MAJOR COASTAL AND TIDAL ECOSYSTEMS

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Summary

The coastal realm is a dynamic environment. Geological and historical records demonstrate continuous change influenced by sea level, long- and short-term erosion and deposition, and local subsidence that has impacted shape and position of the coast. Coastal structures such as wetlands and estuaries act as buffers from storms for the mainland, fish and waterfowl nurseries and habitats, and sinks for sediments, nutrients, and contaminants. Coastal and tidal ecosystems encompass a rich mosaic of marine and

freshwater habitats. Over geologic time, these habitats support thousands of species of plants and animals that are interdependent on each other, and more recently, humans, for their survival.

Marine coastal and tidal ecosystems are fragile, dynamic systems that occupy the narrow interface of saltwater and freshwater environments. In practical terms, however, the areal extent and influence of the tidal ecosystems may be larger, encompassing more terrestrial and marine habitats. In general, the coast provides some of the most diverse and ecologically important niches on Earth.

1. Introduction to Coastal and Tidal Ecosystems

Marine coastal and tidal ecosystems occupy areas on the fringe of saltwater and freshwater. In the strictest terms, this is a narrow zone that is defined by an area from approximately low tide to highest high tide. In practical terms, however, the areal extent may be much larger, encompassing more terrestrial and marine habitats. In general, this zone provides some of the most diverse and ecologically important niches on Earth. For example, the coast contains greater than 50% of the world's biotic diversity. In terms of human impact, the coast houses 70% of the population. In the U.S., over 40% of new commercial and residential development occurs along the coast, and approximately 3600 people settle near the shore every day.

Visitors to any beach seasonally or yearly will recognize that the shape is constantly changing. This is also seen in geologic and historical records, which demonstrate continuous change influenced by sea level, long- and short-term erosion and deposition, and local subsidence that has impacted shape and position of the coast. Coastal structures such as wetlands and estuaries act as buffers from storms for the mainland, fish and waterfowl nurseries and habitats, and sinks for sediments, nutrients, and contaminants. Coastal and tidal ecosystems encompass a rich mosaic of marine and freshwater habitats. Over geologic time, these habitats support thousands of species of plants and animals that are interdependent on each other, and more recently, humans, for their survival.

Numerous factors affect coastal and tidal ecosystems and the organisms that live there, including climate (temperature, transpiration, precipitation, and evaporation), coastal processes (waves, longshore currents, groundwater and river discharge, tides, winds, storms), relative sea level (tectonic subsidence, compactional subsidence, global sea level, and local sea-level changes), sediment budgets (sources and destinations), and human activities (subsurface fluid withdrawal, river basin development, maintenance dredging, beach maintenance, coastal structures, artificial inlets, dune alterations, highway construction). For the complementary information, see ***Coastal and Marine Processes*** and other contributions of the chapter ***Evolution and Function of Earth's Biomes: Aquatic Systems***.

1.1. Function of Coastal Ecosystems

As is the case for all ecosystems, coastal ecosystems function at many different levels, from very broad to very specific, and include biological, geological, and biogeochemical processes, to name a few. Biological functions are diverse and remain difficult to characterize because of the complexity of food webs and multiple trophic levels. One way to look at function of an ecosystem is to measure its net primary productivity (NPP). Net primary productivity is a measure of the rate at which solar energy is converted to plant tissue. Although there are many ways to measure community function, NPP is a fundamental measure, because it represents the energy available to maintain the biomass and diversity of almost all forms of life. The NPP in specific parts of the coastal zone is impressive. In terms of marine communities, coral and algal reefs and estuaries demonstrate highest NPP. In general, coastal zones range from about 50–200 g m^{-2} y NPP. Lagoons, for example, comprise approximately 13% (32 000 km) of continental shoreline and have a primary productivity of 200 gC m^{-1} y^{-1}–500 gC m^{-1} y^{-1}. **See *Net Primary Productivity***.

The geology of coastal environments provides the underpinning and framework on which biological ecosystems exist and interact. The framework of the ecosystem ranges from bedrock, such as found in the rocky shorelines, to sediments, such as found at a sandy beach or muddy estuary, or a mixture of both rock outcrops and sediments. On most of the world's coastlines, coastal sediments are a mixture of Quaternary and more recently deposited Holocene sediments. The sediments most often found in the coastal ecosystem are biogenically or lithogenically derived. The accumulation of these sediments reflects the rise of sea level. The geology of the ecosystem provides the conduit for freshwater and groundwater influxes, which in turn provide dissolved nutrients into the system and can act as a basin for accumulation. Furthermore, these environments form an interface between the marine aquatic realm and freshwater terrestrial environment and often provide a physical buffering against storms to the adjacent land and terrestrial biological ecosystems. The physical gradients set up by the shoreline configuration; fresh- and saltwater regime, temperature, nutrients, climate, and pH; play key roles in the distribution and zonation of marine coastal organisms. Whereas geographic patterns have been recognized, surprisingly little has been agreed upon as to the causes of the zonations. **See *Sedimentary Rocks***.

Biogeochemical processes in coastal environments reflect ecosystem response to natural and anthropogenic environmental perturbations, such as nutrient and carbon cycling and community metabolism. These processes are sensitive to changes in water quality including salinity and nutrients and show distinct rate changes often before visual evidence of environmental disturbances, such as seagrass die-off, algal blooms, and shifts in ecosystem-successful indicator species. See chapters Biogeochemical Cycling of Macro-nutrients, and Biogeochemical Cycling of Micronutrients and Other Elements.

1.2. Sea Level and the Evolution of the Coast

During the ice ages, water that was evaporated from the world's ocean became trapped in cold polar air masses and fell out as snow at the poles, eventually becoming compressed into glacial ice. The result of the creation of these massive ice sheets at the poles was the dramatic dropping of sea level. As global temperatures subsequently increased during the interglacials, the glaciers melted, the water returned to the ocean, and sea level rose again. **See *Quaternary History* and *Sea-level Rise in Geological History***.

Coastal countries and island nations are particularly vulnerable to climate change and sea-level rise where loss of harbors, coastal cities, and wetlands have been and will continue to be affected. It is likely that a change of mean temperatures of only 2–4 ºC will have large impacts on coastal ecosystems throughout the world. Temperature changes in the geologic past have produced significant changes in coastal and open ocean biotas and ecosystems throughout the world. It should be noted that the slope of the coast is important in determining how water-level changes affect it. Steeply sloping coasts will not be affected by water-level changes as dramatically as gently sloping coasts. Wave action, and therefore erosion, is concentrated in a narrow zone.

Crucial in understanding how temperatures will impact species is the knowledge of species tolerance ranges and the effect of climatic parameters. With increased global temperatures, it is estimated that Earth will respond with more frequent hot periods, with coastal areas becoming hotter and in some places drier. This will have significant impact and import for the survival of plants and animals in shallow waters. The hotter and drier periods will lead to increased salt concentrations and water temperatures higher than 30 ºC. Furthermore, as temperatures increase, wind strength and direction will be altered, and the increased likelihood of extreme events occurring and their frequency will control populations (and recovery) in ecosystems. As throughout geologic history, migration and colonization of new species will in part be controlled by the rate of climate change. **See *Atmosphere and Climate***.

Figure 1. Aerial view of the volcanic island of Oahu in the Hawaiian Island chain
This is an example of a primary coastline created by volcanic processes. Photograph

courtesy of NASA.

2. Classification of Coastlines

A variety of coastal classifications have been presented, but no classification encompasses the entirety of the coast, because the land forms are often a mixture in origin. One commonly used coastal classification scheme, first developed by Francis P. Shepard in 1937 and later modified in 1973, classifies the coasts into two different types, primary and secondary. Another type of classification is based on plate tectonics and defines coastal characteristics by whether the coast is on a tectonically active, leading edge of a plate, or a passive, trailing edge. In practice, a combination of classification schemes helps to characterize the coast more completely. **See *Plate Tectonics and Landform Evolution***.

Shepard's classification is based on the global impact of Holocene sea-level rise and distinguishes coasts as being drowned, with little modification by marine processes, and those that have been subsequently modified by marine erosion or deposition. Primary coasts have relatively young geologic features, having only been created by nonmarine processes (i.e., tectonic). Secondary coasts, in contrast, have been influenced by marine processes, including physical and/or biological. Secondary coasts, in general, have lost their nonmarine signal.

2.1. Primary Coasts

Primary coasts that have been shaped by nonmarine processes include land-erosion coasts, subaerial deposition coasts, volcanic coasts, coasts shaped by Earth movements such as earthquakes, and ice coasts.

Land-erosion coasts are those that are a result of sea-level rise from the Pleistocene (last 125 000 years) to the present. Examples of the land-erosion coasts include bays that have formed due to drowned rivers (i.e., Chesapeake Bay) or drowned glacial erosion (i.e., fjords in Norway). Subaerial deposition coasts are those that have been formed by river deposition, such as through delta formation (Mississippi delta, Ganges River delta, as examples). Glaciers have created much of the coastline in the high latitudes, depositing moraines, which are mounds of glacial sediments (till) deposited by glacial ice (i.e., Cape Cod, Massachusetts, USA) and drumlins (elongated hills formed by the movement of glaciers)

Figure 2. Aerial view of Cape Cod
Photograph courtesy of NASA.

Other types of subaerial deposition coasts include those under the influence of wind deposition, forming dunes and sand flats. Parts of the Earth's primary coastlines have been formed by lava flows (example, Hawaiian Islands) and by volcanic collapse (atolls).

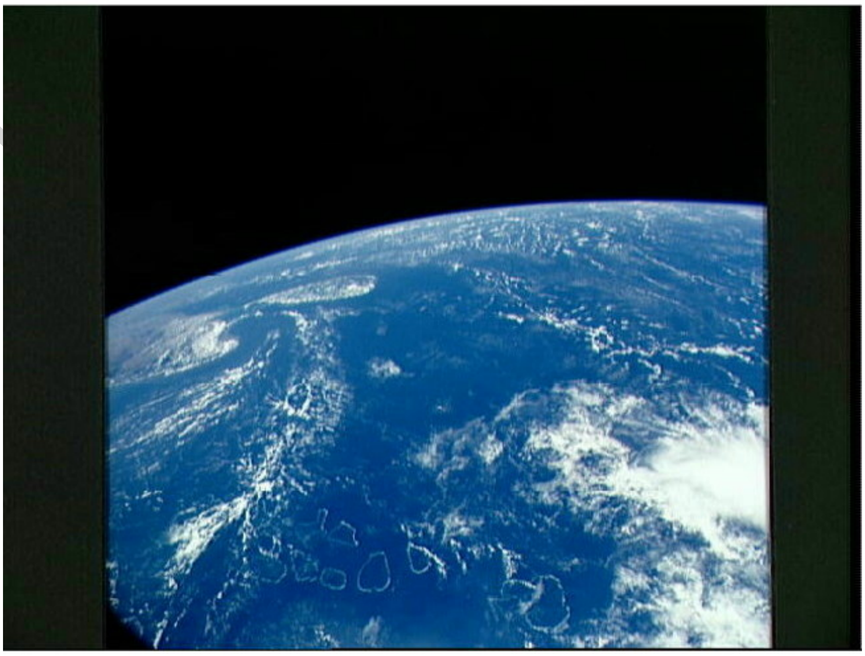

Figure 3. (a) Beautiful view from space shuttle of the Maldives (bottom center), an island chain of atolls in the Indian Ocean
(b) Closer view of Maldives
These atolls have formed by the sinking of volcanic islands, leaving only the ring of reefs visible. Photographs courtesy of NASA.

Furthermore, tectonic activity such as earthquakes, which produce faulting and folding of Earth's crust, is also important in forming primary coastal features. Excellent examples of these include San Francisco Bay and the islands of Japan.

2.2. Secondary Coasts

Secondary coasts, which have been formed by marine processes, include wave-erosion coasts; marine-deposition coasts, such as barrier coasts, cuspate forelands, beach plains, and mudflats and salt marshes; and coasts formed by biological activity, such as coral, oyster, and serpulid reefs, mangrove coasts, and marshes.

Figure 4. A low-gradient, low-energy, mangrove-fringed coast located in the southeast of the United States. Courtesy of USGS.

Wave-erosion coasts are delineated by the coastline or boundary between the shore and ocean (foreshore), which is exposed at low tide and submerged at high tide, and backshore, which extends from the normal high-tide shoreline to the coastline. The beach consists of the wave-worked sediment and extends from the coastline to low-tide line. Wave erosion of the coast produces voluminous amounts of sediments that are both carried inland and deposited on the coast or carried away by longshore movement of water. Sediment that will eventually make up the beach is carried by a current moving parallel to the shore between the shoreline and the breaker line (called longshore currents). The amount of longshore drift in any coastal region is determined by the balance between erosional and depositional forces. When this equilibrium is altered, the dominant force will prevail, allowing either more erosion or deposition to the coastal zone.

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Biographical Sketch

Lisa Robbins is the Chief Scientist at the USGS Center for Coastal and Regional Marine Studies in St. Petersburg, Florida. She also is affiliated as a Professor at the University of South Florida. Robbins received her undergraduate Geology degree at Vanderbilt University in Tennessee, and did her graduate work at the Rosenstiel School of Marine and Atmospheric Science (RSMAS), University of Miami in Marine Geology. At RSMAS, she worked on biomineralization and specifically the biogeochemistry of fossil proteins in planktonic foraminifera. After graduation, Robbins was awarded a USGS–National Research Council Postdoctoral Fellow and continued to study biomineralization and how microbes influence mineralization. In 1988, she was hired by the Geology Department at the University of South Florida were she was later tenured and became Full Professor. Her research has focused in on different microbial systems which promote mineralization and was able to quantify coastal sediment budgets using this information. In 1999, Robbins accepted the position at the USGS, where she now directs a variety of coastal studies that are societal relevant.