5.0 THREATS TO ESSENTIAL FISH HABITATS

Background

The islands of the Caribbean are among the most distinctive in the world possessing a diverse culture, history, and natural heritage. The watery isolation of dozens of islands has enabled one-of-a-kind species to develop throughout the region, resulting in a high level of unique plant and animal diversity. Scientists estimate that up to 40 percent of the plant life in certain Caribbean forests is found nowhere else on Earth. Together, these islands contain almost as many species as the entire land mass of the United States and Canada. Moreover, 13 percent of the world's coral reefs are found here and extensive areas of submerged aquatic vegetation (SAV) exist. The inshore and offshore areas provide vital habitats for fishery species that are a vital component of the region’s economy. These fisheries have a substantial economic impact in both the commercial and recreational fishing sectors.

Puerto Rico

The island of Puerto Rico is almost rectangular in shape, and is the smallest and the most eastern island of the Greater Antilles. Its coasts measure approximately 700 miles and include the adjacent islands of Vieques and Culebra. To the north and south, seascapes measure 8.525 m for the Grave of Puerto Rico and 5.000 m for the Grave of Tanner. In addition to the principal island, the Commonwealth includes: Vieques, Culebra, Mona, Monito, and various other isolated islands. Deep oceans waters fringe Puerto Rico. The Mona Passage, which separates the island from Hispaniola to the west, is about 75 miles (120 km) wide and more than 3,300 feet (1,000 meters) deep. Off the northern coast is the 28,000 foot (8,500 meters) deep Puerto Rico Trench, and to the south the sea bottom descends to the 16,400 foot (5,000 meters) deep Venezuelan Basin of the Caribbean.

The territory is very mountainous (cover 60 precent), except in the regional coasts, but Puerto Rico offers an astonishing variety of habitats such as rain forest, deserts, beaches, caves, oceans, and rivers. Many small rivers and high central mountains ensure land is well watered; the south coast is relatively dry; and a fertile coastal plain belt is found to the north. The Puerto Rico Coastal Zone Management Program identifies Jobos Bay National Estuarine Research Reserve, bioluminescent bays, tropical rain forest, coral reefs, major turtle nesting sites, mangrove lagoons, and caves as significant features of the territory.

Of the 1,200 bodies of water, Puerto Rico only classifies 50 of them rivers. Numerous rivers flow down from the mountains to distinct coastal plains. The Central Range divides the north (Atlantic) and south (Caribbean) watersheds. The northern rivers are long, rich and tranquil waters in comparison to the southern rivers, and the coast is wet and green. The major rivers are: Grande de Loíza (65 km), Bayamón (40 km), La Plata (80 km), and Grande de Arecibo (55 km). To the west and the east are the rivers basins which form the water systems, and these rivers are: Culebrinas (45 km), Grande de Añasco (65 km), and Guanajibo (36 km). Subterranean streams are abundant, especially toward the northwest. In the southwest, mangroves have created a unique nearshore ecosystem. Puerto Rican rivers are not navigable except near the coast, but they provide electrical power and irrigation.

Puerto Rico is mostly mountainous with a coastal plain belt in north; mountains precipitous to sea on west coast; and sandy beaches along most coastal areas. Wetlands along existing shorelines are mostly comprised of buttonwood, black, white, and red mangroves (*Conocarpus erecta*, *Avicennia germinans*, *Laguncularia racemosa*, *Rhizophora mangle*). The shallow-water shelf of the islands has extensive coral reef areas and assemblages. Seagrasses, primarily turtlegrass (*Thalassia testudinum*) abound. Local beaches are extensive and many provide important nesting habitat for marine turtles.

Shipping, tourism, and agriculture are the territory's major industries. The Territory's coastal population is estimated at 3,008,274.

The Puerto Rico Coastal Zone Management Program has identified sedimentation, erosion, coastal hazards, and illegal use of the island's maritime zone (its shoreline, territorial waters, and submerged lands) as major issues.

Section 2.2.E. 2(a) summarizes the large scale characteristics of Puerto Rico including features and descriptions of the most prominent coastal sectors. Section 2.2.E. 2(b) summarizes the information fot the USVI.

US Virgin Islands

These hilly islands were formed by volcanoes over a period of 25 million years. They are all peaks of submerged mountains, most of them extinct volcanoes, rising from a submarine plateau. The US Virgin Islands are part of the Virgin Islands, a group of about 90 small islands and cays in the West Indies. Most of the US Virgin Islands are uninhabited. All of them are considered part of the Leeward Islands and the Lesser Antilles. They cover an area of about 195 sq miles with a coastline of about 175 miles and are administered as two groups, the British Virgin Islands and the Virgin Islands of the United States. St. Croix is entirely surrounded by the Caribbean Sea. The Atlantic Ocean is to the north of St. Thomas and St. John, and on the south they open into the Caribbean Sea.

St. Croix, the largest of the islands, is about 28 miles long and covers an area of 82 sq miles. It's about 40 miles south of St. Thomas and St. John. St. Thomas consists of a range of hills and has little level land. It covers an area of 32 sq miles. Magens Bay in the center of the north coast has more than 3,500 ft of white sand beach and is one of the finest beaches in the Caribbean. St. John, the smallest of the three, has an area of about 20 sq miles. It is the most easterly of the islands and is only half a mile to the west of the British Virgin Islands. More than three quarters of St. John is protected and preserved as the Virgin Islands National Park.

Each of the three main US Virgin Islands has its share of tropical pleasures. St. John, where Virgin Islands National Park is located, is the least developed. Next door is the bustling tourist mecca of St. Thomas, with its large cruise-ship harbor of Charlotte Amalie. On distant St. Croix it is less developed than St. Thomas with quaint towns amid rolling hills and pastoral landscapes. Wetlands along existing shorelines are mostly comprised of buttonwood, black, white, and red mangroves (*C. erecta*, *A. germinans*, *L. racemosa*, *R . mangle*). The shallow-water shelf of the islands has extensive coral reef areas and assemblages. Seagrasses, primarily turtlegrass (*T. testudinum*) abound. Local beaches (e.g., Sandy and Buck Island) provide important nesting habitat for marine turtles. The US Virgin Islands Coastal Zone Management Program identifies mangroves, coral reefs, salt ponds, seagrass beds, sea turtles, leatherback turtle nesting, and peregrine falcons as special features and species associated with the territory.

Tourism is the territory's major industry. Agriculture and marine recreation are also important industries. The coastal population is estimated at 101,809.

5.1 Adverse Impacts of Fishing Activities on Essential Fish Habitat

The Sustainable Fisheries Act requirement for identification of threats to EFH posed by fishing activities will be addressed in a report by Peter Auster and Richard Langton that is being prepared, under contract, for the NMFS. A copy of the draft report (Auster and Langton 1998) is available for review at the Council office. However, there is very little information on the adverse impacts of fishing activities on EFH for the US Caribbean. The following paragraphs summarize the general information contained therein.

The effects of fishing are the subject of numerous, mostly site specific and fishery specific, investigations that focus largely on economic and social factors. Most early fisheries management efforts deal with increased yields, gear, and identifying and locating new target species and markets. With the world wide decline of many fish stocks emphasis has shifted, in recent years, to stock management and recovery. This change in management emphasis has gradually led to realization that reductions in the size and quality of fishery habitats have reached critical levels. It has also furthered the view that, in certain situations, fishing itself may be profoundly changing the physical and biological character of fish harvest and life requisite areas.

Trawling and other fishing activities that involve direct contact between fishing gear and the aquatic environment can alter the structural character of fish habitats. When the change is sufficient enough to preclude or limit use by fishery directed or target species, declines in catch abundance and individual fish size may occur. Although a clear cause and effect relationship is evident, determination of the level of effect inducted by physical change may be complex. Relevant factors, in addition to the magnitude of the direct physical change, may include disturbance frequency and duration, seasonality, and other environmental, ecological, and physiological processes that control recovery and recruitment of requisite species of the community. As noted by Auster and Langton (1998) "... mobile fishing gear reduced habitat complexity by (1) directly removing epifauna or damaging epifauna leading to mortality, (2) smoothing sedimentary bedforms and reducing bottom roughness, and (3) removing taxa which produce structure (i.e., taxa which produce burrows and pits)."

As difficult and complex as restoring habitats and controlling fish harvest has proven to be, success in these efforts still may not yield satisfactory results. Environmental changes brought about by physical alteration of substrates and changes in species composition may create conditions that cannot sustain preexisting plant and animal assemblages or abundances. As noted by Auster and Langton (1998), population response (and successful fishery management) may be linked to parameters that are closely correlated to...ecological relationships (and) population response may be the result of "(1) independent single-species (intraspecific) responses to fishing and natural variation, (2) interspecific interactions such that as specific populations are reduced by fishing, non-harvested populations experienced a competitive release, (3) interspecific interactions such that as non-harvested species increase from some external process, their population inhibits the population growth rate of the harvested species, and (4) habitat mediation of the carrying capacity for each species, such that gear induced habitat changes alter the carrying capacity of the area." As further implied by Auster and Langton (1998), the magnitude of environmental or ecological change needed to affect a fishery may not need to be monumental from a physical perspective. After all, significant reductions in benthic diatoms and microalgae can affect higher trophic levels.

In their conclusion Auster and Langton (1998) state, "...primary information is lacking for us to strategically manage fishing impacts on EFH without invoking precautionary measures. A number of areas where primary data are lacking, which allow better monitoring and improved experimentation, ultimately leading to improved predictive capabilities, are:

> 1. The spatial extent of fishing induced disturbance . While many observer programs collect data at the scale of single tows or sets, the fisheries reporting systems often lack this level of spatial resolution. The available data makes it difficult to make observations, along a gradient of fishing effort, in order to assess the effects of fishing effort on habitat, community, and ecosystem processes.
>
> 2. The effects of specific gear types, along with a gradient of effort on specific habitat types. These data are the first order needs to allow an assessment of how much effort produces a measurable level of change in structural habitat components and the associated communities. Second order data should assess the effects of fishing disturbance in a gradient of type 1 and type 2 disturbance treatments.
>
> 3. The role of sea floor habitats on the population dynamics of harvested demersal species. While there is often good time series data on late juvenile and adult populations, and larval abundance, there is a general lack of empirical information (except in coral reef, kelp bed, and for SAV fishes) on linkages between EFH and survival, which would allow modeling and experimentation to predict outcomes of various levels of disturbance."

Auster and Langton (1998) further state that, "Recovery of benthic communities, especially for sessile invertebrates, is dependent upon recruitment at the larval stages. Two aspects of this process that are necessary for success are 1) proximity of reproductively mature adults, and 2) an undisturbed site for settlement and growth to maturity. If the intensity of fishing is too great then the possibility of a type II disturbance, where a small patch of reproductively animals is isolated by large expanses of sea floor, exists. The frequency of disturbance is equally important because newly settled juveniles may be damaged or destroyed if their settlement surface is perturbed at a critical time in their life cycle. Fishing should therefore be conducted with an intensity that does not create isolated benthic communities that are then expected to recolonize an area if the objective is a sustainable level of harvest. Similarly the habitat requirements of the harvested species have to be taken into account, as suggested in terms of 1 and 3 above, to insure that the habitat itself is not disturbed anymore frequently than is required to maintain the integrity of the benthic community that supports the fishery."

A. THREATS TO ESSENTIAL FISH HABITAT

Every reasonable effort has been made to identify the principal non-fishing and fishing-related threats to EFH; and to provide examples and information concerning the relationship between threat-related activities and EFH. Other information sources and examples undoubtedly exist, and many new studies are underway or in various stages of completion or publication. Accordingly, the following discussion is presented as a starting point in the identification of threats to EFH and is intended to meet the strict time limitations imposed by the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). It is hoped this will lead to further discussions, research and analysis that can be used to update and improve future versions of this document.

The Magnuson-Stevens Act defined EFH as: **"Essential Fish Habitat means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."** The EFH Interim Final Rule (62 FR 66531, December 19, 1997) provided additional interpretation to use in the preparation of EFH provisions for FMPs and amendments: "**For the purpose of interpreting the definition of essential fish habitat: *waters* include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include areas historically used by fish where appropriate; *substrate* includes sediment, hard bottom, structures underlying the waters, and associated biological communities; *necessary* means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.**

From the broadest perspective, fish habitat is the geographic area where the species occurs at any time during its life. This area can be described in terms of location; physical, chemical and biological characteristics; and time. Ecologically, habitat includes structure or substrate that focuses distribution (e.g., coral reefs, topographic highs, pinnacle trends, artificial reefs, marshes, or submerged aquatic vegetation) and other characteristics that are less distinct (e.g., turbidity zones, salinity gradients, or anoxic areas).

Species use habitat for spawning, breeding, migration, feeding and growth, and for shelter to increase survival. Spatially, habitat use may shift over time due to changes life history stage, abundance of the species, competition from other species, and environmental variability in time and space. Distributions and habitat use can be confounded by habitat change and degradation resulting from human uses and impacts, or other factors. The type of habitat available, its attributes and its functions are important to species productivity, diversity and survival.

The role of habitat in supporting the productivity of organisms has been well documented in the ecological literature, and the linkage between habitat availability and fishery productivity has been examined for several fishery species. Because habitat is an essential element for sustaining the production of a species, and therefore fisheries based on those species, the goals of FMPs cannot be achieved if the managed species do not have sufficient quantities of suitable habitat available to each life stage of the animal.

The quantitative relationships between fishery production and habitat are very complex and no reliable models currently exist. Accordingly, the degree that habitat alterations have affected fishery production is unknown. Turner and Boesch (1987) examined the relationship between the extent of wetland habitats in the Gulf of Mexico and the yield of fishery species dependent on coastal bays and estuaries. They found correlations between reduced fishery stock production following wetland losses and stock gains following increases in the areal extent of wetlands. While most of the studies cited examined shrimp productivity, other fisheries show varying degrees of dependence on particular habitats and likely follow similar trends. Accordingly, a significant threat facing fishery production is the loss of habitat by natural and human-related causes.

B. Fishing Activities That May Adversely Affect EFH

The Magnuson-Stevens Act requires that Councils identify adverse effects to EFH caused by fishing activities and further requires that Councils manage the fisheries under their jurisdictions so as to minimize such impacts, to the extent practicable. The EFH Interim final regulation explains that “adverse effects from fishing may include physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem.” Further, the regulations require that FMPs contain an assessment of the potential adverse effects of all fishing gear and practices used in waters described as EFH that considers the relative impacts of gears on different types of EFH. Special consideration is to be given to analysis of impacts from gears that will affect habitat areas of particular concern. Councils are advised to use the best scientific information available, as well as other appropriate information sources, as available. In considering the information gaps identified through the assessment, Councils should consider the establishment of research closure areas and other measures to evaluate the impact of any fishing activity that physically alters EFH.

The following section includes an assessment of fishing gears and practices that are used in the CFMCs fisheries accompanied by conservation recommendations to minimize the potential impacts. Following the assessment is a brief discussion of the scientific review of information relating to fishing impacts to habitat with additional discussion of measures taken by the Council in the past to moderate fishing impacts to habitat and identification of research priorities to provide additional information that can be used to improve future amendments to the EFH provisions of the FMPs. In general, the fishing methods that are used in these fisheries are relatively non-damaging compared to many of the fishing gears used in other Councils’ jurisdictions.

Jennings and Kaiser (1998) and Auster and Langton (1998) in recent reviews of fishing impacts to habitat characterize fishing impacts hierarchically, impacts to structural components of habitat, effects on community structure, and effects on ecosystem processes. Few studies cited in these reviews deal with tropical habitats or with the types of artisanal fisheries common to the US Caribbean. In spite of that lack of scientific study there are some effects that can be discussed for each fishing gear, as shown below.

C. Fishing Gear Assessment on EFH

The following gears have been identified for the fisheries managed by the CFMC:

Caribbean Fishery Management Council	
Fishery	**Allowable Gear Types**
Caribbean Spiny Lobster FMP:	
A. Trap/pot fishery	A. Trap/pot
B. Dip net fishery	B. Dip net
C. Entangling net fishery	C. Gillnet, trammel net
D. Recreational fishery	D. Dip net, trap, pot, gillnet, trammel net
Caribbean Shallow Water Reef Fish FMP:	
A. Longline/hook and line fishery	A. Longline, hook and line.
B. Trap/pot fishery	B. Trap, pot.
C. Entangling net fishery	C. Gillnet, trammel net
D. Recreational fishery	D. Dip net, handline, rod and reel, slurp gun, spear
Coral and Reef Resources FMP:	
A. Commercial fishery	A. Dip net, slurp gun.
B. Recreational fishery	B. Dip net, slurp gun
Queen Conch FMP:	
A. Commercial fishery	A. Hand harvest only
B. Recreational fishery	B. Hand harvest only

Each fishery from the table above is briefly described below with reference to the habitats where gears are used:

1. Caribbean Spiny Lobster FMP:

A. The trap/pot fishery, using traps and pots, primarily targets lobsters in seagrass beds, algal plains and areas adjacent to coral reef. Traps or pots usually are of the arrow head or square wood boxes. Typically numerous traps are attached with lines to one another and attached at either end to surface bouys marked with the fisher's identification. Impacts to habitat can occur if traps are set on top of or dragged into coral reefs or other fragile habitats. Traps set into seagrass beds can abrade seagrass particularly in areas of moderate to heavy surge. The potential for damage to EFH is considered slight since setting traps in coral areas increases the chance of loss of traps. The Council recommends against placing traps on top of corals or in shallow seagrass beds; and further recommends that fishers should take care to lift traps directly to the surface without undue dragging of the traps along the bottom. Every effort should be made to collect traps and pots from the field prior to approaching storms to avoid loss of traps and possible damage as they are moved by storm waves.

B. The dip net fishery, using hand held dip nets, targets lobsters in coral reef and seagrass habitats. Potential impacts include dislodging small coral heads and breaking corals. Council recommends that hand nets be used in a manner to minimize damage to corals and other invertebrates during dip net fishing for spiny lobsters.

C. The entangling net fishery, using gillnets and trammel nets, targets lobsters in most probably hard bottom, but there is no information available to the Council regarding the specifics. These nets are used during the spiny lobster migrations, the only time at which they are numerous and in the open areas. These nets are usually 134 fathoms (about 800 feet) long and 10 feet deep with a mesh size between 0.25 and 6 inches. Impacts to EFH include damage to corals when they area pulled out of the wter in areas with patchy distribution of corals. The potential for impact is considered slight since entanglement in corals increases the chance of damage to the gear and increases the repair time or expense of replacing gear. Council consideration of this matter is presented as the Option Paper (1995) as an Appendix in this section.

D. The recreational fishery, utilizes all of the same gears as the commercial fishery, dip nets, traps, pots, gillnets, trammel nets and the potentials for impacts and recommendations to minimize the impacts to EFH would be the same as for the commercial fishery.

2. Caribbean Reef Fish FMP:

A. The longline/hook and line fishery targets reef fish in shallow and deep coral reef, seagrass lagoon, deep seagrass bed, algal plain habitats. Longlines are typically 700 feet long; hook and line includes hand lines (1 to various hooks per line) and bottom lines (average 11 hooks) lifted either manually or with an electric winch.

B. The trap/pot fishery utilizes traps and fish pots to harvest reef fish from seagrass, algal plains and areas adjacent to coral reef habitats. Traps are typical of the Antillean (or chevron) style fish traps, approximately 1 x 1 m and ½ m high. Wire mesh of 2 inches is accepted, biodegradable side panels are required to allow the escape of fish and reduce ghost-fishing from lost traps. Typically numerous traps are attached to one another with lines and attached at either end to surface buoys marked with the fisher's identification. Impacts to habitat can occur if traps are set on top of or dragged into coral reefs or other fragile habitats. Traps set into seagrass beds can abrade seagrass particularly in areas of moderate to heavy surge. The potential for damage to EFH is considered slight since setting traps in coral areas increases the chance of losing traps. The Council recommends against placing traps on top of corals or in shallow seagrass beds; and further recommends that fishers should take care to lift traps directly to the surface without undue dragging of the traps along the bottom. Every effort should be made to collect traps and pots from the field prior to approaching storms to avoid loss of traps and possible damage as they are moved by storm waves.

C. The entangling net fishery targets reef fish using gillnets and trammel net of various configurations. Common gillnets utilize monofilament line with the same average dimensions described for the spiny lobster fishery as well as for the common trammel nets. They are normally deployed in channels, seagrass beds, encircling mangrove islands on algal plains or near coral reef habitats. They are normally fished for on average 5 hours, but soak time varies greatly. Possible impacts to habitat could include entanglement and breakage of hard and soft corals, trampling of seagrasses, stirring up fine sediments (short term effect). Occasionally nets are lost, causing ghost-fishing and fouling of the habitat from decaying fish entangled in the lost net. The Council recommends increased care in the placement and recovery of nets to avoid entanglement of the gear in underwater obstructions. Entanglement nets should not be placed over the tops of reefs where they can cause breakage and damage to fragile corals.

D. The recreational fishery for reef fish is pursued with dip nets, handlines, rods and reels, slurp guns, and spears. Slurp guns are generally tubular in shape and utilize water pressure to capture fish. Both dip nets and slurp guns are used primarily to capture small species and/or juveniles for personal aquaria or for the aquarium trade. The Council recommends that care should be exercised with these gears in and around fragile corals, or mangrove roots that can be damaged, broken or abraded through careless attempts at fish capture. Handlines and rod and reels target larger species including snappers, groupers, barracudas, porgies, pelagics, and other species. There is no information available to the Council regarding recreational fishing activities. They are typically fished over or around coral reef habitats. They have the potential to snag or hang on hard and soft corals, rocks, and patchy corals over seagrass beds. There is the possibility of fouling of habitat structure with lines and hooks. Recently concerns have been raised over the use of lead weight in both salt water and fresh water fishing. Particularly in fresh water areas high concentrations of lead have been detected in sediments and water samples. Lead weight and traditionally used in the reef fish rod and reel and hand line fishery to control depth at which baits are fished. The Council suggests that lines be tended to minimize the chance of entanglement in structural habitat components. The Council also suggests that research be undertaken to evaluate the effects of recreational fishing activities on habitats and species composition.

3. Coral and Reef Resources FMP:

A/B. The commercial and recreational fisheries for coral and reef resources permit the use of dip nets and slurp guns such as those described above in the reef fish fishery. The potentials for adverse effects on EFH are the same as stated above as are the conservation measures suggested.

The Coral FMP emphasizes that irreparable damage is done to corals when chemicals and destructive gears are used to remove reef-associated invertebrates (e.g., Christmas tree worms or anemones).

4. Queen Conch FMP:

A/B. The commercial and recreational fisheries for queen conch are pursed only through hand capture of conch and related resources. Harvest methods are not regulated in the queen conch fishery and it is allowed everywhere, except for the seasonal closure when all harvesting of queen conch is prohibited. Potential impacts to the habitat include potential trampling and short term disturbance of sediments by divers.

D. Previous Council actions taken that protect habitat

The EFH interim final rules require that Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing practice is having an identifiable adverse effect on EFH, based on the assessment of fishing gears on EFH. Toward this end, Councils should consider whether, and to what extent, the fishing activity is adversely impacting EFH, including the fishery; the nature and extent of the adverse effect on EFH; and whether the management measures are practicable, taking into consideration the long and short-term costs as well as benefits to the fishery and its EFH.

At this time, there is no evidence that the effects caused by fishing under these FMPs are adversely affecting the EFH to the extent that detrimental effects can be identified on the habitat or the fisheries. Mainly, because the lack of information regarding the location, distribution and extent of these habitats. Conservation measures included above as Council suggestions, should help to mitigate any impacts that are currently occurring. Additional study will be recommended to more adequately identify unrealized adverse impacts and to quantify impacts currently happening. The Marine

Conservation District that is being proposed for the Federal waters off the US Virgin Islands (either south of St. Thomas or St. of St. John) would be an ideal location for this research since no fishing will be allowed within its boundaries. Additional areas are under consideration for closure to fishing (e.g., La Parguera, and Culebra, PR and also within the state waters of the USVI) and if established they will be promoted as control sites for research into fishing effects on habitat.

The EFH regulations suggest a variety of options for managing adverse effects from fishing, that include, but are not limited to: (1) Fishing equipment restrictions, such as seasonal and areal restrictions on the use of specified equipment; equipment modifications to allow escapement of particular species or particular life stages (e.g., juveniles); prohibitions on anchoring or setting equipment in sensitive areas; and prohibitions on fishing activities that cause significant physical damage in EFH. (2) Time/area closures, including, but not limited to: closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern. (3) Harvest limits, including, but are not limited to, limits on the take of species that provide structural habitat for other species assemblages or communities, and limits on the take of prey species."

Historically the CFMC has invoked many of these measures to conserve and protect habitat. These measures have been discussed in Section 1.0 of this document. The Council has recently established a Marine Conservation District southwest of St. Thomas where all fishing will be prohibited.

The physical effects to EFH habitat from the use, or cumulative use, of a specific fishing gear in a specified area has not been generally well studied.

E. Further considerations for gear impact research.

Fishing activities that involve direct contact between fishing gear and the aquatic environment can alter the structural character of fish habitats. When the change is sufficient enough to preclude or limit use by fishery directed or target species, declines in catch abundance and individual fish size may occur. Although a cause and effect relationship is evident, determination of the level of effect induced by physical change may be complex. Relevant factors, in addition to the magnitude of the direct physical change, may include disturbance frequency and duration, seasonality, and other environmental, ecological, and physiological processes that control recovery and recruitment of requisite species of the community.

In their conclusion Auster and Langton (1998) state: "Much of the research described herein is not at a scale that is directly applicable to fishery management decisions. What the research on impacts does offer is an indication of the types of changes one might expect in benthic communities over large spatial scales as well as confirmation that benthic communities are dynamic and will ultimately compensate for perturbations. However, as observations show, shifts in communities are not necessarily beneficial to the harvested species. The scale of fishing is a confounding factor in management because systems are being fished to the point where recovery is delayed so long that the economic consequences are devastating. We are seeing that now in many US fisheries. Because our knowledge of ecosystem dynamics is still rather rudimentary, managers bear the responsibility of adopting a precautionary approach when considering the environmental consequences of fishing rather than assuming that the extraction of fish has no ecological price and therefore no feedback loop to our non-ecologically based economic system.

The CFMC has embraced a precautionary approach to habitat and fishery management by proceeding with the proposed establishment of a Marine Conservation District south and will continue to work toward the establishment of additional closed areas to the extent that they show utility as a fishery management tool. The Council will support research within and around these areas to examine response of fish communities to release from fishing pressure, examination of habitat changes under non-fishing conditions and ability of these areas to support fisheries in the surrounding areas. The development of undisturbed communities within these no-take areas will provide valuable reference sites for future scientific study.

Additional consideration to fishing impacts on habitat will be undertaken as more research is undertaken and information becomes available. It will be reviewed for inclusion in future revisions to this EFH amendment.

5.2 Adverse impacts of Non-Fishing Activities on Essential Fish Habitat

The waters and substrate that comprise the essential fish habitat (EFH) as defined by the Magnuson-Stevens *Fishery Conservation and Management Act (MSFCMA) and under jurisdiction of the Caribbean Fishery Management Council (CFMC) are diverse, widely distributed, and closely affiliated with other aquatic and terrestrial environments. These characteristics make them readily susceptible to a large number of human activities.*

The EFH Interim Final Rule (Federal Register 62 FR) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The following definitions apply for interpreting the definition of the EFH rule:

- Waters include aquatic areas and their physical, chemical, and biological properties that are used by fish and invertebrates, and where appropriate may include areas historically used by fish and invertebrates;

- Substrate includes sediment, hard bottom, structures underlying the waters, and biological communities;

- Necessary means the habitat required to support a sustainable fishery and a healthy ecosystem; and spawning, breeding, feeding, or growth to maturity covers species' full life cycle.

Fish habitat is the geographic area where the species occurs at any time during its life. This area can be described by ecological characteristics, location, and time. EFH includes waters and substrate that focus distribution; e.g., coral reefs, mangroves, or SAV, and other characteristics that are less distinct such as turbidity zones, water quality, and salinity gradients. Habitat use may change or shift over time due to climatic change, human activities and impacts, and/or other factors such as change with life history stage, species abundance, competition from other species, and environmental variability in time and space. The type of habitat available, its attributes, and its functions are important to species productivity, diversity, health, and survival.

Convention for Threats Identification

The ecological requirements for managed species and biotic communities, including identification of EFH, are addressed in sections of this document. Threats to inshore and offshore processes include agriculture, silviculture, urban/suburban development, commercial and industrial activities, navigation, dredged material disposal, recreational boating, mining, hydrologic modifications, and natural events and global change. A more comprehensive list of individual activities that may be considered as threats is provided in Appendix A of this section.

Every reasonable effort was made to identify the principal non-fishing and fishing-related threats to EFH; and to provide examples and information concerning the relationship between threat-related activities and EFH. Other information sources and examples undoubtedly exist and many new studies are underway or in various stages of publication. Accordingly, the following discussion is only a starting point in the identification of threats to EFH and intended to meet the strict time limitations imposed by the MSFCMA. It is hoped this will lead to further discussions and information development that can be used to update and improve future versions of this document.

About eighty different bottom types are found around Puerto Rico and the US Virgin Islands. The bottom types vary with depth and consist of various combinations of gravel, rock, sand, mud, and clay. Many of the hard bottom areas consist of reefs both with and without coral assemblages. Nearshore, coral reefs are common and inshore of the reefs, seagrasses, and mangroves are the dominant saline wetland types. These coastal areas interact in very complex ways and are linked to provide food, habitat, and water quality maintenance functions that support the many important fisheries around Puerto Rico and the US Virgin Islands.

The wetlands (i.e., reefs, SAV, and mangroves) also interact to protect each other. The reef structures are efficient dissipators of wave energy and provide the shelter required for the establishment of seagrass beds and mangroves. Mangrove fringes trap fine sediments that would otherwise be carried toward reef areas. Seagrasses bind and stabilize the sediments that could otherwise also impact the reefs. Seagrass beds and reefs are also important sources of sediments in these areas where external sediment inputs are very small.

The quantitative relationship between fishery production and habitat has not been determined. Accordingly, the degree that habitat alterations have affected fishery production is unknown. Turner and Boesch (1987) assembled and examined the accumulating evidence of the relationship between the extent of wetland habitats and the yield of fishery species dependent on coastal bays and estuaries. They discussed evidence of stock losses following wetland losses and stock gains following wetland gains. While most of the studies were related to shrimp production, other fisheries likely follow similar trends. Accordingly, a significant threat facing fishery production is the loss of habitat by natural and human-related causes.

A. Natural Factors

Coastal processes may be dramatically altered by unpredictable, but natural events. These include shorter term forces such as storms, hurricanes, floods, etc., and longer-term events such as global warming and sea level rise. The latter may also be considered as a result of human activity. Affects vary from potentially positive to catastrophic. For example, a moderate storm may provide badly needed fresh water, flush stagnant systems, and provide a supply of nutrients from upland and high marsh surfaces. Severe events can lead to erosion, destruction of wetlands, subsidence, and severe short-term and possibly long range reduction in the ability of EFH to support fishery production. The eventual result of global changes is difficult to predict. However, it is evident that the coast and related wetland systems will change and that the ability of humans to affect this change will largely frame the outcome. With the extensive development along the coastlines, sea level rise can have serious consequences for humans, EFH, and the fishery resources that rely on coastal habitats.

Some of the more important natural factors that affect quantity and quality of habitat around the Islands are discussed below:

1. Tropical Disturbances

The passage of storms and hurricanes through mangroves and seagrasses can cause uprooting, mechanical defoliation, and deposition of sediment and other materials. This stress can eliminate vegetation from some areas. For mangroves, following the acute stress there is rapid re-establishment of new seedlings on suitable habitats, and the system restores itself. Seagrasses also may recover quickly if damage is slight and the substrate has not been too altered. Some storms may have beneficial effects on mangroves such as removing accumulations of materials choking drainage ways and reopening salt ponds to the sea. They are important agents that redistribute materials within the coast.

Damage to coral reefs in Puerto Rico and the US Virgin Islands due to natural phenomena has been well documented. A large portion of the Caribbean lies within the hurricane belt and therefore reefs are frequently exposed to severe hurricane related impacts. Hurricanes can modify substantial portions of shallow reefs. Two tropical storms in 1979 (David and Frederic) caused extensive damage on the outer east coast and southern coastal reefs, especially in the shallow *Acropora palmata* zone, off the eastern point of Vieques and off St. Croix (Goenaga and Cintrón 1979, Rogers 1982). Hurricane Hugo caused a significant reduction in total living scleractinian cover on reefs on the south side of St. John (Rogers *et al* 1991). It devastated portions of coral reefs and seagrass beds off St. Croix (Rogers *et al* 1991). Rogers *et al* (1991) were able to study the effect of Hurricane Hugo that hit the US Virgin Islands in 1989. Analysis of quantitative data collected before and after the storm allowed documentation of the effects of this powerful storm on coral community structure. The total living cover by scleractinians, including the dominant species, *Montastrea annularis*, decreased significantly. The amount of substrate available for colonization increased. Cover by macroscopic algae increased dramatically after the storm, later decreased, and then rose again one year later. In spite of the reduction in live cover by the dominant coral species, neither diversity nor evenness increased.

On the other hand, hurricanes may also be beneficial by displacing large numbers of fast growing, branching, coral species that monopolize the substrate thereby freeing space for slower growing, massive species. This appears to result in an increase in species diversity (Connell 1978), in the absence of additional stresses.

2. Hypersalinity

This affects mainly mangroves. The accumulation of high levels of salt through evaporation is a chronic natural stressor in dry areas. When evaporation exceeds rainfall throughout the year, tidal action and evaporation accumulate salt in the back areas of the swamp. Eventually the soil salinity increases beyond the tolerance of mangroves and a barren zone develops. Mangrove coverage in these areas is unstable, with coverage fluctuating between periods of expansions following storms or a succession of very wet years and contraction triggered by drought or silting of drainage ways. During different periods an area may undergo these changes and subsequently provide a great number of animals with food and other benefits.

3. Reef Diseases

Diseases are presented here as a natural factor because the mechanisms that cause them to proliferate are not well understood yet. Causative factors may eventually be shown to include factors such as water quality deterioration that may reduce an organism’s ability to withstand a disease or cause a disease organism to proliferated above normal background levels.

Coral diseases are known to attack reef corals in Puerto Rico and the US Virgin Islands. The white band disease, for example, has caused population declines in *A. palmata*. Vast stretches of living and healthy and *A. palmata* observed in Cayo Largo, Fajardo, in 1979, were severely decimated possibly as a consequence of this disease, and it has affected over 5 ha. of the *A. palmata* reef at Buck Island National Monument, St. Croix (Gladfelter 1982). The black band disease, caused by cyanobacteria, has been observed to affect corals in reefs of La Cordillera, Fajardo, and at the El Negro reef off the west coast of Puerto Rico, and also on corals in the Virgin Islands National Park on St. John and Buck Island, St. Croix (Peters 1984, Rogers and Teytaud 1988).

There is evidence that stress on coral reef ecosystems in the Caribbean region is increasing (Atwood *et al* 1992). Recently numerous authors have stated that the major stress results from "abnormally high" seasonal sea surface temperatures (SST) and have implicated global warming as a cause, stating that recent episodes of coral bleaching result therefrom. However, an analysis of available SST data sets shows no discernible warming trend that could cause an increase in coral bleaching. Given the lack of long-term records synoptic with observations of coral ecosystem health, there is insufficient evidence available to label temperatures observed in coincidence with recent regional bleaching events as "abnormally" high.

Edmunds (1991) determined the effect of Black Band Disease (BBD) among colonies of *M. annularis*, *M. cavernosa*, *Diploria strigosa*, *D. labryinthiformis*, *Siderastrea siderea* and *Colpophyllia natans* at 7 shallow locations in the Virgin Islands. Between September 1988 and November 1988, 0.2 percent of 9204 colonies of these species were infected with BBD in 6,908 sq meters of reef at 22 randomly chosen areas. Infected colonies were not clumped suggesting that the disease is not highly infectious between colonies. BBD infection rates in areas surveyed 4 times between August 1988 and September 1989 in Greater Lameshur Bay, St. John, US Virgin Islands, were significantly lower in winter compared to summer. BBDs were found on 5.5 percent of the colonies of D. strigosa) in fall 1988, and 7 out of 12 infected colonies lost > 75 percent of their tissue in 6 months. Low level, chronic BBD infections could convert 3.9 percent of the living cover of D. strigosa to free space per year, thereby creating substrata for successional processes.

Another source of stress to Caribbean reefs is massive coral bleaching (i.e., expulsion of zooxanthellae or their *in situ* degeneration) whereby coral growth rates are slowed down, and the capacity to heal from wounds is possibly impaired. Events of this nature occurred Caribbean-wide in 1987 and 1990 (Williams *et al* 1987; Goenaga and Canals, 1990). National Park staff on St. John observed bleaching in several hard coral species and in *Palythoa* in October of 1987. *D. labyrinthiformes* and *D. strigosa* were the most affected species and *Agaricia lamarcki* colonies as deep as 27 m were observed to have been bleached (Rogers and Teytaud 1988). Studies elsewhere in the Caribbean suggest that bleachings have been more severe in polluted areas.

Puerto Rican coral reefs were surveyed with photo-transect and remotely operated vehicle observations, and permanently tagged individual corals were monitored. Seven of eight photo-transect examined between April and October 1988 had bleached or pale colonies of eight species of corals. Between 2.7 and 19 precent of the living coral surface area was affected on a transect (Bunkley-Williams *et al* 1991). These observations indicate that additional bleaching occurred after the recovery of most photosymbiotic hosts in January 1988. This continued bleaching may represent the longest bleaching event ever recorded. Individual coral colonies that were bleached in October 1987 were permanently tagged and photo-documented in the field. Recovery of some of these colonies took more than 5 months. Some previously living parts of these colonies died and were overgrown by algae by January 1988. Surveys by remotely operated vehicle during 10-13 February 1988 disclosed bleached colonies of *Agaricia* spp. to a depth of 60 m and unbleached colonies to a depth of 89 m (Bunkley-Williams *et al* 1991).

The massive recent die-offs of the black sea urchin, *Diadema antillarum*, a major herbivore of coral reef systems, throughout the Caribbean have also contributed to the modification of corals and the coral reef habitat (Vicente and Goenaga 1984). Individuals of this species feed on the substrate, clearing it of fast-growing fleshy and filamentous algae and allowing coral larvae to settle and grow. Algal biomass within coral reefs has increased following the urchin die-offs. If other herbivores do not increase concomitantly, the growth in algal biomass is likely to increase the availability of algal propagules, thereby potentially reducing substrate for coral settlement. This situation is possibly worsened in artificially-eutrophied areas where algal growth is further stimulated.

4. Bioerosion

Bioerosion also constitutes a significant problem for Caribbean reefs. The proportion of reefs containing boring bivalves per coral head is higher in Caribbean reefs than in coral reefs in the Indian Ocean and in the western Pacific region (Highsmith 1981). Loss of skeletal mass by bioerosion obviously reduces reef growth. Although hard corals, coralline algae, and other marine invertebrates secrete calcium carbonate reef material, natural and man-made forces continue to erode these substrates. Therefore, additional pressure on coral and reefs through harvest and other anthropogenic activities could result in net loss of these resources over time.

B. Human-related Factors - Ecosystem-level Threats

The amount and rate of human-induced wetland losses have not been well quantified for the Islands, but development has been extensive and most of the land areas and nearshore areas have been modified as a consequence of urban, industrial, and commercial development. The Islands' economies rely heavily on the tourist trade and this has resulted in extensive nearshore development for hotels, motels, facilities for cruise ships, and the infrastructure needed to support the development. The coastal zone of Puerto Rico is more heavily developed than that of the US Virgin Islands. However, the development in both areas has progressed to the point where remaining coastal systems, including EFH, are already stressed and their ability to produce fishery resources is compromised. Coastal systems have been directly modified (e.g., dredged and filled) and thus they no longer serve as fishery habitat. Remaining coastal systems continue to be stressed indirectly by water quality degradation, sedimentation, thermal additions, and consequences of human activities such as vessel groundings in coral and SAV areas, oil spills, anchor damage to corals and SAV, etc. For example, human impacts on reef habitat result from activities such as pollution, dredging and salvage, boat anchor damage, fishing and diving related perturbations, and petroleum hydrocarbons (Jaap 1984).

Direct habitat removal or modification related to coastal development in the Islands over the last 15 years include barriers and impoundments; beach nourishment projects; bridges, roads, and causeways; docks, piers, and other structures; housing developments; commercial and industrial developments; etc.; maintenance dredging; navigation projects, ports, marinas, etc.; irrigation, flood control, and drainage works related to agriculture and urban development; oil, gas, and chemical pipelines; bulkheads, small fills, groins, etc.; transmission lines; power generating facilities; mining activities; and oil and gas development (Unpublished NMFS data). An additional problem of note is the proliferation of unauthorized fixed and floating structures that provide for human habitation. An example is the many unauthorized houseboats at La Parguera, Puerto Rico. These houseboats mostly have no contained sewage or trash collection facilities and seriously attenuate light needed by SAV that proliferates in the area.

Inshore, water quality degradation also is a threat to fishery habitat. This results from the discharge or spillage of petrochemicals, sewage, heavy metals, and other chemicals in industrial and chemical wastes and from non-point-source discharges such as from septic tanks and parking lots. Urban and agricultural runoff can be laden with toxic substances such as petrochemicals, pesticides, heavy metals, and herbicides. Thermal effluent from power generating facilities cooling can raise the temperature of nearshore waters making them less suitable or uninhabitable by aquatic species, especially during summer. The discharge of sewage also can create problems for the organisms that reside in the waters where the discharge occurs.

Offshore species, may be adversely affected due to the discharge of petroleum products and the Islands have been subject to repeated oil spills over the years . Malins (1982) reviewed laboratory experiments describing the deleterious effects of petroleum fractions on fish. Grizzle (1981) and Pierce et al. (1980) have documented that wild fish have been injured by petroleum pollutants. Grizzle (1983) suspected that severe gill lamella epithelium hyperplasia and edema in fish were caused by toxicants near oil and gas production facilities. These types of lesions are consistent with toxicosis. The kinds of effects listed above also could result from major spills.

Specific information on localized human effects on the Islands' coastal areas are observable, but not well documented. However, their effects on EFH can be discussed in general terms and many of the specific coastal modifications can produce a variety of individual and synergistic effects. For example, a development in or near an aquatic system can directly destroy it and then continue to affect adjacent aquatic systems by way of runoff from hard or other impervious surfaces. Accordingly, the categories of threats that follow can be produced by a number of individual or related and unrelated activities. These threats are discussed in terms of broad categories of issues that can be affected by many different development scenarios and by specific types of developments that have occurred in the Islands. Appendix A provides a listing of the activities that may constitute a threat to EFH.

1. Anthropogenic stressors on Coral Reefs

The effects of human activities on reefs broadly depend on two factors: the distance of the reefs from shore (inshore or offshore), and the general health of the reefs. Many reefs in Puerto Rico have suffered considerable damage from human activities. Extensive coral reef degradation has been observed at the following sites: 1) all reefs from San Juan to Las Cabezas de San Juan, 2) inshore Fajardo reefs, 3) Humacao reefs, 4) annular reef off Puerto Yabucoa, 5) inshore Ponce reefs, 6) all reefs off Bahia Guayanilla and Bahia de Tallaboa, 7) all reefs off, and fringing, Guánica, 8) all west coast inshore reefs from Bogueron to Rincon, 9) reefs off Arecibo, and 10) reefs off Dorado.

In the US Virgin Islands damage is being done to reefs at both inshore and offshore areas: on the shelf edge, Long Reef, Teague Bay reef, of St. Croix, Brewers Bay, north coast, Mandahl Bay, Magens Bay, Sapphire Bay (Red Bay) St. Thomas, and Bays in St. John's National Park (US Department of the Interior), Cruz Bay, Trunk Bay and Trunk Cay, Johnson's Reef, Windswept Beach, St. John.

Damage to reefs around the islands, and, by extension, organisms closely associated with reef habitats, is being caused by one or several of the following factors: sedimentation and siltation;

eutrophication; pollution (toxic and thermal); physical damage and overfishing. The CFMC Coral Reef Conservation Working Group has listed 24 human activities detrimental to coral reefs. Overall, and on a worldwide scale the most serious damage is caused by collection of shells, corals and fish; sedimentation from freshwater runoffs; and dredging activities. These sources of damage are also among those to which reefs of Puerto Rico the US Virgin Islands are most commonly subjected, although not necessarily in the same order of severity.

2. Eutrophication

In many coastal regions, including the wider Caribbean coastal areas, there is large-scale, and in some cases chronic, eutrophication (Gabric and Bell 1993). In some regions, the link between eutrophication and the destruction of an ecosystem is obvious, with excessive algal growth and water-column anoxia. In other cases, particularly in more fragile ecosystems such as coral-reef and seagrass areas, the links are not so obvious, yet the impacts of eutrophication in such regions can be devastating. Eutrophication can have more insidious effects such as contributing directly to the mortality of fish, marine mammals, and sea birds and indirectly to disease or death in humans owing to the accumulation of biotoxins in seafood. Increased development and changes in land-use patterns in the coastal zone have increased the loading of diffuse or non-point nutrients. In areas subject to runoff and soil erosion, most of the nutrient load is transported in particulate form. In such cases, the loads of nutrients discharged from cropping lands are typically an order of magnitude greater than those discharged from pristine forested areas. Nutrient export from pasture lands, whether these are fertilized or not, is also significantly greater than that from pristine areas, and in many cases the total loads from such areas are far higher than those from intensively farmed areas. A reduction in nutrient discharges to coastal waters will require careful land-use planning. The importance of the particulate fraction in the nutrient load necessitates effective control of soil erosion. The hydrological and nutrient linkage between terrestrial and marine ecosystems must be emphasized. Collective management of hinterland and coastal-zone resources could initiate remediation of a serious and growing problem.

Eutrophication by sewage disposal or land drainage in Puerto Rico and the US Virgin Islands stimulate algal blooms which will outcompete or displace slower-growing organisms, such as corals. This can result in the proliferation of organisms that compete with, or damage, corals (e.g., burrowing bivalves and boring algae and sponges). Sewage pollution is known to stress reefs (Rogers 1985). In Puerto Rico, coral reefs growing close to sanitary discharges show proliferations of green algae. When he was head of the Environmental Protection Agency in the Caribbean, Pedro Gelabert stated that "45 percent of the Puerto Rican coasts are too polluted to swim in them..." (El Nuevo Día, 13 March, 1991; page 29) and points to raw sewage discharge as one of the main pollutants. Excessive nutrient enrichment of seagrass beds could result in the replacement of seagrass with phytoplankton or benthic algae. In the US Virgin Islands, the proliferation of residential septic tanks has resulted in high soil loading which, during high rainfall, generates nutrient-rich runoff into the sea. This has caused shortterm eutrophic conditions in various bays around St. Thomas and St. Croix. Nutrient levels (total phosphorus, total Kjeldahl nitrogen, ammonia, nitrate and nitrite, dissolved oxygen, and Ph) were recorded to be generally higher along coastal areas of Puerto Rico than in the US Virgin

Islands (Tetra Tech 1992). The most significant source of nutrients in Puerto Rico was found to be coastal municipal point sources (Tetra Tech 1992).

Extreme enrichment seriously stresses wetlands and associated fauna other than coral reefs. Pollution by fecal bacteria and viral agents pose some very serious health hazards. Commercially valuable species may become vectors of serious water borne diseases and toxic substances which can be incorporated into the food web. Nutrient enrichment of the coastal waters, mainly by the dumping of poorly treated water or raw sewage directly into the ocean or into rivers and creeks stresses mangroves and seagrass. Coral reefs, however, can be the most seriously impacted. High nutrient concentrations stimulate high phytoplankton productivity as well as high productivity by benthic algae (Birkland 1977) which will favor the establishment of organisms that compete or damage corals (such as burrowing bivalves and boring algae and sponges). High recruitment by benthic algae would reduce the substrate available for coral larvae settlement and may result in the young corals being overgrown (Birkland 1977). Heavy metal accumulations in sediment and reef biota near population centers also have been noted (Manker 1975). Disposal of wastes may further create local problems.

3. Sedimentation

The principal concerns in Puerto Rico and the US Virgin Islands are siltation and sedimentation following removal of upland vegetation, and eutrophication particularly in areas adjacent to inshore reefs. Sedimentation and turbidity decrease the amount of light, a vital source of energy, available to corals for the photosynthetic fixation of calcium carbonate, reducing growth rates (Lasker 1980) or causing burial and death of fish, invertebrates and plants. Sedimentation also reduces substrate available for the settlement of coral and other larvae. Turbidity has clearly been shown to influence fish abundance and diversity. In Torrecilla Lagoon, Puerto Rico, sedimentation from dredging and organic pollution from sewage treatment plants almost destroyed reefs northwest of Boca de Cangrejos. Areas of reduced live coral cover occur around Puerto Las Mareas and Ponce due to terrigenous sediments from rivers (Tetra Tech 1992). The low percent coral cover in Guayanilla Canyon was attributed to the resuspension of sediments by local shipping traffic (Morelock *et al* 1979).

A number of examples in both Puerto Rico and the US Virgin Islands are available regarding the detrimental effects of the removal of upland vegetation without the use of appropriate land conservation practices. In southwestern Puerto Rico, for example, it is not uncommon to observe large sediment plumes after heavy rains where mangroves have been removed and replaced with stilt houses. The pattern of estimated sediment loading from point sources was heaviest on the north coast with the south and west coasts running close behind. The lowest estimated point source sediment discharge was for the east coast (Tetra Tech 1992). Nonpoint sources of sediment loading from rivers was greatest on the west coast, followed by the north coast and ranged from 16-59 times greater than sediment loading from point sources in all areas but the north coast (Tetra Tech 1992). Production of sediment may be 10,000 times greater for a construction area than from a vegetation-layered area. For example, the Loiza Basin produces around 115 tons of sediment per square mile, per year and a development area may produce 96, 000 tons annually per square mile (Richard Webb personnal communication). Mitigation of the negative impacts of increased sedimentation is possible and is an important part of soil conservation practice which has been largely ignored in the islands.

In the US Virgin Islands siltation from heavy housing development on the north coast of St. Thomas is a matter of concern in the area, although few data are available on point and nonpoint source sediment loading in the US Virgin Islands. Mean coastal water turbidity was found to be greater for Puerto Rico than for the US Virgin Islands (Tetra Tech 1992).

Sedimentation is an important factor determining the abundance, growth and distribution of corals. Either natural or man induced, it is detrimental to corals (Dodge and Vaisnys 1977). Although most corals have effective means of shedding sediments which have fallen on their tissues, sedimentation and turbidity will decrease the amount of light available to the corals for the photosynthetic fixation of calcium carbonate, thereby reducing calcification rates (Lasker 1980). Other than increasing turbidity, sedimentation may limit reef corals by smothering, increasing energy expenditure in particle rejection, smothering, increasing potential for bacterial infection, abrasion, creation of conditions unsuitable for larval settlement, alteration of feeding habits, alteration of food supplies such as plankton, and alteration of species composition on reefs.

Abdel-Salam *et al* (1988) exposed three species of corals, *A. palmata*, *D. strigosa*, and *M. annularis* to the same weight of sediment. Corals were exposed to sediment during daylight and darkness. Oxygen production and consumption were measured by respirometry; sediment removed by corals was collected simultaneously. All corals exposed to sediments showed an increase in respiration rate at night and a decrease in net photosynthesis during the day. Lowered net photosynthesis was due to both light shading and respiratory increase. Integrated 24 hour P/R ratios for control and sediment-exposed corals were calculated. All control corals had naturally occurring P/R ratios in excess of 1.0, but the sediment treated corals, without exception, had ratios significantly below 1.0, mostly due to high respiration during sediment rejection. *M. annularis* and *D. strigosa* have very high clearing rates relative to *A. palmata*.

Sediments also can affect mangroves by modifying elevations and resulting in species shifts or conversion of wetlands to upland characteristics. SAV can be adversely affected if light transmission is altered or if enough sediments are released that SAV is killed. Within climax SAV communities such as *T. testudinum*, once destroyed, this habitat may never reestablish or at least require an extensive time period to recover.

4. Pollution

Toxic and thermal pollution derive from agricultural, industrial, and residential origin and include toxins, biological pathogens, sediments and thermal inputs (Tetra Tech 1992). This report found that "Fourteen heavy metals were detected rather frequently in the marine and estuarine waters of Puerto Rico. The highest levels of arsenic, cadmium, chromium, cyanide, mercury, nickel, thallium, and zinc were found along the coastal areas of Region 1 (north coast), primarily near San Juan harbor. The highest levels of aluminum, beryllium, copper, lead, and silver were detected in Region 3 (south coast) ... several of these heavy metals may potentially impair aquatic life and may cause risks to human health from ingestion of contaminated fish. Water monitoring for inorganics in Puerto Rico has declined somewhat in the last few years". The location of the principal sources of point and nonpoint pollution along coastal waters of Puerto Rico are shown in a TetraTech report and extend along all four coasts of the main island (TetraTech 1992).

Pollution by fecal bacteria and viral agents from inadequate sewage disposal practices can impact the reef environment and pose serious health hazards in coastal waters. In Puerto Rico numerous coastal locations exceeded the fecal coliform standard by factors sometimes exceeding 100 times the standard. San Juan, Fajardo, Humacao, Guayama, Ponce and Mayagüez are examples of such locations (TetraTech 1992). Beach closures, which can have a negative impact on tourism, have been implemented as a result of elevated pathogen levels in surface waters, trash disposal from ships, lost commercial fishing gear, and inadequate sewer systems. Condado, Guánica and Cataño beaches have all been closed recently due to various pollution problems (TetraTech 1992). As a result of pollution, Puerto Rico's coastal waters did not meet the swimmable goals 31 percent of the time. No data on swimmable goals are available for the US Virgin Islands.

Point source discharges related to urbanization derive mainly from municipal sewage treatment facilities or storm water discharges that are controlled through Environmental Protection Agency (EPA) mandated regulations under the Clean Water Act and by state water quality regulations. Threats related to these discharges are probably less important than the other factors previously discussed because efforts are underway to improve treatment. The primary concerns with municipal point-source discharges involve treatment levels needed to attain acceptable nutrient inputs and overloading of treatment systems due to rapid development of the coastal zone. In locations where treatment is poor or water conditions unsuitable for adequate dilution of discharges, EFH may be adversely affected. The primary concern would be excessive nutrification of receiving waters, but other concerns such as discussed for non-point-source discharges also apply.

The EPA withdrew the storm water Phase II direct final rule published on April 7,1995 (60 FR 17950) and promulgated a new final rule in its place (60 FR 17958). This action by the EPA instituted changes to the National Pollutant Discharge Elimination system (NPDES) stormwater permit application regulations under the Clean Water Act for Phase II dischargers. Phase II dischargers generally include all point-source discharges of storm water from commercial, retail, light industrial and institutional facilities and from municipal separate storm sewer systems serving populations of less than 100,000. This rule establishes a sequential application process in two tiers for all Phase II stormwater discharges. The first tier provides the NPDES permitting authority flexibility to require permits for those Phase II dischargers that are determined to be contributing to a water quality impairment or are a significant contributor of pollutants to waters of the US "Permitting authority" refers to the EPA or States and Indian Tribes with approved NPDES programs. The EPA expects this group to be small because most of these types of dischargers have already been included under Phase I of the storm water program.

The second tier includes all other Phase II dischargers. This larger group will be required to apply for permits by the end of six years, but only if the Phase II regulatory program in place at that time requires permits. The EPA has stated that it is open to, and committed to, exploring a number of non-permit control strategies for the Phase II program that will allow efficient and effective targeting of real environmental problems. As part of this commitment, the EPA has initiated a process to include stakeholders in the development of a supplemental Phase II rule under the Federal Advisory Committee Act. This rule will be finalized by March 1, 1999, and will determine the nature and extent of requirements, if any, that will apply to the various types of Phase II facilities prior to the end of the six-year application period defined by the rule.

5. Physical Damage

Physical damage related to navigation is caused by dredging, anchoring, military maneuvers and certain harvest methods. Dredging activities to remove sand or beachrock not only result in siltation and increased turbidity, but also cause mechanical damage to reefs or complete substrate removal. Moreover, waters over dredged areas have significantly more bacteria than neighboring seawater (Galzin 1981). In Benner Bay, St. Thomas, toxic materials were resuspended into the water column during dredging where toxic metals from antifouling paints had leached into the water and adsorbed onto bottom sediments; metals may be detrimental to corals by impairing their physiological processes and possibly by weakening the structure of the aragonite skeleton (Howard and Brown 1984). Dredging activities are apparently not monitored in waters of Puerto Rico and the US Virgin Islands.

Anchoring on top of corals can considerably disrupt coral reef communities and is a serious concern as boating and tourism increase in reef areas. Between January and March 1987, Rogers and Teytaud (1988) studied anchor damage in several northern and northwestern bays on St. John. Of the 186 boats surveyed, 32 percent were anchored in seagrass and 14 percent in coral. With an estimated 30,000 anchors being dropped in Park waters each year, this can result in considerable physical disruption of these areas. Anchor chains can do more damage than anchors as they drag across the bottom. In 1989, a 440-foot sailing cruise ship, the "Wind Spirit" dropped its anchor on a reef off northern St. John and destroyed some 300 m^2 of coral reef. Extensive touristic activities, including boating and diving, are resulting in considerable damage from anchors and boat groundings. At Windswept Reef on the north shore of St. John, an average of five boats per week were striking the reef prior to installation of marker buoys, which considerably reduced the frequency of groundings. Heavy anchoring from boating activities also occurs in reef areas around La Parguera, southwestern Puerto Rico, off islands of northeastern Puerto Rico, and off the Caja de Muertos Island, south of Ponce.

In 1997, the 326-foot Fortuna Reefer grounded near a Commonwealth of Puerto Rico Natural Reserve off the west coast of Mona island. The vessel injured a barrier reef that extends approximately 10 miles from the eastern end of the island along the southern coast and around to the northwest. The reef is populated with large, branching "old growth" elkhorn corals, which were injured by the grounding. The remoteness of the grounding site hampered salvage efforts and the vessel remained aground for eight days. The grounding and subsequent salvage activities caused a swath of physical damage to the reef surface, measuring approximately 900 feet in length by 50 to 100 feet wide.

Military maneuvers near coral reefs are practiced in Vieques, off eastern Puerto Rico. These activities have resulted in direct physical damage and indirectly from damage from deposition of coarse sediments on Vieques reefs. Large numbers of unexploded ordnance on these reefs limit their future utilization as fishing or touristic centers.

The use of various harvest methods in reef areas can cause direct physical damage to reef structure and can reduce the percentage cover of live coral. For example, the placement of fish traps on top of reefs, careless use of barrier nets to capture fish, the use of crowbars or other tools to remove substrate and live-rock, manual displacement of coral heads to collect organisms underneath, and the use of chemicals, all threaten to damage the reef and reef-associated organisms. Harvest of liverock directly removes substrate and invertebrate communities with the additional problem of inadvertent inclusion of young coral colonies. Reduction of coral and reef heterogeneity due to damage or removal of physical structure can seriously impact available shelter for juvenile fishes and larval settlement and there is likely a correlation between topographic relief and fish abundance.

6. Oil Pollution

Mangroves are extremely sensitive to oil pollution. Oil fouls the intertidal root region where gas exchange takes place. A heavy coating of oil generally leads to death. In addition to the mechanical damage caused by coating, oil may be toxic and poisonous to the trees. Since the toxic fractions come in contact with the roots, where vital functions take place, toxic products cause rapid mortality. Residual amounts of the spilled product may remain trapped in the sediment for a very long time. As a result, natural restoration may be very slow, if at all. There are no effective ways to clean up mangroves because efforts are labor intensive, costly, and inefficient. Only protection by booming can reduce damages. Corals and SAV may be similarly affected if the oil or constituents within the oil come in contact. Mortality would result and prospects for recovery may be poor or very long term if the event is severe and the oil remains persistent for a long time.

7. Channelization

This threat is mostly a problem for Puerto Rico. The extensive development on the uplands has resulted in extensive channelization and other alterations of the rivers and streams related to agriculture, flood control, consumptive water uses, etc. While most of these works are located well above the limits of EFH, the modification of water flows and hydrology often produce serious side effects well down stream. An increase or decrease in nutrient flows may be observed; point and non-point-source discharges of contaminants to EFH may be increased; salinity regimes may be modified and lead to Hypersalinity or hyposalinity; and sedimentation may be increased. Channelization also may adversely affect Puerto Rico's mountain mullet (*Agnostomus monticola*) an anadromous species. No recovery is possible and massive die-offs may occur unless the fresh water source is restored.

8. Global Warming

Global temperature increases of a degree or two can cause sea level rise if melting of the Arctic tundra and ice cap follow. Possible effects include: significant loss of coral reefs, salt marshes, and mangrove swamps that are unable to keep up with sea level rise; loss of species whose temperature tolerance ranges are exceeded (this could be especially problematic for corals); elevated nutrient and sediment loading; saltwater intrusion into freshwater ecosystems such as freshwater marshes and forested wetlands; invasion of warmer water species into areas occupied by cooler habitat species; and physical changes that could have much broader implications by altering flows, food chains, and climate (USDC 1997). The severity of impact on natural resources, including certain EFH will be determined by natural and human obstruction to inland habitat shifts, resilience of species and populations to withstand changes in environmental conditions, and the rate of environmental change (USDC 1997).

Consequences of global warming may include rising sea levels and an overall increase in water temperature. Natural heat sinks are decreasing because coral reefs, as well as rain forests, are being destroyed at an increasing rate (Goreau 1992). A major part of human-induced climate change can be controlled by balancing the sources and sinks of atmospheric carbon dioxide (CO2). To balance CO2 flows it will be necessary to restore and protect both these tropical ecosystems and/or to make drastic cuts in fossil-fuel use. If this is not done, the rural poor will have little choice but to destroy remaining forests and coral reefs (Goreau 1992). Stabilization of CO2 is technically feasible and cheaper than adapting to climate change. It is also extremely urgent because many coral reef ecosystems may already be near their upper temperature limits.

C. Development and Related Threats

1. Barriers and Impoundments

Between 1981 and 1996 the NMFS received for review 31 applications from Puerto Rico and two from the US Virgin Islands to construct barriers or impoundments. In Puerto Rico, these were mostly projects associated with governmental units such as the Puerto Rico Aqueduct and Sewer Authority and mainly for municipal and industrial water supplies. In the US Virgin Islands the few received were mostly minor works associated with industrial or commercial uses. These activities occurred mostly well inland and their affect on EFH is not well known.

Potential threats to EFH include direct effects of impoundments and other barriers are removal of habitat, conversion of habitat away from historic usage, alteration of hydrology, and modification of water quality by modification of temperature, salinity, and nutrient and sediment fluxes. Flow regimes often are controlled and differ substantially from preimpoundment flows. This can adversely affect anadromous fish migration and spawning as well as food production for prey species needed by larvae and juveniles.

Impoundments also can occur when roads are built through wetlands and no provision is made to preserve water flows. In the Islands this practice affects mangrove wetlands the most. Impounding may cause water levels to rise, suffocating the trees (Cintron 1987). The results of impoundment is rapid because tidal range is small and evaporation is high. In some cases when dikes are abandoned, partial recovery may occur.

2. Beach Nourishment Projects

Threats from beach nourishment include those resulting from the dredging of sand for nourishment and the filling of nearshore EFH. Potential threats of sand dredging include removal of substrates that provide habitat for fish and invertebrates; creation (or conversion) of habitats to less productive or uninhabitable sites such as anoxic holes or silt bottom; burial of productive habitats in the vicinity of the dredging site or in nearshore beach nourishment sites; release of harmful or toxic materials either with actual mining, or in connection with machinery and materials used for mining; creation of harmful turbidity levels; and modification of hydrologic conditions that cause erosion of desirable habitats.

Recent studies on beach nourishment effects along the south Atlantic coast of the US have shown that nearshore hard bottom areas provide developmental habitat for many important commercially and recreationally important marine fish (Lindeman 1997; Lindeman and Sayder, in press). The beaches and nearshore waters along the Islands probably provide similar habitat and certainly provide habitat for marine turtles.

In the last 15 years there have been 15 proposals to nourish beaches; eight from Puerto Rico and seven for the US Virgin Islands. These activities have been mostly small and local such as work associated with a specific resort or hotel. Accordingly, these have not entailed the same degree of threat as observed along the beaches of the mainland US However, as information continues to develop on nearshore EFH and coastal processes, future projects must be carefully evaluated against this information to ensure that EFH is not damaged.

3. Bridges, Roads, and Causeways

Potential effects to EFH include the direct destruction of coastal habitats, impounding of wetlands, segmenting of habitats and near and long-term effects on fisheries production by removing nutrient production associated with filled wetlands and by reducing available habitat. Indirect effects may include the alteration of hydrology and increased non-point-source discharges of materials such as oil, gasoline, and grease from vehicle traffic. New roadways may also increase development and this development can result in the destruction, modification, or reduction in quality of remaining habitats.

The NMFS received 60 requests since 1981 (59 in Puerto Rico and 1 in the US Virgin Islands) to build new roadways or improve existing ones. As populations increase and existing infrastructure ages, the demands to build or expand or improve existing roads, causeways, and bridges will present important threats to EFH. These must be evaluated accordingly to ensure that EFH is minimally impacted by new construction and that adverse effects of old construction be mitigated.

4. Docks, Piers, and Other Structures

The overall biological effects of piers and docks has not been well quantified. However, between 1981 and 1996, the NMFS reviewed requests for close to 532 piers and docks from the Islands.

Accordingly, these represent a substantial feature in Caribbean waters and warrant further attention in the future.

Construction of piers and docks undoubtedly impact EFH, but the degree of the impact is not known and would be largely dependent on the size, location, and number of similar structures in a given. Construction involves jetting of pilings and this has a temporary and localized affect on EFH from increased sedimentation and minor habitat displacement. Sedimentation may be a problem in systems that are already stressed such as SAV habitats that are already declining or marginal because of low water clarity. The pilings are treated and undoubtedly release chemicals into the water, but this is not perceived to be a large problem because the pilings eventually support the growth of encrusting and fouling organisms. Perhaps the greatest threat arises from shading and this threat increases in vegetated areas, especially SAV, and where a proliferation of piers and docks occur. Where SAV occurs in light conditions that are poor, shading may reduce available light enough that SAV can no longer survive. It has also been observed that intertidal marsh fails to survive under some of the larger structures. On the positive side, these structures provide some vertical habitat that usually are attractive to various encrusting organisms. This may provide some habitat diversity, but whether or not this is beneficial is unknown.

A concern over pier and dock construction arises when these structures are placed in shallow water areas that are too shallow or only marginally so for navigation. Vessel operation becomes a threat to EFH in these areas. Effects on vegetated and unvegetated bottoms are the same as for prop scarring, wake damage, and propwashing. It has been observed that areas where depths are marginal, habitat damage located around piers and docks may be substantial and disproportionately large for areas where these structures proliferate (Ludwig *et al* 1997).

5. Housing Developments

The coastal areas of the Caribbean are highly sought after as places to live. The amenities of the coast and the water-related activities and climate that people enjoy produce high growth rates. As the population increases so does urbanization. People require places to live as well as related services such as roads, schools, water and sewer facilities, power, etc. These needs often are met at the expense of EFH and may adversely impact the very values that brought people to the coast. Wetlands and adjacent contiguous lands have been filled for housing and infrastructure. Further, the demand for shoreline modifications (docks, seawalls, etc.) and navigation amenities has further modified the coast. Chemicals produced and used by people also find their way into the waters as point-source and non-point-source runoff. An example is the oil from roads, parking lots, etc. This has lowered water quality in waters and wetlands adjacent to urban developments. As a result, the quality of EFH is often much reduced.

Potential threats include conversion of wetlands to sites for residential and related purposes such as roads, bridges, parking lots, commercial facilities, reservoirs, hydropower generation facilities, and utility corridors; direct and/or non-point-source discharge of fill, nutrients, chemicals, cooling water, and surface waters into ground water, streams, rivers and estuaries; hydrological modification to include ditches, dikes, flood control and other similar structures; damage to wetlands and submerged bottoms; and cumulative and synergistic effects caused by association of these and other developmental and non-developmental related activities.

Wetlands and other important coastal habitats continue to be adversely and irreversibly altered for urban and suburban development. Related activities such as navigation are discussed later. One of the most serious of the adverse effects is filling for houses, roads, septic tank systems, etc. This directly removes EFH and degrades EFH that lies next to developed areas. While the total affected area is unknown, it has been extensive in the Islands and its footprint is readily observable. Between 1981 and 1996 the NMFS reviewed more than 265 proposals requesting to alter EFH for housing-related development. The amount of acreage involved in a subsample of these proposals was more than 227 acres for only 17 of the projects that were surveyed (see Tables 1 through 5).

Another major threat posed by housing development is that of point and non-point-source discharges of the chemicals used in day to day activities, in operating and maintaining homes, for maintaining roads, for fueling vehicles, etc. In addition to chemical input, changes that affect the volume, rate, location, frequency, and duration of surface water runoff into coastal rivers and tidal waters are likely to be determinants in the distribution, species composition, abundance, and health of Caribbean fishery resources and their habitat. In the long-term, impacts of chemical pollution (e.g., petroleum hydrocarbons, halogenated hydrocarbons, metals, etc.) are likely to adversely impact fish populations (Schaaf *et al* 1987). Despite current pollution control measures and stricter environmental laws, toxic organic and inorganic chemicals continue to be introduced into marine and estuarine environments.

6. Commercial and Industrial Developments

The Caribbean is a prime location for industrial siting. The climate is favorable, economic incentives exist, there is an adequate labor base, and the infrastructure for shipping of supplies and products is well developed. Further, many industries are heavy water users and rivers and streams are abundant, at least in Puerto Rico. Examples of dominant industries include pharmaceutical production, fish processing, manufacturing, etc.

The hotel and resort industry also is a vital part of the Islands' economies. Most of the Caribbean's most popular vacation spots are located on or near the coast. Together with the growing coastal population, the demand for coastal recreational opportunities and the stress on natural systems as a result of increased tourist visits are expected to grow.

Potential threats from industrial and commercial development include conversion of wetlands to industrial and appurtenant sites such as roads, parking, and administrative and distribution centers; point and non-point-source discharge of fill, nutrients, chemicals, cooling water, air emissions, and surface and ground waters into streams, rivers, estuaries and ocean waters; hydrological modification to include ditches, dikes, water and waste lagoons; intake and discharge systems; hydropower facilities; and cumulative and synergistic effects caused by association of these and other industrial and non-industrial related activities.

Industrial and commercial development affect EFH in a number of ways. The most inexpensive land is usually sought for development near major shipping lanes such as rivers or ports. These lands usually contain wetlands and these wetlands are generally filled for plant siting, parking, storage and shipping, and treatment or storage of wastes or by-products. At locations near EFH these facilities, because of an abundance of hard impervious surfaces, are often a major source of non-point-source contaminants. Many industries are heavy water users. Water often is a vital component of the manufacturing process, serves as a cooling mechanism, and is used to dilute and get rid of wastes or other by-products. Many heavy industries produce airborne emissions that often include contaminants. Albeit the Islands benefits from their location and the almost constant trade winds and atmospheric deposition is likely not a large problem yet.

Commercial development along the Caribbean coast also has been extensive. Few coastal areas or barrier islands exist that have not been subject to some form of commercial development, targeting mainly the tourist trade. Past development practices have been especially abusive where, before adequate regulation, it was not uncommon for extensive nearshore modifications to take place for hotel and resort construction. This has now abated largely because most of the coast has already been developed and because better information and regulation have explained the damage to natural resources caused by this practice. However, it remains a fact that fast land is a decreasing commodity along the coast and that filling of wetlands is viewed as a less expensive alternative. Accordingly, there will continue to be proposals aimed at altering wetlands for commercial development and related infrastructure and these must be carefully assessed to minimize their impact on remaining EFH.

The overall amount of EFH lost to or effected by commercial and industrial development is unknown, but extensive. These form a dominant part of the Islands' landscapes and are a readily observable feature. More specifically, NMFS data showed that between 1981 and 1996, 197 proposals were received for industrial and commercial development. About 299 acres of EFH were requested for alteration by only 16 of these proposals (see Tables 1 through 5). Its is expected that wetland conversion has undoubtedly lessened because available land is at a premium, but where industrial and commercial expansion are proposed, they become a prominent part of the landscape and a major commitment of natural resources. Further, expansion of existing facilities poses the same risks. They must, therefore, be carefully assessed to minimize their long-term effects on EFH.

Point-source-discharges from commercial development follow the same risks imposed for urban and suburban development and the discussions under "Housing Development" apply. Industrial point-source-discharges are of greater concern because of their quantity and content. They can alter the diversity, nutrient and energy transfer, productivity, biomass, density, stability, connectivity, and species richness and evenness of ecosystems and the communities at the discharge points and further downstream (Carins 1980). Growth, visual acuity, swimming speed, equilibrium, feeding rate, response time to stimuli, predation rate, photosynthetic rate, spawning seasons, migration routes, and resistance to disease and parasites of finfish, shellfish, and related organisms also may be altered. In addition to direct effects on plant and animal physiology, pollution effects may be related to changes in water flow, PH, hardness, dissolved oxygen, and other parameters that affect individuals, populations, and communities (Carins 1980). Some industries, such as paper mills, are major water users and the effluent dominates the conditions of the rivers where they are located. Usually parameters such as dissolved oxygen, PH, nutrients, temperature, changes, and suspended materials are the factors that have the greatest affect on EFH. The direct and synergistic effects of other discharge components such as heavy metals and various chemical compounds are not well understood, but preliminary results of research is showing that these constituents will be a major concern for the future. More subtle factors such as endocrine disruption in aquatic organisms and reduced ability to reproduce or compete for food are being observed (Scott *et al* 1997).

The cumulative effect of many types of discharges on various aquatic systems also is not well understood, but attempts to mediate their effects are reflected in various water quality standards and programs in each state and within the various water systems. Industrial wastewater effluent is regulated by the EPA through the NPDES permitting program. This program provides for issuance of waste discharge permits as a means of identifying, defining, and controlling virtually all point-source-discharges. The complexity and the magnitude of effort required to administer the NPDES permit program limit overview of the program and federal agencies such as the NMFS and the FWS generally do not provide comments on NPDES permit notices. For these same reasons, it is not possible to presently estimate the singular, combined, and synergistic effects of industrial (and domestic) discharges on aquatic ecosystems.

Little is known about non-point-source discharges from industrial activities. Their affects, however, are likely to be at least as important as those from urban and suburban development. In some situations, especially for industries that produce hazardous materials, non-point-source discharges can be a traumatic events, especially if there are accidental releases of chemicals. An added concern with industrial operations are contaminants that are emitted into the atmosphere. The types and levels of contaminants reaching Caribbean surface waters is unknown, but hopefully have a marginal effect because of dispersal by the almost constant trade winds.

7. Navigation Projects, Ports, Marinas, and Maintenance Dredging

Navigation in the Caribbean has resulted in the widespread modification of subtidal and intertidal area in support of commercial vessels and recreational boats. These included the construction and maintenance of ports and marinas and related channels. Several major ports exist such as the Port at San Juan, several commercial fishing-related port facilities, and the cruise ship ports in Puerto Rico and the US Virgin Islands. There are numerous recreationally-based marinas and basins that have altered EFH. Dredged material disposal and disposal of contaminated sediments is a dominant issue. The filling of wetlands and the conversion of EFH from shallow to deeper water also are threats as they relate to construction of new facilities or the maintenance and expansion of old ones. In the last 15 years, the NMFS has received for review 224 proposals for new navigation projects and maintenance or expansion of existing facilities and channels. Of the 224 proposals, 18 of them involved the alteration of 294 acres of EFH.

A second major concern is a host of environmental problems associated with vessel operations. These range from contamination of water by oil, grease, anti-fouling paints, sewage discharges, garbage and debris to the direct destruction of EFH by grounding, anchor damage, propwashing and scarring, etc. Most of the physical damage is accidental, but frequent; some such as propwashing can be intentional.

Potential navigation-related threats to EFH located within estuarine waters can be separated into two categories: Navigation Support Activities and Vessel Operations. Navigation support activities include, but are not limited to, excavation and maintenance of channels (includes disposal of excavated materials); construction and operation of ports, mooring and cargo handling facilities; construction and operation of ship repair facilities; and construction of channel stabilization structures such as jetties and revetments. Potentially harmful vessel operations activities include, but are not limited to: discharge or spillage of fuel, oil, grease, paints, solvents, trash, and cargo; grounding/sinking/prop scaring in ecologically/environmentally sensitive locations; exacerbation of shoreline erosion due to wakes; and transfer and introduction of exotic and harmful organisms through ballast water discharge.

The most conspicuous navigation-related activity in many estuarine waters is the construction and maintenance of navigation channels and the related disposal of dredged materials. The amount of subtidal and intertidal area affected by new dredging and maintenance dredging is unknown, but undoubtedly great. These activities have adversely affected and continue to adversely affect EFH by modifying intertidal and subtidal habitats, filling EFH for dredged material disposal and construction of facilities, and in some cases adversely affecting EFH by releasing contaminants and suspending fine sediments. For more extensive dredged features and related disposal sites, hydrology and waterflow patterns also have been modified. While the channel excavation itself is usually visible only while the dredge or other equipment is in the area, the need to dispose of excavated materials has left its mark in the form of confined and unconfined disposal sites, including those that have undergone human occupation and development. Chronic and individually small discharges and disturbances routinely affect water and substrate and may be significant from a cumulative or synergistic perspective. EFH effects generally observed include, direct removal/burial of organisms as a result of dredging and placement of dredged material; turbidity/siltation effects, including increased light attenuation from turbidity; contaminant release and uptake, including nutrients, metals, and organics; release of oxygen consuming substances; noise disturbance to aquatic and terrestrial organisms; and alteration to hydrodynamic regimes and physical habitat. The relocation of salinity transition zones due to channel deepening may, in some cases, be responsible for significant environmental and ecological change.

The expansion ports and marinas has become an almost continuous process due to economic growth, competition between ports, and increased tourism. Elimination or degradation of aquatic and upland habitats are commonplace since port and marina expansion almost always require the use of open water, submerged bottoms, and riparian zones. Ancillary related activities and development often utilize even larger areas, many of which provide water quality and other functions needed to sustain living marine resources. Vessel repair facilities use highly toxic cleaners, paints, and lubricants that can contaminate waters and sediments. Modern pollution containment and abatement systems and procedures can prevent or minimize toxic substance releases; however, constant and diligent pollution control efforts must be implemented. The operation of these facilities also poses an inherent threat to EFH by adversely affecting water quality in and around these facilities. The extent of the impact usually depends on factors such flushing characteristics, size, location, depth, and configuration. For marinas as an example, it is common for any nearby shellfish beds to be closed up to some distance away. It is now a common practice to consider safe zones for siting these facilities near EFH or aquatic resources that may be threatened.

Cargo arriving and departing through ports in the Islands serve as the primary route for needed goods, supplies, and energy. The cargo may be diverse and ranges from highly toxic and hazardous chemicals and petroleum products to relatively benign materials. Major spills and other discharges of hazardous materials are uncommon, but are of constant concern since large and significant areas of coral, SAV, and mangrove habitat are at risk. Any expansion of these facilities occurs at the expense of EFH and operation and maintenance impact EFH to varying degrees.

Maintenance and dredged material disposal to maintain navigable depths for vessels is a major issue at all port facilities and for many marinas. In many cases, dredged materials are contaminated and disposal locations for these sediments are not readily available. Often offshore disposal for clean and contaminated sediments is proposed and for some of the major ports, dredged material disposal sites have been used offshore. Still contaminated sediments remains an issue as does the effects of these materials on offshore systems.

The operation of vessels, both commercial and recreational, also threaten EFH. The USEPA (1993) identified pollutants discharged from boats; pollutants generated from boat maintenance activities on land and in the water; exacerbation of existing poor water quality conditions; pollutants transported in storm water runoff from parking lots, roofs, and other impervious surfaces; and the physical alteration or destruction of wetlands and of shellfish and other bottom communities during the construction of marinas, ramps, and related facilities among a suite of possible adverse environmental impacts.

The chronic effects of vessel grounding, prop scarring, and anchor damage are generally more problematic in conjunction with recreational vessels. While grounding of ships and barges is less frequent, individual incidents can have significant localized effects. Propeller damage to submerged bottoms occurs everywhere where vessels ply shallow waters. Direct damage to multiple life stages of associated organisms, including egg, larvae, juveniles, and through water column de-stratification (temperature and density), resuspending sediments, and increasing turbidity (Stolpe 1997) have been observed. This damage is particularly troublesome where SAV is found.

Anchor scarring is probably less important than other physical disturbances associated with vessel operation. On coral reefs and other sensitive hardbottoms, however, damage caused by anchoring may be significant (Davis 1977). Dragging or pulling anchors through coral reefs breaks and crushes the coral, destroying the coral formation.

The effects of vessel induced wave damage have not been quantified, but may be extensive. The most damaging aspect relates to the erosion of intertidal and SAV wetlands adjacent to marinas, navigation channels, and boating access points such as docks, piers, and boat ramps. The wake erosion in places along navigation channels and elsewhere is readily observable and undoubtedly converts a substantial area of wetlands to less important habitat (e.g., marsh to submerged bottom). In heavily trafficked submerged areas, bottom stability is constantly in flux and bottom communities may be weakened as a result. Indirect effects may include the resuspension of sediments and contaminates that can modify EFH. Where sediments flow back into existing channels, the need for maintenance dredging with its attendant impacts may be increased.

Marinas and other sites where vessels are moored or operate often are plagued by accumulation of anti-fouling paints in bottom sediments, by fuel spillage, and overboard disposal of trash, sewage, and wastewater. However, in areas where vessels are dispersed and dilution factors are adequate, the water quality impacts of boating is likely mitigated. This is especially troubling in areas such as La Parguera, Puerto Rico where house boats have proliferated without authorization. Boating and operations at these facilities (e.g., fish waste disposal) may lead to lowered dissolved oxygen, increased temperature, bioaccumulation of pollutants by organisms, water contamination, sediment contamination, resuspension of sediments, loss of SAV and estuarine vegetation, change in photosynthesis activity, change in the nature and type of sediment, loss of benthic organisms, eutrophication, change in circulation patterns, shoaling and shoreline erosion. Pollutants that result from marinas include nutrients, metals, petroleum hydrocarbons, pathogens, and polychlorinated biphenyls (USEPA 1993).

Marina personnel and boat owners use a variety of boat cleaners, such as teak cleaners, fiberglass polish, and detergents and cleaning boats over the water, or on adjacent upland, creates a high probability that some cleaners and other chemicals will entering the water (USEPA 1993). Copper-based antifouling paint is released into marina waters when boat bottoms are cleaned in the water (USEPA 1993). Tributyltin, which was a major environmental concern, has been largely banned except for use on military vessels. Fuel and oil are often released into waters during fueling operations and through bilge pumping. Oil and grease are commonly found in bilge water, especially in vessels with inboard engines, and these products may be discharged during vessel pump out (USEPA 1993).

One of the more conspicuous byproducts of commercial and recreational boating activities in coastal environments is the discharge of marine debris, trash, and organic wastes into coastal waters, beaches, intertidal flats, and vegetated wetlands. The debris ranges in size from microscopic plastic particles (Carpenter *et al* 1972), to mile-long pieces of drift net, discarded plastic bottles, bags, aluminum cans, etc. In laboratory studies, Hoss and Settle (1990) demonstrated that larval fishes consume polystyrene microspheres. Investigations have also found plastic debris in the guts of adult fish (Manooch 1973, Manooch and Mason 1983). Based on the review of scientific literature on the ingestion of plastics by marine fish, Hoss and Settle (1990) conclude that the problem is pervasive. Most media attention given to marine debris and sea life has focused on threatened and endangered marine mammals and turtles, and on birds. In these cases, the animals become entangled in netting or fishing line, or ingest plastic bags or other materials.

Increased recreational boating activity may contribute significantly to pollution of Caribbean coastal waters by petroleum products. All two-cycle outboard engines require that oil be mixed with gasoline, either directly in the tank or by injection. That portion of the oil that does not burn is then ejected, along with other exhaust products, into the water. Increased use of personal watercraft such as jet skis adds to the volume of hydrocarbon being introduced into Caribbean waters since the engine exhaust from these vessels is discharged directly into the propellant water jet.

The introduction of exotic species is a problem mostly found with commercial vessel travel. Exotic species have been brought into the US in bilge waters of vessels. With the introduction of the zebra mussel into the Great Lakes and its rapid dispersal into other waters, considerable attention is being directed at this problem. According to one estimate two million gallons of foreign ballast water are released every hour into US waters (Carlton 1985). This possibly represents the largest volume of foreign organisms released on a daily basis into north American ecosystems. The introduction of exotic organisms threatens native biodiversity and could lead to changes in relative abundances of species and individuals that are of ecological and economic importance. This has already been observed in other parts of the world . While EFH has not been adversely affected so far, an exotic brown mussel introduction has already occurred in the Gulf of Mexico. The effects and extent of this introduction are currently being studied. With the extent of port development and shipping along the Caribbean this issue must be addressed. It is anticipated that technology such as application of filters or operations such as deep sea exchange of bilge waters, will mitigate the introduction of exotic species.

8. Irrigation, Flood Control, and Drainage Related to Agriculture, Forestry, and Urban Development

The direct effects of Agriculture and forestry in the Islands are not major issues affecting EFH. These activities are relatively static and are more likely to decrease than to increase. The most common crops are sugar cane, bananas, and coconuts. Deforestation is minor. Direct affects on EFH associated with development occur, but are not as important as other threats to EFH in the Islands. In the last 15 years, the NMFS received only seven projects under this category for review and all were in Puerto Rico.

Indirect effects and EFH threats associated with these activities, mainly direct and non-point- source discharge of fill, nutrients, chemicals, and surface and ground waters into streams, rivers, and coastal waters; hydrological modification to include ditches, dikes, farm ponds and other similar structures and water control devices; and cumulative and synergistic effects caused by association of these and other related activities.

9. Mariculture/Aquaculture

Aquaculture in the Islands has occured mainly in Puerto Rico and involved the culture of feshwater species. It is not known whether EFH was previously affected by past aquaculture activities. The blue tilapia (*Tilapia aurea*) and the freshwater shrimp (*Macrobrachium* sp.) were the primary aquacultured species. Other introduced exotics mainly were associated with reservoirs and farm ponds or were introduced for aquatic weed control (Erdman 1984). Aquaculture ponds have been built on the coast and there have been observed cases of accidental release during floods. Only the Tilapia has found its way into salt water. Erdman (1984) believes that these incidental releases have not harmed indigenous species and that the number of Tilapia in salt water is being controlled by marine predators such as snook, tarpon, ladyfish, and jacks.

Proposals have surfaced in the past to culture saltwater penaeid shrimp, but these never went beyond the discussion stage. However, any future culture of marine organisms may involve the alteration of coastal habitats or discharges of wastewater to marine systems. Consequently, they could pose a threat to EFH. Accordingly, these proposals will require scrutiny to ensure that they pose minimal or no affect on EFH.

10. Pipelines

Pipelines have the potential to adversely affect EFH directly; especially when placed in mangrove, SAV or coral habitats. Construction techniques may involve laying the pipeline on surfaces, elevated on structures, or laid in dredged trenches that are subsequently refilled. Pipelines laid on bottom surfaces may crush coral or destroy the SAV under them. If structures are placed to support pipelines, they would have the same or similar effects described for piers and docks. If trenches are dredged, impacts similar to those described for navigation would be expected. Secondary effects may arise from pipeline rupture and the release of contents. This would probably be least severe for water and gas pipelines, but most severe for those carrying oil, gasoline, and chemical products.

Between 1981 and 1996, the NMFS received only 39 requests to build new pipelines. Although few in number, these projects generally entail a large threat to EFH because of their length and because of the sensitive nature of the habitats they must traverse. With regard to secondary effects associated with potential ruptures, most pipelines would pose only a minor risk because, by far, most of them are for water transport. However, pipelines by oil companies were proposed for Yabucoa and Cabo Rojo, Puerto Rico and numerous other pipelines exist where spilled contents would find their way into rivers and streams. All of the pipelines proposed from the US Virgin Islands appear to have been minor and related to water transport.

11. Bulkheads, Small Fills, Groins, etc.

Bulkheads are used to protect adjacent shorelines from wave and current action and to enhance water access. Applications for bulkheads usually specify construction in open water followed by placing fill material behind the structure. Bulkheads may threaten EFH through direct filling; through isolation; and through exacerbation of wave scour. Jetties, groins, and breakwaters can be considered as obstructions to longshore sediment transport that often enhance downdrift erosion and scour. Small fills generally include efforts at reclaiming land lost to erosion, but also include efforts related to expanding fast land and as small refuse dumps. These may proliferate and convert large amounts of EFH to fast land. Further, debris, trash, and floatables from small dumps can adversely affect EFH as well and have the potential of releasing contaminates into adjacent waters.

While most of the projects in this category are considered minor work, they cumulatively are significant and as such can alter relatively large areas of EFH directly and secondary affects (e.g., erosion, long-shore drift alteration) associated with these activities may be even more substantial;

albeit poorly documented. Evidence for the importance of bulkheads, small fills, groins, etc., as modifiers of EFH is evident based on some NMFS data. At least 366 proposals in this category were received by the NMFS between 1981 and 1996. About 281 acres of EFH were proposed for direct alteration by 28 of these proposals.

12. Power Generating Facilities

Power plant siting and power production have the potential to directly impact EFH in a number of ways. EFH can be directly modified for facility siting and construction of cooling water intakes and outlets. Coastal areas may be modified directly for the power plant. These facilities also usually require piers, docks, channels, and related appurtenances for off loading the fuels (e.g., oil) needed to operate the turbines. This often involves dredging and filling with the threats discussed under "Navigation Projects, Ports, Marinas, and Maintenance Dredging. Many power plants also require large amount of water for cooling. Fishery organisms are usually entrained or impinged within the water intake systems. The water discharge is heated and this impacts EFH at the release site. This can be a greater problem in the Caribbean because many aquatic species may already be at their upper tolerance level for temperature. Discharge waters also may contain biocides such as chlorine that are toxic to marine life.

Indirect effects can include non-point-source discharges of contaminants from hard surfaces; release of contaminants in waste water streams, atmospheric deposition of contaminants such as SO2; and the spillage of fuels such as oil during shipping and off loading.

Only three proposals to build or expand power plants in or near EFH have been submitted in the last 15 years. All of these were in Puerto Rico. The latest was the proposal by EcoElectrica, L.P., to build a cogeneration facility in Guayanilla Bay, Puerto Rico, to include a marine terminal for unloading liquid natural gas. While there have been relatively few projects, power generating facilities occupy a substantial amount of land and require a large commitment of natural resources. EFH can be seriously threatened by these facilities with potentially long-term or permanent damage. Accordingly, future requests for new facilities or expansion of old ones must be carefully assessed to ensure that their impacts are fully understood and mitigated.

13. Transmission Lines

Transmission lines include cables, structures, conduits, etc., for power distribution and communications. Potential threats range from disturbances associated with the placement of structures, dredging and filling for placement of conduits and transmission lines, and placement of lines directly on water bottoms. These facilities often entail repeated disturbances associated with maintenance and upgrades. Because these facilities are linear, often crossing large areas of EFH, their impacts can be substantial. This is especially problematic in the Caribbean because of the extensive areas of coral, SAV, and nearshore wetlands such as mangroves. In many areas, it is impossible to run a transmission line without impacting important habitats. In some cases, impacts have been mitigated, but often the destruction of SAV and coral may have permanent or long-term consequences.

In the last 15 years, nine proposals (six for Puerto Rico and three for the US Virgin Islands) were submitted to build power and communications transmission lines in or near EFH. A few of these were relatively minor. However, for the more extensive projects, often covering large areas between islands, adverse impacts to EFH have been observed. In one of the communications conduits constructed from St. Croix in the US Virgin Islands, the original project public notice advised that impacts would be minimal. However, it was later learned that the conduit was not placed along the specified alignment and that deeper water plate corals had been damaged as a result. Accordingly, the key to future planning associated with transmission lines must include detailed bottom surveys, careful attention to alignments and construction techniques that minimize threats to EFH, the development of techniques to restore damage caused by placement, and adequate oversight to ensure that lines are placed as specified in the review process.

14. Mining Activities

There have been no mining proposals involving EFH from the US Virgin Islands within the last 15 years. Four proposals have been submitted for approval from Puerto Rico between 1981 and 1986. Four additional proposals were advertized as part of the US Army Corps of Engineer's permitting process in 1997. All recent mining proposals involve Puerto Rican rivers which have a bed load of quartz sand, pea gravel, or volcanic fragments. The sediment is generally removed by backhoe and placed in a temporary upland deposit site. From there it is generally screened and sold for commercial purposes, mostly related to construction. The 1997 proposals were for work in the Rio Grande de Manati in Jaquas Ward, the Humacao River in Tejas ward, and the Gurabo River in Celada Ward.

Threats to EFH would be similar to those described under the "Navigation" section for mining projects that would directly or indirectly impinge on EFH. These include direct habitat modification with removal of associated biota; hydrological modifications; increased sedimentation; reduced light transmission; and resuspension and relocation of pollutants. Where mining is proposed for rivers that support the anadromous mountain mullet (*Agnostomus monticola*), this species could be adversely affected.

15. Oil and Gas Development

Potential threats to EFH include elimination or damage to bottom habitat due to drill holes and positioning of structures such as drilling platforms, pipelines, anchors, etc; release of harmful and toxic substances form extracted muds, oil, and gas and from materials used in oil and gas recovery; damage to organisms and habitats due to accidental spills; damage to fishing gear due to entanglement with structures and debris; and damage to fishery resources and habitats due to effects of blasting (used in platform support removal); and indirect and secondary impacts to nearshore aquatic environments affected by product receiving, processing, and distribution facilities.

There are presently no ongoing related activities in the region exploration of oil and gas resources in the Islands. Given that this could change, a brief overview of the facilities that might be emplaced on the Outer Continental Shelf (OCS) to facilitate oil and gas exploration, development, and production is provided. This includes drilling vessels (jack-ups, semi-submersibles, and drill ships), production platforms, offshore moored terminals, and pipelines.

Oil and gas related activities are inherently intrusive and pose a considerable level of threat to marine and estuarine ecosystems, including EFH. As discussed below, exploration and recovery operations may cause substantial localized bottom disturbance. Where large scale development is undertaken the area of impact may be greatly expanded and become regional in scale. The toxic nature of hydrocarbon products and certain drilling materials (e.g., drilling muds), spill clean up chemicals, and the large volume of unrefined and refined products that must be moved within the coastal zone places large areas and resource bases as risk.

Structure emplacement can be expected to disturb some bottom area and, if anchors are deployed, the area of disturbance could be expanded. Jack-up rigs and semi-submersibles are generally used in water depths not exceeding 400 meters and disturb about 1.5 ha (3.7 ac) of bottom each. Conventional fixed platforms are also employed where water depths are less than 400 meters and they disturb about 2 ha (4.9 ac). Where water depths exceed 400 meters, dynamically positioned drill ships may be used and sea floor disturbance is usually limited to the well site. Tension leg platforms may also be employed at these depths and the potential bottom disturbance area associated with these structures is about 5 ha (10.25 ac).

Each exploration rig, platform, terminal, and pipeline emplacement on the OCS can be expected to disturb surrounding areas. Exploration rigs, platforms, and pipe laying barges use an array of eight 9,000 kg anchors to position a rig and barge, and to move the barge along the pipeline route. These anchors are continually moved as the pipe laying operation proceeds and the total area actually affected by the anchors will depend on water depth, wind, currents, anchor chain length, and the size of the anchors and chain (MMS 1996). With conventional, fixed multi-leg platforms, which are anchored to the sea floor by steel pilings, explosives are generally used to sever conductors and pilings. These support structures are substantial in size since they must withstand hurricane conditions and have an average life span of about 20 years. The MMS requires severing support structures at 5 meters below the sea floor surface so as to preclude interference with commercial fishing operations.

Possible injury to biota from use of explosives extends horizontally to 900 meters from the detonation site, and vertically to the surface. Based on MMS data, it is assumed that approximately 80 percent of removals of conventional fixed platforms in the Gulf of Mexico, in water less than 400 meters in depth, will be performed with explosives (MMS 1996). Alternative methodologies such as mechanical cutting and inside burning are often ineffective and are hazardous to workers.

Associated bottom debris commonly associated with over water oil and gas operations includes cable, tools, pipe, drums, assorted trash, and structural parts of platforms. The amount of bottom debris deposited around a site may vary and may be measured in tons. Extensive analysis of remotely-sensed data within developed lease blocks indicates that the majority of ferromagnetic bottom debris falls within a 450 meter radius of the site. The Fisherman's Contingency Fund, which was established by the oil and gas industry, provides recourse to commercial fishing interests for recovery of equipment losses due to net entanglement (MMS 1996).

The blowouts occur when improperly balanced well pressures result in sudden, uncontrolled releases of petroleum hydrocarbons. Blowouts can occur during any phase of development: exploratory drilling, development drilling, production, or workover operations. About 23 percent of all blowouts will have associated oil spills, of which eight percent will result in oil spills greater than 50 barrels, and four percent will result in spills greater than 1000 barrels. In subsurface blowouts, sediment will be resuspended and bottom disturbance will generally occur within a 300 meter radius. Whereas larger grain sediment will settle first, fine grained material may remain in suspension for periods of up to thirty days or longer. Fine grained material may be redistributed over a significantly large area depending on the volume of sediment disturbed, bottom morphology, and currents (MMS 1996).

The major operational wastes associated with offshore oil and gas exploration and development include drilling fluids and cuttings, and produced waters. Other important wastes include: from drilling--waste chemicals, fracturing and acidifying fluids, and well completion and workover fluids; from production--produced sand, deck drainage, and miscellaneous well fluids; and from other sources sanitary and domestic wastes, gas and oil processing wastes, ballast water, storage displacement water, and miscellaneous minor discharges (MMS 1996). Major contaminants or chemical properties of materials used in oil and gas operations may include those that are highly saline; have a low ph.; contain suspended solids, heavy metals, crude oil compounds, organic acids, priority pollutants, and radionuclides; and those which generate high biological and chemical oxygen demands.

Accidental discharge of oil can occur during almost any stage of exploration, development, or production on the OCS or in near shore base areas. Oil spills may result from many possible causes including equipment malfunction, ship collisions, pipeline breaks, human error, or severe storms. Oil spills may also be attributed to support activities associated with product recovery and transportation. In addition to crude oil spills, chemical, diesel, and other oil-product spills can occur with OCS activities. Of the various potential OCS related spill sources, the great majority are associated with product transportation activities (MMS 1996).

A major oil refinery was built and operates on St. Croix, but there are no immediate plans for additional facilities. Despite this, millions of barrels of crude oil and refined product transit Caribbean waters by tank vessel every year and the potential exists for the discharge of thousands of barrels of oil due to vessel collision or sinking. There have in fact been several major oil spills in recent years.

5.3 Cumulative Impact Assessment

This section analyzes "cumulative" impacts, which are defined as "impacts on the environment that result from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of who undertakes such actions." The overall cumulative impact of human-induced activities and natural events remains poorly document and understood and in dire need of more study. Even so, it is evident that the effect of human activity on aquatic systems has been substantial in locations where access and economically profitable modification could be readily accommodated.

As an indication of the scope of developmental pressure, hence one aspect cumulative effect on EFH (coastal and tributary wetlands), NMFS data show receipt of more than 1,832 individual development proposals (COE permit applications, federal projects , etc.) in Puerto Rico and the US Virgin Islands between 1981 and 1996 (See Tables 1 through 5). A subsample of 90 of these development proposals involved over 1,284 acres of various wetland habitats.

While it is believed that most regulated activities are implemented as planned, Mager and Thayer (1986) report that limited monitoring indicate that about 20 percent of the projects they examined did not comply with provisions of the associated permits. Notably, most of the differences observed related more to design of structures and not the area of habitat affected. As shown in the following tables, individually and cumulatively significant impacts to EFH can be moderated through federal regulatory programs; however, significant wetland perturbations persist. This situation is largely perpetuated by (1) regulatory provisions that exempt regulation of certain wetland types and activities and (2) by severe staffing limitations within regulatory and environmental review agencies. In the absence of substantial correction in these two areas, significant wetland areas will continue to be adversely altered or eliminated, and regulatory and review agency effectiveness will be limited.

In addition to the direct cumulative effect incurred by developmental type activities, EFH is also jeopardized by persistent increases in certain chemical discharges. In that case incremental change in habitats, hydrology, and chemical inputs produced, over time, an enormous and extremely harmful result whose negative economic and social implications may far exceed any benefits related to the causative factors. Unfortunately, the effect of adding ever greater volumes and varieties of chemicals to surface waters is often insidious and resulting declines in the abundance and quality of affected and harvested resources may be slow and difficult to identify. As illustrated by Scott *et al* (1997), the effects may be realized at rudimentary trophic and ecological association levels in key portions (including EFH) of estuarine environments.

The rate and magnitude of anthropomorphic change on EFH, whether cumulative, synergistic, or individually large, is influenced by natural parameters such as temperature, wind, currents, rainfall, salinity, etc. Consequently, the level of threat posed by a particular activity or group of activities may vary considerably from location to location. This situation may be most acute in locations that are subject to extreme weather and oceanic conditions such as hurricanes and large waves, or where the effects of periodic or global change is most prevalent.

Enrichment of estuarine algal and bacterioplanktonic communities by excessive nutrients is probably the most often cited example of estuarine degradation globally (Nixon 1995, NRC 1994, Ryther and Dunstan 1971). In general, the ecological pathway involves enhanced algal or bacterial production and metabolism followed by excessive oxygen uptake and subsequent deoxygenation. Associated processes may be complex. For example, nutrient uptake and excessive autotroph production may result in deposition of organic material into benthic sediments, where increased sediment oxygen demand may occur at some later time. In stratified estuaries, the process may even be exacerbated by the re-release of nutrients as sediment oxygen demand is exerted in bottom, anoxic waters. The ecological effects of modification of production patterns also includes hypercapnia (elevated levels of carbon dioxide), which exerts powerful effects on some organisms.

Table 1
Acres of habitat alterations requested by type of projects reviewed in Puerto Rico between 1981 and 1996.

Project Type	N1	N2	Proposed By Applicants	Accepted By NMFS	Potentially Conserved	Mitigation
BA	31	0	-	-	-	-
BE	8	1	2	2	0	0
BR	59	2	93	0	93	0
DO	458	0	-	-	-	-
EL	3	0	-	-	-	-
HO	258	15	219	6	213	33
IN	180	11	167	50	117	38
IR	7	0	-	-	-	-
MD	103	0	-	-	-	-
MI	4	0	-	-	-	-
NA	84	9	205	30	175	15
OI	1	0	-	-	-	-
OT	56	5	110	8	102	0
PI	31	0	-	-	-	-
SH	331	25	122	1	121	116
TR	6	0	-	-	-	-
WR	1	0	-	-	-	-
Total	**1,621**	**68**	**918**	**97**	**821**	**202**

(BA) barriers and impoundments; (BE) beach nourishment projects; (BR) bridges, roads, and causeways; (DO) docks and other minor structures; (EL) electric generating facilities; (HO) housing developments; (IN) commercial and industrial developments, etc.; (IR) irrigation and drainage works; (MD) maintenance dredging; (MI) mining and mineral exploration; (NA) navigation projects, marinas, etc.; (OI) oil and gas construction; (OT) unclassified; (PI) oil, gas, and chemical pipelines; (SH) bulkheads, small fills, groins, etc.; (TR) transmission lines; (WR) wetland restoration projects.

N1 = Total number of projects reviewed.
N2 = Number of projects where acreage was determined.

Table 2
Acres of habitat alterations requested by type of projects reviewed in the U.S. Virgin Islands between 1981 and 1996.

Project Type	N1	N2	Proposed By Applicants	Accepted By NMFS	Potentially Conserved	Mitigation
BA	2	0	-	-	-	-
BE	7	0	-	-	-	-
BR	1	0	-	-	-	-
DO	74	0	-	-	-	-
HO	7	2	8	0	8	0
IN	17	5	132	45	87	68
MD	6	0	-	-	-	-
NA	31	9	89	10	79	49
OT	20	2	19	16	3	0
PI	8	0	-	-	-	-
SH	35	3	27	27	0	18
TR	3	1	1	0	1	0
Total	**211**	**22**	**276**	**98**	**178**	**135**

(BA) barriers and impoundments; (BE) beach nourishment projects; (BR) bridges, roads, and causeways; (DO) docks and other minor structures; (HO) housing developments; (IN) commercial and industrial developments, etc.; (MD) maintenance dredging; (NA) navigation projects, marinas, etc.; (OT) unclassified; (PI) oil, gas, and chemical pipelines; (SH) bulkheads, small fills, groins, etc.; (TR) transmission lines.

N1 = Total number of projects reviewed.
N2 = Number of projects where acreage was determined.

Table 3 (Puerto Rico)
Acres of habitat alterations proposed by applicants and reviewed by NMFS between 1981 and 1996 under the various regulatory programs.

Project Kind	N1	N2	Acres Proposed By Applicants	Acres Accepted By NMFS	Potential Acres Conserved	Mitigation
10	604	3	3	3	0	0
10/404	289	23	425	75	350	43
404	201	11	256	13	243	11
CFP	26	9	213	0	213	109
CG	5	0	-	-	-	-
FERC	1	0	-	-	-	-
GP	1	0	-	-	-	-
I10	157	1	*	0	*	0
I10/404	120	18	16	2	14	39
I404	179	3	5	4	1	0
NEPA	11	0	-	-	-	-
NWP	18	0	-	-	-	-
PI	7	0	-	-	-	-
PRE	2	0	-	-	-	-
Total	**1,621**	**68**	**918**	**97**	**821**	**202**

N1 - Total projects reviewed in this category.
N2 - Number of projects where acreage was determined.
* - one-tenth of an acre.

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10 = projects requested pursuant to Section 10 of the River and Harbor Act; 404 = projects requested pursuant to the Clean Water Act; 10/404 = projects advertised under Section 10 and 404 authorities; CFP = Corps Federal Project; CG = U.S. Coast Guard bridge/causeway permit application; FERC = Federal Energy Regulatory Commission permits and licenses; GP = General Permits; I10, I404, and I10/404 = unauthorized projects; NEPA = environmental impact statements and assessments; NWP = Nationwide permits; PI = public inquiries; PRE = preapplication planning.

Table 4 (U.S. Virgin Islands)
Acres of habitat alterations proposed by applicants and reviewed by NMFS between 1981 and 1996 under the various regulatory programs.

Project Kind	N1	N2	Acres Proposed By Applicants	Acres Accepted By NMFS	Potential Acres Conserved	Mitigation
10	123	2	1	0	1	0
10/404	65	17	250	82	168	135
404	7	1	6	0	6	0
CFP	3	1	18	16	2	0
CZM	1	0	-	-	-	-
EPA	1	0	-	-	-	-
I10	1	0	-	-	-	-
I10/404	2	0	-	-	-	-
I404	1	1	1	0	1	0
NEPA	3	0	-	-	-	-
PI	2	0	-	-	-	-
PRE	2	0	-	-	-	-
Total	**211**	**22**	**276**	**98**	**178**	**135**

N1 - Total projects reviewed in this category.
N2 - Number of projects where acreage was determined.

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10 = projects requested pursuant to Section 10 of the River and Harbor Act; 404 = projects requested pursuant to the Clean Water Act; 10/404 = projects advertised under Section 10 and 404 authorities; CFP = Corps Federal Project; CZM = Coastal Zone Management Act interaction; EPA = Environmental Protection Agency regulated or sponsored projects; I10, I404, and I10/404 = unauthorized projects; NEPA = environmental impact statements and assessments; PI = public inquiries; PRE = preapplication planning.

Table 5
Acres of habitat alterations proposed by applicants and reviewed by NMFS between1981 and 1996 for Puerto Rico and the U.S. Virgin Islands under the various regulatory programs.

State	N1	N2	Acres Proposed By Applicants	Acres Accepted By NMFS	Potential Acres Conserved	Mitigation
PR	1,621	68	918	97	821	202
VI	211	22	276	98	178	135
Total	**1,832**	**90**	**1,194**	**195**	**999**	**337**

N1 - Total projects reviewed in this category.
N2 - Number of projects where acreage was determined.