APPENDIX I: COASTAL HABITATS

In most cases, coastal habitats are multi-dimensional, complex ecosystems defined by a variety of structural and functional characteristics. One of the critical steps in developing a monitoring plan is to determine the characteristics that accurately reflect the goals and objectives of the restoration effort and are therefore appropriate for monitoring. The habitat descriptions below, coupled with the 3 matrices involving habitat characteristics and measurement parameters (Appendix II), are designed to assist restoration practitioners in determining which habitat characteristics are considered important for inclusion in monitoring plans by expert opinion, depending on the goals of the project. These characteristics are ecological parameters to evaluate the progress toward project goals.

For organizational purposes, the habitat descriptions roughly follow a progression from open water inland. Wherever appropriate, definitions apply to both freshwater and marine examples. The habitats are as follows:

- Water column
- Rock bottom
- Coral reefs
- Oyster reefs
- Soft bottom
- Kelp and other macroalgae
- Rocky shoreline
- Soft shoreline
- Submerged aquatic vegetation [SAV; seagrasses (marine/brackish) and freshwater]
- Marsh (marine/brackish and freshwater)
- Mangrove swamps
- Deepwater swamps
- Riverine forests

WATER COLUMN

Physical Description – The water column is a conceptual volume of water extending from the water surface down to, but not including, the substrate. It is a dynamic environment subject to waves, currents, tides, and riverine influences. It is found in marine, estuarine, river, and lacustrine systems.

In marine systems, water regimes are determined primarily by the ebb and flow of ocean tides, movement of nearshore currents, freshwater inputs from tributaries, and ice cover (Day et al. 1989). The quality of the water column affects all associated habitats. Estuarine water regimes are dominated by their widely varying salinities, from seawater (approximately 35 ppt) to fresh water (approximately 0.5 ppt) (Day et al. 1989; USEPA 2001). Water level may be controlled by lunar tides and wind events; the relative importance of each varies with location. In Great Lake systems, water regimes are dominated by the annual and seasonal water level fluctuations of the lakes and short-term (daily) fluctuations caused by seiches (Bedford 1992; Herdendorf 1990). Seiches are

Figure 19. Water body running through marsh vegetation on the Mid-Patuxent River, Maryland. Photo courtesy of Mary Hollinger, NOAA National Oceanographic Data Center. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line0619.htm

wind driven tides that may last from a few minutes to several hours and range in size from a few centimeters to several meters depending on the severity and duration of storms or wind creating them.

Biological Characteristics – In all water columns (from marine to freshwater) food webs are supported almost entirely by phytoplankton (photosynthetic organisms that account for about 95% of the ocean's primary productivity) (Day et al. 1989). In some systems and at certain times of year, it is likely that benthic algae and detritus suspended by wave action and other forms of disturbance may also be important (Day et al. 1989). The presence of pelagic fauna and flora within the water column results from both physical factors as they relate to topography and to mixing of communities from adjacent areas (Gibson et al. 2000). Salinity determines which fauna and flora ultimately reside in the estuary water column (Bulger et al. 1993).

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ROCK BOTTOM

Physical Description – Rock bottom habitats may consist of bedrock, rocks, boulders, gravel, or pebbles. These rocky materials are transported and sorted by geologic activity, ice, currents, or continuous wave action. Rock bottom habitats occur in freshwater as well as marine environments. However, the freshwater rocky bottom habitats are not as well studied as their salt water counterparts described below.

Biological Characteristics – Rock bottom habitats support a variety of marine organisms ranging from seaweed and algae to fish and shorebirds. Many organisms rely on rock bottom substrates for attachment in order to survive, grow, and reproduce. Rock bottoms support filter-feeding organisms such as barnacles and oysters that help maintain water quality and stabilize bottom sediments, reducing turbidity and lowering shoreline erosion rates. Species such as fish, crustaceans, and some worms live in crevices of the rock bottom habitat. Shorebirds rely on rock bottom habitats for feeding and resting.

Plant species that commonly colonize rock bottoms include macroalgae (*Furcellaria lumbricalis)* (Kotta and Orav 2001), kelp (*Macrocystis)*, seaweed, brown algae (Phaeophyta), red algae (Rhodophyta), green algae (Chlorophyta), and coralline algae found on coral reefs. Predation, grazing, and physical factors help control zonation of attached species in these habitats (Barnes and Hughes 1988).

Some animal species occupying rock bottoms include mussels (e.g., zebra mussels, *Dreissena polymorpha*), queen conch (*Strombus gigas* around Florida Keys) (McCarthy et al. 2001), sea urchins (e.g., *Strongylocentrotus purpuratus*), chitons (e.g., spiculed chiton, *Acanthoplera gaimardi*), and limpets (*Fisurella* spp.). Fish too, use rock bottom habitats for feeding and protection from predators. Fishes such as Goliath grouper (*Epinephelus itajara*), common snook (*Centropomus undecimalis*), spotted seatrout (*Cynoscion nebulosus*), cobia (*Rachycentron canadum*), and red snapper (*Lutjanus erythropterus*) are commonly found in rock bottom habitats. Shrimp (Family Hippolytidae), the Chesapeake Bay whelk (*Rapana venosa*) (Harding and Mann 2000), oysters (*Crassostrea gigas*), brittle stars (*Ophiopteris papillosa*), and sessile organisms such as sponges, sea anemones, soft corals, bryozoans, barnacles, and tube-dwelling polychaetes are also common residents of these systems. Physical characteristics in areas such pebble or cobble beaches can have a significant impact on the reproductive success of both transient and resident organisms.

Figure 20. A rock bottom habitat in the Great Lakes covered with zebra mussels (*Dreissena polymorpha*). Photo courtesy of John Janssen, Great Lakes Water Institute, University of Wisconsin, Fl.

Figure 21. Marine rock bottom (basalt flows) with Duckbill eel (*Nessorhamphus ingolfianus*) in a sand channel in Hawaii. Photo courtesy of J. Moore, NOAA Oceanic and Atmospheric Research/National Undersea Research Program (NURP). Publication of the NOAA Central Library. http://www.photolib.noaa.gov/nurp/nur05024.htm

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CORAL REEFS

Physical Description – Coral reefs are rough three-dimensional structures of many small individual, interconnected corals. The reefs generally sit on continental shelves and submerged bases of volcanoes in depths ranging from emergent on low tides to around 150ft (46.72 m). They exist in the cool, shallow, clear waters of tropical and subtropical seas. Most corals cannot survive temperatures below 60º – 65ºF (16º – 18º C) (Turgeon et al. 2002).

Biological Characteristics – Coral reefs are highly diverse ecosystems. They are composed of marine polyps that secrete a hard calcium carbonate skeleton, which serves as a base or substrate for the colony. The living colony continuously deposits calcium carbonate over time, adding to the size of the structure. They are centers of high biodiversity and productivity, providing essential feeding, shelter, breeding, and nursery habitat for a variety of reef fishes, algae, mollusks, and crustaceans.

There are three general types of reefs: fringing reefs around islands, barrier reefs along continents, and atolls. Each is distinctive in its structure and development.

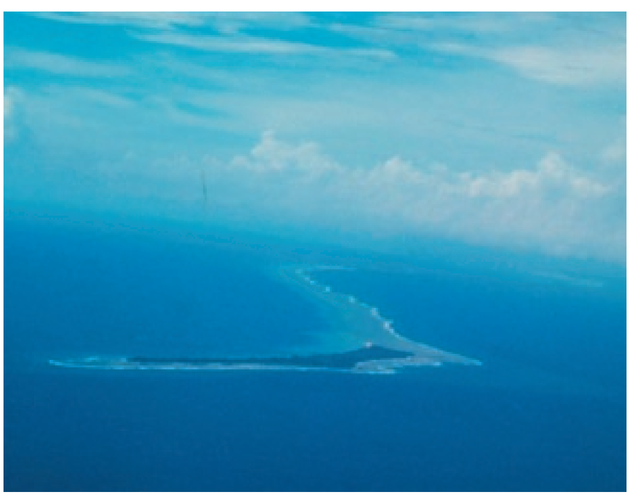

Figure 22. Aerial view of atolls located in Eniwetok. Photo courtesy of James P. McVey, NOAA Sea Grant Program. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/mvey/mvey0237.htm

Fringing Reefs Around Islands – These reefs grow in shallow waters and closely border the coast or are separated from it by a narrow stretch of water. They are comprised of numerous zones characterized by depth, reef structure, and dominant plant and animal communities.

Barrier Reefs Along Continents – These reefs are separated from land by a lagoon. They are large, grow parallel to the coast, and form a continuous barrier between the shoreline and the open ocean. These reefs have zones similar to those found in fringing reefs as well as patch reefs (small reefs), back reefs (the shoreward side of the reef), and bank reefs (reefs that

Figure 23. Koror Harbor east entrance showing barrier reef to outside and patch reefs in lagoon located in Malakal, Koror. Photo courtesy of James P. McVey, NOAA Sea Grant Program. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/mvey/mvey0131.htm

occur on deep bottom irregularities).

Atolls – These develop at or near the surface of the sea when islands that are surrounded by reefs subside. They can be horseshoe-shaped or circular with a central lagoon. There are two types of atolls: those that rise from deep sea and those found on the continental shelf (Goreau et al. 1979).

Many types of fish (e.g., grouper and snapper), crabs (e.g., blue crabs, *Callinectes sapidus*), shrimp (*Parapenaeopsis* or *Solenocera* sp.), sea urchins (*Paramoeba invadens)*, starfish (such as *Echinaster)*, sponges (*Vasum* and *Xestospongia*), and lobster (such as red lobster, *Enoplometapus sp*.) are found on or around coral reefs. The corals also have a symbiotic (mutually beneficial) relationship with algae called zooxanthellae. The algae live inside the coral polyps, photosynthesizing and producing food that is shared with the coral. In exchange, the coral provides the algae with protection and access to light, necessary for photosynthesis (Rowan and Powers 1991). Other vegetative species that live on coral reefs include crustose coralline algae (red algae), calcareous algae, coralline green alga, and green alga.

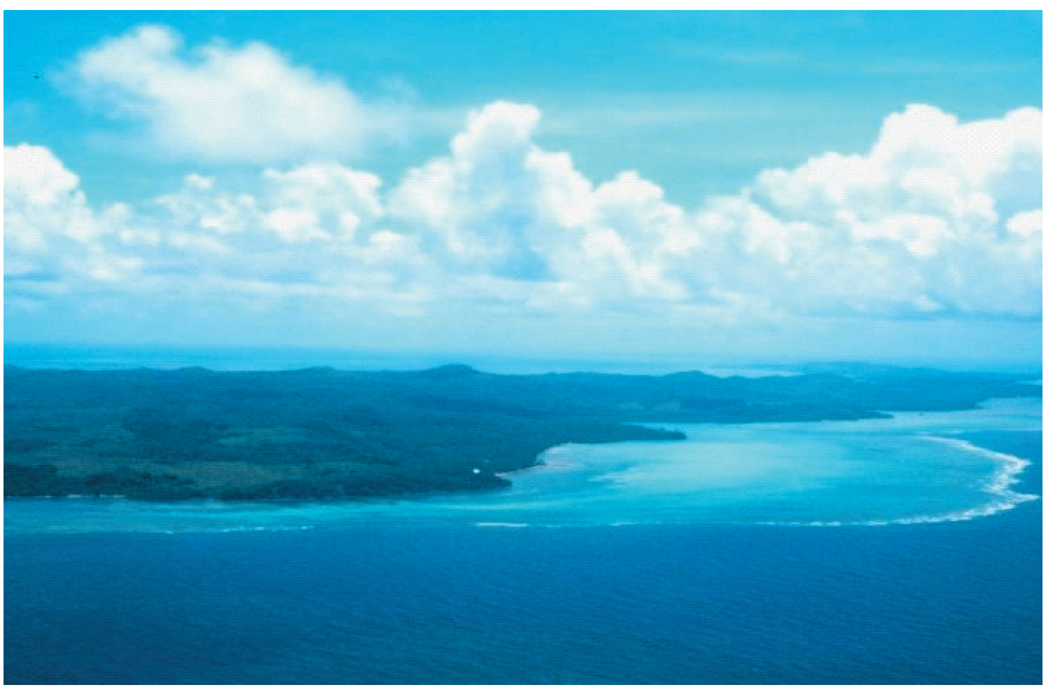

Figure 24. Aerial view of fringing reef adjacent to high volcanic island, located in Palau, Western Caroline Islands. Photo courtesy of James P. McVey, NOAA Sea Grant Program. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/mvey/mvey0038.htm

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OYSTER REEFS

Physical Description - Oyster reefs are dominant features in estuarine systems along the Atlantic and Gulf of Mexico coasts. Oyster reefs form best where bottom currents sweep sediments away, otherwise the oysters can be inundated with their own feces and pseudofeces (material expelled by the oyster without having gone through the animal's digestive system) or other particulate matter to the point where filter feeding is inhibited. These communities occur across many acres of bay bottom and in intertidal and subtidal areas.

Natural oyster reefs may be divided into upward thrusting reefs, which normally occur in deeper estuarine waters, and fringing oyster reefs found in shallow embayments, lagoons, creeks, and shallow tributaries of estuaries. The natural geomorphic, hydrologic, and biologic features present during their development determine reef shape, location, and size.

Biological Characteristics – An oyster reef community is primarily dependent on the import of food resources from other habitats, principally the open-bay water and peripheral emergent marshes (Shipley and Kiesling 1994). Oyster reefs are capable of filtering massive amounts of water, and feeding on plankton and other suspended organic matter. These activities greatly increase water clarity and quality.

Plant species that occupy this habitat, particularly in shallow shoreline areas, include crustal algae. This type of algae attaches to shell substrates and supports a small grazing food chain (GBNEP 1994).

On the Atlantic and Gulf Coasts *Crassostrea virginica* is the common species of oyster. On the Pacific coast, *Crassostrea gigas* is the common species. Fiddler crabs (*Uca* sp.), blue crab (*Callinectes sapidus*), rock crab (*Cancer productus*), grass shrimp (*Palaemonetes sp.)*, mussels (*Mytilus edulis*), rockfish (*Sebastes* sp.), oyster toadfish (*Opsanus tau*), sea ducks (scaups and scooters), and California bat ray (*Myliobatis californica*) are also commonly found using oyster reef habitats (Couch and Hassler 1989). This mosaic of fish and invertebrate species implies close linkages with adjacent habitats as they move in and out of reefs with the changing tides.

Figure 25. Intertidal oyster reefs being built on Fisherman's Island, Virginia. Photo courtesy of Mark Luckenbach, Professor of Marine Science, Director of Eastern Shore laboratory. Virginia Institute of Marine Science, Wachapreague, VA.

Figure 26. New growth seen in Palmetto Island County Park, Mount Pleasant, 2001. South Carolina Oyster Restoration and Enhancement Program. Photo courtesy of South Carolina Department of Natural Resources. http://www.csc.noaa.gov/scoysters/html/photos/sites/palmetto/palm4746.htm

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SOFT BOTTOM

Physical Description – Soft bottom habitats are composed of loose, unconsolidated substrate characterized by fine to coarse-grained sediment. The water depth is relatively shallow and located adjacent to beaches (or other sediment sources). These areas are generally not exposed during low tide. Marine soft bottom habitats include worm mounds and sand dollar beds and are not vegetated. Within the Great Lakes, soft bottom habitats tend to develop in low energy zones such as harbors, embayments, or drowned river mouths.

In most soft bottom areas, wave action produces a relatively coarse, poorly consolidated, well-sorted (low grain size variation), and easily moved sediment deposit. Large waves lift these surface sediments into a suspension that is tossed shoreward and then seaward by the passing waves (Bascom 1981; Clifton et al. 1971). Extreme storm waves can remove as much as a meter of surface sediments at water depths greater than 10 m. The physical stability of the beach deposit increases with increasing water depth as wave-generated bottom currents decrease. As a result, bottom sediments grade from coarse to fine sand with increasing water depth and decreasing wave disturbance (Hodgson and Nybakken 1973; Oliver 1980).

Biological Characteristics – Movement of bottom sediments by waves and currents is a dominant physical process influencing the structure of benthic communities in these areas (Oliver 1980; Simenstad et al. 1991).

The benthic community of these habitats is composed of a wide range of bacteria, plants, and animals from all levels of the food web. Benthic animals are divided into three distinct groups: infauna (animals that live in the sediment), epifauna (animals living on the surface of the sediment or other substrate such as debris), and demersal (bottom-feeding or bottom-dwelling fish and other free moving organisms). Benthic organisms link primary producers, such as phytoplankton, with the higher trophic levels, such as finfish, by consuming phytoplankton and then being consumed by larger organisms. They also play a major role in breaking down organic material. Benthic invertebrates are among the most important components of coastal ecosystems.

In marine soft bottom habitat, the dominant benthic organisms include worms (polychaetes), amphipods, clams, crabs, and flatfish (Simenstad et al. 1991). The invertebrate community includes mud crabs (e.g., *Panopeus* spp.), amphipods (e.g., *Corophium lacustre*, *Jassa falcate*, *Gammarus* spp.), sea squirts (e.g., *Molgula manhattensis*), red ribbon worms (*Micrura leidyi*), whip mudworms (*Polydora ligni*), glassy tubeworms (*Spiochaetopterus oculatus*), common clam worms (*Nereis succinea*), Atlantic oyster drills (*Urosalpinx cinerea*), hard clams (*Mercenaria mercenaria*), soft shell clams (*Mya arenaria*), and blue crabs (*Callinectes sapidus*). Vertebrate organisms include flounders (e.g., southern flounder, *Paralichthys lethostigma*), puffers (e.g., *Sphoeroides parvus*), sea robins (*Peristedion* spp., *Prionotus* spp.), cownose rays (*Rhinoptera bonasus*), spot (*Leiostomus xanthurus*), croaker (*Micropogonias undulatus*), striped bass (*Morone saxatilis*), white perch (*Morone americana*), sablefish (*Anoplopoma fimbria*), shortspine thornyhead (*Sebastolobus alascanus*), longspine thornyhead (*S. altivelis*), and Dover sole (*Microstomus pacificus*).

Within the Great Lakes, the fauna are characterized by low abundance, high diversity, and great variability in both time and space. This variability is due to the physical instability of this zone. Downwelling and oscillating thermoclines cause wide fluctuations in bottom temperatures, and waves and bottom currents cause resuspension of bottom substrates (Cook and Johnson 1974). Dominant freshwater benthic organisms include oligochaetes (*Stylodrilus heringianus*, *Tubifex spp*., *Limnodrilus spp*.), amphipods (*Diporeia, Gammarus spp*.), mayfly (*Hexagenia*), pea mussel (*Pisidium* spp), and chironomid larvae (Barton and Hynes 1978).

Less common is a habitat that develops in low energy zones such as harbors, embayments, or drowned river mouths. These sediments consist of three primary components: particulate mineral matter, organic matter in various stages of decomposition, and inorganic component of

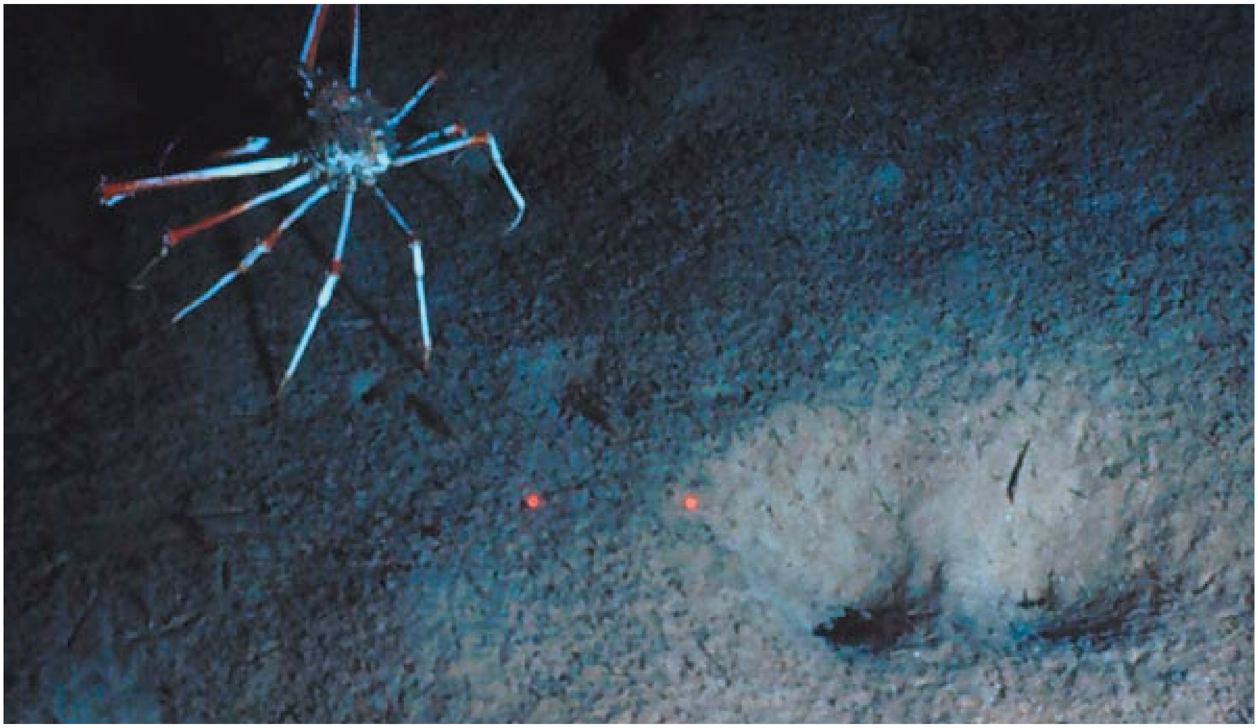

Figure 27. The inflated spiny crab (*Rochinia crassa*) in its preferred habitat, the soft-bottom ooze. Photo courtesy of Betty Wenner, South Carolina Department of Natural Resources. http://oceanexplorer.noaa.gov/explorations/03bump/logs/aug02/media/figure3.html

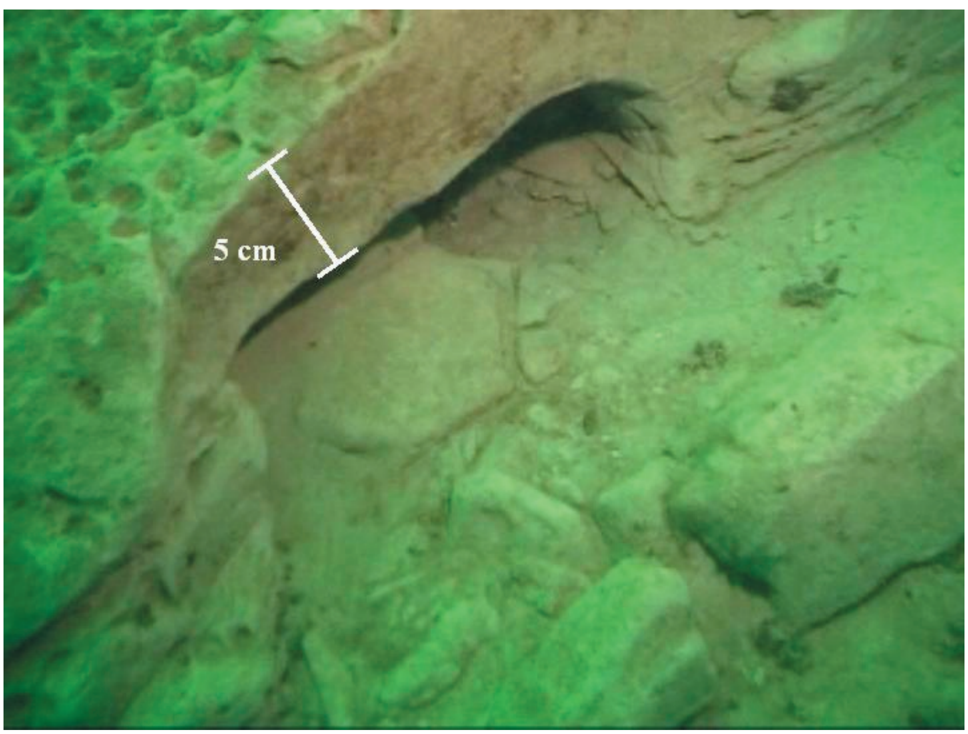

Figure 28. Soft bottom habitats are not just empty expanses of mudflat. Small holes and irregularities such as this one offer haven to animals such as crayfish. Photo courtesy of Marc A. Blouin, United States Geological Survey.

biogenic origin, e.g., diatom shells. Particle size and organic matter of sediments is important to the distribution and growth of benthic invertebrates. Sediments with large amounts of organic matter are found in areas dominated by littoral production (Wetzel 1983). Organisms found in these areas include a variety of aquatic insects and benthic organisms, as well as fish such as adult northern pike (*Esox lucius*), largemouth bass (*Micropterus salmoides*), brown bullhead (*Ameiurus nebulosus*), longnose gar (*Lepisosteus osseus*), common shiner (*Notropis cornutus*), bluegill (*Lepomis macrochirus*), white sucker (*Catostomus commersoni*), creek chub (*Semolitus atromaculatus*), and bluntnose minnow (*Pimephales notatus*).

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KELP AND OTHER MACROALGAE

Physical Description – Kelp and other macroalgae are relatively shallow (less than 50 m deep) subtidal algal communities dominated by very large, brown algae. Kelp and other macroalgae grow on hard substrates forming extensive three-dimensional structures that support numerous floral and faunal assemblages. These forests are commonly found along the west coast.

Kelp forests form canopies that reach 20 – 30 m in water. Kelp beds form at low tide or when the kelp is growing in shallow water (1 - 2 m) (Foster and Schiel 1985). Kelp are restricted to cold water climates because warmer waters tend to lack the rich supply of nutrients that kelp need to flourish. The extent of kelp forests and beds depends on the availability of a hard substrate for attachment and on the availability of light for young plants to grow (a function of water clarity). In addition, kelp is limited by high water temperature, associated low nutrient concentrations, and by grazing.

Biological Characteristics – Kelp beds and forests are highly productive and provide a structurally complex habitat to numerous other seaweeds, invertebrates, and vertebrates found in the kelp community (reviews in Foster and Schiel 1985, Van Blaricom and Estes 1988, Witman and Dayton 2001). In fact, kelps are among the most productive marine communities in temperate waters. This is due to the interaction of a complex habitat structure; high biomass production; intensive invertebrate, finfish, and marine mammal utilization; and large nutrient import and export.

Kelps are large brown algae (Class Phaeophyceae). They include the largest seaweed in the world, the giant kelp (*Macrocystis* spp.), as well as numerous other genera such as *Laminaria*, *Alaria*, and *Nereocystis* that range in size from a few to tens of meters long. Other macroalgae, such as wracks (*Fucus* spp.), are smaller on average than the kelps and can be diverse in form, with serrations, branches, or bladders occurring on their fronds.

Habitats dominated by kelps such as *Macrocystis* have floating fronds that form a canopy on the surface of the water. These are known as 'kelp forests' because of their forest-like structure, while habitats with only a bottom kelp canopy produced by non-float bearing genera such as *Laminaria* are referred to as 'kelp beds.' *Fucus* occurs in high energy intertidal areas, strongly anchored by holdfasts to hard surfaces. Kelp generally requires rocky substrate for attachment (Foster and Schiel 1985; Van Blaricom and Estes 1988; Witman and Dayton 2001). Fronds develop from these holdfasts and may grow to the surface if floats are produced.

Holdfasts and dense mats of understory algae and sessile invertebrates (sponges, bryozoans, and tunicates) on the substrate provide sub-habitats and feeding areas for a variety of mobile invertebrates and fishes. In Giant Kelp forests, fishes include garibaldi (*Hypsypops rubicundus*), sheephead (*Semicossyphus pulcher*), and lingcod (*Ophiodon elongatus*). Mobile invertebrates are usually numerous and include crustaceans, echinoderms, and mollusks. Benthic herbivores such as sea urchins (*Strongylocentrotus* spp.) are common, particularly in areas without sea otters (*Enhydra lutris*), and can eliminate almost all macroalgae except corallines.

The mid-water structure and surface canopies produced by float-bearing kelps such as *Macrocystis* spp. provide additional habitat for invertebrates and fishes. Bryozoans, hydroids, isopods, serpulid worms, and turban snails can be found in kelp beds and forests. Fishes such as the senorita (*Oxyjulis californica*), blue rockfish (*Sebastes mystinus*), and kelp bass (*Paralabrax clathratus*) are also associated with kelp communities. Kelp beds and forests are common foraging areas for birds, such as cormorants, and mammals, including harbor seals and sea otters. The latter forage for benthic invertebrates such as sea urchins, abalone (*Haliotis* spp.), and small crustaceans and mollusks when larger prey is depleted. Sea otters also wrap themselves in the surface canopy while resting, presumably to prevent drifting away.

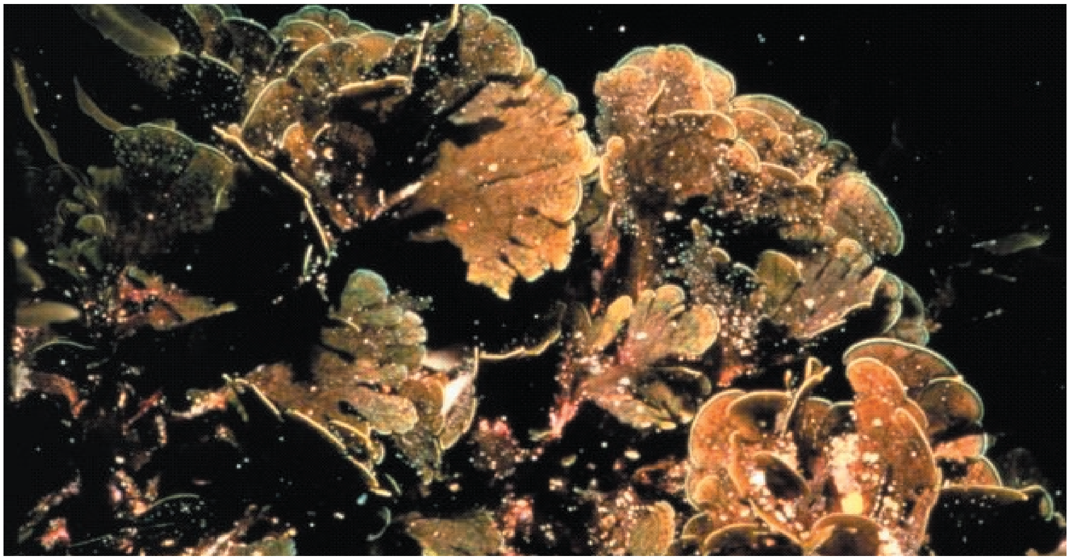

Figure 29. Brown algae on a temperate Carolina reef. Photo courtesy of A. Shepherd, NOAA Oceanic and Atmospheric Research/National Undersea Research Program (NURP); University of North Carolina at Wilmington. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/nurp/nur03508.htm

Figure 30. A giant kelp forest located in Channel Islands National Marine Sanctuary. Photo courtesy of Sanctuary Collection. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/sanctuary/sanc0001.htm

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ROCKY SHORELINE

Physical Description – Rocky shorelines are extensive littoral habitats on wave-exposed coasts. Rocky shores are characterized by sharp environmental gradients from low rocky intertidal to upper intertidal.

Rocky shores are composed of bedrock and cobble in tidal and non-tidal areas. Tidal rocky shorelines are commonly exposed to the pounding of waves and the water level can vary substantially. For non-tidal rocky shorelines, the water level varies annually and seasonally. Variation within a single day is less common than on tidal shores. There are three zones on the rocky shores. The supralittoral zone is known as the splash zone; the eulittoral zone is the intertidal range between the low and high water level; and the sublittoral zone extends below the low water mark (Little and Kitching 1996). Rocky shores provide several functions such as biomass export, wave energy attenuation, spawning and nursery habitat for fish, invertebrate habitat, and bird and mammal feeding grounds. In the Great Lakes, cobble and bedrock rocky shorelines are recognized. In many marine areas rocky shorelines are habitat for some kelp and many gastropods.

Biological Characteristics – Predation, grazing, and physical factors are important in controlling the zonation of sessile species in these habitats (Menge 1983). The species success in non-tidal and tidal areas varies based on local conditions and the physiological tolerance of the organism (Connell 1972). For example, macroalgae thrive in areas not exposed to high light intensity, high temperatures, and desiccation (upper shorelines). Therefore, macroalgae tend to live in intertidal to tidal zones where the water depth is greater (Barnes and Hughes 1988). Seaweed (e.g., *Fucus*) also is found along rocky shorelines, mainly in the eulittoral to the infralittoral zone, and provides a source of nutrition to mobile organisms that live throughout the tidal zone and are tolerant of exposure to light and air (Barnes and Hughes 1988).

Common plants found on rocky shores are red algae, green algae, and brown algae. Examples of these species include *Microcladia coulteri* and Turkish towel (*Gigartina exasperata*) which are red algae; feather boa kelp (*Egregia menziesii*) which is brown algae; and sea moss (*Bostrichia montagnei*) which is green algae (Little and Kitching 1996). Some mobile animals occupying rocky shores include crabs [e.g., hermit crabs (*Coenobita brevimanus)*], sea urchins [e.g., purple sea urchin (*Strongylocentrotus purpuratus)*], lobsters [e.g., rock lobster, (*Panulirus ornatus*)], snails [e.g., olive snail (*Oliva sayana*), polychaetes (*Phragmatopoma californica* and *Tetraclita rubescens* found in Central California) (Taylor and Littler 1982), and zebra periwinkle (*Littorina lineolata*)], fish [e.g., striped bass (*Morone saxatilis)* and toadfish (*Tetractenos Hamiltoni)*], and birds [e.g., egrets (*Casmerodius albus)* and ducks (*Somateria spectabilis*)]. Some sessile species (immobile) such as barnacles [e.g., the goose barnacle (*Pollicipes polymerus*, *Balanus* spp., and *Chthamalus* spp.), sponges (*Spinosella* spp.), mussels (*Mytilus edulis*), hydroids, oysters *(Crassostrea virginica)*, and tubicolous polychaetes] live in the non-tidal areas. Currents provide food for these organisms because they are unable to obtain the food themselves (Barnes and Hughes 1988). Mammals, such as sea otters (*Enhydra lutris*), brown bears (*Ursus arctos)*, California sea lions (*Zalophus californianus californianus)*, and Steller sea lions (*Eumetopias jubatus*), also use rocky shorelines for feeding, breeding, and resting areas.

Figure 31. Rocky shore of Lake Michigan in Door County, Wisconsin. Photo courtesy of Karen Rodriguez, United States Environmental Protection Agency, Great Lakes National Program Office.

Figure 32. Rocky shoreline protecting shores from wave action in Gloucester Area, Massachusetts. Photo courtesy of Mary Hollinger, NOAA National Oceanographic Data Center. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line0739.htm

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SOFT SHORELINE

Physical Description – Soft shoreline is referred to as unconsolidated shore (Cowardin et al. 1979) which includes sand and mud. Sandy beaches are stretches of land that are covered by loose material (sand) exposed to and shaped by wind or waves (Brown et al. 1990). These beaches and shorelines range from intertidal beaches to mudflats normally comprised of unconsolidated sediment.

Mud and sand flats are usually associated with marine environments, especially where tides expose a large expanse of shore. The flats are exposed to extremely low tides and inundated at high tides with the water table at or near the surface of the substrate. The substrate of mudflats contains organic material smaller in size than sand (EPA 1980). Mud banks form when biologically produced debris is transported by waves allowing accumulation of debris and coverage of a relatively flat, limestone surface. In some areas, mud bank formation may also be influenced during monsoon seasons. Mud banks form barriers that protect the coast from severe erosion and sea water intrusion (Purandara et al. 1996).

Biological Characteristics – These habitats generally lack aquatic macrophytes but are rich in diatoms that provide a major food source for invertebrates and some fishes. On sandy and muddy beaches and flats, the only vegetation consistently present is micro- and macroalgae. However, vegetation can stabilize the supralittoral regions by trapping sand grains to form dunes.

Sand flats also keep conditions moist by absorbing water, producing a suitable environment for some species. When sand flats are completely covered by water, they provide habitat for invertebrates, such as marine worms. Also because water is shallow when covering the sand flats, shore birds are able to obtain food such as small fishes and invertebrates without having to land onto the sand flat.

Soft shorelines provide valuable habitat and feeding grounds, as well as other functions to many organisms including fish, birds, macro- and microinvertebrates, algae, and microbial organisms. These are habitats for beach-nesting birds, burrowing invertebrates, and feeding grounds for wading birds and fish.

Benthic infauna provide food sources for many transient and resident species. Similar to sandy beach habitats, sheltered sand flats are dominated by macro-, meio-, and microfauna. These habitats act as a sink for particles and a source for soluble nutrients.

On the mud shorelines, seaweed, blunt spike rush (*Eleocharis obtu,* mainly on mudflats), bullrush (*Scirpus* spp., found in mud banks), and brown algae (e.g., sea colander) are some of the common vegetative species of the lower intertidal zone. On mud flats, members of the higher trophic levels appear as transients with the tides. At high tide, planktivorous and detritivorous organisms move onto the flats to feed, followed by carnivorous birds and fishes. At low tide, gleaning and probing shorebirds feed on and in the exposed surface while waders seek prey stranded in tidal pools (GBNEP 1994). In all flat habitats, foraging pressure increases as the benthic community increases. Animals such as shorebirds and skates (*Raja* spp.) are able to obtain food by probing the sediment surface or creating localized disturbances to concentrate prey.

Figure 33. Sandy beach in Kauai, Hawaii. Photo courtesy of John Bortniak, NOAA Corps (ret.). Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line0430.htm

Figure 34. Tidal flats exposed to early morning tide in Dunedin, Florida. Photo courtesy of William Folsom, NOAA National Marine Fisheries Service. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line1182.htm

Figure 35. Volunteers making efforts to preserve shoreline by replanting of marsh grass along Chesapeake Bay, Maryland. Photo courtesy of Mary Hollinger, NOAA National Oceanographic Data Center. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line2019.htm

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SUBMERGED AQUATIC VEGETATION

Physical Description – Submerged aquatic vegetation (SAV) beds are areas of flowering plants found in shallow, subtidal, or intertidal unconsolidated sediment. SAV is found in areas of clearer water where light penetrates to the sediment surface, yet where water is deep enough to prevent emergent vegetation from becoming established.

SAV beds are complex habitats that allow for high biological productivity. SAV habitats are typically a mixture of open water, rooted SAV, floating leaved plants, and occasionally short emergent vegetation. SAV is physically stable. Plant blades slow water currents and prevent the water column from being vertically well mixed; this increases sedimentation and nutrient uptake.

General Biological Characteristics – The combination of plants depends on water depth, turbidity, and degree of protection from wind and waves (Mitsch and Gosselink 2000; Wilcox 1989). The physical stability, reduced mixing, and shelter of complex SAV habitats provide for a highly productive environment, functioning as nursery areas for fish and invertebrates and as feeding grounds.

In this document, SAV habitats are divided into marine/brackish (salinity 0.5 to 35 ppt) and freshwater (salinity less than 0.5 ppt). Though there are functions, structural components, and parameters common to both, each is introduced separately here.

Figure 36. Seagrass with a jack in the background in the Florida Keys. Photo courtesy of Heather Dine, Florida Keys National Marine Sanctuary. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/sanctuary/sanc0208.htm

Seagrasses (Marine/Brackish)

Physical Characteristics – Marine and brackish SAV, which are largely termed seagrasses, grow on soft sediments of sheltered shallow waters of estuaries, bays, lagoons, and lakes.

Marine/brackish SAV has horizontal underground stems called rhizomes. At intervals along the rhizome are erect shoots that bear the leaves and leaf sheaths. The leaves range in length from a few millimeters to well over a meter. Scars left from old leaves along the rhizome are termed nodes that divide the rhizome into areas called internodes. Roots branch off of these rhizomes. The roots absorb nutrients and help anchor the plants in the substrate (Thayer et al. 1984; Larkhum et al. 1989). This root rhizome structure provides complexity of habitat for infaunal invertebrates (Zieman 1982; Thayer et al. 1984).

Biological Characteristics –SAV is considered among the most productive plant communities in the world (Zieman 1982; Thayer et al. 1984). Adding to this productivity is the organic carbon contribution by epiphytic microalgae that grow abundantly on SAV blades.

However, marine SAV does not typically enter the food web by being eaten directly by herbivores. Once it dies, SAV supports an extensive detritus-based food chain for such organisms as crabs, benthic fish, and others. Decaying SAV also releases nutrients for meiofauna and flora, benthic flora and fauna, epiphytic organisms, plankton, and microbes (Keulen 1999). The herbivores that do feed directly on seagrasses include green sea turtles (*Chelonia mydas*), dugongs (*Dugong dugon*), manatees (*Trichechus manatus*), and a variety of waterfowl.

Most marine taxa tolerate a wide range of salinity, from hypersaline to brackish water. However, their tissues suffer osmotic stress at very low or very high salinity, a condition that may eventually lead to death (Biebl and McRoy 1971). Several lists of the seagrass taxa of the world are available (Thayer et al. 1984; Hemminga and Duarte 2000). Among the most common in the United States are eelgrass (*Zostera marina*), turtle grass (*Thalassia testudinum*), and Cuban shoalgrass (*Halodule wrightii*). Widgeon grass (*Ruppia maritima*) is common to all coasts of the United States, and is found in fresh, brackish, and coastal marine waters.

SAV provides shelter, breeding grounds, and feeding areas for many aquatic organisms such as juvenile fish, shrimp, and benthic invertebrates. Larval and juvenile animals inhabit seagrass beds seasonally, not only to feed but also for protection by the SAV blades from predators (Orth et al. 1984; Day et al. 1989; Heck et al. 1989; Mattila et al. 1999). For instance, on the eastern and western sides of Florida Bay, large numbers of juvenile spotted seatrout (*Cynoscion nebulosus*) and gray snapper (*Lutjanus griseus*) were reported in seagrass areas where plant densities are high (Chester and Thayer 1990). Other species that inhabit or move into seagrass beds for food and protection include pink shrimp (*Farfantepenaeus duorarum*), blue crabs (*Callinectes sapidus*), bay scallops (*Argopecten irradians*), juvenile cod (*Gadus morhua*), winter flounder (*Pleuronectes americanus*), manatee (*Trichechus manatus*), dugong (*Dugong dugon*), green sea turtles (*Chelonia mydas*), and some waterfowl (Jupp et al. 1996; Lefebvre et al. 1996).

Freshwater

Physical Characteristics – Hydroperiods for this habitat type range from subtidal and intermittently exposed to semi-permanently and seasonally flooded (Cowardin et al. 1979). Similar to emergent vegetation, freshwater SAV is well adapted to the short- and long-term water level fluctuations common with freshwater ecosystems. High water levels eliminate dominant emergent species and provide more space for SAV to grow. Low water levels reduce the dominance of SAV. This combination of high and low water levels in a single location from year to year allows a diversity of plant types to sprout from seed on the exposed sediment, reproduce, and replenish the seed bank (Keddy and Reznicek 1986; Van der Valk and Davis 1978; Wilcox and Meeker 1995).

Freshwater submerged aquatic vegetation (referred to as *aquatic bed* in Cowardin et al. 1979 and also as *SAV*) consists of plants that grow below the surface of the water for most of the growing season in most years. Submerged aquatic vegetation habitats are often a mix of open water, rooted SAV, floating leaved plants, and short emergent vegetation (depending on water depth, turbidity, and degree of protection from wind and waves).

Most of the physical habitat associated with SAV and available to wildlife is provided by the vegetation itself. SAV provides structure for algae and microbes to colonize; invertebrates to graze, hide from predators, and deposit eggs; and fish to spawn, protect young, and feed. SAV also creates a structured canopy, much like a forest, that shades lower portions of the water column, setting up temperature and light availability gradients, thus, vertically diversifying habitats. SAV reduces wave energy and water velocity, causing deposition of fine sediments that would otherwise be eroded (Carpenter and Lodge 1986). SAV also provides important biochemical functions by transporting oxygen to the sediment and in return, transporting nutrients from the sediment into the water column (Wilcox 1995).

Biological Characteristics – Freshwater submergent plants such as muskgrass (*Chara vulgaris*), the pondweeds (*Potamageton* spp.), coontail (*Ceratophyllum demersum*), and naiads (*Najas spp.*) typically dominate submergent communities, providing important feeding and spawning grounds for fish, invertebrates, waterfowl, and diving birds (Mitsch and Gosselink 2000; Wilcox 1995). Clasping-leaved pondweed *(Potamogeton perfoliatus),* sago pondweed *(P. pectinatus)*, curly pondweed *(P. crispus),* wild celery *(Vallisneria americana)*, and horned pondweed (*Zannichella palustris*) also are common freshwater SAV species.

Species of freshwater SAV have significant morphological differences. Several species, such as white and yellow water lilies (*Nymphaea* and *Nuphar* spp.), floating-leaf pondweed (*Potamogeton natans)*, and water shield (*Brasenia schreberi*), are submerged vascular plants with floating leaves

(Cowardin et al. 1979). Other species, such as yellow water lily (*Nuphar luteum*) and water smartweed (*Polygonum amphibium*), have floating leaves, stand erect above the water surface and may be considered short emergents (Cowardin et al. 1979).

Different communities of SAV provide differing habitats; the type and quantity of organisms that can use a particular area depend upon the species diversity, density, and structural aspects of the individual plants. SAV with finely branched foliage maximizes biomass production and habitat structure. Dense SAV beds are often completely devoid of fish and can provide an important refuge for invertebrates to escape predation. Lesser dense beds provide nursery areas for smaller fish by excluding larger fish. Openings in the SAV canopy can be used as cruising lanes for piscivorous fish such as pike (*Esox lucius*) to forage on smaller fish (Wilcox 1995). SAV is also used by a variety of waterfowl as food and foraging areas (Knapton and Scott 1999).

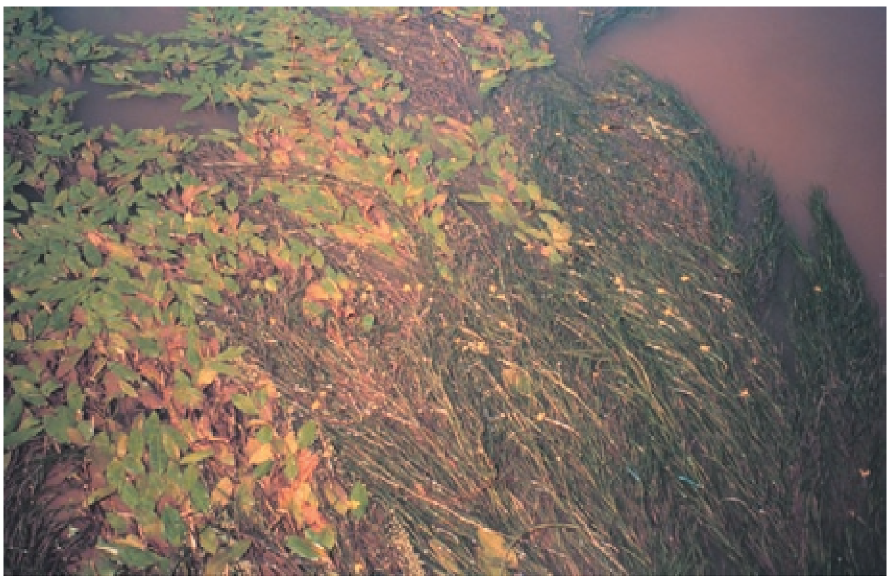

Figure 37. Submerged aquatic vegetation (SAV) within a pond in the Mississippi Delta in Louisiana. Photo courtesy of Terry McTigue, NOAA Office of Response and Restoration. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line1211.htm

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MARSHES

Physical Description – Coastal marshes are transitional habitats between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is covered by shallow water tidally or seasonally. These coastal areas are influenced by floods, tides, and Great Lakes water level fluctuations. The substrate is predominantly undrained hydric soil (Cowardin et al. 1979). Marshes filter and temporarily store flood water and runoff, mitigating the impacts of floods and helping to improve downstream water quality.

Marshes have salinity levels from saline (approximately 35 ppt) to freshwater (less than 0.5 ppt) further inland. Approximately 70 percent of coastal wetlands of the United States are marine/brackish marshes (Charbreck 1988). Complex topography, such as saltpans, tidal creeks, ridges, and berms characterizes most coastal marshes. In tidal rivers, salinity gradients occur due to the mixing of freshwater with saltwater.

Great Lakes coastal wetlands are dominated by the hydrologic processes of the Great Lakes, including waves, wind tides, and seasonal and long-term water level fluctuations. These processes determine the vegetation communities and structural complexity of the marshes along Great Lake's shorelines.

General Biological Characteristics – The defining structural feature of marshes is the presence of upright, emergent plants (e.g., cattails, grasses, and sedges) that can live all or part of the time with their roots submerged (Cowardin et al. 1979).
In salt marshes, the flora and fauna have adapted to the stresses of salinity, periodic tidal inundation, exposure to air, and temperature fluctuations. Vegetation is adapted to lower salinity in some areas. In the Great Lakes, flora and fauna have adapted to periodic water level fluctuations resulting from seiches or changes in the water levels of the lakes themselves. Both marine and Great Lakes marshes provide spawning and nursery habitat and feeding grounds for numerous species of mammals, fish, waterfowl, migratory birds, reptiles, amphibians, and invertebrates. Coastal marshes of either type are among the most productive habitats on Earth.
In this manual, marshes are divided into two categories: marine/brackish (salinity 0.5 - 35 ppt) and freshwater (salinity less than 0.5 ppt).

Marine/Brackish

Physical Characteristics – Marine and brackish marshes are composed of a mix of open water and vegetated areas, including short and tall salt marsh grasses and other plants. These are divided into zones based on elevation. Plant community composition is highly influenced by slight differences in elevation. Therefore, slope and elevation are defining aspects of the habitat.

Biological Characteristics – Coastal marshes include plants that are adapted to salty or brackish water. Common plant taxa along the continental United States include cordgrass (*Spartina* spp), dominant in low intertidal zones, and needlerush *(Juncus* spp.*),* dominant in upper intertidal areas. Some other vegetative species include spike grass (*Distichlis spicata*), salt marsh plantain (*Plantago maritima*), cattail (*Typha latifolia*), common reed (*Phragmites australis*), and saltwort (*Batis maritima*).

Macroalgae is an important primary producer in marine/brackish marshes, occurring on the sediment surface and attached to the lower portion of the emergent vascular plants. Macroalgae is a seasonal and ephemeral portion of the marsh community. Macroalgae can contribute to annual variability of oxygen concentrations by producing oxygen during growth, then consuming it as bacteria break down the decaying remains after the plants die back. Inputs from intertidal macroalgae and marsh microalgae contribute to the organic matter that support invertebrates, fish, and shorebirds such as the light-footed clapper rail (*Rallus longirostris levipes*) (Kwak and Zedler 1997).

Marine/brackish marsh habitat provides food, protection from predation and an abundance of niches for fish, waterfowl, and other animal species. The lifecycles of animals using brackish and marine marshes are keyed to the seasonal patterns within the habitat, including variation in temperature, water level, salinity, and food availability. Transient species (aquatic, terrestrial, and avian) use marsh habitat as feeding and resting areas during migrations. These transients receive benefits from the marsh habitat and can contribute to the lifecycles of other species in the area. For instance, birds assist in dispersing propagules of various marsh plants (Stout 1984). Some birds found in brackish or marine marshes include the California least tern (*Sterna antillarum browni*), great blue heron (*Ardea herodias*), clapper rails (*Rallus longirostris obsoletus*), snowy egret (*Egretta thula*), marsh wren (*Cistothorus palustris*), Canada geese (*Branta canadensis*), and tundra swans (*Cistothorus columbianus)*.

Other mobile species occupying marshes include fish and crustaceans, such as blue crab (*Callinectes sapidus*), lined shore crab (*Pachygrapsus crassipes*), yellow shore crab (*Hemigrapsus oregonensis*), white shrimp (*Litopenaeus setiferus*), brown shrimp (*Farfantepenaeus aztecus*), flounder (e.g., *Paralichthyes* spp.), mullet (*Mugil* spp.), spotted seatrout (*Cynoscion nebulosus*), and red drum (*Sciaenops ocellatus*). Diamondback terrapins (*Malaclemys terrapin*) are found in both saline and brackish marshes. Mammals inhabiting these habitats include mink (*Mustela vison*), weasel (*Mustela frenata*), swamp rabbit (*Sylvilagus aquaticus*), lemming (*Lemmus trimucronatus*), rice rat (*Oryzomys palustris*), and muskrat (*Ondatra zibethicus)*. Larger mammals, such as wolves (*Canis lupus*), bears (*Ursus* spp.), and feral horses (*Equus caballus*) can seasonally use coastal marshes as feeding grounds.

Figure 38. Sapelo Island, Georgia. Black needle rush (*Juncus*) in the far left corner of photo and Saltmarsh cordgrass (*Spartina*) on both sides of the stream. Photo courtesy of Sapelo Island National Estuarine Research Reserve. Publication of the NOAA National Oceanic and Atmospheric Administration Central Library. http://www.photolib.noaa.gov/coastline/line0926.htm

Freshwater

Physical Characteristics – As with saline/brackish marshes, freshwater marshes are characterized by erect, herbaceous hydrophytes, rooted in soft substrates, typically extending above the water surface. All water regimes can occur except subtidal and irregularly exposed (Cowardin et al. 1979).

Biological Characteristics – Marsh vegetation supplies the habitat structure for invertebrates, fish, and other wildlife (Mitsch and Gosselink 2000). Marsh vegetation is also well adapted to short- and long-term water level fluctuations characteristic of freshwater systems. If water levels rise and remain high long enough, woody vegetation along marsh edges may be killed off and herbaceous, emergent plant species come to dominate. Eventually, when water levels fall woody species may once again become established. If water levels fall low enough, SAV can be eliminated from areas in which it was once dominant, sediments are exposed, seed banks germinate, and emergent plant species become established (Keddy and Reznicek 1986). In essence, marshes move horizontally, back and forth across the permanent water/terrestrial interface with vertical water level fluctuations (Minc 1997).

Cowardin et al. (1979) subdivides freshwater marshes into persistent and non-persistent types based on the difficulty with which the dominant vegetation is decomposed and nutrients cycled back into the system. Persistent marshes are dominated by species that normally remain standing at least until the beginning of the next growing season. Persistent marshes are often dominated by narrow-leaved cattail (*Typha angustifolia*), sedges (*Carex* spp.), common reed (*Phragmites australis*), and southern wild rice (*Zizaniopsis miliacea*). There is also a variety of broad-leaved persistent species common to these systems such as purple loosestrife (*Lythrum salicaria*, an invasive species), dock (*Rumex mexicanus*), and waterwillow (*Decodon verticillatus*).

In non-persistent marshes, there may be no obvious sign of emergent vegetation at certain times of the year due to the quick decay rate. Vegetation in non-persistent marshes is related to the seasonal succession of vegetation emergence. For example, wild rice (*Zizania aquatica*) does not become apparent in some coastal marshes until midsummer and fall, when it may form dense stands. Non-persistent emergents also include arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), arrowheads (*Sagittaria* spp.), and many species of smartweeds (*Polygonum* spp.). Unlike persistent marsh species, these plants quickly decompose upon senescence and return accumulated nutrients and carbon back to the water column, often within a few days or weeks.

Figure 39. Freshwater marsh near Ridgetown Ontario, Canada. Photo courtesy of Romy Myszka, United States Department of Agriculture, Natural Resources Conservation Service. http://www.epa.gov/glnpo/image/viz_nat1.html

Marsh habitats provide a variety of necessary habitats for fish, waterfowl, and other wildlife (Mitsch and Gosselink 2000). Freshwater fishes use marsh areas during high water periods for feeding, spawning, and nursery areas. The high stem densities typical of marshes provide excellent cover for young fish and small invertebrates to feed on algae and one another while escaping predation from larger fish and wading birds. Canada geese and some ducks feed on the tender shoots of emergent vegetation. Wading and songbirds use marshes as critical feeding

Figure 40. Great Lakes coastal marsh dominated by cattails with adjacent floating leaved plants and open water areas allowing fish and waterfowl access to all three habitats. Photo courtesy of Doug Wilcox, USGS.

areas along migration routes or as seasonal destinations. Though many species of mammals use marshes, nutria (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) are dependent upon them to provide the majority of their habitat needs.

Nutria is an invasive species and causes extensive and permanent damage to marshes while foraging for food. Muskrats too, can denude marshes of vegetation but typically do not cause as much structural damage as nutria. There are also some beneficial aspects to muskrat foraging. At some point in their succession, freshwater marshes often become dominated by cattails. Muskrats feed voraciously on cattails, clearing the marsh of vegetation, opening it up for waterfowl use. In the process, they pile the unused portions of the cattails into large piles (feeding stations). Once the marsh is depleted of edible vegetation, ducks and geese can use feeding stations as nesting spots safe from predation. Feeding stations also provide topographic diversity to the marsh basin. This allows a greater diversity of plant species to establish (Weller 1994).

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MANGROVE SWAMPS

Physical Description – Mangrove swamps are dominated by mangrove trees that live between the sea and the land in areas that are inundated by tides. Mangroves thrive along protected shores with fine-grained sediments where the mean temperature during the coldest month is greater than 20º C, which limits their northern distribution.

Mangroves are found throughout the Caribbean and Pacific, as well as in coastal Louisiana, Texas, and Florida. (Mitsch and Gosselink 2000). The most northern occurring black mangroves (*Avicennia germinans*) are found on the barrier islands of Louisiana. In both Texas and Louisiana, mangroves occur in a shrub-like form.

Biological Characteristics – Mangroves are salt-tolerant woody plants. They have adapted to survive high salinity, occasional harsh temperatures, and anoxic soils, forming unique communities known as mangals or mangrove forests along shorelines (Chapman 1976; Teas 1984) These habitats are frequently placed in the following classes: fringe, riverine, basin, and dwarf or scrub mangroves (Mitsch and Gosselink 2000).

Mangrove species occurring in the United States include black mangrove, red mangrove (*Rhizophora mangle*), and white mangrove (*Laguncularia racemosa*) (Massaut 1999). The restoration strategies for these three species will differ, based on their physical characteristics and tolerances. Red mangroves have distinct prop roots that are tangled and reddish, and aerial roots that originate from the trunk and branches. Black mangroves are recognized by their root projections, called pneumatophores that project from the soil around the tree's trunk. They are found in slightly higher elevations than red mangroves (Jimenez and Lugo 1985). White mangrove trees have no visible aerial root system and are located mainly in elevations higher and farther upland than the red or black mangroves.

Mangroves support many terrestrial and aquatic fauna and flora like birds, mammals, crustaceans, and fish, and a diverse understory (Lugo and Snedaker 1974). The mangrove prop roots disperse wave energy, increase surface area for organisms such as sponges and mollusks, and provide shelter for marine organisms such as the gray snapper (*Lutjanus griseus)*, spotted seatrout (*Cynoscion nebulosus*), and red drum (*Sciaenops ocellacurema*) (recreational fish seen in Florida mangrove systems). However, in Florida the most abundant fish species among red mangrove prop roots include fishes of the silverside, killifish, mojarras, anchovy, and gobi families (Thayer and Sheridan 1999).

Mangrove roots anchor trees firmly in the soft mud and allow sufficient oxygen to reach the base of the tree. The above ground component of the root system is porous and provides oxygen to the lower submerged and buried portion for respiration. New prop roots grow from branches that project over the water (Hogarth 1999).

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Figure 41. Mangroves showing root system below the water surface. Photo courtesy of NOAA Corps Collection. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/corps/corp2269.htm

Figure 42. Red mangrove with prop roots located in John Pennekamp State Park, Florida. Photo courtesy of Richard B. Mieremet, NOAA Office of Sustainable Development and Intergovernmental Affairs. Publication of the NOAA Central Library. http://www.photolib.noaa.gov/coastline/line0008.htm

DEEP WATER SWAMPS

Physical Description – Deepwater swamps are forested wetlands that develop along edges of lakes, in alluvial river swamps, in slow-flowing strands, and in large, coastal-wetland complexes. They can be found along the Atlantic and Gulf Coasts and throughout the Mississippi River valley from Louisiana to southern Illinois. They are distinguished from other forested swamps by the tolerance of the dominant vegetation to prolonged flooding (Mitsch and Gosselink 2000).

Though once common throughout the southeastern United States, only a small portion of the original deepwater swamps remains (Allen et al. 2001; Wharton et al. 1982). Historically, losses were due to extensive logging but recently altered hydrology, herbivory from exotic nutria, saltwater intrusion, and sea level rise have further reduced acreage (Allen et al. 1996; Conner and Toliver 1990; Myers et al. 1995; Sklar 1985).

The soils of cypress swamps range from mineral to accumulated peat depending on the hydrodynamics and topography of the specific system (Bondavalli et al. 2000; Giese et al. 2000). In some swamps, floating logs and tree stumps provide the only substrate for understory vegetation and regeneration of overstory species. Deepwater swamps that are continually flooded and have high nutrient concentrations may develop thick mats of duckweed (e.g., *Lemna* spp., *Spirodela* spp., or *Azolla* spp.) (Mitsch and Gosselink 2000).

Deepwater swamps are essential to the health and functioning of downstream areas. Swamps associated with alluvial systems allow floodwaters to spread out and deposit suspended sediment loads. They also absorb and transform nutrients in floodwaters, helping prevent eutrophication of receiving water bodies (Mitsch and Gosselink 2000).

Biological Characteristics – Bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), and black gum (*N. sylvatica*) are the dominant tree species of these habitats. Adult cypress and tupelo can survive permanent inundation, although seedlings require exposed sediment in order to germinate and become successfully established (Keeland et al. 1997; Middleton 2000; Schneider and Sharitz 1988).

The presence and abundance of understory vegetation depend upon both the amount of light penetrating the canopy and the local flooding regime. Some areas with open canopies and moderate flooding have a diverse shrub layer [e.g., buttonbush (*Cephalanthus occidentalis*), swamp-privet (*Forestiera acuminata*), and water-elm (*Planera aquatica*)] (Conner and Buford 1998). Other swamps, with closed canopies or longer flooding times, may be devoid of any ground layer vegetation.

Deepwater swamps support a diversity of wildlife. Macroinvertebrates (crawfish, shrimp, insects, clams, snails, and worms) are commonly found in deepwater swamps (Sklar 1985; Thorp et al. 1985). Fish can be temporary or permanent residents. While flooded, these areas provide spawning, nursery, and foraging habitats. Reptiles and amphibians, too, are often found in deepwater swamps (Mitsch and Gosselink 2000). Nutria, an exotic rodent, is common to deepwater swamp habitats. They graze heavily on the roots and shoots of newly planted or germinating trees and are one of the major obstacles to successful reforestation efforts (Llewellyn and Shaffer 1993; Myers et al. 1995).

Figure 43. Deepwater swamp in the Atchafalaya basin, Louisiana. Photo courtesy of Aaron Podey, Louisiana State University.

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RIVERINE FORESTS

Physical Description – Riverine forests are wetlands dominated by trees and usually found along sluggish streams, drainage depressions, and in large alluvial floodplains (Mitsch and Gosselink 2000). In winter and spring, riverine forests can flood with a meter or more of water but by late summer, water levels in most cases recede and expose the soil (Wharton et al. 1982). Soils are typically mineral though limited peat accumulation may occur in deeper depressions and wetter areas (Giese et al. 2000).

Riverine forests are essential to the health and functioning of downstream areas. These forested wetlands allow floodwaters to spread out, slow water down, reduce flood peaks, and deposit suspended sediment loads. They also absorb and transform nutrients in floodwaters, preventing eutrophication of receiving bodies of water (Conner and Day 1982; Giese et al. 2000; Gilliam 1994; Osborne and Kovacic 1993; Stanturf et al. 2000).

Biological Characteristics – Riverine forests are extremely diverse communities, exhibiting a variety of canopy/ground cover combinations influenced by the hydrodynamics of the associated river (Gregory et al. 1991). Dominant woody vegetation may include bald cypress (*Taxodium distichum*), cottonwoods (*Populus* spp.), green ash (*Fraxinus pennsylvanica*), silver and red maple (*Acer saccharinum and A. rubrum,* respectively), and a variety of oaks (*Quercus* spp.) (Allen et al. 2001; Barnes and Wagner 1981; Mitsch and Gosselink 2000). The presence and abundance of understory vegetation depend upon the amount of light that penetrates the canopy and the local flooding regime. Some areas with open canopies and moderate flooding may have a diverse shrub and herbaceous ground flora. Others, with closed canopies or longer flooding times may be devoid of any ground layer vegetation (Mitsch and Gosselink 2000).

Riverine forests support a variety of wildlife. Many species of macroinvertebrates (crawfish, shrimp, insects, clams, snails, and worms) can be found in riverine forests (Bowers et al. 2000; Wharton et al. 1982). Fish make extensive use of flooded and backwater areas as spawning, nursery, and foraging grounds (Killgore and Hoover 1992; Wharton et al. 1982). Mammals such as white-tailed deer (*Odocoileus virginianus*), nutria, rabbits (e.g., the Eastern cottontail, *Sylvilagus floridanus*), beaver (*Castor canadensis*), and mink (*Mustela vison*), as well as migrating songbirds, waterfowl, and wading birds all can commonly be found in riverine forest habitats (Guilfoyle 2001; O'Neal et al. 1992; Wharton et al. 1982).

Figure 44. A riverine forest in spring. High flows from snowmelt and rain have flooded the forest floor. Photo courtesy of Eric Thobaben, Michigan State University.

Figure 45. A riverine forest in late summer. Summer river flows are much lower than those in spring, the forest floor is dry allowing herbaceous vegetation to grow. These two seasonal views are of a riverine forest adjacent to the Kalamazoo River, Lower Michigan. Photo courtesy of Eric Thobaben, Michigan State University.

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