2.0 IDENTIFICATION AND DESCRIPTION OF ESSENTIAL FISH HABITAT

Essential fish habitat (EFH), as defined in the Magnuson-Stevens Fishery Conservation and Management Act, means those waters and substrate necessary to the fish for spawning, breeding, feeding, or growth to maturity.

This document is to comply with the Act. The Council recognizes the large gaps in the data to fulfill the detailed requirements of the Act. However, the Council has also taken action throughout its history to protect habitats even in the absence of complete data sets or information.

The following sections describe the principal habitats identified in the US Caribbean but it mostly references the work done by the various other agencies under whose jurisdiction these habitats lie.

The CFMC summarized in the Coral Fishery Management Plan (FMP) the information available regarding types and frequency distribution of marine bottoms (Coral FMP 1995; CFMC 1984). The distribution by coast and depth varies. For example, at depths less than 10 fathoms, the north coast includes gravel, hard and rocky bottoms. The East Coast includes reefs, corals, and hard bottoms. Reefs, hard and rocky bottoms are found in the South Coast and rocky, reefs and hard bottoms are found on the West Coast. The percent corresponding to each type per coast varies significantly. Although more than 30 bottom types have been identified (i.e., from marine charts); the most general description allowed is for hard, rocky, corals and reefs which predominate in depths of less than 20 meters. However, in the west coral predominates in deeper water. Sand and mud are the predominant bottom types at greater depths.

The identification of the varied habitats, mangroves, seagrasses, reefs, etc. cannot be viewed separately. The interactions among these habitats (as organisms and as habitat) are complex and are also under the influence of the organisms that move within and between them. These interactions are further complicated by the presence of natural and anthropogenic factors (See Section 5).

For example: mangroves, seagrass beds, and reefs afford each other protection. Mangrove fringes serve as depositional areas for fine sediment that would otherwise be carried toward reef areas. Seagrasses bind and stabilize these sediments. Reef structures are efficient dissipaters of wave energy and provide the shelter required for the establishment of seagrass beds and mangroves. These areas in turn serve as shelter, food, foraging grounds, nursery and mating areas for a very high number of fish species (See below). The populations of fish are continuously changing, as they are dependent on larval/juvenile/adult recruitment that has been shown to be so variable.

2.1 HABITAT TYPES AND DISTRIBUTION: ESTUARINE.

The coastal habitats (i.e., reefs, seagrasses, and mangroves) are all interconnected physically, chemically and biologically providing mutual support and operating as one system. For example, the reefs are efficient at dissipating wave energy and provide the quiescence required for establishment and maintenance of seagrass and mangrove habitats. Mangrove fringes trap fine sediments that would otherwise be carried into reef areas and smother sensitive corals. Seagrasses bind and stabilize the sediments that could also damage the reefs. Seagrass beds and reefs are also important sediment sources in areas where external sediment inputs are very small (Cintrón, 1987). Each of these habitats is used in turn by various ontogenic stages of fishery species and their prey. Coral reefs, seagrass beds, and mangrove wetlands are the most productive of the habitat types found in the Caribbean, but other areas such as soft-bottom lagoons, algal plains, mud flats, salt ponds, sandy beaches, and rocky shores are also important in overall productivity. Jacobsen and Brower (unpublished manuscript) have identified seven distinct subsystems (mangrove estuary, seagrass bed, coral reef, algal plain, sand/mud bottom, shelf break and overlying pelagic) that contribute to fishery productivity in the Puerto Rico-Virgin Island (PRVI) area. The use of these habitats has been reviewed for preparation of this document based on the use of these habitats by managed species. The habitats that make up these subsystems are briefly described as EFH for the specific species managed by the Caribbean Council; references to the species that utilize these habitats are included. General distributions of these habitats are included in the sections that follow.

A. Tidal Wetlands

Wetlands are classified on the basis of their hydrology, vegetation, and substrate. Coastal (emergent) wetlands can occur in either the estuarine or marine systems. Estuarine emergent wetlands are described as tidal wetlands in low-wave-energy environments, where the salinity is greater than 0.5 parts per thousand (ppt) and is variable owing to evaporation and the mixing of seawater and freshwater. Marine emergent wetlands are described as tidal wetlands that are exposed to waves and currents of the open ocean and have a salinity of greater than 30 ppt. Although many types of coastal wetland ecosystems are found and provide EFH for managed species in the PRVI, two types predominate. These are (1) mangrove wetlands [estuarine/marine intertidal forested and shrub, under the Cowardin, et al. (1979) classification method.] in Puerto Rico and (2) intertidal flats or salt ponds in the Virgin Islands. Additionally, tidal salt marshes (estuarine/marine intertidal emergent) provide habitat functions for some managed species.

B. Salt Marshes

Tide, salinity, nutrients, and temperature influence structure and function of a saltmarsh. The saltmarsh can be a stressful environment to plants and animals, with rapid changes occurring in these abiotic variables (Gosselink 1980; Gosselink et al. 1974). Although species diversity may be lower than in other systems, the salt marshes are some of the most biologically productive ecosystems in the world (Teal 1962; Teal and Teal, 1969). The high primary productivity that occurs in the marsh, and the transfer of detritus into the estuary from the marsh, provide the base of the food web supporting many marine organisms.

Many salt marshes are drained by an intricate network of tidal creeks. These tidal creeks and the adjacent marsh function as nursery areas for larval and juvenile finfish, crustaceans, and mollusks, and as an important habitat for adult fisheries species. Many of the species landed both in commercial and recreational fisheries in the PRVI utilize wetlands during some portion of their life cycle. The marsh provides food, structure, and refuge from predators to various life stages of fishery organisms. In addition to its function as an essential fish habitat, the marsh plays a vital role in the health and water quality of the estuary and coastal areas by regulating the amounts of freshwater, nutrient and sediment inputs into the estuary. The position of salt marshes along the margins of estuaries and coastlines and their dense stands of persistent plants make them valuable for stabilizing shoreline and for storing floodwaters during coastal storms.

Estuarine marshes (emergent wetlands) are uncommon in Puerto Rico. They usually form a narrow transition zone between mangrove-dominated wetlands and adjacent freshwater wetlands. Plant species in estuarine marshes typically include sawgrass, cattails, and leather ferns. Although marshes may develop in sandy sediments, especially in high-energy areas, marsh development typically leads to sediments with fine particle-size (mud) and high organic matter content. In most physical settings, marshes can accrete sediments, and thus maintain their elevation in relation to the rising sea level. Salt marshes persist longest in low-energy protected areas where the rate of sediment accretion is greater than or equal to the rate of subsidence (Mitsch and Gosselink, 1986).

C. MANGROVES

Low energy depositional environments within the tropics are colonized by an assemblage of salt tolerant trees or bushes that have received the collective designation "mangroves" (Cintron, 1987). These all share similar adaptations and growth habits that allow them to colonize waterlogged oxygen deficient and saline soils. These grow as trees or shrubs along most tropical estuaries and sheltered shores. Although worldwide there are more than 56 mangrove species, only four are found in the U.S. Virgin Islands and Puerto Rico. These are red mangrove, *Rhizophora mangle*; black mangrove, *Avicennia germinans*; white mangrove, *Laguncularia racemosa*; and the buttonwood, *Conocarpus erectus* (Cintron, 1987). The dominant species is the red mangrove, *Rhizophora mangle*. These are wetlands classified as estuarine intertidal systems (Cowardin et al. 1979). These species singularly or in combinations occupy wide ranges in the coastal zone from regularly flooded tidal regimes to higher elevations that may receive tidal waters only several times per year or during storm events. Mangrove habitats are very productive coastal systems that support a wide variety of organisms. The mangrove food web is based largely on the release of nutrients from the decomposition of mangrove leaves, and in part on the trapping of terrestrial material. Red mangroves, with their distinctive aerial prop roots, grow along the shoreline, often in mono-specific stands. The roots of the red mangrove help to trap sediments (and pollutants) associated with terrestrial runoff and help to buffer the shore from storm waves. Red mangrove forests support a diverse community of sponges, tunicates, algae, larvae, and corals, as well as juvenile and adult fish and shellfish. Black mangroves and white mangroves grow landward of the red mangroves. They also act as important sediment traps. The fourth species commonly associated with mangroves, the buttonwood grows inland of the more salt-tolerant species. The buttonwood, although frequently referred to as a mangrove, does not meet the strict mangrove definition proposed by Tomlinson (1986). In some instances all four species may be present in a location and segregate among themselves and other wetland plants based on elevation, salinity, substrate suitability, availability of sediments and nutrients, and seed source availability. Exposed and sheltered mangrove shorelines are common throughout the PRVI.

Mangroves represent a major coastal wetland habitat in the southeastern United States, occupying in excess of 200,000 hectares along the coastlines of all Gulf coast states, Puerto Rico, and the U. S.

Virgin Islands. Mangrove wetlands are the dominant type of emergent wetlands in Puerto Rico. Mangroves inhabit low energy intertidal areas in Puerto Rico and the USVI (Cintrón, 1987).

Cintrón-Molero (1992) provides a summary of the functional values of mangrove ecosystems that is not dissimilar to that presented for seagrass ecosystems (Wood et al. 1969, Thayer et al. 1975). [Figure 1] indicates the location of mangrove areas in Puerto Rico as the most recent inventory found in the archives of the PR/DNER (Martinez, 1994). The PR/DNER has prepared a final document (April 1997) which constitutes the management plan for mangroves. This document, and its appendices, review the literature available for the mangrove forests in Puerto Rico, reviews the inventories of mangrove forests, establishes the functional criteria of mangroves and the need for conservation and appropriate management of development of these areas which are in need of special preservation efforts. The PR/DNER document establishes definitions of mangrove areas that need to be preserved and conserved as areas of great ecological significance, uniqueness, and great ecological sensitivity. These mangrove areas are recognized as important substrates for nursery grounds, protection, and feeding areas of marine organisms. These areas sustain important populations of fish and shellfish important in the commercial and recreational catch. The flux of nutrients (organic and inorganic matter) from mangrove areas creates the link.

In general, mangroves tend to form fairly uniform forests dominated by a single species. In some instances all species may be present in a location and form banded stands, which is known as "banding" or "zonation", due to a series of factors. The forests dominated by mangrove trees support a very complex assemblage of marine plants and animals and can be highly productive.

Mangrove forests are open; they receive significant energy input from the land by river flow and runoff and from the sea by tides, current, and waves. The materials received from these sources favor the maintenance of high photosynthetic rates. In addition, mangroves are considered "plastic"; these can adapt to the particular mix of environmental factors in a given location. The degree of growth and development they reach will be a function of all the environmental factors that characterize the site. If one of these environmental factors does not lead to the development of mangrove forests, other non-mangrove systems, such as seagrass beds or coral communities may emerge.

There are a number of environmental factors which impact size and area coverage of mangroves. These include the following:

(1) Suitable topography meaning flat terrain and where salt water can reach inland
(2) Saline water that eliminates many plant species that would otherwise compete for space and eventually exclude mangroves
(3) High tidal range which causes flooding by salt water
(4) Moist or wet climates; where rainfall exceeds evaporation
(5) Availability of shelter seedlings and mature trees which are vulnerable to uprooting by waves and current scour often reduced by offshore reefs, shoals and other structures, such as behind sand dunes or storm built coral ramparts

(6) Availability of external sources of sediments; terrestrially derived sediments that are rich in nutrients and are used by plants and which also provide sediment inputs that are essential for land building and encroachment.

Mangroves are highly productive structures; a significant amount of the net production is incorporated into woody tissues and roots and a large proportion goes into the production of leaf tissues and fruits. Part of this yield is exported and eventually routed into the food web. The abundance of shellfish and finfish in these areas, as well as the diversity and abundance of the other associated fauna, is an indicator of the utilization of part of this productivity.

Leaf tissues and fruits are constantly being produced and fall to the forest floor at the rate of upwards of 2 grams per square meter per day, more than 7 tons per hectare per year. The freshly fallen material is quickly broken down into fine fragments by the activity of grazing organisms such as amphipods. In the earlier stages of breakdown organic materials are released which microbial populations in the water column may also utilize. As the leaf material decomposes it is transformed into microbial protein. Microscopic examination of this material reveals that the leaf substrate is permeated by fungi, and covered by attached bacteria, protozoans, and microalgae. These "enriched" fragments become a valuable food source and energy base for a complex food web (Odum and Heald, 1975 in Cintrón, 1987).

Mangrove roots are a very complex community containing numerous organisms belonging to diverse groups; burrowing organisms consume dead wood, underwater mangrove is eaten by Teredo worms. Filter-feeding mollusks, sponges, and tunicates receive shelter and food from mangrove roots. Mangrove roots are used by many organisms as nurseries because these provide shelter and concentrations of food sources. These export high quality protein to coastal areas in the form of the living tissue of animals that migrate offshore after completing their early development in mangrove areas. Massive migrations of mullets and shrimps, among others, are well known. These migrations link mangroves directly to other coastal systems like coral reefs and seagrass beds.

Since mangroves are an important component of our coastal landscape, it is important to assess their response to stresses of various types. A stress is a condition that drains energy that could be used to do useful work away from a system. The stressor, the force impinging on the system, may operate in a sustained manner (chronically) or in a brief, transient episode (acutely). A chronic stressor will impede a system from attaining its full development, while an acute stressor causes only a relatively brief period of energy loss. Stressors may be the result of natural events, or man-made.

A significant amount of the plants' net production is incorporated into woody tissues, roots, leaf tissues, and fruit. Part of this productivity is exported as detritus material and eventually enters the marine food web. In mangrove areas where access for fish and invertebrates is available, considerable nursery and forage habitat is provided. Diurnal migrations into and out of mangroves are well known. These migrations link mangroves directly to other coastal systems such as coral reefs, and seagrass beds. Important inhabitants of mangrove wetlands are invertebrates (sponges, crabs, tunicates, bivalves (oysters), and lobsters, fish (grunts, snappers, parrotfish, barracuda, eels, surgeonfish, doctorfish, tangs), and algae, (particularly red and green algae). Thayer and Sheridan (In press) and

Gilmore and Snedaker (1993) have provided syntheses of most recent available information on fishery organism use, in terms of presence, in mangrove habitats; information prior to about 1981 on faunal use is provided by Odum et al. (1982). Based on these publications and references cited, there is little doubt that mangrove habitats provide nursery, feeding and growth, and refuge for both recreationally and commercially important fishery organisms and their food resources when flooded.

Spiny lobsters (*Panulirus argus*) are the most important commercial and recreational invertebrates commonly found among the prop roots of mangroves. Snook (*Centropomus undecimalis*), jewfish (*Epinephelus itajara*), leatherjacket (*Oligoplites saurus*), gray snapper (*Lutjanus griseus*), dog snapper (*L. jocu*), sailor's choice (*Haemulon parra*), bluestriped grunt (*H. sciurus*) also are common to this habitat, using it as refuge and as a ready source of food. Collections in both seagrass beds and mangroves suggest that there is an integral link between these habitats with tripletail, snook, gray snapper, and jewfish, for example, occurring over seagrass beds or other adjacent bottoms as adults or large juveniles but using the mangrove prop-root during juvenile stages.

Mangroves are considered resilient and display characteristics of some "pioneer species" in that they have broad tolerances to environmental factors, rapid growth and maturity, continuous or almost continuous flowering and propagule production, high propagule outputs in a wide range of environmental conditions, and adaptations for short and long distance dispersal by tides (Cintrón-Molero 1992). Even with these pioneer (or "r-strategist" species) characteristics mangroves are both sensitive and vulnerable to disturbance. Odum et al. (1982) point out, however, that one of the adaptations of mangroves--the aerial root system, is also one of the plant's most vulnerable components because of their susceptibility to clogging, prolonged flooding, and boring damage from invertebrates. Any process that coats the aerial roots with fine sediments or cover them with water for long periods has the potential of being a destructive agent. Diking, impounding and long term flooding as has occurred in mosquito control situations has caused considerable damage, as have spraying of herbicides and inundation by oil spills. Gilmore and Snedaker (1993) provide good discussions of the impacts of urbanization, impoundment, and flood control.

Salt ponds, common in the USVI, are formed when mangroves or fringing coral reefs grow or storm debris is deposited, effectively isolating a portion of a bay. The resulting "pond" undergoes significant fluctuations of salinity with changes in relative evaporation and runoff. The biotas associated with salt ponds are, therefore very specialized, and usually somewhat limited. Salt ponds are extremely important in trapping terrestrial sediments before they reach the coastal waters.

Section 2.1.C Figure 1 Mangroves

2.2 HABITAT TYPES AND DISTRIBUTION: MARINE

About eighty different bottom types are found around Puerto Rico and the USVI (CFMC, 1984 and Coral FMP, 1994)). The bottom types vary with depth and consist of combinations of gravel, rock, sand, mud, and clay. The bottom types greatly influence which organisms are found in each habitat. Many of the hard bottom areas consist of coral and non-coral reefs. Nearshore, coral reefs are common. Inshore of the reefs, the dominant habitats are seagrasses (Section 2.2.B) and tidal wetlands, primarily mangrove wetlands (Section 2.1). The overlying waters form the "blood supply" of these systems and are also essential fish habitat. Acting together these coastal areas provide food, habitat, and water quality maintenance functions that support the areas' important fisheries.

A. Water Natural Characteristics

The waters of the Caribbean are relatively nutrient poor and as such have low rates of primary and secondary productivity, but the inshore waters of the Caribbean islands display some of the greatest diversity of any part of the US south Atlantic region. Highly diverse and highly abundant concentrations of biota are found where habitat is abundant.

The following description of water movements and marine habitats is presented as summarized by UNEP/IUCN 1988 and Appeldoorn (1993). Hydrologic patterns link the waters of the U.S. Caribbean with the Florida Keys and southeastern Florida. The waters of the westward flowing North Equatorial Current primarily influence the marine waters of the U.S. Caribbean. The North Equatorial Current is the predominant hydrological driving force in the Caribbean region. It flows from east to west along the northern boundary of the Caribbean plateau and splits at the Lesser Antilles. The North Equatorial Current flows westward along the north coasts of the islands. North of the Mona Channel it splits, with one branch flowing north of Silver and Navidad Banks, past Turks and Caicos to form the Bahamas Current. The southern branch parallels the north coast of Hispaniola about 30 km offshore. A small gyre has been documented off the northwest corner of Puerto Rico resulting in an easterly flow nearshore in this area.

The north branch of the Caribbean Current flows west into the Caribbean Basin at roughly 0.5 meters (1.7 feet) per second. It is located about 100 km south of the islands, but its position varies seasonally. During the winter it is found further to the south than in summer. Flow along the south coast of Puerto Rico is generally westerly, but this is set-off by gyres formed between the Caribbean Current and the island. The Antilles Current flows to the west along the northern edge of the Bahamas Bank and links the waters of the Caribbean to those of southeastern Florida.

Current flow (and water transport) in the Caribbean is generally described on average as a westward flow. To the north of the PRVI there is a westward flow of the North Equatorial current and to the south is the Caribbean current. The Caribbean current flows at an average speed of 0.5 to 1 knot and it is located about 100 km to the south of the Islands. The westward flow of nearshore water along the south coast of Puerto Rico has been reported by Yoshioka et al., (1985) and Colin and Clavijo (1988). The westward flow of nearshore waters along the north coast is "interrupted" by a gyre off the northwest coast of Puerto Rico that results in an eastern flow in the area.

This general description does not represent the intricate and complex nature of the smaller scale flows of the area. For example, in the Mona Passage -still a larger scale flow- the net surface flow is to the northwest, especially during the summer. Alongside the Mona Passage there is a strong southwest flow into the Caribbean and countercurrents have been described for the area.

More complex yet are the disturbances created by the numerous reefs and numerous islands in the area that are subject to eddies and meanders.

Several rivers exert intermittent but important influence on the waters of the Caribbean Basin including the Amazon, the Orinoco, the Magdelana, and the Columbian. The plume from the Orinoco River that flows up the Lesser Antilles and along the Greater Antilles, for example, can carry with it high concentrations of suspended particles, unique chemical properties, and biota near to the south coast of Puerto Rico. The plume, therefore, can be responsible for events of high turbidity and algal blooms that usually occur in the Caribbean Basin in October.

Non-point sources reduce the transparency of the water and reduce the amount of PAR (photosynthetic active radiation) reaching autotrophic species such as seagrasses and corals. These factors contribute to light attenuation, especially near shore (e.g., river plumes). For example, seagrasses require 10-20% of PAR reaching the surface; branching corals require 60% and massive corals about 40% of PAR.

It is believed that no upwelling occurs in the waters of the PRVI (except perhaps during storm events) and, since the waters are relatively stratified, they are severely nutrient-limited. In tropical waters nitrogen is the principal limiting nutrient. Primary productivity rates in the area range between 55-90 gC/m^2/yr with rates in the south varying between 37-55 gC/m^2/yr.

Oceanic currents flow from east to west on both coasts of Puerto Rico, although there is a periodic reversal on the north coast. The north and east coasts are exposed to winds and waves from the Atlantic Ocean striking the island from the east and northeast. The Cordillera Central, oriented east west across the island, causes a considerable reduction in rainfall from northeast to southwest. Average rainfall varies from over 5,000 mm in the Sierra de Luquillo to less than 1,000 mm on the south coast. There are two rainy seasons, one between July and November (the hurricane season) and one in May. Tropical storms and hurricanes develop with easterly air streams and are accompanied by torrential rain and high seas. Occasional cold fronts during the winter months bring torrential rain for several days and cause extensive flooding. Average temperatures vary very little from 28.1E C in September to 25.5E C in February.

Sea surface temperature (SST) ranges from a minimum of 25EC in February-March to a maximum of 28.5EC in August-September. Inshore temperatures may be higher (e.g., 30EC) due to shallower depths or may be influenced by thermal plumes from generator plants (see below). Attempts have been made to correlate SST to changes in the marine biota under the surface (i.e., at depths greater than 3 meters, for example) but as reviewed by Quinn and Kojis (1994) these works show no consensus specifically when dealing with rising SST and coral bleaching. Changes in SST associated with coral bleaching are reviewed in detail in the Coral FMP.

Quinn and Kojis (1994) best summarize the importance of long-term and high-resolution sea temperature (both surface and subsurface) data sets in assessing environmental changes and the effects on marine organisms. Also, these authors summarize the meaning of these long-term data sets to the coastal areas (e.g., global warming, and sea level rise). There is no doubt that there are some long-term data sets (e.g., USVI Department of Planning and Environmental Resources/ Division of Environmental Protection) on water quality for a number of specific sites but in terms of temperature most information available are surface measurements. Sea surface temperature is recorded from the upper 3 meters of water while very seldom is subsurface temperature recorded (Quinn and Kojis 1994).

There are differences in the tidal regimes between the north and south coasts with the fluctuations being highest in the north coast (where waves are also larger). The fluctuations range from a diurnal tide of about 10 cm in the south coast to a semi diurnal regime of between 60 and 100 cm along the north coast (Kjerfve, 1981). Tidal range is slight (0.18-0.34 m) and tides are normally semidiurnal except on the south coast where these are diurnal. Velazco-Domínguez et al. (1985) give a detailed account of coastal currents.

There are no perennial streams in the USVI. The extensive alteration of the islands' ecosystems, through burning, mono-crop agriculture (sugar cane), and the subsequent regrowth of scrub vegetation have eliminated free flowing streams. During the periods of intensive rainfall, up to 6 inches in 24 hours, runoff through “guts” can produce serious lowland flooding and a temporary lowering of coastal water quality. As a general condition the coastal waters are exceptionally clear due to the lack of sediments and nutrients from rivers (CZM plan).

B. Sea Grasses

This section cannot begin in any other way except by recognizing the lack of knowledge in relation to the location, distribution and quantification of seagrass beds in the U.S. Caribbean, a common problem for most other areas. The very near shore seagrass beds have been identified, and are for example being mapped from aerial photographs in the USVI (CDC at the Eastern Caribbean Center and The Nature Conservancy). The second most relevant point is that it is one of the most used habitats as nursery grounds and yet the least well documented in terms of their geographic distribution and area extent.

Puerto Rico has one of the most diverse seagrass floras of the north Atlantic Ocean with seven species recorded: *Thalassia testudinum* (turtle grass), *Halophila dicipiens, H. baillonis, H. engelmannii* (sea vines), *Halodule wrightii* (shoal grass), *Syringodium filiforme* (manatee grass) and *Ruppia maritima* (widgeon grass) (Vicente, 1992). Turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) are the three most abundant species.

Seagrass beds are highly productive ecosystems that are quite extensive in the Caribbean and often occur in close association with shallow-water coral reefs. Seagrasses are true flowering plants that spread through the growth of roots and rhizomes. Out of the estimated 250,000 flowering plants existing on earth today, only about 60 species have adapted to life in the marine environment (den

Hartog 1970). Collectively, we refer to this group of submersed aquatic vascular plants (SAV) as seagrasses. Seaweeds (macro-algae) are often mistakenly referred to as “grasses”. Despite the fact that these frequently co-occur and provide similar ecological services, these two plant taxa have distinctly different growth forms and contrasting life requirements. Taxonomically, seagrasses are divided into two families and 12 genera (den Hartog 1971, Phillips and Meinez 1988).

Seagrasses are the only vascular plants able to complete their life cycle fully submerged in the marine environment. These have a high rate of net primary production that provides a large supply of organic matter. To obtain light for growth these require shallow, or clear deep, water. The biomass of turtle grass is, for example, lower in more polluted environments (Fonseca et al., 1992). Sea vines (*Halophila* spp.), on the other hand do not usually occur in mixed species beds but may be found in shallow turbid water, in silty muddy substrates, or to depths of 50 m in clear water because they are adapted to low light intensity (Ogden, 1980). These characteristically occur as pure strands but may be mixed with *Syringodium filiforme* and are eaten by a variety of fishes and the queen conch, *Strombus gigas*. Sea vines occur widely in the tropical western Atlantic (Colin, 1978). Manatee grass has rounded leaves and a dense mat of rhizomes about 5 cm deep. It often occurs with turtlegrass in mixed stands and is eaten by various herbivorous fishes and the queen conch.

Thalassia testudinum, the turtle seagrass is the most abundant and important seagrass found in tropical waters (Buesa, 1974). These plants grow on sand or mud bottoms, from the shoreline to depths of 20 to 30 feet, depending on the species and sunlight penetration (Margalef and Rivero, 1959; Stephens, 1966). In the clear waters of the USVI, turtlegrass beds have been found at depths of 43 feet (Randall, 1965). *Thalassia testudinum* has a horizontal rhizome, buried as much as 25 cm deep in the sediment which gives rise to erect, flattened green leaves (Colin, 1978). In Puerto Rico, male and female turtle grass flowers may be found from March-June in the shallow subtidal zone (Vicente, 1992). Turtlegrass beds exposed to high wave energy, sand burial, poor water quality and heated effluents do not reproduce sexually (Vicente, 1992).

Thalassia (seagrass) leaves are the primary source of food for a wide range of organisms that include fishes, sirenians, turtles, urchins, and gastropods. This great number of species which feed exclusively or nearly so on *Thalassia testudinum* leaves or the epiphytes on their blades, make them a unique resource (Ogden, 1976; in Medina et al). Turtlegrass leaves provide a substrate for more than 100 species of algae and other organisms (crustaceans, hydrozoans, snails) which live on the blades. The beds themselves provide shelter and nursery grounds for larvae and juveniles of several fish and invertebrate species such as grunts, wrasses, parrotfish and snappers and conch (Stephens 1966). More than one hundred species are known to rely on turtlegrass beds for protection and food (Croz et al. 1975).

Thalassia leaves provide a substrate for more than 100 species of algae that live as epiphytes on the blades. Other organisms (crustaceans, snails) live encrusted on the blades. Seagrass beds also provide shelter and nursery grounds for larvae and juveniles of several fish and invertebrate species. Also, small fishes and invertebrates use the area as their habitat where these can hide and camouflage between the leaves (Stephens 1966 in Medina et al.).

The multi-species invertebrate and plant assemblages which form the backbone of reef and seagrass communities constitute an array of habitats and microhabitats which are the very basis of a wealth of natural resources exploited by man. Although reef and seagrass communities may be distinguished relatively easily, these are not distinct entities. These are intimately interconnected with each other and with other marine and terrestrial habitats (Cintrón and Schaffer-Novelli, 1983). Seagrass beds serve as secondary feeding grounds for many coral reef animals and protect coral reefs by trapping sediment and lowering the potential for sediment resuspension and transport. Reef environments, including both coral and rocky reefs, dissipate wave energy, protect seagrasses and provide shelter for many animals that feed in seagrass areas (Tetra Tech, 1992). There is also an important interchange between seagrass beds and reefs by animals such as grunts and snappers that migrate between the two habitats (Helfman et al. 1982). When they return to the reef these fishes deposit organic compounds in the form of feces that become available to detritivores and are thereby introduced into the food web. The ecological relationships and interdependencies both within and between these two communities are thus wide-ranging and complex.

High species diversity and abundance are associated with seagrass meadows, especially in tropical areas. Many vertebrates and invertebrates, including a substantial number of commercial importance, occur in seagrass beds at some phase in their life history. Juveniles utilize this habitat as a nursery area for food and shelter and both adults and young graze on the organisms and detritus attached to the blades, such as numerous shrimp, amphipods, mysids, snails and small fish. These, in turn, are preyed upon by larger carnivores (Thayer et al. 1978). Macroalgae are foraged extensively by a large assemblage of herbivores and the prey of many commercial species may be found in these meadows (e.g., conch, clams, parrotfish, snappers and grunts, among many others) (Thayer et al. 1978; Fonseca et al. 1992). Postlarvae of shrimp and spiny lobster recruit into seagrass beds and lobster reside in these areas for their first 9-12 months, then migrate to deeper water from which they return at night to feed. More than one hundred species of organisms are associated with the *Thalassia* beds for protection and food (Croz et al. 1975; in Medina et al.).

Seagrasses provide canopy and substrate for attachment and refuge (Fonseca et al. 1992) and have a high rate of net production which provides a large supply of organic matter. According to Marsh (1976) algae, other than those symbiotic with corals, are the most important producers making energy available to non-coral consumers on the reef. The majority of nitrogen fixation occurs on the algal flat (Wicke, 1976). It is also of note that one threatened and one endangered species heavily depend on seagrass meadows for forage in the region; both adults and juveniles of the threatened green turtle, *Chelonia mydas*, feed almost exclusively on seagrasses and extensively on the younger portions of seagrass blades throughout the wider Caribbean area (Fonseca et al. 1992; Vicente et al. 1992). The endangered manatee, *Trichechus manatus*, excavates the sediment in grass beds and feeds on roots, rhizomes and leaves.

Besides being a food resource and substrate for the attachment of several plants and animals, seagrass meadows are important in controlling and reducing erosion by trapping and consolidating bottom sediments with their extensive root and rhizome network. They also promote the accumulation of organic matter for further utilization by the resident population. All these conditions support the great fauna and productivity that is characteristic of *Thalassia testudinum* beds (Ferguson 1967; in Medina et al.).

Vicente (1992) stated that, " previous research has shown that seagrass beds are difficult to establish artificially and are slow to recover from damage. Essentially they are irreplaceable." The seagrass beds of Culebra have been given a Resource Category 1 Designation in a document titled The Seagrass Beds of Culebra, Puerto Rico, signed by the Regional Director (Region 4) of the U.S. Fish and Wildlife Service. Category 1 means that areas are considered unique and irreplaceable and that loss of this system is not acceptable. Thus, protection of these beds is afforded since Federal permits required by Section 404 of the Clean Water Act and Section 10 of the River and Harbor Act are required for development in these areas. The strong Federal interest in protecting these areas will be relayed to the permitting authorities (e.g., Corp of Engineers) by agencies such as the National Marine Fisheries Service and U.S. Fish and Wildlife Service as part of the permit review process. Because the Council identifies these areas as EFH, it also will seek strong protection measures (See Coral FMP).

Of great importance in the conservation of seagrass beds is the maintenance of the successful hydrophilic pollination, pollen grains produced at time of reproduction with floating capacity, which is susceptible to poor water quality. Under poor water quality conditions flowering and thus pollination are interrupted.

One of the most important functions of seagrass beds is the entrapment of large amounts of sediment, which in turn modify, in time, the shorelines. Specifically, water quality is maintained because the leaves of the seagrasses help in the precipitation of suspended matter, prevent resuspension of anoxic sediments and transform nutrients into biomass. The root system and rhizomes hold the sediment in place.

These habitats sustain populations of turtles, manatees and fish (including shellfish). The relationships vary from serving as food (e.g., leaves are eaten by green turtles), and as foraging habitat e.g., fish use them as hunting grounds (see Section 4.0), to providing surface area for egg-lying by fish (e.g., leaves of *Thalassia*) or habitat for reproductive purposes (e.g., nurse shark, *Ginglystoma cirratum*). Among the many species which forage either on the leaves/rhizomes of the seagrass beds or in the meadows (foraging for invertebrates, epiphytes, etc.) are: *Strombus gigas*; *Sparisoma* spp.; *Haemulon* species; nurse sharks; West Indian manatees and green turtles (both endangered species) as well as the brown pelican (*Pelecanus occidentalis*, also endangered) which prey on invertebrates associated with seagrass beds (*Argopecten* i*rradians*).

These meadows are intricately associated with green algae (also in the Coral FMP's FMU) species such as *Caulerpa*, *Halimeda* and *Penicillus* spp (Phylum Chlorophyta). These green algae are of importance in stabilizing disturbed bottoms.

Also, seagrasses are ecologically associated with coral reefs. The exact nature of this association is not known.

The autotrophic nature of seagrasses sets the depth limits at between 30 cm and 20 m. The shallower limit might be set by tidal considerations (exposure) and sediment load (buried meadows). The deeper limit might be set by water transparency, allowing the required amount of PAR to reach deeper in the water column and turbidity. Width of insular shelf, depth and patchy distribution of non-optimal bottom (rocky substrate) limit the aerial extent of seagrass beds.

Vicente (1992) reported that in Puerto Rico, primary production and biomass of seagrasses are very high (6,898 $gC/m^2/yr$ and 2,260 gC/m^2, respectively). Seagrassess and coral reefs are among the highest primary production systems in the tropics.

Among the threats to this "habitat" are: (1) raw sewage disposal (specifically in areas where there is no sewage treatment plants) since raw sewage inputs high concentrations of nutrients into the environment; (2) construction of ramps, piers, docks, and other construction on the coast (shading of large portions of the beds); (3) telephone, water and electricity underwater pipes (specially those not held in place); (4) anchoring, scaring, groundings (no information is available for the areas of PR and USVI); (5) any upland development in Puerto Rico and the U.S. Virgin Islands generates sediment erosion which inevitably runs off to the nearshore environments; (6) deforestation (ibid.; increased turbidity);(7) storms and hurricanes (sand burial and also ecological intricate relationship to Mangroves since after destruction of the mangrove forest there is sediment resuspesion and redistribution, increased turbidity); (8) diseases; (9) sea level rise threatens seagrass beds indirectly since the effects of increased turbidity and poor water quality may prevent vertical accretion of seagrasses as sea level rises.

1. Seagrasses and Their Function as Essential Fish Habitat

As in terrestrial grasslands, individual seagrasses and associated species form recognizable biological and physical assemblages known as seagrass meadows. The meadows are usually defined by a visible boundary delineating unvegetated and vegetated substrate and vary in size from small, isolated patches of plants less than a meter in diameter to a continuous distribution of grass tens of square kilometers in area. Seagrass meadows are dynamic spatial and temporal features of the coastal landscape (den Hartog 1971, Patriquin 1975). Some of the smaller species have been shown to be capable of establishing meadows annually in the seasonal waters of the South Atlantic. Alternatively, meadows formed by the larger bodied species which have either limited or irregular sexual reproduction, may require decades to reach full maturity. For example, the slowest growing species in the south Atlantic region, *T. testudinum*, produces relatively few fruits and seeds at irregular intervals (Tomlinson 1969, Moffler and Durako 1987). When turtlegrass is compared to its' congeners, *H. wrightii* and *S. filiforme*, it has the slowest rate of vegetative expansion (Fonseca et al. 1987). Depending on the environmental conditions, rates of vegetative expansion for *H. wrightii* and *S. filiforme* are normally 4 to 10 times faster than *T. testudinum*. Thus, *T. testudinum* meadows form more slowly than any of the other species, yet if the environmental conditions allow the full development of a turtlegrass meadow its biomass and productivity will usually exceed any other seagrass (Zieman 1982).

Regardless of developmental stage or species composition, small seagrass patches and entire meadows can move, the rate of which may also vary on a scale of hours to decades. These dynamic spatial and temporal features of seagrass meadows are important aspects of fishery habitats. Seagrass habitats must be recognized as including not only continuously vegetated perennial beds but also patchy environments with the unvegetated areas between patches as part of the habitat. In fact, available data show that patchy habitats provide many ecological functions similar to continuous meadows (Murphey and Fonseca 1995, Fonseca et al. 1996). Also, it must be recognized that the absence of seagrasses in a particular location does not necessarily mean that the location is not viable seagrass habitat. It could mean that the present conditions are unfavorable for growth, and the duration of this condition could vary from months to years.

Because of seagrasses are rooted, they can become nearly permanent, long-term features of coastal marine and estuarine ecosystems coupling unconsolidated sediments to the water column. No other marine plant is capable of providing these properties of seagrasses. Seagrass meadows provide substrate and environmental conditions which are essential to the feeding, spawning and growth of several managed species (see Laney 1997, Zieman 1982, Thayer et al. 1984). The specific basis of seagrass as fishery habitat is recognized in four interrelated features of the meadows: 1) primary productivity, 2) structural complexity, 3) modification of energy regimes and sediment and shoreline stabilization, and 5) nutrient cycling. On a unit area basis seagrasses are among the most productive ecosystems in the world (McRoy and McMillan 1977) . High rates of primary production lead to the formation of complex, three dimensional physical structures consisting of a canopy of leaves and roots and rhizomes buried in the sediments. The presence of this physical structure provides substrate for attachment of organisms, shelter from predators, frictional surface area for modification of water flow and wave turbulence, sediment and organic matter deposition, and the physical binding of sediments underneath the canopy. Linked together by nutrient absorbing surfaces on the leaves and roots and a functional vascular system, seagrass organic matter cycles and stores nutrients, and provides both direct and indirect nutritional benefits to thousands of species of herbivores and detritivores.

2. Specific Examples of Seagrass As Essential Fish Habitat

Experiments and observations have shown that juvenile and adult invertebrates and fishes as well as their food sources utilize seagrass beds extensively. In fact, the habitat heterogeneity of seagrass meadows, the plant biomass, and the surface area enhance faunal abundances. Predator-prey relationships in seagrass beds are influenced by canopy structure, shoot density, and surface area. Blade density interferes with the efficiency of foraging predators and the reduction of light within the leafy canopy further conceals small prey which includes young-of-the-year of many ecologically and economically important species. High density of seagrass shoots and plant surface area can inhibit movement of larger predators, thereby affording shelter to their prey. Additionally, some organisms can orient themselves with the seagrass blades and camouflage themselves by changing coloration. The food availability within grass beds for young stages of managed species may be virtually unlimited. These attributes are particularity beneficial to the nursery function of seagrass beds and while there is continuing debate and research on whether refugia or trophic functions are most important (when and to which organisms), there is little debate that these are important functions provided by this habitat type.

The spiny lobster (*Panulirus argus*), has a strong reliance on seagrass habitats including seagrass-supported trophic intermediaries. There have been few studies dealing with larval fish settlement and use of seagrass habitats while there have been numerous publications listing juvenile and adult fishes collected in seagrass meadows. Seagrass beds are important for the brooding of eggs and for fishes with demersal eggs. Many fish reside only temporarily in grass beds either to forage, spawn, or escape predation. Economically important species use these habitats for nursery and/or spawning grounds including grunts (Haemulids), snook (*Centropomus* spp.), tarpon (*Megalops atlanticus*) and several species of snapper and grouper.

For the most part, the organisms discussed above utilize the grass bed structure and trophic elements associated with the bed, but many species of herbivorous invertebrates (e.g., urchins *Lytechinus variegatus*, *Tripneustes ventricosus*), birds (e.g., black brant *Branta bernicla*), fishes (e.g., pinfish *Lagodon rhomboides*, parrotfish *Sparisoma radians*), the green turtle (*Chelonia midas*) and the manatee (*Trichechus manatus*) feed directly upon coastal and estuarine seagrasses.

C. Non-vegetated bottom

1. Rocky Shores and Sandy Beaches

Throughout the U.S. Caribbean, both rocky shores and sandy beaches are common. While many of these beaches are high-energy and extremely dynamic, buffering by reefs and seagrasses allows some salt-tolerant plants to colonize the beach periphery. Birds, sea turtles, crabs, clams, worms, and urchins use the intertidal areas. Over 190 species of fishes, almost all occurring in PRVI, have been recorded from nearshore hard bottom reefs of Southeast Florida (Lindeman and Snyder, in press).

2. Sand/Mud Bottom Habitats

The sand/mud subsystem includes all non-live bottom habitats or those with low percent cover (< 10%) to 100 fm. Sandy and mud bottom habitats are wide-ranging, found in coastal and shelf areas, and include inshore, sandy areas separating living reefs from turtle grass beds and shorelines; rocky bottoms near rocky shorelines; and mud substrates along mangrove shorelines (VIERS 1969) and near river mouths (Erdman 1956).

Queen conch and milk conch occur in soft-bottom euphotic habitats and on sandy bottoms with coral rubble and macroalgae (Appeldoorn 1985). Other species commonly found in these habitats include spiny lobsters, Gerreids, goatfishes, lizardfishes, yellowtail snapper, coney, doctorfish, parrotfish, and the silk snapper (*Lutjanus vivanus*), as well as numerous pelagic species found in the waters overlying these sand/mud bottoms.

Mud plains have been shown to become a dominant bottom type at depths greater than 100 fathoms (CFMC 1984, Coral FMP, Table 1). Although it has been reported that dramatic changes have taken place in nearshore areas no information is available at this time except for the identification of this habitat type as related to species in the EFH tables (see Section 4.0).

3. Sand

Table 2 shows the areal extent of marine biotopes, including shallow sand. The extent and characterization of these habitats is unknown. Sand has been shown to be important in association to a number of marine species most significantly the sand tile fish (*Malacanthus plumieri)*. The distribution of sandy habitats can be estimated from the presence or absence of this species. The work in progress by NOS using the SEAMAP-Caribbean database can be previewed at the following Internet address: http://christensenmac.nos.noaa.gov/briefing.html.