotic factors that influence the survival of aquatic life in estuaries. • Determine the range of pH, temperature, salinity, and dissolved oxygen tolerated by some common estuarine species.
The flow of matter and energy in the estuarine ecosystem reflects the flow, mixing, and circulation of estuary waters.	**Activity 2 — Nutrients in an Estuary** Students model estuaries, artificially enriching both fresh and salt water samples with different amounts of nutrients and observing the growth of algae over a several weeks. They relate their results to the phenomenon of algae blooms in estuaries. They then analyze data for different sites in a NERRS Reserve in Florida to discover the relationships between nitrogen, chlorophyll, and dissolved oxygen. Finally, they study how nutrients cycle through an estuary and suggest recommendations for reducing nutrient inputs to estuary waters.	**Students will be able to:** • Understand how water quality and nutrient parameters in an estuary can indicate disruptions to ecological processes in estuaries. • Interpret data from an experiment to explain the effects of over-enrichment on water quality and living things; and relate this lab experience to the phenomenon of algae blooms and eutrophication in an estuary. • Explain the phenomena of algae blooms and eutrophication in terms of total nitrogen, chlorophyll-a, and dissolved oxygen. • Describe the effects of eutrophication on the nitrogen cycle. • Explain how nutrients cycle in an estuary and how natural processes and human impacts affect this cycle. • Identify sources of nitrogen inputs to estuaries and identify some ways to limit them.
The biology of estuary species reveals their adaptations to the unique and variable estuarine habitats.	**Activity 3 — Biodiversity in an Estuary** Students investigate the incredible biodiversity that exists in estuarine environments. They begin by exploring the Rookery Bay National Estuarine Research Reserve using Google Earth. Students then produce an estuary biodiversity concept map and individual organism profile that becomes part of an estuary wildlife exhibit.	**Students will be able to:** • Describe the physical and biological components of habitats that exist as part of an estuary. • Explain the relationships between primary producers, consumers, and secondary consumers. • Describe some adaptations of living organisms to the changing conditions within an estuary. • Explain why biodiversity is important and worth preserving in an estuary.

Parts of the Activity	Estuary	Science Concepts	Assessment
• The Estuarine Environment • Surviving Changes: Abiotic Factors that Affect Life • Surviving in an Estuary: Extreme Conditions • *Optional*: Investigating Other NERRS sites	Elkhorn Slough NERR, California	Adaptation, habitats, communities, abiotic vs. biotic environment, biodiversity, zonation, water cycle, coastal processes, communities, adaptation	• Direct your students to the Central Data Management Office Web site: <cdmo.baruch.sc.edu/>. Help students navigate through the site until they can successfully download trend analysis data for 2005 from one monitoring station at four other NERR sites. Encourage them to choose sites both in your region and in other parts of U.S. coastal areas. OR, download sample data from four sites and hand them out to students. • Direct students to fill out an Extreme Conditions table for each site. • Have students create graphs comparing parameter ranges and time between extremes for new sites with South Marsh data. • Discuss with students the patterns they see and ask them to explain why the ranges and rates of change for each factor vary at different estuary sites. Or ask them to write their answers down and collect student work to serve as a summative
• Nutrients in an Estuary • Using Data to Study Eutrophication and Conditions in an Estuary • Eutrophication and the Nitrogen Cycle	Guana Tolomato Matanzas NERR	Food webs, trophic interactions, biogeochemical cycles, coastal circulation, life cycles, migration	Students write a short letter to the town council of this region outlining your recommendations about steps to take to reduce the amount of nutrient flow into the estuary.
• Investigating Habitats in an Estuary • Biodiversity in an Estuary • Portrait of Life in an Estuary	Rookery Bay NERR, Florida	Adaptation, habitats, trophic interactions, cell biology concepts, physiology concepts	• Use the concept maps from Part 2 as an assessment of student understanding of the relationships between habitats, characteristics of the habitats, and the species that inhabit the estuary. • A simple way to do this is to give 1 point for each link on the concept map between two of the three variables. Then, award 2 points for each double link (two lines that reveal a relationship). Add 3 points for complex interrelationships in the concept map (3 or more lines coming from one box). Establish a class scale based on the total points given for each poster. • Evaluate the Wildlife Exhibit posters as a summative performance assessment for this activity. • Have a discussion with students after the Wildlife Exhibit viewing has ended. Ask students: a. Which animals or plants in Rookery Bay are endangered? b. What conditions in the estuary have caused populations of each of the endangered species to decline? Are any actions being taken or projects underway to protect the remaining population

Curriculum Map—Physical Science Module

Enduring Understanding	Activities	Learning Objectives
Estuaries are unique, dynamic transition zones, between the watershed and the world ocean system. Earth processes create and determine the physical features of estuaries.	**Activity 1 — Chemistry in an Estuary** Students investigate water quality parameters to study the nature of, and the cyclical changes inherent in, the chemistry of estuarine water. They study key water quality factors at several stations in a single reserve over time—current, daily, and yearly time scales—and compare water quality values over a yearly time scale in three different estuaries. Then students take water quality measurements at a site near them and compare it to the water in the three geographically diverse NERR estuarine environ-	**Students will be able to:** • Describe how different chemical and physical properties affect and interact within an estuarine environment. • Explain how analyzing chemical and physical water quality data can lead to an understanding of estuary dynamics. • Name and describe four basic water quality monitoring parameters—pH, dissolved oxygen, salinity (conductivity) and temperature. • Explain how change in chemical water quality is evidence for change in the estuary system.
The mixing of water in estuaries creates unique habitats for estuarine organisms. The water chemistry of an estuary affects the health of the estuarine ecosystem.	**Activity 2 — Dissolved Oxygen in an Estuary** Students learn about dissolved oxygen (DO) and its effects on life, with a focus on the chemistry. First, they are introduced to, and analyze data gathered from, water quality sensors in Narragansett Bay NERR, observing how DO and chlorophyll-a change from the surface to the bottom and considering the relationships between DO and temperature. Then, in the unique environment of Azevedo Pond in the Elkhorn Slough NERR, CA, they analyze DO data and speculate about how hydrodynamics, abiotic factors, and biological processes cause extreme fluctuations in DO in the pond.	**Students will be able to:** • Explain the relationships between dissolved oxygen and water depth, chlorophyll-a and water depth, and dissolved oxygen and temperature. • Explain how these parameters interact during estuarine processes and in such phenomena as eutrophication, algal blooms, and supersaturation-hypoxia fluctuations. • Understand how photosynthesis, respiration, and decomposition affect dissolved oxygen. • Explain the role of these processes in daily or seasonal dissolved oxygen fluctuations in some estuaries. • Explain how hypoxia and anoxia occur, using data as evidence, and explain the affect on estuarine animals.
Human activities affect the chemistry of estuary waters and the estuarine ecosystem.	**Activity 3 — Human Impact on Estuaries: A Terrible Spill in Grand Bay** Students make a model of a pollution spill that occurred at Bangs Lake, a tidal lake within the Grand Bay NERR in Mississippi, in April 2005, and measure water quality parameters in their model. They then study the actual spill, analyzing various forms of data to determine the date of the spill and identify how the spill changed water quality parameters in the estuary during and after the spill. They speculate on how various life forms in the estuary were affected. Finally, students produce a timeline of the spill event with recommendations to the state Department of Environmental Quality about how to prevent large-scale pollution spills like this in the future.	**Students will be able to:** • Describe how a chemical reaction affects water quality parameters of a sample of estuary water. • Use their lab results to predict the effects of an actual pollution event on water quality and life forms in an estuary. • Revise predictions based on new evidence. • Analyze water quality and nutrient data to identify variables that are out of a typical range and that may be indicators of a disturbance to the estuary, such as a pollution event. • Explain how estuarine species are threatened by drastic changes in water quality and nutrients. • Explain how the water chemistry of an estuary affects the health of the estuarine ecosystem and how monitoring estuary water chemistry can account for and predict changes to the health of the ecosystem. • Summarize data and develop a hypothesis to make a timeline that describes the spill and explains how it affected the chemistry of and life in an estuary. • Suggest ways to prevent adverse human impacts on estuaries.

Parts of the Activity	Estuary	Science Concepts	Assessment
• What is an Estuary? • Investigating Water Quality in an Estuary • Investigating Water Quality Over a Day • Investigating Water Quality Over a Year • Comparing Water Quality Data Between Two Different Estuarine Environments	South Slough NERR, Oregon Delaware NERR Old Woman Creek NERR, Ohio	Physical properties of water, water circulation, solubility, physical properties of water, watersheds, tides	• Ask students to summarize the factors that make estuaries such dynamic sites of transition and change for all the organisms that live within their boundaries. • If at all possible, take students to one or more sites on or near your school grounds to measure water quality. Have students measure each of the four water quality factors if possible at each site and record their results. Then have students compare their values for water quality with values taken from each NERR water quality graph on the date of students' observations. How do the parameters differ between your local site (s) and NERR sites? Explain the cause of differences you find.
• Dissolved Oxygen in Narragansett Bay • What's Happening in Azevedo Pond?	Narragansett Bay NERR, Rhode Island Elkhorn Slough NERR, CA	Physical properties of water, light, tides, water chemistry monitoring	• Discuss the following: a. In general, what is the pattern of DO levels in a pond over the period of a single day? b. In general, what is the pattern of chlorophyll-a in the same pond over the period of a single day? c. What causes hypoxic conditions in an estuary? • Have students compare DO levels at various sites within NERRS. Download or let students download graphs using SWMP data to compare DO stability between an area where eutrophication is common (e.g. Childs River, Waquoit Bay NERR) and a well-flushed area (e.g. Menauhant). How are the DO levels different? Explain why differences occur.
• Modeling a Chemical Spill • Learning More about the Spill • Analyzing Data Before and After the Spill	Grand Bay NERR, Mississippi	Water pollution, chemistry of specific pollutants, biochemistry of specific pollutants, nutrient cycles, dissolved oxygen, turbidity, land use, watersheds, erosion and sedimentation	• Discuss the following: a. What caused the massive spill in Grand Bay? What could have been done to prevent it? b. What were the immediate effects on organisms living in the bay? c. What are the reasons that water quality returned to normal after a brief span of weeks?

Curriculum Design

Modular Approach

Estuaries 101 was developed as a series of Modules for very specific educational reasons. *AAAS Benchmarks* (1993) notes that an overstuffed curriculum overemphasizes short-term memorization and impedes “the acquisition of understanding." A modular approach can help combat the difficulty of "a mile wide and an inch deep". Modules that focus on select concepts can facilitate deeper interaction with content and allow for project-based work.

Modules also offer usability advantages. Modules allow teachers to diversify their curricula by selecting standards-relevant content from various sources. The *NSES Standards* recognizes that integrated and thematic approaches can be powerful. Indeed, it is rare for high school science teachers to have the opportunity to dedicate a full-year or semester-long curriculum to the study of estuaries exclusively. However, it is quite common for high school teachers to incorporate several plug-in modules that allow them to cover standards and meet curriculum objectives in novel ways, through different perspectives, or with a particular focus in a topic such as estuaries.

The concepts within a study of estuaries can be woven into existing Earth, life, or physical science courses via plug-in modules by meeting standards and without contributing to an "overstuffed" curriculum.

Types of Experiences

Students learn best when they are immersed in topics they care about and are pursuing questions of personal relevance. The Estuaries 101 Modules take advantage of this, embedding the learning in investigations of dynamic estuaries.

Specifically, there are three different types of experiences in the activities:

* Data analysis,
* Field experiences, and
* Classroom experiments.

In the data analysis experiences, students work with actual data collected at the estuary upon which an activity focuses. They analyze graphs, data tables, and maps for the purpose of understanding a broader concept, relationship, or system, just as the scientists who study the estuaries do. For example, in Earth Science Activity 4: Extreme Weather and Estuaries, students monitor and interpret the changes in water quality factors, such as salinity and turbidity, day by day as a severe storm approaches, strikes the estuary, and then dissipates.

In the field experiences, students explore actual estuary locations virtual and in person. The activities do not assume that teachers and students will be able to get outdoors and to an actual estuary for hands-on experiences, so virtual field trips are included, using Google Earth and other online systems. For example, in Physical Science Activity 2: Dissolved Oxygen in an Estuary, students use the Web to take a virtual field trip to two sites in Narragansett Bay, Rhode Island, where an interactive tool allows them to access various water quality sensors at different depths for the purpose of considering the relationships between dissolved oxygen and water temperature. In addition, the NERR system provides a range of award winning education programs, including hands-on field experiences for students, and the Estuaries 101 Modules are designed to complement and relate to such experiences if you are able to actually visit one of the 27 reserves around the country. (See the Web site for additional information.)

Finally, in the classroom experiments, students get hands-on with some of the various factors and conditions important to estuaries and to the data they are studying from those estuaries. Aspects of the estuaries are brought into the classroom, where variables can be controlled and changed, models can be made and manipulated, and experiments can be conducted. For example, in Life Science Activity 2: Nutrients in an Estuary, students create estuary models in which they artificially enrich both fresh and salt water samples with different amounts of nutrients, observe the growth of algae over time, and relate their results to the phenomenon of algae blooms in estuaries.

Scaffolding and Supports

In the activities, these experiences are scaffolded and supported by background information for both the teachers and students, since there is a role for reading and direct delivery of content in learning, as part of the overall process; by student sheets, which provide guidance through the experiences and ask both specific response and reflection questions to ensure that students are on track and are thinking about what they are doing and why; by assessment pieces for individual activities and for entire Modules, providing a means for both grading, as appropriate, and checking in with student advances in understanding; and finally by optional extension inquiries, which provide suggestions on how the concepts, skills, data, and questions addressed in the activities can be pursued in more depth by classes or individuals interested in taking their explorations to the next level.

Estuaries 101 takes a rich educational approach, with opportunities to engage a wide-variety of school and classroom situations and all types of learners in exploring the science and excitement of estuaries.

Design, Review, and Testing of the Materials

A great deal of thought and energy went into the initial design and development of the Estuaries 101 Modules. This involved extensive work on defining a scope, conceptual sequence, and detailed rationale for all of the activities; standards matching; the development of and alignment with core principles and concepts; and the identification of activity-specific learning objects. (See the Core Principles section of this guide, the Standards Matching materials available on the Web, and the individual activities for more details.)

In addition, the Modules were reviewed by NERRS educators and scientists at numerous stages during their design, development, and revision to ensure that the final activities are scientifically rigorous and meet the educational needs of the NERRS and the teachers and students with whom they work.

Finally, all of the Estuaries 101 activities were pilot tested by teachers and students. Feedback was gathered from this testing, and revisions and additions were then made to the activities and assessments to specifically address the needs, desires, and realities of implementing the Modules within real classroom settings.

How Learning about Estuaries meets State and National Science Education

When NOAA/NERRS launched Estuaries 101, it also decided to conduct a national study to see how estuaries can meet state and national standards. TERC, an educational non-profit, was contracted to conduct this study, the results of which are published in this site. This study relates broadly to the concepts and skills that can be embedded in estuaries learning activities, and specifically to Estuaries 101, NOAA's newly released high school curriculum materials. This study and the curriculum were developed in collaboration with NOAA's National Estuarine Research Reserve System.

For this study, we compared the Estuaries learning goals with the National Science Education Standards as a common framework, and sample state standards to illustrate the diversity among states. While the National Science Education Standards (NRC, 1996) provides a common framework on which many states base their standards, each state defines and vets its own standards. In some cases, differences among states reflect issues of local relevance (e.g. coastal states might have a greater emphasis on oceans and coastal processes), or policy priorities (e.g. the balance between content and process standards). For the sample states, TERC selected California, Illinois, Massachusetts, Virginia and Washington, as (relatively populous) representatives of the nation, including coastal and inland states. TERC looked at high school standards in biology, Earth science, chemistry and physics (combined into Physical sciences, below), as the context in which these modules will be used. While Estuaries ultimately will become a full K-12 program, the first released modules are for high school. They are designed as supplemental modules, for inclusion in Earth science, biology and physical science courses, although they may also be used by other educators.

TERC conducted the analysis at four levels of concepts and skills:

- *estuaries* – TERC began with a narrow focus, searching for the term "estuaries" and directly related terms in these standards. This is often the first level that people consider when deciding to use curriculum materials – if their state standards include "estuaries" per se.
- *big ideas in science* – TERC next broadened the scope, to explore how the estuaries activities support the learning goals of the three major subject domains of the modules: Earth science, biology and physical science – looking especially at the "big ideas" in each field.
- *developing science thinking skills* – TERC focused on how estuaries modules meet standards for science thinking skills, such as inquiry, experimental design and data analysis. These fundamental skills permeate science, and are well supported by the Estuaries 101 activities.
- *ocean and climate essential principles* – As an effort to develop a common framework for ocean and climate literacy, NOAA and other agencies have developed a set of essential principles for each of these fields. TERC cross-referenced the estuaries modules with these important documents.

The full report, "How Learning about Estuaries meets State and National Science Education Standards", details the findings in each of these levels. In brief, the study found that estuaries per se are inadequately represented in the state standards. Remarkably, only four states refer to estuaries by name. While other states used comparable terms like marine and salt water environments, freshwater habitats, tidal environments, wetlands, brackish, bay, salt marsh, coastal swamp, etc., the study concluded that there is not a strong enough explicit need for covering estuaries per se to drive large scale use. On the other hand, estuaries can be an exceptional vehicle for conveying the "big ideas" of science – such as "habitat adaptation" in biology, and "water as solvent" in chemistry and "interacting systems" in Earth science. These concepts are included in ALL state standards we reviewed, in one form or another. The study also found strong correlations between the inquiry-based approaches used in the modules and the scientific thinking skills, such as experimental design and data analysis, called for in all state science standards. Finally, the study found a strong alignment between the proposed modules and the essential principles of ocean and climate literacy.

Summary - Conclusions of the Study

Conclusion #1 – The specific word "estuaries" does not have a prominent role in most state standards, but estuaries-related terms do. If we use related terms, like tidal environments and fresh and saltwater habitats, the concept of estuaries is included in the standards of nearly a quarter of the states, Hence, we should use such terms in describing the learning goals and activities.

Conclusion #2 – To make a more compelling case for the estuary curricula, we should emphasize the big ideas that are covered in each module. Most of the topics in the modules align well with the big ideas in life, physical and Earth science, as well as the over-arching "unifying concepts and processes". This is true at the national level and in the individual state standards.

Conclusion #3 – The estuaries modules align well with standards for science process and thinking skills. This is true in the national standards, and in our five representative states. Estuaries are an especially good domain for developing and applying these skills. We recommend making this point clearly when trying to establish the value of the estuaries modules.

Conclusion #4 – The estuaries modules strongly support ocean and climate literacy. The appeal and value of the estuaries models to help students learn about and apply these principles will increase as the Ocean Literacy and Climate Literacy documents become more visible and increase their impact on state and national standards.

The full report, "How Learning about Estuaries meets State and National Science Education Standards", can be found at::

http://www.estuaries.gov/estuaries101/Resources/Default.aspx?ID=151

Monitoring and Evaluation

All the Estuaries 101 activities are scaffolded and supported by:

- background information for both the teachers and students, since there is a role for reading and direct delivery of content in learning, as part of the overall process;
- by student sheets, which provide guidance through the experiences and ask both specific response and reflection questions to ensure that students are on track and are thinking about what they are doing and why;
- by assessment pieces for individual activities and for entire Modules, providing a means for both grading, as appropriate, and checking in with student advances in understanding; and
- finally by optional extension inquiries, which provide suggestions on how the concepts, skills, data, and questions addressed in the activities can be pursued in more depth by classes or individuals interested in taking their explorations to the next level.

Each Module concludes with an assessment piece, designed for use after completion of all the activities within that Module. These assessments, which overarch all the activities within a Module, provide a means for both grading, as appropriate, and checking in with student advances in understanding.

NATIONAL ESTUARINE RESEARCH RESERVE SYSTEM

NOAA National Estuarine Research Reserve System

NOAA's National Estuarine Research Reserve System (NERRS) strives "to enhance public awareness and understanding of estuarine areas, and provide suitable opportunities for public education and interpretation." The NERRS comprises 27 reserves, and is a great resource for all things related to estuarine ecology. The reserve system provides a range of award winning education programs ranging from hands-on field experiences for students to professional development opportunities for teachers. Reserve educators provide regularly scheduled public programs and special events and partner with local schools, community-based organizations and volunteers.

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