Principles and Concepts for Estuaries 101:

The Big Ideas and Essential Details Students Should Learn About Estuaries

NOAA Office for Coastal Management

Estuaries are ideal environments to excite students about science because of the strong personal connections people have with estuaries—from remembering treasured recreational experiences and scenic coastal views while traveling, to making a living from the bounty of estuarine waters.

Estuaries embody rich domains for inquiry, exploration, and discovery. They are fertile spaces where rivers and oceans mix, where diverse habitats reflect diverse environmental circumstances, and where life flourishes and adapts over relatively narrow spatial and time scales. These ecosystems offer powerful opportunities to learn core concepts in Earth science, biology, chemistry, and physics, and to develop essential scientific-investigation skills for the 21st century.

Estuaries provide a powerful context for students to develop a broader set of lab skills, learn about Earth as a dynamic system, explore connections between habitats and life, analyze real-world data, and apply concepts of chemistry and physics to understand the dynamics of estuaries as fascinating and accessible examples of science in the world around us.

Building on this excitement and engagement, we can use estuaries as a model topic to introduce multi-disciplinary, real-world studies incorporating science, technology, math, social studies, and history. Existing education standards[1] and curricula rarely include broad knowledge or lesson plans related to estuaries. Because of this gap, educators within NOAA's National Estuarine Research Reserve System took it upon themselves to define key principles and concepts about estuaries that students need to master in order to become estuary literate.

Contents

[1] D. Barstow and J. Hammerman, **"**Excellence in Estuaries Education (EEE)," TERC proposal to the National Estuarine Research Reserve System for Estuaries 101.

Estuarine Principles and Concepts

Principle 1: Estuaries are interconnected with the world ocean and with major systems and cycles on Earth.

Concept: Estuaries are part of important biological, chemical, and physical cycles such as food webs, nutrient cycles, and hydrologic cycles. For example, estuarine salt marshes can sequester carbon and filter out toxic substances or nutrients from groundwater.

Concept: Estuarine ecosystems are affected by changes in global systems and cycles such as climate and weather cycles. For example, sea level rise can inundate salt marshes, reducing the habitat available for resident species and eliminating the flood protection important to upland areas.

Concept: Estuaries form an interface linking watersheds and oceans, and receive groundwater and surface water from their entire watersheds. Estuaries are affected by air quality and precipitation from far beyond watershed boundaries.

Principle 2: Estuaries are dynamic ecosystems with tremendous variability within and between them in physical, chemical, and biological components.

Concept: Estuaries have various geologic origins and morphology.

Concept: Estuaries can change slowly over hundreds to thousands of years. For example, they are transformed by changes in sea level, precipitation, and vegetation patterns within their watershed, and by sediment movement.

Concept: Estuaries can also change quickly, within hours or days. They are constantly shaped by water flowing from uplands as well as tidal cycles moving and mixing of fresh and salt water within the estuary. They can be dramatically changed by single, severe events such as a hurricane or the building of a levee.

Concept: The dynamic nature of estuarine processes presents a challenge to the organisms living there. Organisms that reside in estuaries are adapted to the rhythm of change. For example, tides can change local sea level by several feet each day, leaving sessile organisms alternately inundated with water or exposed to air.

Principle 3: Estuaries support an abundance of life and a diversity of habitat types.

Concept: Estuaries provide vital nursery and spawning grounds for numerous fish and invertebrates, including a significant proportion of commercially harvested species.

Concept: Estuaries incorporate diverse habitat types. Oyster reefs, salt marshes, mangroves, mudflats, and freshwater tidal marshes can be found in estuaries.

Concept: Estuarine plant and animal species have specialized physical, biological, and behavioral adaptations that allow them to survive in the ever-changing estuarine

environment. For example, some plants that grow in salt marshes can excrete excess salt through their leaves.

Concept: Estuaries provide a rich food source for a wide variety of organisms.

Principle 4: Ongoing research and monitoring is needed to increase our understanding of estuaries and to improve our ability to protect and sustain them.

Concept: Through research and monitoring in the National Estuarine Research Reserve System and elsewhere, humans gather scientific data in estuaries that allow us to understand estuarine processes and track changes in estuaries. For example, the System Wide Monitoring Program allows scientists to track short-term variability and long-term change.

Concept: Technology plays an important role in how estuarine data are collected, analyzed, and interpreted. Technological innovations have led to increased understanding of estuaries. Technology such as data loggers, sampling equipment, and remote sensing can provide data that can help people identify the cause of degraded water quality and verify the recovery of a restored system.

Concept: Estuarine research is interdisciplinary. The expertise of many different specialists (e.g., meteorologists, sociologists, geologists, biologists, chemists, economists, computer scientists, engineers, and community planners) is required to study and understand estuaries.

Concept: Since estuaries incorporate many interacting factors and conditions, research investigations must be carefully designed and results must be considered in context.

Principle 5: Humans, even those living far from the coast, rely on goods and services supplied by estuaries.

Concept: Estuaries provide social services and cultural value to humans. Millions of people use estuaries for recreational activities such as fishing, bird watching, and boating. Estuaries are also a source of inspiration, rejuvenation, and discovery. They have played an important role in determining the lifestyle and culture of different human populations over time.

Concept: Estuaries provide flood protection to human communities. Coastal wetlands absorb and slowly release water from storms, mitigating storm surge and preventing floods.

Concept: Estuaries provide significant economic value to humans. Many species of fish, crabs, and shellfish, which live in estuaries for part or all of their lives, provide essential food for humans.

Principle 6: Human activities can affect estuaries by degrading water quality or altering habitats; therefore, we are responsible for making decisions to protect and maintain the health of estuaries.

Concept: Human activities within an estuary system, its watershed, and in distant areas impact the biological, chemical, and physical components of estuaries. In particular, land use changes within an estuary's watershed can change erosion and subsequent sedimentation rates within the estuary, affecting water clarity or bottom substrate.

Concept: The quantity and quality of goods and services provided by estuaries to humans is dependent on the good health of estuarine ecosystems. Real estate values can decline in areas near overenriched or eutrophic estuaries.

Concept: Humans can use their understanding of estuaries to make informed decisions on how to best protect and manage estuaries, while still allowing for the enjoyment of estuaries. For example, when a city on an estuary improves its wastewater treatment, eliminating sewage outfalls, the water quality in the estuary improves.

Concept: Organizations such as the National Estuarine Research Reserve System, federal agencies, state and local governments, nonprofit organizations, and educational institutions work together to protect estuaries. Estuarine protection and restoration can be implemented by way of governmental regulations, community education, citizen engagement, and stewardship.

Concept: Actions that will help improve and maintain estuary health include energy conservation, water conservation, habitat protection and restoration, proper wastewater treatment, and education about estuaries.

What Are Principles and Concepts, and How Do They Relate to One Another?

1. **The Principles – a small set of *big ideas.*** These *big ideas* are broad and inclusive. They provide a breadth of meaning by connecting and organizing many facts, skills, and experiences. The six *big ideas* presented in this document aim to capture the major ideas that teachers and students should understand about what estuaries are and how they function. The principles and concepts can also inform their understanding of how human choices and natural processes impact estuarine systems, and the social and economic activities that depend on estuaries.
2. **The Concepts – a set of *essential details.*** Each big idea, or principle, is supported through its *essential details*. These details are broader than specific topics or facts that a lesson plan might address, but are specific enough to shape and define the concepts that should be explored under each *big idea*.

In summary, these principles and concepts represent an attempt to define content that will describe what learners should know about estuaries, why estuaries are important to the learner, and why learners should act as stewards and promote behavior that will maintain or improve the health of estuarine systems.

How Were the Estuarine Principles and Concepts Developed?

A National Estuarine Research Reserve System education workgroup reviewed a variety of documents related to this subject, including an overview of estuarine education concepts that appeared in the National Marine Educators Association's *Current* Magazine;[2] the Final Report by NOAA's Education Objectives Workgroup; National Science Education Standards; the North American Association for Environmental Education's Guidelines for Excellence; Ocean Literacy concepts and essential principles; California's Environmental Principles and Concepts; and the American Association for the Advancement of Science's Climate Literacy efforts.

[2] L. Spence and M.G. Jones, 1990, "Top Priorities in Estuarine Education Concepts," *Current*, Volume 10, Number 1.

What Is the Connection between the Estuarine Principles and Concepts and the Ocean Literacy Essential Principles and Concepts?

Ocean literacy is an understanding of the ocean's influence on you and your influence on the ocean.

An ocean-literate person

- Understands the essential principles and fundamental concepts;
- Can communicate about the oceans in a meaningful way; and
- Is able to make informed and responsible decisions about the oceans and its resources.

Essential Principles of Ocean Literacy:

1. The Earth has one big ocean with many features.
2. The ocean and life in the ocean shape the features of the Earth.
3. The ocean is a major influence on weather and climate.
4. The ocean makes the Earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

Examples of Estuary-Related Topics in the *Ocean Literacy Standards*

1. The Earth has one big ocean with many features.
   - g. The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to coastal **estuaries** (where rivers meet the sea) and to the ocean.
5. The ocean supports a great diversity of life and ecosystem.
   - a. Most life in the ocean exists as microbes, although ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
   - b. Microbial organisms are the most important primary producers in the ocean. They not only are the most abundant life form in the ocean but also have growth rates that range from hours to days.
   - c. Most major groups of organisms (phyla) have many representatives living in the ocean.
   - d. Ocean biology provides many unique examples of important relationships among organisms (such as symbiosis, predator-prey dynamics, and energy transfer).
   - e. There are examples of life cycles in the ocean that are not often seen on land.

f. The ocean is three-dimensional, offering a lot of living space from the surface through the water column to the seafloor. As a result, most of the living space on Earth is in the ocean.

g. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substratum, and circulation, ocean life is not evenly distributed temporally or spatially, that is, it is "patchy."

i. Zonation patterns of organisms along the shore are influenced by tidal ranges and waves.

j. Coastal **estuaries** (where rivers meet the ocean) provide important and productive nursery areas for many marine species.

6. The ocean and humans are inextricably interconnected.

b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

c. The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is an important element of our cultural heritage.

d. Most of the world's population lives in coastal areas.

e. Humans affect the ocean in a variety of ways. Wastes (such as trash, sediments, and sewage) enter the ocean from runoff (nonpoint source pollution) and dumping (point source pollution). The pollution leads to habitat degradation, development of harmful algal blooms, and depletion of oxygen, as well as the endangerment, depletion, and extinction of ocean species. Coastal development, such as building structures along coasts and damming rivers, leads to loss of beaches and increased coastal erosion. Through fishing, humans have removed most of the large vertebrates from the ocean, either directly or by harvesting their prey.

g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth, and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Source: Francesca Cava, Sarah Schoedinger, Craig Strang, and Peter Tuddenham. 2005. *Science Content and Standards for Ocean Literacy: A Report on Ocean Literacy*. Accessed at *http://www.cosee.net/files/coseeca/OLit04-05FinalReport.pdf*.