EXECUTIVE SUMMARY

The Fishery Management Plan (FMP) for corals and reef-associated plants and invertebrates includes over 100 species of coral (including stony corals, sea fans and gorgonians) and over 60 species of plants (including seagrasses) and invertebrates. The Plan covers two distinct components. The first is a fishery for live invertebrates which are marketed for the marine aquarium trade. Aside from reef-associated invertebrates, this fishery includes what is widely known as live-rock - rock substrate supporting diverse invertebrate life forms. Live-rock is highly valued by aquarists and there is a rapidly growing market for this resource. The second component of the Plan comprises corals and coral reefs. These resources are of enormous value for the reef communities that they support, for their physical capacity to protect coastlines and for their aesthetic value. Indeed traditional coastal fisheries in the Caribbean may best be characterized as coral reef fisheries intimately dependent on the backbone of habitats created by coral reefs and associated invertebrates.

Corals and invertebrate communities not only comprise the physical basis of the reef ecosystem and the fish and invertebrate resources that depend on it, but also exhibit considerable beauty. This means that they are not only essential for the persistence of commercial and recreational fisheries, but are also of incalculable value for tourism and other recreational activities. It also means that, because of their slow regeneration rates and limited distribution on the insular platform of Puerto Rico and the U. S. Virgin Islands, many species are extremely vulnerable to unregulated harvest by commercial and amateur collectors and damage from growing tourist activity. Furthermore, because of their largely sedentary nature, they are unable to escape the impact of a variety of anthropogenic activities, including anchoring and pollution.

Because current scientific evidence indicates that corals and certain other reef-associated invertebrates are extremely slow-growing, at least as measured against human time horizons, it is widely believed that their removal through harvest is likely to result in the net loss of these resources. Hence, corals and resources like them are essentially non-renewable in the typical fishery sense. Since they provide the Nation with substantial economic benefits unrelated to direct harvest, there appears to be little doubt that their greatest value lies in non-consumptive uses. Moreover, it is not clear whether typical fishery management approaches directly apply to reef resources and such standard measures have yet to be evaluated. In the meantime, given the current rates of degradation of coral reefs, their limited distribution and the consequent potential for their overexploitation, and the growing demand for reef-associated invertebrates, a decidedly conservative management approach must be applied. Scarcity of biological and harvest data is no excuse for lack of management.

The Plan was developed largely for two reasons. The first concerned the increasingly serious impacts of anthropogenic activities on the condition of coral reefs and the communities of organisms with which they are closely associated in both Puerto Rico and the U. S. Virgin Islands. The second related to the relatively new and rapidly expanding fishery for the marine

aquarium industry, especially in Puerto Rico. Concern was apparent over the possible impact that this fishery could have on both the organisms exploited and the reef habitat from which they are collected because of increasing market demand and various of the harvest methods being applied (such as chemicals and removal of reef substrate as live-rock). Although state laws are in effect that regulate the harvest of corals, no laws are in effect for corals in the federal zone. No laws exist to protect reef-associated invertebrates, including live-rock (other than those species covered by management plans in effect or under development i.e., the spiny lobster and the queen conch) in the federal area of authority. This Plan, therefore, in combination with state laws, provides for a uniform set of regulations to be applied to waters of Puerto Rico and the U. S. Virgin Islands for corals and live-rock and provides a management scheme for other, currently unregulated, invertebrates.

This FMP addresses various concerns over the present and probable future condition, in the absence of further regulation, of component species through a number of management measures as follows: it prohibits the harvest or possession of stony corals, sea fans, gorgonians and any species in the fishery management unit if attached or existing upon live-rock, except under legal permit for research, education, and restoration; it prohibits the sale or possession of any prohibited species unless fully documented as to point of origin; it prohibits the use of chemicals, plants or plant derived toxins, and explosives for harvest (consistent with the Caribbean Council's Reef Fish Plan); it limits harvest of other invertebrates to dip nets, slurp guns, by hand and other non-habitat destructive gear with an exception for permitted scientific, education and restoration programs; and it requires permitting and reporting by harvesters, dealers and exporters of invertebrates.

Among the greatest impediments to the management of these resources is the lack of biological information, which makes it currently impossible to estimate a Maximum Sustainable Yield for exploitable invertebrate species. Also, while estimates of exports are available, there is no information on what is thought to be a substantial on-island trade in these resources which means that current harvest may be considerably underestimated. Recommendations are made for research and monitoring activities necessary to better characterize the current fishery of species in the FMP.

It is also recognized that management cannot be successfully achieved without public and government cooperation and support. Education of resource users, the general public and of officials in charge of enforcing current laws should be considered a high priority. Finally, the most serious and difficult problems that stand in the way of management of reef communities concern the control of land-based activities, such as discharge of raw sewage, sedimentation caused by poor land use practices and point and nonpoint source pollution. If these problems are not addressed there would appear to be little hope for the long-term persistence of nearshore reef communities.

Solutions to the problems of reef management may only be accomplished through a combination of local and federal action, and since larval phases cross international boundaries, with promotion and support of international cooperation. The management of

reefs and associated communities is a challenge that must be faced head-on if the very substantial benefits of these resources are to be fully realized by the nations that possess them.

DEFINITIONS

Commercial Fisher: a person who derives income by catching and selling fish, for whatever purpose, including for the commercial extraction of biocompounds.

Corals: species of the Cnidarian Classes Anthozoa and Hydrozoa.

Coral Reef: biologically constructed reef framework with or without active coral growth.

Dealer: one who buys and sell species in the FMU without altering their condition.

Dip Net: a hand-held net consisting of a mesh bag suspended from a circular, oval, square or rectangular frame attached to a handle. A portion of the bag may be constructed of other material, such as clear plastic, rather than mesh.

Ecosystem: the interdependence of species in a community with one another and with their non-living environment.

Education: the act or process of imparting or acquiring scientific knowledge, conducted at accredited schools or other appropriate institutions, such as authorized aquariums and museums, for the purpose of disseminating information about the biology and ecology of the species in the FMU.

Environmental Impact Statement (EIS): a document required under the National Environmental Policy Act which addresses the impact on the environment of the proposed Fishery Management Plan.

Exclusive Economic Zone (EEZ): the area adjacent to the United States that, except where modified to accommodate international boundaries, encompasses all waters from the seaward boundary of each of the coastal states to a line on which each point is 200 nautical miles from the baseline from which the territorial sea of the United States is measured.

Exporter: one who sends species in the FMU to other countries or places for sale, barter or any other form of exchange.

Federal Waters: the EEZ plus beyond for anadromous and continental shelf species.

Fish: means finfish, mollusks, crustaceans, and all other forms of marine animal and plant life, other than marine mammals and birds.

Fishery Management Plan (FMP): a plan prepared by a Regional Fishery Management Council or by NMFS (if a Secretarial plan) to manage a particular fishery, as directed by the Magnuson Act.

Fishery Management Unit (FMU): the fish included in the Fishery Management Plan which include stony coral, certain species associated with live-rock, reef-associated invertebrates and plants. The species included in the FMU of this Plan are listed in Table 1.

Habitat: living place of an organism or community, characterized by its physical or biotic properties.

Harvest: the catching or taking of a marine organism by any means. Marine organisms that are caught but immediately returned to the water free, alive, and undamaged are not harvested.

Harvester: one who harvests (see Harvest).

Inshore reef: reefs next to, or close to but separate from the shoreline and in shallow water.

Live-Rock: any hard substrate (including dead coral or rock) to which is attached, or which supports, any living marine life form listed in the Fishery Management Unit.

Magnuson Act: the Magnuson Fishery Conservation and Management Act of 1976, as Amended.

Marine Conservation Districts (MCDs): are marine areas with special value or significance to the marine ecosystem that will be maintained in their natural state.

Maximum Sustainable Yield (MSY): an estimate of the largest average annual catch or yield that can be taken over a significant period of time from each stock under prevailing ecological and environmental conditions.

National Marine Fisheries Service (NMFS): the component of the National Oceanic and Atmospheric Administration (NOAA), Department of Commerce, responsible for conservation and management of living marine resources.

Offshore reef: reefs distant from shore but on the insular plat-form.

Optimum Yield (OY): as defined by the Magnuson Act, means the amount of fishery resource that can be taken from a fishery that will provide the greatest overall benefit to the Nation with particular reference to food production and recreational opportunities, and which is prescribed as such on the basis of the MSY from each fishery, as modified by any relevant economic, social or ecological factor.

Recreational Fisher: someone who harvests any marine organism but does not sell his catch or otherwise derive economic benefit directly therefrom.

Reef: a ridgelike or moundlike structure built by sedentary calcareous organisms and consisting mostly of their remains, is wave-resistant and stands above the surrounding sediment. It is characteristically colonized by communities of encrusting and colonial invertebrates. Also such a structure built in the geologic past and now enclosed in rock commonly of differing lithology.

Regulatory Impact Review (RIR): an assessment of the ability of the proposed measures to achieve the overall objectives through analysis of the associated economic, social, biological and ecological impacts.

Restoration: the transplanting of live organisms from their natural habitat in one area to another area where losses of, or damage to, those organisms has occurred with the purpose of restoring the damaged or otherwise compromised area to its original, or a substantially improved, condition. Restorative activities are subject to approval of a work plan and receipt of a permit.

Rock: Any consolidated or coherent and relatively hard, naturally formed, mass of mineral matter.

Scientific research: either research, conducted according to scientific methods, or education in science conducted at accredited schools, in either case for the purpose of enhancing knowledge of the biology and ecology of organisms in the FMU, or of exploring the medical potential of species in the fishery management unit. Scientific activities are subject to approval of a work plan and receipt of a permit.

Secretary: means the Secretary of Commerce or a designee.

Sessile: attached to a substrate; non-motile for all or part of the life cycle.

Slurp gun: a self-contained, typically hand-held, device that captures organisms by rapidly drawing seawater containing the organism into a closed chamber.

State waters: waters seaward of the baseline from which the territorial sea is measured to a distance of nine nautical miles in the case of Puerto Rico and 3 nautical miles for the United States Virgin Islands.

Stony corals: Individuals of the Class Hydrozoa, and scleractinians and antipatharians of the Class Anthozoa.

Total Allowable Level of Foreign Fishing (TALFF): the portion of the Optimum Yield on an annual basis which will not be harvested by U. S. vessels.

1.0 INTRODUCTION

Under the authority of the Magnuson Fishery Conservation and Management (Magnuson) Act, the Caribbean Fishery Management Council (CFMC) manages marine resources in the federal waters of Puerto Rico and the United States Virgin Islands (U.S.V.I.). However, recognizing that the vast majority of fisheries and fisheries-related resources occur in waters under the authority of the local governments, the CFMC has promoted, and the local governments have accepted, a cooperative management program in Puerto Rico and the U. S. Virgin Islands that includes waters under both state and federal authorities. Section 302(h)(1) of the Magnuson Act authorizes the Caribbean Fishery Management Council to prepare and implement a Fishery Management Plan (FMP) with respect to any fishery needing management and conservation within its geographical area of authority. The Fishery Management Unit (FMU) under consideration in this FMP is comprised of corals and coral reefs, reef-associated invertebrates, live-rock and plants.

The CFMC recognizes the need for development of this FMP for corals and reef associated plants and invertebrates due to concerns regarding recent marked and uncontrolled increases in the harvest of certain components of the fishery management unit. In addition, there is considerable concern regarding the growing negative impact of a number of other unregulated human activities on the condition of reefs and associated organisms, and on seagrass ecosystems. Given the significance of reefs and seagrass habitats as the basis for communities of invertebrate and vertebrate organisms of commercial, medical and recreational importance and tourism, the health of these habitats is clearly of critical importance for the coastal marine resources of the Nation. The principal value of reefs (including live-rock) and seagrasses is considered to be non-consumptive and they are essentially viewed as non-renewable resources.

Reef-associated invertebrates, on the other hand, are considered to be renewable, although insufficient information is currently available to assign a definitive level of Maximum Sustainable Yield (MSY). The objectives of this FMP are to conserve and protect the species in the FMU for the maximum benefit of the Nation, to fairly allocate resources among different user groups, to reduce the potential for user conflict, to identify data gaps which impede management, and to provide relevant recommendations to the states. There is no history of management of component species of the FMU in federal waters; various laws are in effect in state waters. The information used in the preparation of this FMP is based on the best available scientific data.

The importance of corals and reef associated plants and invertebrates lies in their relationship to the marine ecosystem. The coral reef areas are the most productive tropical marine systems and thus are the backbone of the food chain. At the end of this food chain are the fishery resources managed under other FMPs. Coral reefs serve as breeding grounds, nurseries, feeding grounds, and refuge for most protected species, all of which, and including coral reefs, are vulnerable to overfishing. Additional threats have been identified in the form

of natural and anthropogenic stressors. Thus the combined effect of detrimental factors adversely affect the resource. The fisheries are dependent on the well being of the habitat and thus wise management is needed in the form of MCDs.

2.0 DESCRIPTION OF RESOURCE

The invertebrates and plants of the reef and seagrass communities which comprise the fishery management unit involve a wide diversity of species. These include components which may be considered of greatest value to the Nation as either consumptive or non-consumptive resources. Communities of shallow water tropical zones tend to be dominated by sessile organisms which form the back-bone of coral reefs. The following overview of the components included in this FMP covers biology and socio-economic importance, distribution, ecological relationships, and lists the species in the fishery management unit. The present condition of the resource and probable future condition, if current trends continue, are also discussed.

2.1 Corals:

Strictly speaking, all extant corals belong to the Order Scleractinia of the Class Anthozoa (Phylum CNIDARIA). Flexible usage of the word coral, however, is applied in this FMP and 'coral' is taken to include other taxa within, and in addition to, Anthozoa. Octocorals (Sub-class Octocoralia) and black corals (Order Antipatharia) are other anthozoan orders including 'corals', as are Hydrocorals which belong to the Class Hydrozoa. For the purposes of this FMP, the term coral shall apply to all organisms of the Classes Hydrozoa and Anthozoa and will be further qualified when necessary (e.g., stony coral = Hydrozoa, Scleractinia and Antipatharia). Details of the biology of the major coral groups are given by Class.

2.1.1 Class Hydrozoa - Hydrocorals are distantly related to the rest of the skeleton-forming cnidarians. Many are colonial. As for other members of the phylum the living animal is comprised of polyps which often secrete a solid skeleton. The polyps possess stinging cells (nematocysts), generally more powerful than those of other Cnidaria (hence the common name of fire corals), that enable them to paralyze and capture prey. Hermatypic (corals capable of forming reefs) hydrocorals play a significant role in coral reef construction, particularly in shallow, windward substrates, and are important in shallow waters for their buffering effect which contributes substantially to the protection of coastal lands during times of high seas. Their importance will be considered within this context when coral reefs are discussed. For the purposes of this FMP, hydrocorals are considered stony corals.

2.1.2 Class Anthozoa - Anthozoans consist of black corals (Order Antipatharia), gorgonians, sea fans (Sub-class Octocoralia), sea anemones and like organisms (Orders Actinaria, Zoanthidea and Corallimorpha) and the true reef-building corals (Order Scleractinia).

2.1.2.1 Antipatharian anthozoans (black corals) are typically deep sea, colonial, anthozoans usually occurring under ledges (Grigg, 1965). The axial skeleton is black, spiny and scleroproteinaceous and is secreted in concentric layers around a hollow core. The ecology and life history of these organisms is, for the most part, unknown but the available evidence suggests that recruitment is episodic with the success of a few strong year classes critical to local population abundances (Grigg, 1976). Therefore, populations of commercially important species are likely to be extremely vulnerable to overharvest; colonies are harvested for artisanal purposes in some regions of the Caribbean. Their taxonomy, to a large extent, is also unknown. Black corals may prove to be important as sclerochronological tools. They are known to produce growth rings although the periodicity of these is not well known. If the temporal cycle of growth rings is defined they may prove to be important assets in the elucidation of environmental variations in deeper habitats (i.e., below the thermocline) where hermatypic corals are absent or rare. For the purposes of this FMP, antipatharians are considered stony corals.

2.1.2.2 Octocorallian anthozoans (gorgonians and sea fans) form soft, flexible colonies that may be bushlike, fanlike or rodlike, depending on the species. As in hydrocorals and antipatharians, their skeleton is internal, and consists of a central axis composed of a collagenous protein (gorgonin). The axial skeleton is absent in some species. Gorgonians may live for more than 20 years (based on size-age relationships) (Yoshioka, 1979) with annual growth rates (in terms of increase in colony height) ranging from 0.8 - 4.5 cm/year for 13 species studied in southeastern Puerto Rico over a 5-year period. Growth rates were found to be highly variable both intra- and interspecifically (Yoshioka and Yoshioka, 1991). At study sites in southeastern Puerto Rico mortality was found to be low in large (i.e., > 10 cm high) colonies and high in smaller (i.e., < 6 cm) colonies, the major causes of death being damage to the colony base or detachment. Adults were generally larger than 25 cm (Yoshioka and Yoshioka, unpubl. data).

The key features of gorgonian life history are low and uncertain (variable) recruitment and survival of small gorgonians, and high and predictable survival of larger colonies. Given uncertain recruitment, the predictable survival of adults is critical to the persistence of gorgonian populations (Paul Yoshioka, pers. obs.). In a management context, it is important to note that there are positive (mutualistic) interactions among adult and juvenile gorgonians which indicate that classical fishery models (which are based on the assumption of negative (competitive) interactions whereby harvest of fish enhances recruitment, survival and growth, within certain limits) may not be applicable to gorgonians or to organisms with similar size-specific demographies (possibly many other sessile colonial organisms of coral reefs) (Paul Yoshioka, pers. obs., Jackson, 1985). Gorgonians are conspicuous members of coral reef ecosystems in Puerto Rico and the U. S. Virgin Islands and can be abundant in some sites where scleractinian corals apparently are unable to proliferate. Several species of gorgonian have been shown to have important medical significance.

2.1.2.3 Actinarian and other anthozoans, known commonly as sea anemones, include a diversity of organisms which may be solitary or colonial. The polyps vary greatly in morphology and colonial structure. Species are often brightly colored and are usually attached to rocks, although some forms bury themselves. Solitary (non-burying) anemones are essentially sessile but can change location by slow gliding. Colonies of anthozoids are comprised of numerous polyps, each 1-2 cm in diameter and interconnected as a mat, which may pave rocks or form large encrusting masses. While a number of sea anemones are included in the management unit, the principal species are those of the genera Bartolomea, Stoichactis, Condylactis, Ricordea, Rhodactis, Phymanthus and Zoanthus. The giant Caribbean or pink-tipped anemone, C. gigantea provides shelter for a variety of juvenile and adult fishes and crustaceans. This species spawns in late spring at Key West and may become reproductively active as small as 4.5 g (Jennison, 1981). No information on its age and growth is available.

2.1.2.4 Scleractinian anthozoans (stony corals) are calcium-secreting animals that can form colonies comprised of many physically and physiologically linked polyps, or else can be solitary or consisting of one polyp. In contrast to anemones they produce calcium carbonate, aragonitic, skeletons that can reach considerable sizes (e.g., over 5 m in diameter and height in individuals of Montastrea annularis). The skeleton is internal, in contrast to other skeleton-forming cnidarians. Many species possess annual growth bands related to variable skeletal densities, that can be used to infer past environmental variations.

Scleractinians can be divided ecologically into those that are capable (hermatypic) and those that are not capable (ahermatypic) of forming reefs. Reef-building species differ from non-reef-building species in that only the former contain algal endosymbionts commonly referred to as zooxanthellae. Zooxanthellae promote growth and enable hermatypic corals to form large colonies. These colonies accumulate over time and form the largest biogenically-produced calcium carbonate buildups on Earth. These buildups are commonly known as coral reefs which are important assets to nations that possess them. Coral reefs provide the habitat on which other vertebrate and invertebrate reef-associated organisms depend. Because of this their principal value is determined to be in non-consumptive uses (Goenaga and Boulon, 1992) (Appendix 1).

Corals reproduce both sexually and asexually. Sexual reproduction results in the formation of minute larvae (planulae) that spend a variable amount of time in the water column as plankton (from days to weeks), eventually settling on an appropriate substrate. If reproduction is asexual, larvae are brooded in the gastric pouch of the parent and released when ready to settle. Most corals have well defined seasonal patterns of sexual reproduction (Szmant, 1986), and many have quite specific requirements for appropriate settlement substrate. Different coral species have different colony turnover rates but are in general remarkably long-lived, and slow-growing (Loya, 1976). In the La Parguera area, southwestern Puerto Rico, for example, corals of the species Montastrea annularis have growth rates of slightly less than 10 mm per year (Goenaga and Winter, unpubl. data) and may live for many hundreds of years.

The range of estimated annual rates of linear growth for five corals in the U. S. Virgin Islands during periods of highest and lowest annual water temperatures was 6.6-8.9 mm/yr for M. annularis and 3.0-3.5 mm/yr for Porites asteroides, respectively. The fastest growing coral species of the genus Acropora, exhibited growth rates of 71 mm/yr for A. cervicornis, 59-82 mm/yr for A. prolifera and 47-99 mm/yr for A. palmata (Gladfelter et al., 1978). With few exceptions, therefore, coral generation rates are extremely slow. From a worldwide survey, maximal sustainable growth by a coral reef was estimated at 10 mm/yr (Buddemeier and Smith, 1988). Studies on a barrier reef at the insular shelf break off La Parguera in southwestern Puerto Rico indicated that growth of 20 m registered over approximately 6,000 years gives a rate of 0.3 cm/yr for these reefs (Morelock et al., 1977).

Coral communities exist under a variety of water depths, bottom type, water quality, wave energy and currents. Well-developed active coral reefs usually occur in tropical and subtropical waters of low turbidity, low terrestrial runoff, and low levels of suspended sediment. Corals may occur scattered in patches attached to hard substrates. Coral reefs in the Caribbean are formed by the major reef-building coral genera, Acropora, Montastrea, Porites, Diploria, Siderastrea and Agaricia (Tetra Tech, 1992). General coral reef types may be defined as follows:

Fringing reefs: emergent reefs extending directly from shore and often extensions of headlands or points, or separated from the shore by an open lagoon.

Submerged reefs: submerged fringing reefs that have not developed to the surface; they may be predominantly composed of active coral growth or covered with abundant communities of colonial gorgonians, sponges and corals.

Patch reefs: small irregular shaped reefs that rise from the bottom and are separated from other reef sections.

The Council should evaluate an Advisory Panel (AP) recommendation (75th CFMC meeting) that, for the purposes of management consideration, reefs be divided into inshore and offshore areas because of the different factors that impact reefs close to, and distant from, shore. Inshore reefs would include reefs adjacent to the shoreline (fringing and patch reefs) and close to, but separate from, the shoreline. These reefs are heavily used by different user groups and especially by the commercial sector. Land-based activities, anchor, diver and fish trap damage are of concern inshore. Offshore reefs would include those distant from the shoreline (submerged and patch reefs) and would be most heavily impacted by fish traps and anchoring.

The importance of coral reefs to man is well documented. They are among the most productive ecosystems on earth, supporting a higher biological diversity than any other ecosystem, with the exception of tropical rain forests. Their socioeconomic importance can be divided into three broad, albeit interrelated, categories. These encompass, first, their

physical reef-forming activities. Second, the biological diversity of associated fauna and flora which both support many of the species exploited recreationally and commercially by man, and generate a wealth of biocompounds of tremendous actual and potential medical importance. Third, they are of considerable aesthetic significance for recreation- and tourism-related activities (Goenaga and Boulon, 1992; Tetra Tech, 1992).

Stony corals provide a buffer against seas pounding the shoreline, preventing its erosion and influencing the deposition and maintenance of sand on the beaches which they protect. This is particularly important for regions with low-lying coastal plains. Beaches of touristic importance in Puerto Rico and the U. S. Virgin Islands are protected by offshore coral communities from direct wave action. The structural complexity of these reefs produces a baffle effect, which acts to reduce the wave energy. Reef ecosystems also play an important role in the marine carbon budget primarily through the deposition of aragonitic calcium carbonate ($CaCo_3$). Reported rates of $CaCo_3$ deposition by coral reefs demonstrate that these ecosystems are an important buffer in the Earth's carbon dioxide cycle. This aspect of coral reefs means that their importance transcends the national level (Goenaga and Boulon, 1992).

The biodiversity of the reef ecosystem sustains coastal reef fisheries in the tropics and has yielded a host of chemical compounds of significant medical importance. This diversity has also stimulated the rapid growth of water-oriented touristic activities. An example is the underwater trail in Trunk Bay, St. John, U. S. Virgin Islands, which is utilized daily by hundreds of tourists. The National Park on St. John has documented annual increases of visitors to Trunk Bay beach from 20,000 people in 1966 to almost 170,000 people in 1986 (Rogers and Teytaud, 1988). A study in the Biosphere Reserve of St. John, U. S. Virgin Islands, indicated an increase in the average number of boats using the park for recreation from 10 boats daily to about 80 boats daily over two decades, between 1966 and 1986 (Rogers et al., 1988).

Puerto Rico is interested in developing 'eco-tourism' which depends heavily on aesthetic enjoyment and appreciation of nature (e.g., the underwater trail at Caja de Muertos Island). "The ecological habitats, marine aquatic life, consumption of fish and shellfish, swimming, boating, and the aesthetic enjoyment of the islands are reasons that consumers visit Puerto Rico and the U. S. Virgin Islands. The degradation of these resources, resulting in use impairments, will present problems if it becomes too severe, and once it becomes obvious that coastal areas are impaired, tourism is likely to decline" (Tetra Tech, 1992).
The fact that hermatypic corals are capable of forming reefs sets them apart from the other types of corals. Reef-forming corals are habitat-generating organisms and this aspect poses important management considerations. Management of the reef-building corals will need to focus on the habitat rather than on individual organisms (Goenaga and Boulon, 1992). Coral reefs are highly complex and diverse communities of biota the distribution and condition of which are regulated by their requirements for suitable substrate, temperature, light and water conditions. Their greatest socioeconomic importance lies in their non-consumptive value. Moreover, the slow regeneration rates of removed or damaged corals, in the order of

geological, rather than human, time scales, means that reef-building corals should essentially be viewed as a non-renewable resource, at least until data become available to indicate otherwise, and managed accordingly.

2.2 Live-Rock:

Live-rock is a special term used by aquarists and the marine aquarium industry to describe hard substrate colonized by sessile marine invertebrates and plants (Wheaton, 1989). The value of live-rock to aquarists is for 'living reef' or 'mini-reef' systems, generally in private aquaria, or as a substrate 'base' in aquaria. Demand has increased in recent years for live-rock because technical advances in saltwater aquarium systems have led to shifts from ornamental fish to live-rock. Increased demand is reflected in the increase in reported harvest of live-rock in Florida, the principal source of this resource in the U.S., from 133 tons for a 9-month period in 1990 (the first required reporting period), to over 226 tons for the same 9 month-period in 1991 (Norris and Wheaton, 1991).

Typically, live-rock is any non-living substrate which is collected to obtain the associated organisms (e.g., sea fans/whips, hydroids, anemones, sea squirts, bryozoans, tube worms, molluscs). Any combination of plant or sessile invertebrate in the FMU and attached rock, dead coral or other non-living substrate is considered in the present plan to be live-rock. For this reason the definition of live-rock includes, in addition to the four categories below, any sessile invertebrate the harvest of which requires the removal of attached substrate (e.g., Spirobranchus spp. - the christmas tree worm, encrusting sponges, tunicates, bryozoans, etc.) (see Table 1). The substrate may exist as reef framework, outcroppings of hard bottom, or unconsolidated rubble in a variety of habitats. Four categories of live-rock have been distinguished (modified from Wheaton, 1989 and references contained therein):

2.2.1 Rubble-Rock - this possesses little live covering and is desired for the boring animals living in the rock (endolithic) and as a substrate 'base' in aquaria. Rubble-rock is generally comprised of dead coral and occurs in shallow water back reef areas supporting a diversity of biota within its interstices. In the northern Florida reef tract, at least 80 species of cavity dwellers were collected from coral rubble. It is not known to be an important category of live-rock in FMU.

2.2.2 Algae-Rock - this is colonized chiefly by algae and secondarily by feather duster worms and other invertebrates. It is also known as plant-rock. The importance of macroalgae in reef processes has been well documented. Macroalgae are foraged extensively by a large assemblage of herbivores and, other than symbiotic algae, are the most important producers making energy available to non-coral consumers on the reef. These communities are of great importance as sources of fixed nitrogen and carbon for adjacent communities, and the energy and nitrogen to support the rest of the system are derived from this reef habitat.

2.2.3 False-Coral - this is covered with anemones, particularly of the genera Ricordea, Phymanthus and Rhodactis, which are usually accompanied by encrusting gorgonians, chicken liver sponges, other invertebrates, and algae. It is also known as anemone rock or green/blue anemone and is collected from a variety of habitats. Many fish and invertebrate species are associated with the organisms that comprise false-coral which constitutes an important microhabitat for a wide diversity of organisms (Smith and Tyler, 1972; Hanlon and Hixon, 1986).

2.2.4 Sea-Mat - this is colonized almost exclusively by anemone-like organisms, usually of the genus Zoanthus and is also called gravel rock or colony rock. Like false-coral, sea mat provides a microhabitat for a wide diversity of associated organisms.

Algae-Rock, False-Coral and Sea-Mat are the important categories of live-rock harvested in Puerto Rico. Typically, they are collected by dislodgement from the reef, or removal from substrate adjacent to reef complexes. As a fishery resource, live-rock is valued by the marine aquarium trade for the invertebrate communities which it supports. The rock substrate for these communities is essential for their survival and development and the desired organisms cannot be harvested successfully without this base. However, as for the reef-building corals, this hard substrate is also an integral component of the reef habitat and hence of significance for the general well-being of reef-associated flora and fauna. The importance of live-rock in the reef environment is threefold. First, the sessile invertebrate communities that comprise and associate with, live-rock are a significant food base for species of fish and shellfish of long-established importance to island economies. Second, the physical and topographical complexity of the hard substrate and attached living communities provides critical shelter and habitat to a wide range of organisms. Indeed, many studies attest to positive correlations between increased habitat complexity and increased fish abundance and diversity (e.g., Carpenter et al., 1981; Roberts and Ormond, 1987; Hixon and Beets, 1993).

Third, rock and dead coral surfaces are also vital substrates for the settlement of larval phases of benthic organisms which cannot settle onto living coral. Suitability of substrate is one of the major factors controlling the distribution of many species. For example, natural, rough, substrate covered with other living organisms, presence of other larvae, and absence of certain organisms are all necessary for octocoral settlement. Many other coral species also have specific substrate requirements for larval settlement. Kinzie (1971) found that natural substrate cleared of other organisms had no appreciable octocoral colonization even after six months (Wheaton, 1989). Other factors that influence the settlement of sessile organisms include total surface area available for settlement, conditioning period of substrate, surface relief including crevices and ridges, substrate orientation, and substrate composition (Wheaton, 1989). Thus, both physical and biological complexity are essential for the development of the reef ecosystem. Coral reefs and live-rock habitats form the backbone of this complexity.

There is little known of the generation rates of live-rock complexes. In terms of the hard substrate, replacement is likely to be in the order of geological time and harvest is expected to result in net loss of this substrate. This substrate is essential for the settlement of many of the organisms that form the invertebrate communities of coral reef ecosystems. Given the diversity of invertebrate organisms that comprise live-rock, wide variations in colonization patterns and establishment of climax communities are inevitable and are likely to be slow. Available information shows, for example, that colonization rates for some organisms are highly species-dependent, with some fast and others extremely slow. Observations on artificial (tire) reefs in Trinidad indicated that after about two months, colonization by filamentous algae and barnacles with some bryozoans and barnacles was noted. Four to five months later, filamentous algae and barnacles continued to dominate but ascidians, octocorals and arrow crabs were also noted. After about 8 months, the number of invertebrate species had increased while hydroids and corals had begun to colonize the artificial substrate (Manickchand-Heileman et al., in press). Preliminary experiments on the cultivation of live-rock in Tampa Bay, Florida likewise indicated that although bare rocks seeded by the authors exhibited sufficient growth of a low diversity of organisms (e.g., algae, hydroids, barnacles, tube worms and some anemones) producing live-rock with market value within six months, other species arrived at a substantially slower rate, suggesting that a mature community may take years to (re) establish itself (Ehringer and Webb, 1992). Nonetheless, this study provides promising indications for the viability for live-rock culture which could potentially replace harvest from the wild.

In Florida, in 1992, the Florida Marine Fisheries Commission (FMFC) voted to phase out live-rock landings from the EEZ over a 3-year period with an exemption for aquaculture (Florida Administrative Code, Chapter 46-42, July 1, 1992). Concerns that resulted in the phase-out were twofold: 1) the only current net production of carbonate substrate underlying live-rock occurs on living coral reefs and, in Florida, these reefs are either in equilibrium or eroding; and 2) Florida DNR personnel testified that more than 90% of live-rock examined contained visible colonies of corals. The FMFC concluded that live-rock removal violates state and federal laws prohibiting the take of corals and reduces the surface area and topographic complexity of Florida's coral reefs, removing entire micro-communities along with targeted aquarium species (Florida Marine Fisheries Commission, 1991). Live-rock harvest in Puerto Rico raises similar concerns.

The assemblage that makes up live-rock comprises a community of organisms that have recruited at different times, grown at different rates and pursued different life history strategies (Wheaton, 1989), supported by a hard substrate, often comprised of dead coral, that is essentially non-renewable on a human time-scale. The implication is that the regeneration rates of live-rock will inevitably be too slow for the replacement of harvested rock in a foreseeable future, resulting in net loss of live-rock habitat over time. The physical importance of live-rock as habitat parallels that of reef-building corals. As a result, and because no information is currently available which could be used to determine whether sustainable harvest is feasible, and if so, to allocate a biologically-sound level of harvest, live-rock must

be viewed as a non-renewable resource, its harvest akin to mining. Every effort must be made to collect information on distribution, abundance and regeneration rates of live-rock resources. The distribution of live-rock around the islands is unknown but, like coral reefs, is likely to be limited.

2.3 Invertebrates Associated with Reefs and Live-Rock

Reef-associated invertebrates comprise a wide diversity of organisms that shelter within, on or close to coral or rocky reef habitats. Some are solitary animals, while others live in groups or in association (e.g., commensalism or mutualism) with other organisms. In general, little is known of the biology of the individual organisms and even less of the communities that they form. Some are sessile (do not move) for all of their adult life, some move slowly or rarely, being essentially sedentary, while others range extensively over the habitat. They are members of a variety of species of the Phyla Porifera (sponges), Cnidaria (anemones and gorgonians), Annelida (polychaete worms), Mollusca (bivalves, snails and octopus), Arthropoda (shrimp, lobsters and crabs), Bryozoa, Echinodermata (starfish, brittlestars, urchins), and Chordata (tunicates or sea squirts). A brief summary is given of the general characteristics of each group (from Barnes, 1987). Details on the anemones and gorgonians are given under Section 2.1.

2.3.1 Porifera - Sponges (Phylum PORIFERA) are typically attached to hard substrate. They are all sessile and exhibit little detectable movement. They display great variability in size and shape, with growth rates and body form highly dependent on space availability, the inclination of the substrate and current velocity. Several species of sponges are harvested for the marine aquarium trade although only Haliclona is identified to genus.

2.3.2 Annelida - Segmented tube worms (Phylum ANNELIDA: Polychaeta) in the FMU live in tubes of varying degrees of complexity attached to hard surfaces and filter feed with their 'fans'. The fan worms, feather dusters and christmas tree worms, are among the most beautiful of the sedentary polychaetes (Colin, 1978). Because they firmly adhere to the substrate, in many cases it is necessary to remove the underlying rock to collect segmented worms. For this reason the christmas tree worm, Spirobranchus spp. is included under the category of live-rock. The principal species of segmented worm in the management unit are those of the genera Sabellastarte and Spirobranchus.

2.3.3 Mollusca - The molluscs (Phylum MOLLUSCA: Gastropoda; Bivalvia; Cephalopoda) comprise a diverse group of organisms including such common forms as snails, nudibranchs, clams, oysters and octopus. The gastropods (snails and nudibranchs, or sea slugs) constitute the largest class of molluscs and have adapted to a wide range of habitats. Snails generally have a spiral shell and an operculum (shell cover), while the shell is reduced in nudibranchs which have no operculum. Molluscs can be herbivorous, scraping algae from rocks, or predaceous, like the triton Charonia variegata, one of the most spectacular of Caribbean gastropods. This species occurs near reefs and is most active at night. Other gastropods

harvested for the aquarium trade are Cyphoma gibbosum, the flamingo tongue, family Ovulidae, which preys on gorgonians in shallow water, and Oliva reticularis, the reticulated olive, a small carnivorous gastropod which crawls over sandy areas near reefs usually at night, and grows to about 6 cm.

Nudibranchs are often highly colored animals. The commonly harvested species, Tridachia crispata, occurs on the surface of living or dead coral, or in algal covered areas, and may reach 10 cm in length. A gastropod of considerable commercial significance, Strombus gigas, the queen conch, will be managed under a separate FMP. Many gastropods reach adult size and maturity in 6 months to two years, but slow growth continues and larger species may not reach maximum size for many years. The life span is highly variable.

Bivalve molluscs (clams and oysters) are laterally compressed and possess a shell with two valves, hinged dorsally, that completely enclose the body. Rates of growth and life span of bivalves vary greatly. In general, bivalves grow most rapidly during their early years. Ages of 20 to 30 years are now known to be common in some bivalves, although small scallops may only live one to two years. Most bivalve molluscs are either burrowing or sedentary in form; others may be capable of free-swimming. Species marketed in the aquarium industry in Puerto Rico are the flame scallop (rough lima, fileclam), Lima scabra (the most commonly harvested mollusc in the marine aquarium trade in Puerto Rico) and the Atlantic thorny oyster (spiny oyster), Spondylus americanus. The flame scallop measures up to 8 cm across and occurs in narrow rock crevices, occasionally in groups with several piled on top of one another. They may be attached or swim jerkily by opening and closing the valves, producing a jet of water (Colin, 1978). The spiny oyster is well camouflaged in natural habitats due to thick accumulations of sediment and organisms on its shell. The shell may be 10 cm across with spines reaching 5 cm in length.

Octopus (Octopus spp.) are taken very occasionally for the aquarium trade. More importantly, they are a significant component of the traditional artisanal fishery for which they are harvested by bleach, spear and by hand. In 1990 and 1991, a total of 20,028 lbs and 24,787 lbs, respectively, of octopus were reported, predominantly from the south and west coasts (Fisheries Research Laboratory, Puerto Rico Department of Natural Resources, 1991, 1992). Octopus occur on coral reefs, rocky areas and in seagrass beds and feed at night on invertebrates. They may live little longer than a year (Colin, 1978).

2.3.4 Arthropoda - The shrimp, crab and lobster (Phylum ARTHROPODA: Crustacea decapoda) in the management unit include important reef-associated resources. They are characterized by their segmented bodies, chitinous exoskeleton and compound eyes and they usually have a larval developmental phase in early life history. The shrimp species harvested for the marine aquarium trade are characteristically highly colored and are often closely associated with anemone species, from which many derive protection. Some of them exhibit the interesting, and important from the viewpoint of fish health, habit of cleaning fishes and may play an important role in reef fish health (e.g., Periclimenes spp., Stenopus spp., and

Lysmata spp.). The spiny lobster, Panulirus argus, is managed under separate plans. Among the crab species of principal importance, the red hermit crab is distinctive in coloration. It is most active at night and is found on reefs from 5-30 m (Colin, 1978). The urchin crab (Percnon gibbesi) is usually associated with the long-spined sea urchin, Diadema antillarum, and shelters among the spines. It feeds on filamentous algae by both day and night and is shallow (2-7 m) in depth distribution. The emerald crab, Mithrax sculptus occurs among the branches of the coral Porites furcata and feeds on the polyps at night. It has also been observed to feed on organisms attached to seagrasses (Colin, 1978). Various species of spider crab, known as 'decorator crabs' (family Majidae) have the interesting behavior of attaching bits of sponges and algae to their bodies, presumably for camouflage. The arrow crab (Stenorhynchus spp.) is a distinctive and popular crab in the marine aquarium trade. It is spidery in form and has a long pointed body. On reefs it commonly occurs on sponges or close to sea anemones (Colin, 1978). Little is known of the natural abundance, growth, longevity or replacement rates of the decapod crustacea included in the management unit.

2.3.5. Echinodermata - The starfish, brittlestars, feather stars and sea urchins are all members of the Phylum ECHINODERMATA. They possess an internal skeleton of calcareous plates and, despite an underlying bilateral symmetry, often appear circular, or exhibit 5-rayed symmetry. Among the most commonly harvested echinoderms are the brittlestars and basket stars, particularly of the genera Ophioderma, Ophiocoma and Astrophyton. The former two genera have long arms and can move actively over the reef, while the basket star, attached to gorgonians or tall coral heads, is relatively sessile and may reach nearly 1 m in diameter when expanded and feeding. They are all most active at night. Also frequently harvested are the starfish, especially the red Bahama or West Indies starfish, Oreaster reticulatus, the largest starfish in the region, attaining 50 cm in diameter and which occurs in shallow water in sandy and seagrass areas. Oreaster in natural populations has been reported at densities varying from 2-14 individuals per 100 m^2 but may occur in dense aggregations of 13 per m^2 possibly due to spawning activities. The species feeds on sessile or slow-moving animals and is likely a keystone species in shallow-water, sedimentary, Caribbean environments. The only known natural predator of adult Oreaster is the triton snail, Charonia variegata. Reproduction usually occurs in later summer to early fall and individuals reach reproductive maturity at an arm radius of about 12 cm. Juvenile Oreaster apparently occur in dense seagrass beds where they burrow into sediments among the seagrasses (Scheibling, 1980).

Sea urchins, especially the pencil urchin, Eucidaris tribuloides, are also taken. This species which is distinctive for its thick spines, occurs in rocky habitat and is probably slow-growing (Colin, 1978). Tripneustes esculentus is a valuable research organism and in some areas of the Caribbean is highly valued for its eggs. No data could be located on the natural abundance, longevity, growth or replacement rates of echinoderms harvested in Puerto Rico for the aquarium trade.

2.3.6 Bryozoa and Chordata - Other Phyla, principally the BRYOZOA (ectoprocts or 'moss' animals) and CHORDATA (ascidians or sea squirts), although not named specifically as

harvested groups are, nonetheless significant because they are typical components of the community of animals of interest to collectors of live-rock for their water-filtering capabilities. Bryozoans, for example, secrete a tough external covering to colonies of animals which are either perceived as a thin encrusting layer over rock surfaces, or are erect and branching. As adults, sea squirts usually live attached, singly or in colonies, to hard substrates or to bases such as old gorgonian stalks, and vary greatly in size and coloration.

The benthic invertebrates included in the FMU are a highly diverse group which share in common their desirability to aquarists either as individuals or as members of communities that comprise live-rock. Although many of the organisms have been identified to species, many more have only been characterized to the level of family or genus, either because of the use by the aquarium trade of all-encompassing common names that do not permit identification without detailed inspection, or because identification to species is difficult even under the best of circumstances (e.g., many sponges, gorgonians, brittlestars). Data are needed to document the distribution and abundance of harvested species around the islands and to evaluate their relative contribution to reef communities. As an indication of the importance of various benthic organisms in coral reef communities, a study on a reef south of Ponce, Puerto Rico, yielded percentages of 13-17 percent of calcareous algae, 2-15 percent of boring sponges, 5-15 percent of encrusting gorgonians among 11-22 percent of live coral cover in sample quadrats (Hansen and Mora, 1985).

For most species included in the FMU, little is known of their general biology. Of particular interest, from a management perspective, is consideration of recruitment and growth rates, at least as far as the more heavily harvested species are concerned (e.g., Condylactis and brittlestars). Since, for many species, growth rates are likely to be slow and recruitment episodic, data are needed for determining levels of OY for sustainable exploitation. In determining harvest levels, consideration should also be given to the interdependencies of various species. For example, the excessive removal of sea anemones important as hosts to cleaner shrimp could ultimately impact the health of reef fish that depend on such cleaning 'services'. Finally, while little is known of the distribution around the islands of these species, since they are all reef-associated their distribution is expected to typically mirror that of coral reefs and rocky substrates. Given the sessile nature of many reef-associated invertebrates, these are likely to be as vulnerable to conditions of poor water quality and other perturbations as the reef-building corals.

2.4 Marine Algae and Flowering Plants:

Several marine algae are valued by the marine aquarium trade. Algae lack true roots, stems, leaves and flowers and are photosynthetic. The species of algae include Caulerpa and Halimeda species, Valonia ventricosa and Penicillus capitatus. V. ventricosa is an oval or spherical thin-walled body attaining 5 cm or more in diameter and is found on rocky surfaces. The shiny balloon-like wall is fragile and easily ruptured, resulting in the death of the plant. Penicillus capitatus has a tuft of filaments on an erect stalk, giving it the common name of

'shaving brush', and reaches 15 cm in height. It occurs in a variety of habitats down to a depth of 40 m. Species of the genus Caulerpa have erect branches arising from a horizontal stolon attached to the sediment at intervals by descending rhizomes. Species occur from shallow muddy bays to sandy areas to clear water reef environments and range from Bermuda and Florida to Brazil, including all of the Caribbean at depths from near the surface to 100 m. Halimeda species are comprised of highly calcified segments and are usually densely branched. These algae can thickly cover large areas and form an important shelter for a diversity of invertebrate species. They are important contributors of material to shallow marine sediments. They range variously from Florida to Brazil at depths down to 100 m (Colin, 1978).

These marine algae generally occur in close association with a number of species of seagrasses which are flowering plants (angiosperms). Although not harvested directly, seagrasses provide a critically important habitat for vertebrate and invertebrate organisms of commercial significance and are perceived to be under considerable threat from human activities. Seagrasses form meadows (beds) over largely shallow unconsolidated sediments and their ecological role includes the provision of nutrients and habitat for a wide range of organisms including many coastal fishery resources (including fishes, queen conch, Strombus gigas, the chicken liver sponge, Chondrilla nucula and the white sea urchin, Tripneustes ventricosis), or their prey, such as molluscs, crabs, shrimp and urchins, one endangered species (manatee) and a threatened species (green turtle) (Tetra Tech, 1992). Seagrass meadows also play an important role in the modification of physical, chemical and geological properties of coastal areas such as water filtration and protection from shoreline erosion (Fonseca et al., 1992; Vicente, 1992). The longevity of seagrass meadows mediates short and long-term biological and chemical interactions because of the plants' physical stability.

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

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

Of all the seagrasses, turtle grass is the most ubiquitous. This species occurs throughout the Caribbean and the Gulf of Mexico. It has a horizontal rhizome, buried as much as 25 cm deep in the sediment which gives rise to erect, flattened green leaves (Colin, 1978). In Puerto Rico male and female turtle grass flowers may be found from March-June in the shallow subtidal zone (Vicente, 1992). Turtle grass beds exposed to high wave energy, sand burial, poor water quality and heated effluents do not reproduce sexually (Vicente, 1992).

Seagrass communities are highly productive systems. They provide nutrients and habitat for many reef species of plants, and both vertebrate and invertebrate organisms, and protect coral reefs by trapping sediment and reducing the possibility of resuspension of sediment. While their distribution patterns around Puerto Rico and the Virgin Islands are poorly described, enough is known to cause considerable concern: seagrass communities are highly susceptible to, and have already been seriously damaged by, sedimentation, pollution and other human activities around the islands (Tetra Tech, 1992).

2.5 Ecological Relationships

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

High species diversity and abundance are associated with seagrass meadows, especially in tropical areas. Many vertebrates and invertebrates, including a substantial number of commercial importance, occur in seagrass beds at some phase in their life history. Juveniles utilize this habitat as a nursery area for food and shelter and both adults and young graze on the organisms and detritus attached to the blades, such as numerous shrimp, amphipods, mysids, snails and small fish. These, in turn, are preyed upon by larger carnivores (Thayer et al., 1978). Macroalgae are foraged extensively by a large assemblage of herbivores and the prey of many commercial species may be found in these meadows (e.g., conch, clams, parrotfish, snappers and grunts, among many others) (Thayer et al., 1978; Fonseca et al.,

1992). Postlarvae of shrimp and spiny lobster recruit into seagrass beds and lobster reside in these areas for their first 9-12 months, then migrate to deeper water from which they return at night to feed.

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

As for seagrass meadows, coral and rock reef habitats are critically important for their productivity and for providing shelter, food and settlement substrates, for fishes and invertebrates. Coral reefs are among the most productive habitats in the world (Lewis, 1977). Fisheries in the Caribbean can be defined, with few exceptions, as coral reef fisheries. Reef fishery products are often the primary source of dietary protein for coastal and island people. According to the Caribbean Fishery Management Council, 59% of the total fish products consumed in Puerto Rico and the U. S. Virgin Islands come from coral reefs. The organismal diversity associated with the reef environment has also produced an array of specialist life styles. These have yielded a broad variety of chemical compounds, evolved largely for defense purposes, which have tremendous medical and research potential and are very different from the great bulk of biocompounds found in land-based organisms. These include antimicrobial, antiviral, cardioactive, cytotoxic, neurophysiologic, coagulatory and anti-coagulatory and antibiotic. Out of over 2,000 species of Cnidarians tested, 40% were found to be active anti-cancer agents and particularly high yields of anti-cancer products have been found in organisms tested from Fiji, Australia, Grand Cayman and Puerto Rico (Myers, 1983).

The frequency of commensalism (relationship between two organisms in which one species benefits and the other species, the host, is neither benefited nor harmed) in the coral reef environment is one of the most important contributory factors to high species diversity (Bruce, 1974). Hanlon and Hixon (1986) recorded over 30 small West Indian reef fishes dwelling within the tentacles of anemones. The complexities of reef interactions is well illustrated in the case of cleaning organisms. Several fish and shrimp species, living in close association with sea anemones, are believed to play an important role in reef health by their 'cleaning' activities. Work by Limbaugh (1961) in the Bahamas recorded one cleaning 'station' to be visited by 300 fish over a six-hour period. On removal of cleaner species from two reefs this author noted both a marked decline in fishes in the area over the following few weeks and, among those remaining, an increase in infections and parasitic infestations. Cleaner shrimp

and fish are clearly important for the health of reef fishes. Cleaner shrimp included in the FMU are Periclimenes, Lysmata spp. and Stenopus spp. which are often closely associated with the sea anemones Bartholomea annulata, Stoichactis helianthus and Condylactis gigantea (Limbaugh, 1961).

Distribution patterns of grouper, one of the principal species of commercial and recreational importance in Puerto Rico, have been reported to depend on those of cleaning stations, and public aquaria include cleaners in many of their tanks for fish health purposes. The removal of cleaners has been shown to influence fish distribution patterns and health. Since many cleaners depend on certain host anemone species, it is conceivable that the removal of certain anemones may ultimately influence fish health through removal of important cleaner habitat. In allocating harvest levels of both anemones and cleaners in such circumstances such interrelationships must be taken into account.

Other interspecific associations have been documented for numerous fishes, cnidarians, molluscs, crustaceans, echinoderms and bryozoans (Wheaton, 1989). For example, sponges are inhabited by a wide variety of animals including crustaceans, polychaetes and fishes. Several reef fish species feed on sponges, and Zoanthus (a colonial anemone) is a food source of major importance for at least 16 species of fishes in 7 families (Randall, 1967). In this study, polychaetes were among the most important food items of 62 West Indian reef-fish species in 24 families and were surpassed as preferred foods only by crustaceans (copepods, barnacles, amphipods, stomatopods, shrimps, crabs and lobsters). Ophiuroids (brittlestars) were food for 33 fish species and 16 species fed on benthic tunicates. Octocorals have been noted to provide important habitat for fish and invertebrates and may be especially critical for lobster in the 20-40 mm size range (Jenny Wheaton, pers. obs.).

The endangered hawksbill turtle, Eretmochelys imbricata, is almost exclusively a spongivore; an important hawksbill foraging ground was located between Cayo Luis Peña and Culebra island from 122 - 152 m. The most frequently taken sponge species was Niphates digitalis with N. erecta, Aphimedon compressa, Spinosella plicifera, S. vaginalis utilized to a lesser extent (Vicente and Carballeira, 1991). Other studies indicated that additional sponge species foraged in waters around Puerto Rico were Geodia neptuni, Chondrilla nucula, Myriastra sp., Cynachirella alloclada and Tethya crypta confirming that sponges are an important food source for hawksbill turtles (Vicente and Carballeira, 1991).

Invertebrates in the reef environment are the intermediate link in the food web between primary producers and many species of fishes. The benthic communities they comprise provide habitat, biomass and associated production, often for very specific, complex and specialized organisms. This complexity is of major value to man for the organisms that it supports, for its aesthetic qualities sought for recreation and tourism, and for the wealth of biocompounds that the system generates. Preventing disruption of the integrity of such a diverse and interdependent ecosystem, through overharvest or excessive anthropogenic stress, should be a top marine resource management priority.

2.6 Fishery Management Unit:

Table 1 of this FMP contains all species in the fishery management unit. (Appendix A comprises species that are specifically excluded from the taxonomic groups listed in the FMU). Other species may be added as needed following the procedure described in section 7.2.

2.7 Distribution of Species in the Fishery Management Unit:

Natural distribution and abundance of different species in the FMU depend largely on prevailing environmental conditions. Along many portions of the Puerto Rican north coast, for example, which is a high wave energy environment, reef-forming corals are represented only by small sparse colonies with low vertical relief and coral diversity is low. In turbid, silted reefs under the influence of river discharge, reef corals may be dying or dead below a few meters depth. In general, the further offshore, and the greater the water transparency, the healthier and more abundant are corals and reef communities (Goenaga and Boulon, 1992). Like most islands of the Caribbean, the most extensive reef development occurs on the eastern coasts.

For Puerto Rico, largely qualitative descriptions of the major inshore reefs may be found in Goenaga and Cintrón (1979), Acevedo et al. (1989), Hernández-Delgado (1992), Goenaga and Boulon (1992) and Tetra-Tech (1992, Fig. 2-1). For a number of areas, information on the percent of living coral tissue covering the substrate is available. These estimates of coral cover are calculated from measurements taken from the surface of the coral colony underlying transects placed across a reef site and expressed in terms of percent coral cover (Tetra Tech, 1992).

Figure 1 provides a generalized overview of the percent cover of various substrate types around the coast of Puerto Rico at two depth ranges, 0-20 m and 21-40 m (the east coast includes the U. S. Virgin Islands) ('reefs' = live coral reefs; 'rocky' = rocky habitats; 'hard' = flat hard eolianite substrate; 'corals' = solitary corals; 'soft' = muds and silts) (CFMC, 1984). In waters of 20 m or less, percent cover of reefs is highest off the east coast (41%), followed by south (33%) and west (21%) coasts, respectively. Solitary corals are found predominantly on the east (19%) and north coasts (8%). Rocky habitats show highest percent cover on the west (43%) and south (26%) coasts. Quantitative maps of the distribution of coral and rocky substrates on the insular platform are scarce, although some details are published in a number of small-scale studies carried out around the coast. Of the six published United States Geological Survey (USGS) marine geologic maps of the marine substrate of the insular platform around Puerto Rico and the U. S. Virgin Islands, only one specifically indicates these features (Beach and Trumbull, 1981).

Figure 2 shows the distribution of submerged reefs (no active reef framework coral growth but abundant growth of gorgonians, sponges and small encrusting corals), and live reefs indicated by this map.

With few exceptions, the distribution of stony corals is homogeneous among the coral reefs of Puerto Rico and the U. S. Virgin Islands (i.e., most species occur on most reefs), although their relative abundance may differ among reefs. Certain species are distributed in relation to prevailing physical factors, for example Millepora squarossa has a higher relative abundance where water movement is greater. The scleractinian Agaricia lamarcki occurs in reefs that generally are exposed to deep or turbid waters. Other species may be most strongly influenced in their distribution by depth gradients. For example, one of the major coral reef-building species, Montastrea annularis, varies in both shape and size according to depth. A detailed qualitative listing of habitat type and predominant coral species by location is given in Goenaga and Boulon (1992; Appendix 1), and in literature cited therein.

Completion of a reef inventory was considered to be a high research priority in Puerto Rico in 1978 (CZMP-EIS, 1978). While significant coral research has been completed over the last 15 years, especially concerning inshore coral reef areas, little is known of offshore submerged reefs which are known to be extensive on the south, east and west coasts but are poorly documented (one exception is Fig. 2). The following summary of the available data on coral reef distribution is based on both qualitative and quantitative data.

In Puerto Rico, coral communities on the north coast mainly consist of a low percentage of scattered stony coral colonies (quantitative observations have not exceeded 7-8% coral cover) (Tetra Tech, 1992, Fig. 2-2). Poorly developed reefs have been noted near Bayamón and encrusting growth occurs on rock reefs off San Juan (Goenaga and Cintrón, 1979). Further east, coral reefs become better developed and form patch and fringing coral reefs, especially in areas around the islands of La Cordillera and on cays offshore of Fajardo, Ceiba, and Humacao (Goenaga and Cintrón, 1979). The percent live stony coral cover on these reefs ranges from 6-100 percent (Tetra-Tech, 1992, Fig. 2-3). A review of the major reef systems in northeastern and eastern Puerto Rico, including Vieques, is given by Hernández-Delgado (1992). Along the south coast, reefs are generally well developed both inshore and along the submerged shelf-edge (Morelock et al., 1977; Goenaga and Cintrón, 1979, Weinberg, 1981) although total coral cover is clearly reduced near sources of terrigenous sediment influx which have drastically reduced coral cover and diversity (e.g., Acevedo et al., 1989).

In some places, such as La Parguera, coral communities form extensive fringing and patch reefs and soft coral communities have been described (Goenaga and Cintrón, 1979; Yoshioka and Yoshioka, 1989, 1991). The recorded percent cover of live stony coral on these reefs ranges from 1-100 per cent (Tetra Tech, 1992, Fig. 2-4). The most extensive reef complex in Puerto Rico is found off La Parguera where species diversity at individual sites may reach 28 species (Morelock et al., 1977; Acevedo et al., 1989). At the La Parguera shelf edge, where the water is clear, living coral was observed beyond 70 m (Jack Morelock, pers. obs). The shelf break off La Parguera is a barrier reef at 20 m depth dissected by numerous narrow channels. Between the shelf edge and the coast in this area, two elongate reef systems divide the shelf into an inner, middle and outer shelf (Morelock et al., 1977).

On the west coast corals are poor to well developed, depending largely on their relationship to terrigenous sediment sources (Goenaga and Boulon, 1992). Coral cover ranges from high (El Negro reef has approximately 80 percent cover) (Loya, 1976), to low on the reefs off the industrial town of Mayagüez (Tetra Tech, 1992, Fig. 2-5). Other reef types (e.g., incrusting algal reefs in deeper water (> 43 m) on the north coast of Puerto Rico and red algal ridges on the east coast of St. Croix, hardgrounds, and other types of benthic assemblages have been recorded. These may functionally be as important as coral reefs in many ways (Vance Vicente, pers. obs.).

For the U. S. Virgin Islands, no USGS marine geologic maps are available. In St. Croix an extensive barrier reef runs along the eastern and southeastern bank. At 37 km long, it is the most extensive reef on the Puerto Rico-Virgin Island shelf (Adey et al., 1981; Tetra Tech, 1992, Fig. 2-6). A submerged shelf edge reef is located on the shelf of the north coast. The percent of live coral cover ranged from a few percent on the south coast to almost 50 percent in Mannings Bay (Tetra Tech, 1992, Fig. 2-7). Transects of the bays within the Virgin Islands National Park on St. John indicate from < 5 to 70 percent live coral cover in this area. Information on coral distribution and coral species composition around St. John is also included in Beets et al. (1986). The greatest coral cover appears to occur where there is least terrestrial runoff or where there is exposure to sufficient wave energy to effectively disperse excess sediment (Tetra Tech, 1992). In St. Thomas little information is available on coral community distribution in coastal waters. Where data are available, coral cover may reach 49 percent (Tetra Tech, 1992, Fig. 2-9). A guide to the general location and areal extent of coral reefs in coastal areas of St. John is given in the Virgin Islands National Park Mooring and Anchoring Guide.

The distribution and areal extent of ecological habitats, in general, is poorly documented in Puerto Rico and information is particularly sparse for seagrass communities. Seagrass areas composed of turtle and manatee grass have been noted near Tortuguero (Wood et al., 1975), in Ensenada Boca Vieja, and east of Punta Salinas near Bayamón. Beds of Halophila have been noted in deeper, coastal waters off the mouth of San Juan harbor. On the eastern coast of Puerto Rico, turtle and/or manatee grass have been noted off Humacao, in Bahía las Cabezas, in Laguna Grande, Cabo de San Juan and in waters off Cayo Icacos in La Cordillera. Information is not available from Culebra and Vieques (Tetra Tech, 1992). Seagrasses occur mainly on the south coast because of the protection afforded by coral reefs (Vicente, 1975). However only limited data are available on distributions on the south coast and none were found on west coast seagrasses. In the south, turtle grass and manatee grass have been recorded in the area of Puerto Las Mareas, Punta Petrona, Ponce, Guayanilla Bay, Guánica and La Parguera and Jobos Bay. Three hundred West Indian Manatees are known to forage in the Cayos Caribes area of Jobos Bay, the second largest population on the island (cited in Tetra Tech, 1992).

In the Virgin Islands, the areal extent of seagrass communities is poorly documented. Around St. Croix, well-developed seagrass communities occur with records of turtle, manatee and

shoal grass in Manning Bay and Tague Bay Lagoon. Halophila has been reported from the Salt River submarine canyon (cited in Tetra Tech, 1992). Around St. John, seagrass communities occur in Hawksnest, Trunk, Cinnamon, Majo, and Francis Bays. In St. Thomas, turtle and manatee grass are known from Saba Island, in Perseverance Bay, Brewers Bay and Lindberg Bay (cited in Tetra Tech, 1992).

The distribution of reef-associated organisms is obviously closely linked to that of the corals and rock substrate with which they are associated. There are no detailed listings of the distributions of reef-associated invertebrate species around Puerto Rico and the U. S. Virgin Islands. However, as with reef-building corals, the distribution and relative abundance of sessile reef-associated invertebrates is likely to be strongly influenced by local environmental conditions and onshore human activities. Figure 2 suggests that, as for coral reefs, submerged rock reef habitats may be similarly limited in distribution.

There is an urgent need to conduct comprehensive quantitative surveys of seagrass and reef habitats throughout the insular platform area of Puerto Rico and the U. S. Virgin Islands. Without such information, it is not possible to adequately document the extent of these habitats, to identify those that may be particularly critical to various life phases of significant commercial and recreational species, or to best locate marine reserves. The collection of this information, which should clearly document and distinguish between living coral and rock substrates, should be considered a key research priority for the management of marine resources around the islands. Given the likelihood that reef habitats are generally quite limited in distribution they should be considered as 'significant habitats of limited distribution' and managed accordingly.

2.8 Present Condition of Components of the FMU:

Both natural and anthropogenic stressors seriously impact the distribution, condition and potential productivity of reefs and reef-associated plants and invertebrates. Natural stressors influence both inshore and offshore habitats, while anthropogenic stressors most seriously affect those inshore. Caribbean coral reefs differ in several respects from reefs in other parts of the world which makes them more vulnerable to sources of disturbance than Indo-Pacific reefs. For example, Caribbean reefs are subjected to influences from five major rivers, the Mississippi, the Río Grande, the Río Magdalena, the Amazon and the Orinoco, which produce less than optimal ecological conditions. Also, Caribbean reefs show much lower species diversity and are much more exposed to bio-erosion than reefs in the Indo-Pacific region because they are developing in water where the primary production is significantly higher than that of the Indo-Pacific (Highsmith, 1980). These characteristics render the ecological integrity of Caribbean reefs more susceptible to anthropogenic or natural disturbances.

2.8.1 Natural stressors

Damage to coral reefs in Puerto Rico and the U. S. 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 et al., 1982). Hurricane Hugo caused a significant reduction in total living scleractinian cover on reefs on the south side of St. John (Rogers et al., in press). It devastated portions of coral reefs and seagrass beds off St. Croix (Gladfelter et al., 1991). 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.

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, 1980). 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. Reports on the status of the Florida Reef Tract, for example, indicate that accretion and erosion processes may, at best, be in equilibrium (Norris and Wheaton, 1991). Therefore, additional pressure on coral and reefs through harvest and other anthropogenic activities could result in net loss of these resources over time.

Coral diseases are known to attack reef corals in Puerto Rico and the U. S. Virgin Islands. The white band disease, for example, has caused population declines in A. palmata. Vast stretches of living and healthy 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; Goenaga and Boulon, 1992). 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 (Goenaga and Boulon, 1992), and also on corals in the Virgin Islands National Park on St. John and Buck Island, St. Croix (Peters, 1984; Rogers and Teytaud, 1988).

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 (Goenaga and Boulon, 1992).

Another recent 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. Diploria 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.

2.8.2 Anthropogenic stressors

2.8.2.1 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 (Goenaga and Boulon, 1992). 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 Bahía Guayanilla and Bahía de Tallaboa, 7) all reefs off, and fringing, Guánica, 8) all west coast inshore reefs from Boquerón to Rincón, 9) reefs off Arecibo, and 10) reefs off Dorado.

In the U. S. 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. Johns's National Park (U. S. 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 (Goenaga and Boulon, 1992): sedimentation and siltation; eutrophication; pollution (toxic and thermal); physical damage and overfishing. These problems are not exclusive to the FMU under consideration. The 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: 1) collection of shells, corals and fish; 2) sedimentation from freshwater run-offs; and 3) dredging activities (Salvat, 1981). These sources of damage are also among those to which reefs of Puerto Rico the U. S. Virgin Islands are most commonly subjected, although not necessarily in the same order of severity.

Sediment - The principal concerns in Puerto Rico and the U. S. Virgin Islands are siltation and sedimentation following removal of upland vegetation, and eutrophication (see below), particularly in (although not necessarily restricted to) areas adjacent to inshore reefs (Goenaga and Boulon, 1992). Sedimentation and turbidity decrease the amount of light (a vital source of energy) available to corals for the photosynthetic fixation of calcium carbonate, reducing calcification (growth) rates (Goreau, 1961; 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 the Pacific, both were significantly reduced in areas with fine sediments, where these were allowed to accumulate (Amesbury, 1981). In Torrecilla Lagoon, Puerto Rico, sedimentation from dredging and organic pollution from sewage treatment plants almost destroyed reefs northwest of Boca de Cangrejos (cited in Goenaga and Boulon, 1992). 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 U. S. Virgin Islands are available regarding the detrimental effects of the removal of upland vegetation without the use of appropriate land conservation practices (Goenaga and Boulon, 1992). 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, pers. obs.). 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 U. S. 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 U. S. Virgin Islands. Mean coastal water turbidity was found to be greater for Puerto Rico than for the U. S. Virgin Islands (Tetra Tech, 1992).

Eutrophication - Eutrophication (nutrient enrichment) by sewage disposal or land drainage can 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 in Puerto Rico and the U. S. Virgin Islands (Rogers, 1985; Goenaga and Boulon, 1992). 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% 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 (Goenaga and Boulon, 1992). Excessive nutrient enrichment of seagrass beds could result in the replacement of seagrass with phytoplankton or benthic algae (Zieman, 1982). In the U. S. 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 short-term 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 U. S. 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).

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 Tetra-Tech report and extend along all four coasts of the main island (Tetra-Tech, 1992, Fig. 3-1).

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 (Tetra-Tech, 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 (Tetra-Tech, 1992, Fig. 5-19). As a result of pollution, Puerto Rico's coastal waters did not meet the 'swimmable' goals 31% of the time. No data on swimmable goals are available for the U. S. Virgin Islands (Tetra-Tech, 1992).

A serious source of impairment of waterbodies in Puerto Rico and the U. S. Virgin Islands are NPDES-permitted effluents. The majority of these effluents are from Secondary Treatment Plants (STPs) (Tetra-Tech, 1992, Fig. 3.3, 3.4). In the last federal inspection of Puerto Rico's STPs in August, 1991, 16 out of 46 (35%) failed the inspections, nine of these from the Humacao area (EQB, 1990; Tetra-Tech, 1992). Coastal pollution seriously impacts nearshore reef areas and the communities and habitats associated with them.

Physical Damage - Physical damage 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 anti-fouling 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 U. S. 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 (e.g., Allen, 1992). Between January and March 1987, Rogers et al. (1988) studied anchor damage in several northern and northwestern bays on St. John. Of the 186 boats surveyed, 32% were anchored in seagrass and 14% 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 ft. 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 (Goenaga and Boulon, 1992). 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.

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 (Goenaga and Boulon, 1992)

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 (Russ, 1991). 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 (Sadovy, 1991). Harvest of live-rock directly removes substrate and invertebrate communities with the additional problem of inadvertent inclusion of young coral colonies e.g., impounded live-rock shipments in Florida have consistently contained coral (Project ReefKeeper, 1993). 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 a number of studies have shown a correlation between topographic relief and fish abundance (e.g., Carpenter et al., 1981).

Overfishing - The effects of overfishing on reef community structure, and thereby on the condition of the reefs themselves, are little understood. However, community imbalances in reef-associated organisms may result from large-scale reduction in cover or structural heterogeneity of live coral or other substrate, or from overfishing of certain components of the commercial fishery. For example, Carpenter et al. (1981) showed that biomass of fishes increased with greater structural diversity of the substrate. Work by Hughes et al. (1987) in Jamaica indicated that increasing fishing pressure on coral reef herbivores, such as parrotfish, may account for observed increases in algal biomass which, in turn, reduces living invertebrate cover. Reef herbivores may reduce the abundance of certain competitively superior algae, thus allowing corals and cementing coralline algae to survive (Birkeland, 1977; Ogden and Lobel, 1978). Overfishing of fish predators in St. Croix was suggested to be the cause of unusual abundances of the sea urchin Diadema antillarum in 1973, which, in turn, can reduce coral reef recruitment (Ogden et al., 1973; Sammarco, 1980). Removal of excessive numbers of cleaner shrimps, or their host anemones, for the aquarium trade could potentially compromise reef fish health (see Section 2.5). The Scientific and Statistical Committee has recommended that commercial stocks of fishes not be allowed to drop below the level where the interaction between reef fishes and the substrate are altered in some way (75th CFMC meeting).

2.8.2.2 Seagrasses - There is concern over a number of activities which can severely impact the biological integrity of seagrass meadows. Activities such as dredging and filling, propellor scarring and boat wake wave energy will increase turbidity and kill seagrasses (Fonseca et al., 1992). Poorly planned development, sediment runoff, increased turbidity and poorly treated sewage have destroyed seagrass beds in many areas of Puerto Rico (Vicente et al., 1992). Conditions of low turbidity are critical to permit photosynthesis - a minimum of 20-25% incident solar radiation at the surface is necessary for the plants to survive (Fonseca et al., 1992). Oil spills and chemical pollution can seriously impact this habitat not only through acute physical effects such as smothering but also indirectly through reduction of stress tolerance following exposure to oil and chemicals (Fonseca et al., 1992). Although losses of seagrasses from short-term effects can potentially be mitigated by restoration procedures (transplanting mature naturally-occurring plants), chronic disturbance such as long-term high turbidity cannot be so easily rectified and restoration should not be viewed as an alternative to management of water quality (Fonseca et al., 1992): undue faith has been placed in the technology of

restoration (Colby, 1989). The United States Fish and Wildlife Service is in the process of identifying and protecting those seagrass beds in Puerto Rico and the U. S. Virgin Islands which appear to be critical for green turtles and other wildlife (Vicente et al., 1992).

The reefs and seagrasses of Puerto Rico and the U. S. Virgin Islands are impacted by a range of natural and anthropogenic stresses. In Puerto Rico, of particular concern are the effects inshore of siltation and sedimentation derived from nonpoint sources. Eutrophication and sedimentation are believed to be higher in Puerto Rico than in the U. S. Virgin Islands, with greater mean coastal water turbidity in Puerto Rico and the greatest source of nutrients coming from coastal municipal point sources. Physical damage from fishing, diving and boating activities has been noted on seagrasses and on inshore and offshore reefs in both Puerto Rico and the U. S. Virgin Islands. The possibility of community imbalances due to overfishing that may indirectly affect reef and seagrass environments need further investigation. There is a need for data on sedimentation for the U. S. Virgin Islands and on the actual and potential effects of anthropogenic activities on all offshore reefs. Lack of enforcement and monitoring of water quality standards are serious impediments to the preservation of reef habitats, especially in nearshore areas.

Although coral reef and seagrass communities are adapted to natural cyclical changes and can generally recover from major disturbances, such recovery may be seriously compromised if reefs are impacted when already in poor condition due to anthropogenic stresses. For this reason, the impact of human activities on reefs must be minimized to enable them to recover fully from natural environmental disturbances.

2.9 Probable Condition of Habitat in the Future:

The future condition of reefs, associated invertebrates, plants and seagrass beds depends on the extent to which concerned government agencies properly manage the coastal zone of Puerto Rico and the U. S. Virgin Islands. If management policies fail to address current problems, or those in effect continue not to be implemented, or enforced, current trends indicate that coral reefs and associated habitats will continue to degrade. Education programs are also needed to address the importance and significance of coral reef environments. It is not unreasonable to state that this degradation will be irreversible in terms of human generations (Goenaga and Boulon, 1992). Impacts on reef environments, especially in inshore areas of the coastal zone, are likely to be particularly severe. Concerns over possible overharvest by marine life collectors of the red Bahama sea star, Oreaster reticulatus, Condylactis anemones and live-rock have already been expressed in Florida, after less than a decade of marine life collecting. The effects of possible community imbalances resulting from overfishing also need to be addressed. The paucity of information available on the abundance, growth and replacement rates of most species in the FMU and the intensity of exploitation on certain species means that these may similarly be at risk. Implementation of this FMP, in combination with adoption by the states and federal agencies of

recommendations contained therein, is expected to address many of the concerns expressed and to promote sustainable use of these resources for the maximal benefit of the Nation.

3.0 DESCRIPTION OF FISHERY

3.1 History of Exploitation:

Historically, collection of coral was a common activity, particularly off eastern Puerto Rico (Goenaga and Boulon, 1992), with more limited harvest in southwestern Puerto Rico (Miguel Rolón, pers. obs). Mackenzie and Benton (1972) reported damage to coral reefs caused by coral harvest from Icacos Cay, off Fajardo, in the late 1960's and early 1970's. Most harvesters, mainly local fishers, ceased these activities following implementation, in 1979, of the regulation covering extraction of corals prepared by the Puerto Rico Department of Natural Resources (PRDNR). The taking of coral is regulated in the U. S. Virgin Islands. Black corals were not systematically harvested for commercial purposes, although pieces were sporadically taken by individuals for jewelry (Yvonne Sadovy, pers. obs.).

Intact coral heads, including the hydrozoan Stylaster roseus, gorgonian colonies and larger shells in good condition, were harvested and prepared for sale as ornamental pieces. Coral fragments and smaller shells were often incorporated into local craftwork and jewelry in Puerto Rico and the U. S. Virgin Islands (Yvonne Sadovy, pers. obs.; Jack Damman, pers. obs.), and cured starfish and sea urchins sold as curios. Harvest of coral and associated invertebrates has been important for scientific and educational purposes in both Puerto Rico and the U. S. Virgin Islands. Octopus have been harvested in the commercial fishery for many years and echinoid populations of the sea urchins Tripneustes ventricosus and Lytechinus variegatus have been heavily exploited for scientific purposes in the San Juan/Luquillo area; they are used as model organisms by developmental biologists, and to a lesser extent as food (Hernández-Delgado, 1992).

The taking of reef-associated organisms for the aquarium trade is a relatively new activity that began in about 1970 in Puerto Rico. Not until the mid- to late 1980's, however, was there a rapid expansion from a handful of harvesters/dealers/exporters to an industry that employs as many as 100 people (Sadovy, 1991). This activity has remained relatively undeveloped in the U. S. Virgin Islands and is regulated (since 1990) by permits, for both harvest and export. The expansion of the aquarium trade in Puerto Rico over the last two decades is attributable to three factors. First, there is a general increase in demand for live marine organisms, especially in the U.S.A. and western Europe, since improvements in technology have enabled more people to successfully maintain marine aquaria and 'mini-reefs' in their homes.

Second, the excellent transport facilities from San Juan airport have made Puerto Rico a very attractive location for the harvest and export of Caribbean species. Finally, as restrictions increase on the collection of organisms in Florida waters, and following declines in abundance in the Philippines and a recent trade embargo against Haiti (a historic source of cheap marine

fishes and invertebrates), Puerto Rico has been increasingly viewed as an important source of Caribbean organisms. Historically, harvesters of live organisms destined for marine aquaria are not licensed in any way in Puerto Rico, and no regulations exist to manage this industry. There is no historical seagrass harvest.

3.2 Current Commercial Use:

Commercial harvest of reef-associated organisms is allowed in U. S. Virgin Islands state waters under permit (Indigenous and Endangered Species Permits Act 5665, December, 1990). Permits are reviewed on a case-by-case basis and permit applications include estimated number of organisms to be harvested and retention and shipping details. Transit permits are also required for shipment of organisms out of the state. Twenty-eight harvest/retention/transit permits have been issued in St. Thomas since implementation of Act 5665 for both commercial (N=2) and private use (N=26); the 'private use' category includes permits for both U. S. Virgin Islands and continental United States public aquaria facilities and research institutions. St. Croix has issued 25 permits for the harvest/retention/transit of small numbers of organisms for private use (10 permits) and commercial sale (15 permits - one dealer) (Toby Tobias, pers. obs.). Information on the species composition of individuals collected is not available although inspection of permit applications indicated that these typically included low numbers of a variety of vertebrate and invertebrate species.

In Puerto Rico state waters, commercial harvest of black coral or octocorals is allowed under permit (Regulation to Control the Extraction, Possession, Transportation, and Sale of Coral Resources in Puerto Rico No 2577, 5th November, 1979). No information regarding the number of permits issued was available from the PRDNR but there is currently no known legal harvest of corals in state waters. However, gorgonians and at least one stony coral species (Tubastrea aurea) are listed as available for the aquarium industry and shipments of corals by Express Mail and United Parcel Service to mainland U.S.A. have been reported (Sadovy, 1991). It has also been alleged that boxes of coral and live-rock are shipped out of regional airports (e.g., Aguadilla and Ponce) where there is currently no inspection by PRDNR personnel of shipments, and on occasion, undetected out of San Juan airport. A recent export shipment of 300 live corals was recently intercepted by PRDNR suggesting that harvest and export may occur in substantial quantities.

In early 1993, approximately six companies were known to export live invertebrates from Puerto Rico for the aquarium trade. An additional seven businesses engage in the intra-island trade, either wholesale or retail, of this resource and also import Indo-west Pacific species, while a further 14 enterprises, mostly pet shops, sell imported marine fishes and invertebrates, largely of Indo-west Pacific origin. While the majority of the marine aquarium trade concerns fish species, a substantial proportion is estimated to comprise invertebrates, live-rock and some corals (25% by number in 1992, Table 2). The percentage of invertebrates was lower in 1991 but since 1991 data did not constitute a random subsample of export shipments (Sadovy, 1991), the 1992 data better represent the relative importance of invertebrates versus

fishes in export shipments from Puerto Rico. It is also possible that a small number of divers and fishers are engaged in the collection of corals to supplement their incomes but evidence is unavailable (Valdés-Pizzini, 1992).

Several components of the FMU are harvested and prepared for trade as marine animal products. For example, gorgonian colonies (Gorgonia spp.) are marketed dried or as components of jewelry and other craftwork (Yvonne Sadovy, pers. obs.). It is not known to what extent this material originates from the collection of live animals and subsequent preparation, or from dead organisms collected at the shoreline, although the quality of some intact gorgonian colonies indicate that animals were collected and preserved with marketing in mind (Yvonne Sadovy, pers. obs.). Likewise, the shells of many species of gastropod and bivalve mollusc, cured starfish (especially the West Indian sea star, Oreaster reticulatus and Astropecten), cured sea urchins (especially the West Indian sea egg, Tripneustes esculentus), and spines of the slate pencil urchin (Eucidaris tribuloides) are occasionally used in craftwork. However, the majority of organisms sold as curios and used in craftwork are imported. Contact with retail businesses involved in the sale of marine animal products indicated that such items, either assembled (mirrors, lampshades, jewelry, souvenirs, etc.), or untreated, are imported and that there is no local harvest or export of marine animal products.

This conclusion is supported by trade figures from The Puerto Rico Planning Board (Office of the Governor) which provides annual import and export figures by weight and by value of marine animals products (coral, mollusc shell, natural sponges, dead fish and crustaceans; Planning Board codes 0508.00, 0509.00, 0511.91). For the years 1988, 1990, 1991 and 1992 these figures show no exports of marine animal products and indicate imports of between 20,000 and 37,000 kg of these products from the United States mainland. A major, if not the principal, source of these products was determined to be dealers in Florida. A random survey of 30 companies from a list of 200 marine life dealers in Florida (source: Florida Department of Natural Resources) indicated that 11 businesses export marine products (mainly originating in the Philippines) to Puerto Rico.

The commercial value of components of the FMU, therefore, is principally derived by harvesters of live organisms for the aquarium trade. On the basis of an analysis of 214 export shipping lists covering the period 1990-1992, invertebrate species harvested for the export trade were determined to be sponges, anemones, fan worms, shrimp, crabs, molluscs, starfish, brittlestars and sea urchins (Figure 3). The most heavily exploited species (> 50% by number) was the sea anemone, Condylactis (Sadovy, 1991). Starfish, especially brittlestars, were also among the more heavily exploited species groups. Although live-rock, gorgonians and corals were exported, combined these groups only constituted 3.7% of all organisms recorded (Table 2).

Principal harvest areas around Puerto Rico are north and south of the Rincón peninsula, Punta Arenas in Cabo Rojo, along the northwest coast to Arecibo, the island of Desecheo, La Parguera, the southwest coast and southeast of Ponce at the island of Caja de Muertos

(Sadovy, 1991). Harvesters interviewed indicated that they are careful to rotate the area of collection to avoid fishing too heavily in any one location (Sadovy, 1991). Seagrasses are not harvested commercially in either Puerto Rico or the U. S. Virgin Islands.

3.3 Current Recreational Use:

Harvest of many components of the FMU for personal use in home aquaria, or as curios, occurs to an unknown degree. Diving and snorkeling by individuals has rapidly grown over the last decade, and the importance of the coral reef environment for pleasure activities is widely recognized. Thousands of residents in Puerto Rico and the U. S. Virgin Islands use SCUBA gear to dive, or snorkel on nearshore coral reefs for recreation and SCUBA has grown markedly as a leisure activity and business (Valdés-Pizzini et al., 1988; Goenaga and Boulon, 1992).

The principal direct recreational importance of coral reefs and associated organisms is perceived to lie in the tourism and diving industry. In Puerto Rico in the 1970's there were 3-4 dive schools (Carlos Rodríguez, FMP Committee Meeting, 1991, Dec. 12). There are currently about 35-45 diving operations (Efra Figueroa, pers. obs.). Data from 1992 indicate that these businesses were registered with the diving organizations PADI (Professional Association of Diving Instructors) (N=3), NAUI (National Association of Underwater Instructors) (N=4), SSI (Scuba Schools International) (N=4), with the remainder trained by RTSC (Recreational Training SCUBA Council), and IDEA (International Diving Education Association). Most of these businesses are small family concerns and the majority provide diving certification courses for island residents. A minority (about five) offer both diving courses and diving and snorkeling facilities for tourist divers. The principal diving areas in Puerto Rico are La Parguera, Caja de Muertos, the east coast (Humacao, Fajardo, Vieques, Culebra), and the west coast (Rincón, Aguadilla, Desecheo and Mona).

The interests of divers are to view and photograph reef life, to spear reef fish and to collect marine life for aquaria. The Puerto Rico Board of Tourism is promoting Puerto Rico as a destination of interest for its underwater environment and sport fishing as part of a drive towards eco-tourism (Natural History Magazine, 1991; San Juan Star, April 23, 1993). The PRDNR is also concerned with the development of various areas for eco-tourism such as the underwater trail planned for Caja de Muertos Island (south of Ponce) which is visited by hundreds each weekend. SCUBA and spearfishing are key elements of the recreational fishing sector with approximately 17% (N=37) of a total of 221 marine recreational facilities recorded in Puerto Rico and the U. S. Virgin Islands dedicated partially or wholly to SCUBA training and equipment sales (Valdés-Pizzini et al., 1988).

Other tourist-related recreational activities in Puerto Rico which depend on the reefs are the glass-bottomed boat (e.g., in La Parguera) which allows tourists to view the reef from safety. This is also a popular boating area where many hundreds of boats may moor each weekend (Yvonne Sadovy, pers. obs.). For many commercial fishers in a number of areas, recreational

activities as a source of income are becoming increasingly important as traditional commercial fisheries diminish (Ruperto Chaparro, pers. obs.); a growing sector of commercial fishers supplement their income by taking divers out to reefs to dive or fish. Off northeastern Puerto Rico popular boating areas are Icacos and Palominos where on a weekend 300-400 boats may anchor; almost 4,000 boats are moored in 7 marinas in the Fajardo area (Carlos Rodríguez, pers. obs.).

The U. S. Virgin Islands is the major diving destination of the U. S. Caribbean. Indeed a major attraction to the islands is based on reef-related activities. Approximately 25-30 dive businesses are currently operating in the U. S. Virgin Islands, an increase from 20 in 1980s (Peter, 1989), predominantly offering diving and snorkeling trips to tourists (George Mitcheson, Ralf Boulon, pers. obs.). In 1992 diving businesses were registered with NAUI (N=7), PADI (N=19) and other organizations. These businesses operate dive boats and hire and sell diving gear. An underwater trail in Trunk Bay, St. John, is utilized daily by hundreds of tourists. The National Park on St. John has documented annual increases of visitors to Trunk Bay beach from 20,000 people in 1966 to 170,000 people in 1986 (Rogers and Teytaud, 1988). Buck Island in St. Croix is a well-known and popular destination. Among other reef-related tourist activities may be counted the tourist submarine in St. Thomas.

3.4 Research and Medicine:

Octocorals hold much potential as a source of important biomedically active compounds. Prostaglandins are among the most potent biological materials known and were a major discovery from a western Atlantic gorgonian, Plexaura homomalla. Prostaglandins, upon purification, stimulate uterine contractions to induce labor and/or therapeutic abortion, speed healing of stomach ulcers, reverse effects of cyanotic congenital heart disease, and hold much promise for medical research. Three species of Pseudoplexaura contain compounds active against human carcinoma of the nasopharynx and lymphocytic leukemia (SAFE report - GMSAF). Gorgonians have been intensively collected in the La Parguera (Puerto Rico) area for scientific/commercial purposes, namely for the assessment of compounds for pharmacological activity. Similar, though not as intensive, collections have been made off the southwest coast of St. Thomas. The impact of this activity, intensive for short time spans, is unknown and needs to be assessed (Goenaga and Boulon, 1992). Periodic collection has also been noted of soft corals, sponges and macroalgae for extractions of chemicals for pharmacological purposes. The frequency and extent of such collection is not known but this activity has been noted to incur considerable local damage (Vance Vicente, pers. obs.).

A number of highly active biocompounds have also recently been isolated from reef-associated invertebrates with antimicrobial, antileukemic, anticoagulant and cardioactive properties. Coral reef organisms have been used as tools in the elucidation of physiological mechanisms (e.g., sea hare), fertilization (e.g., sea urchin), regeneration and cell association (e.g., sponges) and mechanisms of drug action (e.g., squids) (Goenaga and Boulon, 1992).

It is not known to what extent collection activities on these species may change in the future or what additional compounds are yet to be discovered.

3.5 Science and Education:

The diversity of organisms associated with reef and seagrass environments has produced ecosystems that are important scenarios, or natural laboratories, for testing ecological hypotheses related to the coexistence of species (Goenaga and Boulon, 1992). Education covering the importance and significance of the reef environment is essential for long-term preservation and to ensure maximum benefit to the Nation. Harvest for scientific and bona fide teaching purposes occurs in both Puerto Rico and the U. S. Virgin Islands and is an essential component of research and education objectives.

3.6 User Conflicts:

Given the broad socioeconomic significance of reefs, reef-associated organisms and seagrasses, there is much potential for user conflict. Commercial fishers in Puerto Rico, for example, have already expressed concern that collectors of organisms for the marine aquarium trade may negatively impact the commercial fishery by removing prey species, or juveniles, of commercial fishes (e.g., Benedetti, 1991); as landings from commercial fisheries continue to decline, such conflicts are likely to become increasingly intense. Diving operations are concerned about increased sedimentation on reefs from land-based activities, and about live fish collection and other commercial and recreational fishing practices which they believe degrade the reefs sought by their clientele.

3.7 Landings and Value Information:

An estimated 5,507 boxes of live marine aquarium fish and invertebrates were exported from January 1990 to December 1992 out of San Juan airport in Puerto Rico (Sadovy 1991; Table 3), containing approximately 182,000 organisms (at an average of 33 organisms per box). This figure is considered to substantially underestimate annual harvest levels for 4 reasons: 1) it does not include mail shipments; 2) it does not include exports from regional airports (although these are believed to be relatively minor; 3) it does not include on-island sales which may be substantial given the number of businesses involved (see Section 3.2), and; 4) it does not include losses due to pre-shipment/sale mortality (possibly 10-20%). Shipments from Puerto Rico to the United States by Schedule B (United States Department of Commerce, International Trade Administration, San Juan) for 1992 were recorded as 18,000 kg (=US$249,000) of live aquarium fishes (commodity No. 0301100000 - marine and freshwater ornamentals, vertebrate and invertebrate). Since each box weighs approximately 8-14 kg (Sadovy, 1991), the number of boxes exported in 1992 according to DOC records ranged between 1,286 and 2,250. Based on DOC figures, and given that substantial exports of freshwater ornamentals are known to occur, and that few direct international exports are made, the PRDNR marine ornamentals export figure for 1992 of 1,419 boxes is likely a

reasonable estimate of export shipments from Puerto Rico. The absence of information concerning intra-island trade is considered to be the major data gap impeding assessment of harvest levels of marine aquarium organisms in Puerto Rico.

Of the total shipped, an estimated 25% (45,500) were reef-associated invertebrates (Sadovy, communication to CFMC). Wholesale unit prices of invertebrates vary from US $0.25-12.00 (Table 2), averaging about $2.00-$3.00 a unit. It was determined that the current wholesale export value of invertebrates marketed for the aquarium trade is likely to be in excess of $114,000 annually and may well be several times this value if on-island trade is included. These estimates are subject to revision as more information becomes available. The extent of trade in live-rock is reportedly important although only about 3% of recorded exports were classified as live-rock (Sets 1 & 2; Table 2). Because of growing demand for live organisms for marine aquaria in the United States and because of increasing restrictions on the harvest of many desired organisms from Florida waters and a trade embargo against Haiti (an important source of Caribbean organisms), there is considerable concern that pressure to exploit Puerto Rico and Virgin Island stocks is likely to increase rapidly in the near future.

The major economic value of reef and seagrass habitats lies in their importance for the commercial fisheries of reef-associated fishes, conch and lobster, as well as their significance to the tourism industry for diving, snorkeling and related recreational activities. The commercial fishery of 1,219 fishers had an ex-vessel value of $4,300,000 in 1991 (FRL, DNR, annual report 1992). The economies of the U. S. Virgin Islands and Puerto Rico are based on tourism. In 1991, the visitor expenditure in the U. S. Virgin Islands was $708,100,000 and in Puerto Rico was $1,390,800,000 (Tetra Tech, 1992). What proportion of this total may be attributable to reef resources is likely to be significant but incalculable. Reef habitats are also of incalculable value for their role in the reduction of coastal erosion and storm damage, and for the organismal diversity that has generated valuable pharmacological compounds. On balance, therefore, the greatest biological and economic value of reefs and associated organisms is undoubtedly non-consumptive in nature.

3.8 <u>Vessels, Gear, Employment and Marketing</u>:

Components of the FMU which are harvested commercially are predominantly those organisms marketed live for the marine aquarium trade; the reef-associated invertebrates and live-rock. Many harvesters are exporters, although some harvesters sell their catch to an exporting middleman, or to island pet shops. There are about 6 export businesses in Puerto Rico, a further 7 businesses operating exclusively on-island (Sadovy, communication to CFMC) and 3 commercial enterprises in the U. S. Virgin Islands (St. Thomas and St. Croix). Businesses in Puerto Rico depend on about 40 regular harvesters working on a full- or part-time basis, with less than an estimated 100 people involved in all phases of the aquarium trade, including harvesters and their assistants, biologists, packers and shippers. Most exporters depend for the majority of their income on the export trade, but some also depend

on other means of income outside of the aquarium industry (Sadovy, 1991). On-island distributors are generally pet shops at the wholesale or retail level.

Major harvesters have their own boats, diving and collecting gear. Boats are in the order of 7 m in length. Collecting trips may be made on 3-7 days weekly. Collection is predominantly by SCUBA, generally down to 20 m but occasionally to 40 m for certain species. Mask and snorkel are commonly used in shallow water areas. Collection of reef-associated invertebrates is by hand, net (mainly hand or dip nets), chemicals such as 'quinaldine', and slurp gun (Sadovy, 1991). Powerheads have been used to dislodge live-rock (Toby Tobias, pers. obs.). There are also reports that bleach, formalin and gasoline have been used on occasion, especially in the area of La Parguera (Sadovy, 1991). Quinaldine is mixed with isopropyl alcohol or acetone, diluted with seawater and dispensed from bags, small plastic bottles or pressure sprayers. Crow bars, or like instruments, are used for the removal or displacement of coral and rock.

Following collection, harvested organisms are temporarily maintained in holding facilities which vary from simple 'paddling pools' fed by a flow-through water system, to a series of glass and concrete tanks, under-gravel and ultra-violet filters, and protein skimmers. Animals are generally maintained for a few days prior to shipping or sale to local island pet shops. Estimates of mortality from the time of capture to the time of export reportedly vary between 10-20% depending on the species, capture and handling methods, the level of skill of harvesters and conditions of holding facilities. Within the aquarium trade, 10% mortality is considered to be high while some wholesalers consider more than a few percent to be unacceptable (Sadovy, 1991). Mortality in fishes may be high; 30% or more has been noted in rock beauty angelfish (Héctor López, pers. obs.). Mortality of specific invertebrate species is unknown and needs to be evaluated.

For shipping and export, animals are packed in single or double plastic bags which are filled with oxygen by some shippers and placed in boxes for shipping. Boxes vary in dimensions and may be lined with insulating material for stabilization of temperature, depending on the shipper, destination and season. The majority of marine organisms are shipped out of San Juan airport to the east and west coasts of the U.S.A. Canada, and to Europe, particularly to the United Kingdom and Germany. However, exports have also been shipped out of Aguadilla and, possibly, out of Ponce airports. The significance of the shipments through the latter two airports is that there is currently no government inspection of exports from any airport other than San Juan. Given the fact that a substantial proportion of the businesses are located nearer to regional airports than to San Juan, the traffic through these is potentially substantial. Shipments from San Juan are inspected, at no charge, by PRDNR personnel, and, if destined for outside of the U.S.A., also by the U. S. Division of Fish and Wildlife, who charge a $25 inspection fee. Some exports allegedly take place through the postal system (Federal Express) and United Parcel Service. In the U. S. Virgin Islands only a couple of small businesses are involved in the export of marine organisms. Transit permits are required for exporting any live, indigenous species from the state. Marine invertebrates are harvested for

display and educational purposes in public and private aquaria in both St. Thomas and St. Croix.

Recreational activities involve approximately 65, generally small, diving operations in Puerto Rico and the U. S. Virgin Islands combined. Diving operations typically carry out diving instruction courses and organize diving trips. Boat size varies from 8-13 m in length and boats take small to large groups of divers, generally on day trips. Longer trips may be planned on occasion, for example from Cabo Rojo to Mona island, west of Puerto Rico. In Puerto Rico the businesses are generally small family concerns, sometimes incorporating dive boats, while those in the U. S. Virgin Islands operate with 2-10 employees and 0-4 boats.

Other recreational activities include submarine trips in St. Thomas, a glass-bottomed boat in La Parguera, which is also a popular boating and diving destination, and an unknown, but growing number of individuals, many of them active or retired commercial fishers, who service tourists and divers, often on an informal paying basis (Chaparro, pers. obs.). The National Park on St. John has documented annual increases of visitors to Trunk Bay beach from 20,000 people in 1966 to 170,000 people in 1986 (Rogers and Teytaud, 1988). Buck Island in St. Croix is a well-known and popular snorkeling destination. The value of recreational activities to the economies of the islands is unknown but is undoubtedly substantial if boat and fuel sales, docking facilities, refreshments, etc., are all taken into account.

3.9 International Activities:

There are no international activities e.g., foreign fishing, agreements or treaties, which bear directly on components of the coral management unit.

4.0 CAPACITY LIMITS

Title 50 CFR 601.11(C)(1) requires that an objective and measurable definition of overfishing be prepared for each stock or stock complex managed under an FMP. The definition of overfishing is required to guide management in determinations of whether the capacity of a stock to maintain itself through reproduction might be destroyed by fishing. The ultimate goal of a definition of overfishing is to obtain Optimum Yield (OY).

Optimum Yield and Maximum Sustainable Yield (MSY) for stony corals, octocorals (Cnidaria), and for live-rock and seagrasses in the EEZ are zero except as authorized for scientific research, education and restoration purposes. Accordingly, the Domestic Annual Harvest (DAH) and the Total Allowable Level of Foreign Fishing (TALFF) are both zero. It was determined that the greatest overall benefit to the Nation, and the most effective use, of these resources is overwhelmingly non-consumptive, as habitats providing food and shelter for important species of fish, conch and lobster, turtle and manatee, for their biochemical properties, and for their aesthetic value to non-consumptive users. Given their restricted

distribution and their typically slow growth and regeneration rates, these resources must be considered non-renewable, limited habitats of special concern and managed accordingly.

Under the Plan, harvest of stony corals, octocorals, live-rock and seagrasses will not be permitted except for purposes of scientific research, education and restoration. The Department of Planning and Natural Resources (DPNR) of the Government of the U. S. Virgin Islands prohibits the unpermitted harvest of live-rock and all corals (Cnidaria) for commercial or recreational purposes. Permits are provided on a one-time case-by-case basis and require submission of details of species name and number, location of activity, capture methods and holding facilities, among others. PRDNER prohibits the harvest of coral or live-rock for commercial purposes except under permit. Harvest of reef-associated plants and invertebrates will be allowed under permit subject to possible future harvest limits should information on stock abundance and/or harvest levels merit the establishment of these in the future. Efforts will be made to establish OY and MSY and a TALFF, if applicable, for reef-associated invertebrates. The DAH is not known and must be determined.

5.0 PROBLEMS IN THE FISHERY

5.1 Overfishing:

Definition of overfishing: overfishing is defined as an annual level of harvest that exceeds OY.

5.1.1 Stony Corals, Octocorals, Live-Rock and Seagrasses

OY for stony corals, octocorals, live-rock and seagrasses is set at zero (0) except as may be authorized for scientific and restorative purposes. Under this definition, stony corals, octocorals and live-rock are overfished. These resources are considered to be distinctive habitats of limited distribution the greatest value of which is perceived to be as habitat for reef-associated and reef-dependent organisms, as a buffer against coastal erosion and for their aesthetic significance for tourism and related activities i.e., in non-consumptive uses. Given the limited distribution and slow regeneration rates of the majority of these species, they are considered to be non-renewable resources for which an OY of zero is the only level which can reasonably be expected to ensure no net loss. Although current harvest of corals and live-rock is low there is considerable concern over increasing pressure to harvest these resources and over the growing intensity of anthropogenic stresses to which they are being subjected. Moreover, the importance of seagrass beds as a foraging area for the endangered manatee is also considered to be of critical significance in the protection of this resource. The socioeconomic impact associated with this level of OY is considered to be negligible at the present time. The amount taken recreationally for personal use is not known but is believed to be a fraction of that taken commercially.

5.1.2. Other Reef-associated Invertebrates

Information is not available regarding natural abundances of these organisms, sustainable harvest levels or the precise quantities currently being harvested. The estimated numbers of organisms exported provides only a minimum estimate of harvest in Puerto Rico as on-island trade is completely unaccounted for and has yet to be assessed. Because of insufficient data, no level of OY can be set until further information is obtained. However, since there is valid concern that harvest will increase and that, from experience elsewhere, heavy uncontrolled harvest has the potential to reduce the abundance of certain species in the reef ecosystem (as has occurred with the Bahamas starfish in Florida, and the starfish Acanthaster planci in Sri Lanka) (Wood, 1985), every effort must be made to collect sufficient data to estimate OY and MSY as soon as possible. Information is urgently needed on reef-associated invertebrates to determine abundances, current and sustainable harvest levels and capture-induced mortalities to permit establishment of OY, especially for more heavily exploited species in the FMU such as Condylactis and brittlestars; quotas have been established for several invertebrate species harvested for the marine aquarium trade in Florida's Marine Life Rule because of concerns over excessive harvest. The recommended data collection program to accompany permitting for harvest of components of the FMU, and research initiatives, will enable OY to be determined.

5.2 Lack of Management:

At present, reefs, reef-associated plants and invertebrates in the FMU, live-rock and seagrass beds are not managed in federal waters (with the exception of spiny lobster). Some management is afforded corals and live-rock in state waters of both the U. S. Virgin Islands and Puerto Rico. There is no management of reef-associated invertebrates or of seagrasses in either state or federal waters. Given the vulnerability of all components of the Coral FMU, throughout their distribution, to land-based activities and to activities in state waters, it is critical that these resources be managed consistently and comprehensively throughout the area. Furthermore, given the importance of the reef and seagrass habitats for other fisheries of commercial and recreational importance, their condition is clearly of significance for the management of other consumptive resources in waters under both state and federal authority. Lack of management of commercial and recreational fisheries can also impact the reef ecosystem by disturbing the natural biological balance of interacting and co-dependent organisms. For example, overfishing of carnivores may disrupt fish communities by producing excessive numbers of herbivores, which, in turn, may compromise recruitment on excessively-grazed substrates.

The very real potential for a rapid increase in the exploitation of components of the FMU may soon result in Puerto Rico becoming the principal source of tropical western Atlantic organisms for the U. S. market, thereby further increasing pressure on resources and intensifying the need for management action. Moreover the substantial importation of marine exotic species by pet shops (e.g., Indo-west Pacific species) into Puerto Rico (3,967 boxes in 1990; 1,220 boxes in 1991; PRDNR figures) (Sadovy, 1991) introduces the potential for exotic introductions into marine waters through release or escape; successful establishment

of introduced marine fishes has been recorded in Hawaii (Oda and Parrish, 1981). Regulations pertaining to the release of exotics in marine waters need to be developed by the states. Finally, the widespread occurrence of a larval dispersal phase for many corals and reef-associated organisms means that the activities on reefs of one island may profoundly influence recruitment of organisms on other islands. Hence, compatible and consistent management of reef resources on a regionwide basis is to be strongly encouraged and supported.

5.3 Lack of Effective Environmental Policies/Enforcement:

There is serious concern over the lack of monitoring and enforcement of harvest and other anthropogenic activities which are actually, or potentially, detrimental to coral reefs and associated organisms. For example, a major cause of mortality of corals and associated invertebrates is sedimentation and pollution. These are caused predominantly by land-based or nearshore activities such as deforestation and discharge of untreated sewage. The Council is aware of these problems and recommends that every effort be made for state and federal agencies to work together to resolve them. In particular, the reduction of terrigenous sediment input from upland sources, the elimination of discharge of untreated sewage and petroleum products into coastal waters and higher standards for NPDES permits should be addressed. Current law does not adequately address the loss of Special Aquatic Sites (SAS) such as coral reefs and seagrass beds in the U. S. Caribbean (Clean Water Act, Section 404).

The illegal use of quinaldine for the harvest of live organisms is known to be widespread but laws prohibiting its use in Puerto Rico are not enforced. Statements made at public hearings and scoping meetings indicated that on numerous occasions illegal activities such as nearshore ship tank cleaning, and nighttime discharges went unenforced despite reports to local authorities. Holding facilities where live organisms are maintained prior to shipment or sale are not inspected in Puerto Rico to ensure that these conform to the requirements of Law 67. Airport inspections in Puerto Rico are not comprehensive and enforcement personnel are not always familiar with fish and wildlife managed under state laws.

5.4 Inappropriate Harvest Techniques and Holding Facilities:

Certain harvest techniques, such as the use of chemicals, powerheads to dislodge live-rock, the physical removal of live-rock and coral, or the disturbance of substrate necessary to collect organisms closely associated therewith, are considered to be damaging to the coral reef habitat. Such activities can cause death or damage to corals or associated invertebrates, or unnecessary disturbance to the habitat. Some conditions encountered in the holding facilities and shipping conditions of live organisms are considered likely to result in unacceptably high rates of mortality. This produces inefficient harvest and unnecessary wastage of the organisms concerned. A set of standards must be developed for the handling, holding and transport of live organisms to minimize wastage and to ensure most efficient use of the resource, as authorized under the Magnuson Act (Subsection 303(a)(1)(A)). In a fishery for

small and delicate species where mortality can be high due to poor harvest methods, ease of localized overfishing and poor post harvest handling, regulations are necessary to reduce mortality and to prevent waste consistent with the objective of National Standard Five to promote efficiency in the utilization of the fishery resource by preventing waste due to overharvest (16 U.S.C. 1851 (a)(1) and (5)). Once animals enter the chain of commerce the Lacey Act applies (see Section 9.1).

5.5 Inadequate Information Base:

There is insufficient scientific and fishery information on reefs, reef-associated plants and invertebrates and seagrasses regarding growth rates, life span, colonization patterns, distribution, abundance, landings, catch, effort and mortality, for most species, with which to develop species-specific recommendations, or on which to base appropriate levels of OY, MSY and allowable harvest for reef-associated invertebrates. Moreover, little is understood of the importance of interspecific associations for reef species' health and distribution although these are known to be of critical importance to the integrity and diversity of the coral reef ecosystem. Information on water quality in the U. S. Virgin Islands, and on the impacts of anthropogenic activities, especially in offshore areas of both Puerto Rico and the U. S. Virgin Islands is urgently needed. The applicability of traditional fishery management approaches to colonial and non-colonial reef invertebrates needs to be evaluated (see Section 2.1)

5.6 Limited Public Information/Education:

There is a general lack of public understanding of the importance of reef ecosystems. The Council considered that incoming visitors to the Islands should be given a summary sheet covering local laws protecting the marine environment. It was recommended that an extensive education program be established which includes visits to fishing communities and diving establishments, and more interaction with government officials in charge of conservation and enforcement activities in Puerto Rico, the U. S. Virgin Islands and the federal government.

5.7 Habitat Loss and Degradation:

Reef habitats around Puerto Rico and the U. S. Virgin Islands are considered to be limited areas of special importance and concern. Degradation that occurs through man-made and natural causes, despite laws designed to mitigate some of these trends further compromises these significant ecosystems. Anthropogenic stresses on coral reefs not only directly compromise their condition, and that of the organisms that depend on them, but are also believed to undermine their ability to recover from natural stressors. Loss of coral reef and seagrass habitats directly affects a wide range of organisms including fisheries of considerable commercial and recreational significance in the region. These resources are heavily dependent on reef habitats for food and shelter. Important sources of habitat degradation, other than land-based activities, are dredging and dumping, anchor damage, ship groundings, unmonitored or unsupervised tourist and diver activities, and careless

collection by scientists or commercial harvesters. Some of these effects can be mitigated by appropriate management action. For example, heavy levels of diving can be sustained by reefs without irreversible damage where mooring buoys exist (Callum Roberts, pers. obs.).

Of particular concern is the loss or degradation of habitats critical for certain life history stages or phases of development. Critical habitats should be identified. Quantitative relationships between reef habitat and associated organisms have not been established but it is certain that continuing degradation of reef or seagrass habitat will adversely impact reef- or seagrass-dependent resources.

5.8 User Conflicts:

Given the importance of coral reef and seagrass habitats for commercial and recreational fisheries, for tourism-related activities, and the role of coral reefs in reducing coastal erosion, it is clear that there is much potential for user conflicts (see Section 3.6). As the commercial fisheries decline, and as human populations grow and tourism increases in the area, the condition of reefs is expected to continue to deteriorate if present trends continue. Efforts must be made, through recommendations and management, to ensure equitable allocation of resources and to reduce actual and potential user conflict. One approach to reducing possible user conflict would be to introduce a scheme of zoning whereby different activities would only be permitted in specific pre-allocated zones.

6.0 MANAGEMENT OBJECTIVES

The FMP contains one general and eight specific objectives to address the problems of coral resources.

Objective 1: To optimize the benefits to the Nation generated from the resources of coral, live-rock, seagrasses and reef-associated plants and invertebrates, while ensuring their conservation and long-term preservation, through implementation of a management plan consistent with other management plans in the federal waters of the U. S. Caribbean.

Objective 2: To minimize adverse human impacts on coral, live-rock, seagrasses and reef-associated plants and invertebrate resources by reducing fishing pressure, wasteful harvest practices and other anthropogenic stressors directly affecting them, and allowing for the restoration of naturally-balanced reef systems.

Objective 3: To establish resource data collection and permitting systems, and a research and monitoring program to collect fishery information and develop scientific data necessary to best utilize and preserve components of the management unit and to enable establishment of an OY for reef-associated invertebrates.

Objective 4: To provide, where appropriate, for special management of reef and seagrass habitats of particular concern or ecological importance through the establishment of reserves or other protected areas.

Objective 5: To increase public and government awareness of the importance and vulnerability of reef, seagrass and reef-associated resources. Informing and educating the general public of the importance of these resources will reduce adverse human impacts and foster support for management. Education of resource users, such as tourists and fishers, will promote more conscientious resource use.

Objective 6: To provide for and promote a consistent, coordinated and enforced management regime for the conservation and best utilization of reefs, seagrasses and reef-associated resources, in cooperation with state governments and other nations in the region.

Objective 7: To provide a flexible management system which minimizes regulatory delay while retaining substantial Council and public input into management decisions and which can rapidly adapt to changes in resource abundance, new scientific information, and changes in fishing patterns among user groups, or by area.

Objective 8: To reduce user conflicts in the fishery management unit through management and recommendations.

Objective 9: To eliminate or significantly reduce terrigenous sediment anthropogenic input from upland sources into coastal waters, and the discharge of untreated sewage and petroleum products into coastal waters. This objective may be addressed through recommendations to local governments to encourage compliance with, and enforcement of, laws regulating activities that result in products that negatively affect the condition of reef and seagrass habitats and reef-associated organisms.

7.0 MANAGEMENT PROGRAM

7.1 Management Measures Proposed:

Seven management measures are proposed to address the management objectives. Rejected options for each management measure are discussed.

7.1.1 Management Measure 1 - Prohibit the harvest or possession of stony corals, whether dead or alive, except for legally permitted research, education, and restoration programs.

Discussion - Corals and coral reefs represent distinctive habitats of limited distribution. The principal value of stony corals lies overwhelmingly in its role as a non-consumptive resource,

as essential habitat for the shelter of reef-associated vertebrate and invertebrate species, and in its aesthetic importance for recreational and touristic uses. Current harvest of stony corals is negligible. Given the characteristically slow growth rates of stony corals, recovery and regeneration following harvest and other human perturbations (such as discharge of pollutants and sewage) are far slower than observed in most other living resources. These sessile resources are vulnerable to both natural and anthropogenic stressors because of their sedentary nature and slow regeneration rates. Stony corals must therefore be considered a non-renewable resource on a human time-scale and harvest prohibited to ensure no net loss. Since the potential for increase in intensity of harvest and physical damage is high, as demand for marine aquarium organisms and recreational use grows, regulations that protect this resource are urgently needed. However, an exception is appropriate for scientific research, education and restoration activities to allow data collection, study and recovery of the depleted resource. Permits would be required for scientific collection and education and restoration programs and would be assessed on a case-by-case basis. Unpermitted harvest of stony corals, where the majority of stony corals in the FMU occurs, is already prohibited in state waters of Puerto Rico and the U. S. Virgin Islands.

Option 1A - Permit the regulated harvest of stony corals.

Discussion - Although the majority of corals and coral reefs are essentially non-renewable resources, commercial harvest may be possible on some of the faster growing species, such as Acropora spp. However, to avoid risk of overharvest, any permitted harvest levels would have to be based on sound scientific data on growth and replacement rates. Since relevant information is not available to indicate a safe level of harvest for any species of stony coral in the FMU, this is not currently a viable management option. If information becomes available that indicates that harvest may be resumed, the Council intends to amend this FMP accordingly.

Option 1B - Prohibit all harvest of stony corals.

Discussion - Total prohibition of harvest of stony corals would provide maximum protection for this resource. However, the Council believes that an exemption permitting limited harvest for bona fide scientific, educational and restorative activities is necessary to enhance our understanding and appreciation of coral resources and to allow for mitigation measures in damaged areas.

Option 1C - No action.

Discussion - Stony corals receive no protection whatsoever in waters under federal authority around Puerto Rico and the U. S. Virgin Islands. While the resource does have commercial value, its principal worth is in non-consumptive uses. To maintain and conserve corals and coral reefs and to prevent their damage or destruction, regulations are necessary. The proposed preferred management option (Option 1) provides for the protection of this

resource. While 'No action' would benefit those now taking stony corals, ultimately status quo would negatively impact the resource, and in turn, industries dependent on the healthy condition of coral and the exploitation of coral-dependent organisms.

7.1.2 Management Measure 2 - Prohibit the harvest or possession of sea fans and gorgonians (octocorals), live or dead, and any species in the fishery management unit if attached or existing upon live-rock, except for legally permitted research, education and restoration programs.

Discussion - Octocorals have as their greatest value their role as habitat and as a source of biomedically active compounds. They are also aesthetically pleasing to recreational divers and have a limited commercial worth for the marine aquarium trade. Live-rock is an integral part of the reef community and is of value as habitat and as a resource for the marine aquarium trade. Such sessile resources are particularly vulnerable to natural and anthropogenic stressors because of their sedentary nature and because, especially in the case of live-rock, the replacement rates of the communities they comprise are characteristically too slow for live-rock to be considered a renewable resource. Moreover, in the case of gorgonians, the population dynamics render this resource less amenable to traditional fishery management approaches and, therefore, possibly more than normally vulnerable to overfishing. Pressure to exploit octocorals and live-rock is expected to grow rapidly as market demand for live marine invertebrates increases and as regulations elsewhere (e.g., Florida) concerning the harvest of sea fans and live-rock become increasingly restrictive. Octocorals and live-rock are perceived to be of greater value to the Nation as habitat, for viewing opportunities, and, in the case of octocorals, as a potential source of medically important compounds, than as a commercially harvested resource. Accordingly, the proposed measure contains a provision for research, education and restoration. Permits would be required for research, education and restoration programs.

Option 2A - Prohibit the harvest or possession of octocorals and any species in the fishery management unit if attached or existing upon live-rock, except for legally permitted research, education and restoration programs, or in the course of bona fide aquaculture operations.

Discussion - Local governments could adopt live-rock aquaculture leasing programs, similar to those under development in Florida, to allow individuals to lease submerged lands for commercial purposes. Siting criteria, marking requirements, and other regulations would need to be developed to mitigate potential adverse impacts on the environment and so as not to compromise law enforcement. Open-water aquaculture operations could affect marine ecosystems by changing species composition and distributions of natural communities, and if allowable substrate is not strictly controlled, introduce organic and inorganic contaminants. Additionally, stony corals will settle on the aquaculture substrate and their harvest and sale will need to be specifically addressed. Stony coral aquaculture and sale will be an inevitable by-product of live-rock aquaculture operations.

Open-water live-rock culture has not yet been attempted on a commercial scale. One 5-acre lease site off Florida's west central coast (Tarpon Springs) could begin operations shortly. Land-based, closed systems for live-rock aquaculture would also require a permitting process for harvest of "seed-stock", or the introduction of any specially developed substrate, some type of facilities inspection, and testing of discharge waters. Open-water systems require much less capitol investment and are therefore favored by potential investors in Florida. Degree of interest in live-rock

aquaculture in the U. S. Caribbean is unknown. In the future, the Council may consider amendment of the FMP to accommodate a special aquaculture exemption.

Option 2B - Permit the regulated harvest of octocorals and any speciesin the fishery management unit if attached or existing upon live-rock.

Discussion - Given the importance of octocorals and live-rock as a non-harvested resource and the lack of information regarding growth and replacement rates and natural abundance, recommendations of harvest levels concomitant with preservation of these resources are not possible. However, because octocorals rejuvenate removed portions and grow faster than stony corals, limited harvest of certain octocoral species may be permitted in the future based on appropriate scientific data for establishing harvest levels. Once information becomes available that indicates that harvest can be resumed, the Council intends to amend this FMP accordingly.

Option 2C - Prohibit all take of octocorals and any species in the fishery management unit if attached or existing upon live-rock.

Discussion - Total prohibition of take of octocorals would provide maximum protection for this resource. However, the Council believes that an exemption permitting limited harvest for scientific, educational and restorative activities is necessary to enhance our understanding and appreciation of these resources and to allow mitigation measures in damaged areas.

Option 2D - No action.

Discussion - Octocorals and live-rock receive no protection whatsoever in waters under federal authority around Puerto Rico and the U. S. Virgin Islands. While these resources do have commercial value, their principal worth is in non-consumptive uses and as sources of biomedically active compounds. To maintain and conserve octocorals and live-rock and to prevent their damage or destruction, regulations are required. The proposed preferred management option (Option 2) provides for the protection of these resources. While 'No action' would benefit those now taking octocorals and live-rock, ultimately status quo would negatively impact the resource, and in turn, industries and other exploited organisms dependent on these resources.

7.1.3 Management Measure 3 - Prohibit the sale or possession of any species whose harvest is prohibited unless the specimen entered the management area in interstate or international commerce and is fully documented as to point of origin.

Discussion - It is necessary to document the legal possession of prohibited species that were harvested, or purchased from, outside the area and arrived in interstate or international commerce. The burden of proof, however, should be upon the person possessing such prohibited species (for sale or exchange) to establish the chain of possession beginning with (1) the name and home port of the vessel or the name and address of the individual harvesting the species, (2) the date and port of landing of the species, (3) information specified in 50 CFR 246 for marking containers or packages of organisms that are imported, exported, or transported in interstate commerce, and (4) a statement signed by the dealer attesting that the species was harvested from an area other than the management area. Failure to maintain such documentation or to promptly produce it at the request of an authorized law enforcement agent is prima facie evidence that the prohibited species was harvested from the management area and is in illegal possession. An exception for sale of aqua-cultured products may be necessary in the future (see Option 2A).

Option 3A - No action.

Discussion - Failure to establish the origin of, or path of commerce through which are obtained, prohibited species, would compromise enforcement and hence weaken the effectiveness of several of the proposed measures. It is not considered that the required maintenance of transport and other information relating to origin of commercially handled organisms is unduly onerous.

7.1.4 Management Measure 4 - Prohibit the use of chemicals, plants or plant derived toxins, and explosives to harvest organisms in the coral fishery management unit, except for legally permitted research, education, and restoration programs.

Discussion - Synthetic chemicals, natural products derived from plant species and explosives, including powerheads on spear guns, would be prohibited. Chemicals used to harvest reef-associated organisms include the fish anesthetic, quinaldine, gasoline and bleach. These substances are known to be detrimental to both vertebrate and invertebrate species on both a long- and short-term basis. Since other, less damaging, methods are available to successfully harvest reef-associated invertebrates, the prohibition of these means of harvest would not preclude capture of the majority of desired organisms.

Option 4A - Permit the regulated use of chemicals, plants or plant derived toxins, and explosives to harvest organisms in the coral fishery management unit.

Discussion - The harvest of corals and associated invertebrates with synthetic chemicals, derivatives of plant species, and explosives would be allowed under permit. However, in the

opinion of the Council, the toxic nature of the most commonly used chemical method of capture, quinaldine, and the destructive nature of explosives combined with the availability of effective alternative methods of harvest precludes the need for allowing their use under permit.

Option 4B - No action.

Discussion - Continued unregulated use of chemicals is expected to result in both short- and long-term detrimental effects in many of the organisms harvested and particularly on sessile reef-associated organisms in areas of harvest. The use of explosives is well-known for its devastating effect on reef communities. Quinaldine, the most popular chemical collection method, is a coal tar derivative used in the manufacture of dyes and explosives. Although the effects of using quinaldine to harvest invertebrates is inconclusive for most species, it is known to be variously toxic for certain organisms. Its use is currently prohibited, along with the use of other chemical substances and explosives, under the Reef Fish Plan in federal waters, and by state laws in waters of Puerto Rico and the U. S. Virgin Islands.

7.1.5 Management Measure 5 - Limit harvest methods of fishery management unit organisms to hand-held dip-nets, slurp guns, by hand and other non-habitat destructive gear, except for legally permitted research, education and restoration programs.

Discussion - Gears currently used to harvest marine aquarium invertebrates include hand-nets, chemicals such as quinaldine and slurp gun. A crow bar, or similar instrument, is sometimes used to remove some forms of live-rock, and corals and coral heads are overturned to allow access to organisms sheltering underneath. Organisms are also taken by hand. Several of these gears (e.g., chemicals and crow-bar) have serious potential for damaging the reef habitat and as a source of inadvertent mortality to the reef and reef-associated organisms. Of the traditional gears employed in the harvest of marine aquarium organisms, only hand-held dip nets and slurp guns do not represent a threat to coral reefs or associated organisms and may be used to harvest the majority of desired organisms. Hand harvest would also be permitted provided this was applied in a non-destructive fashion. Harvest levels or OY of invertebrates cannot be specified due to insufficient information. However, if harvest should increase, if additional information suggests that harvest limits should be applied, or if certain species appear to be in danger of overharvest, the Council will review this option. While the majority of invertebrates may be collected with dip nets and slurp guns, certain collections for scientific research, education or restorative purposes may require the use of chemicals (such as anesthetics) or nets such as cast nets for the harvest of certain species. For this reason an exemption for specialized gears, to be allowed under permit, is included.

Option 5A - Limit harvest of organisms in the fishery management unit to hand-held dip nets and slurp guns and to current levels of harvest.

Discussion - There are insufficient data to allow evaluation of OY for reef-associated invertebrates in the FMU. Although an estimate of harvest may be based on known reported exports, this would underestimate the current harvest because of the occurrence of substantial on-island trade. Hence, limiting harvest to this estimated level could be expected to result in a reduction of current harvest activities. The Council does not believe that, at current levels of estimated harvest, any species in the FMU is in imminent danger of being overfished, with the possible exception of Condylactis spp. which constitutes over 50% of the export trade, by number. When additional information becomes available, this option will be re-evaluated and measures such as the introduction of quotas or limited entry into the fishery will be considered.

Option 5B - Prohibit harvest of organisms in the fishery management unit.

Discussion - Maximum protection of invertebrates in the FMU would be afforded by a total prohibition on their harvest. However, because the majority of species are currently harvested in low numbers and, at present harvest levels, are thought to be able to sustain limited harvest activity for the marine aquarium trade, a total prohibition was not felt to be justified. If, however, harvest trends increase or certain species are considered to be particularly vulnerable to harvest, the Council will reconsider this option.

Option 5C - No action.

Discussion - Reef-associated invertebrates, with the exception of lobster, receive no protection whatsoever in waters under federal authority around Puerto Rico and the U. S. Virgin Islands. There is growing pressure to increase exploitation of this resource in Puerto Rico and, to a lesser extent, in the U. S. Virgin Islands as demand for marine aquarium organisms grows and as restrictions are increasingly applied elsewhere. Puerto Rico has the potential to become the major world source of Caribbean invertebrate species for the aquarium trade. While 'No action' would benefit those now taking invertebrates by all means of harvest, because of the potential for damage to reefs and reef-associated resources by certain methods of harvest such as toxins or crowbar, ultimately status quo would negatively impact the resource, and in turn, industries dependent on the exploitation of invertebrates in the FMU.

7.1.6 Management Measure 6 - Require a permit (up to a year) to harvest or possess organisms in the fishery management unit in the EEZ.

Discussion - A permit would be required to harvest, maintain and/or to sell reef-associated invertebrates from the fishery management unit. The permit system would include both state and federal areas of authority and would be operated by local governments with the assistance of NMFS. Permit applicants would have to supply information regarding species to be collected, quantities, unit value, collection areas and gears to be used. A permit would be denied anyone with an outstanding violation in any fishery. Granting of a permit would be subject to acceptance by permittees who harvest, handle and transport live organisms to

abide by minimum standards of maintenance and handling (standards to be determined). Local governments would charge an appropriate fee to recover costs of administering the program. A uniform permitting system is necessary to cover the entire fishery to determine present participation at different levels within the fishery and to identify the universe of participants. It would also facilitate introduction of a limited access program in the event that one is warranted in the future. Special permits would also be available for research, education and restoration purposes for other components of the FMU (stony corals, octocorals and live-rock). These permits would be awarded on a case-by-case basis following submission of a research plan which includes species and volumes to be collected, collection and restoration areas and edecational or restoration goals.

Option 6A - No action.

Discussion - Harvesters and exporters of invertebrates for the marine aquarium trade and other commercial purposes are not licensed in Puerto Rico and their activities are not regulated. The U. S. Virgin Islands requires permits for both harvest and export; however, the vast majority of activity occurs in waters around Puerto Rico. A permit system for the entire management area is requisite to establishing participation in the fishery, for limiting access to the fishery should this prove to be necessary, and for consistency throughout the FMU.

7.1.7 Management Measure 7 - Require harvesters, dealers and exporters of species managed under the Plan to acquire a permit (up to a year), to submit records on a regular basis and to report harvest, shipments, and unit costs.

Discussion - Reports would be required by the agencies administering the permit program to more accurately determine actual participation as well as the catch and amount of effort expended in the fishery. The data collected would allow fishery scientists and managers to better assess the status of resources in the management area and make informed judgments for conserving those resources as well as to estimate mortality of organisms harvested for the marine aquarium trade between the time of capture and that of shipping. The data would also serve as the foundation for developing limited access programs for the fishery, if necessary, and are needed to establish OY for invertebrate resources. Reporting intervals and other requirements should be patterned after systems already tested and proven successful in other fisheries. A monthly reporting period, for example, would be compatible with the existing reporting program for commercial fisheries in the U. S. Virgin Islands and a month is expected to provide the most practical and comprehensive sampling interval.

Option 7A - No action.

Discussion - No action would result in a continued lack of data upon which to base informed management decisions and a growing potential for overharvest as activity is expected to increase. A number of management actions and recommendations have been deferred by the Council, Scientific and Statistical Committee (SSC) and Advisory Panel (AP) because of

insufficient data. Indecision on proper management actions, including establishment of OY, would be expected to continue in the absence of current information on reef fish harvest. Information on the number of participants and amount of catch and effort is currently too incomplete to develop limited access should this prove to be necessary. Lack of information, however, should not be an excuse for no action.

7.1.8 Management Measure 8 - (Establish a Marine Conservation District (MCD) in the EEZ due South of St. John, U.S.V.I.). RESERVED. This measure will be reserved until more information is available and further consultation with the user groups is carried out. (See Section 7.3.1 for more information about MCDs).

7.2 Procedure for Adjusting Management Measures

A final rule revising the guidelines for fishery management plans was published on July 24, 1989, and became effective August 23, 1989. Section 602.12(e) of the guidelines describes a Stock Assessment and Fishery Evaluation (SAFE) Report that is used by the Councils to evaluate the success of management programs implemented for each FMP. The SAFE report should summarize the biological condition of species in the management unit, contain information on the social and economic condition of the fishery, and provide information needed to determine harvest specifications. Each SAFE report should be updated periodically as new information becomes available, and reviewed annually by the Councils or as significant changes occur in the fishery. The SAFE report serves as one of the bases for making adjustments in the management program implemented under the FMP. Additionally, new scientific reports or other information on species in the management unit may periodically become available to Council staff, Committees, or members.

Each Committee can evaluate alternatives for adjusting the management program and present them to the Council for consideration and action. The Councils will conduct one or more public hearings, depending on the nature of the proposed adjustments, prior to taking final action. The Scientific and Statistical Committee must advice the Council on the adequacy of all support analyses and whether they are based on the best available scientific information, and on the efficacy of the proposed adjustments. The Advisory Panel and any other Council committee may also be consulted. For adjusting measures within the regulatory scope of the FMP, a regulatory amendment, consisting of a regulatory impact review, environmental assessment, and a proposed rule, will be prepared for submission to the Regional Director. After reviewing the proposed regulatory adjustment for consistency with the Magnuson Act, other applicable laws, and the objectives of the FMP, the Regional Director will forward the proposed rule for publication in the Federal Register. The proposed rule will describe the proposed change(s) and make the supporting documents available for public review and comment. After a 30-day comment period, public input will be addressed by the Council and Regional Director and a final rule prepared for publication. In addition to overfished conditions of a resource, other concerns may trigger the adjustments of

management measures. These concerns may involve the need to establish MCDs, significant changes in fishery practices, environmental disasters, etc.

Adjustments that may be made by this procedure include additions to the fishery management unit, the list of prohibited species, harvest limitations, including quotas, trip or daily landing limits, gear restrictions, closed seasons or areas, additions to Appendix A (species specifically excluded from the fishery management unit), and establishment of MCDs.

7.3 Future Management Considerations:

Several management measures were identified during the development of this FMP which merit consideration for future management initiatives. These were not included in this FMP because of insufficient data. However, information collected under the Plan will be reviewed by the SSC and AP and, if determined appropriate, these measures may be added by amendment to this FMP. These measures include: 1) establishment of Marine Conservation Districts in the EEZ to protect components of the FMU; 2) introducing quotas for the harvest of reef-associated invertebrates; 3) limiting entry into the fishery including establishment of a control date for possible use in determining historical participation in the fishery; 4) establishing temporary closures (e.g., spawning season or areal closures); 5) prohibiting harvest of vulnerable or rare species; 6) developing handling, maintenance and transportation standards to minimize mortality; 6) prohibiting the introduction of exotic marine organisms into federal waters. Inspection of NPDES permits by the Council would enable any Council to express any concerns that arise therefrom to federal agencies.

7.3.1 Marine Conservation Districts (MCDs)

Marine Conservation Districts are marine areas with special value or significance to the marine ecosystem that will be maintained in their natural state. The MCDs can be maintained or restored to their natural state by prohibiting all harvesting within the designated districts. The Council's objectives for establishing MCDs are to: (1) conserve and manage representative samples of marine habitats and ecosystems, and to maintain marine biodiversity; (2) conserve and manage economically important species; (3) preserve, enhance, protect and restore coral reefs and associated organisms which are critical to fisheries resources; (4) protect and preserve coral beds as natural areas for the greatest benefit of the Nation.

The Council established a Marine Reserve Zoning Committee (MRZC) to evaluate areas for inclusion as reserves or MCDs. The MRZC is composed of representatives of the Council staff, the National Marine Fisheries Service (NMFS), the Department of Natural Resources (DNER) of Puerto Rico, the Department of Planning and Natural Resources (DPNR) of the U.S. Virgin Islands, and the Sea Grant College Program.

The criteria for selection of MCDs include:

(1)	Ecological values:	Diversity of species
		Endangered species habitat
		Uniqueness of the area
		Representative ecosystem
		Importance to commercial species
		Maintenance of "natural" areas
(2)	Economic values:	Traditional fishery location
		Snorkel/dive site
		Charter boat anchorage
		Hurricane shelter
		Tourist attraction
		Watershed management
(3)	Social values:	Cultural significance
		Recreation area
		Aesthetics
		Education
		Research opportunities

Similar to marine fishery reserves proposed for reef fish in the U.S. South Atlantic (Plan Development Team, 1990), MCDs are areas of non-consumptive usage which are designed to ensure persistence of reef fish stocks and habitat. MCDs, by analogy with the marine fishery reserves, are intended primarily to protect older and larger fish. The benefits derived from this is the protection of the critical spawning stock biomass, intra-specific genetic diversity, population age-structure, recruitment supply, and ecosystem balance while maintaining reef fish fisheries. It has been proposed that reserves are most effective in addressing the problem of recruitment overfishing, specially for sedentary species (DeMaritini, Coral Reef Symposium in Guam, 1992). Thus, these serve to maintain ecosystem balance and productivity. MCDs are expected to supply larvae to other fishing areas. MCDs are believed to have been important in maintaining the high abundance of many species of reef fish in certain protected areas worldwide (e.g., Alcalá and Russ, 1990; Roberts and Polunin, 1991; Russ, 1985). In addition, MCDs can provide some insurance against management measures and recruitment failures, simplify enforcement and assist in the development of eco-tourism. The prohibition of anchoring within the MCD reduces destruction of habitat and species in the FMU as well as the costs of enforcement.

In summary, MCDs are expected to offer the following benefits: (1) provide refuge and replenishment areas to ensure continued abundance and diversity of reef resources; (2) protection of critical spawning stock and recruits from depletion and overfishing, thus increasing abundance of fishery resources; (3) protect coral and coral habitat; (4) the passive, non-consumptive use of this non-renewable resource (corals) would improve the opportunities for eco-tourism.

The disadvantages of MCDs include the displacement of effort to other areas already under stress or potentially under stress. A short-term dislocation and loss of revenues is possible, but long-term benefits will far outweigh the short-term losses.

Coral reef areas of special significance and particularly stressed or vulnerable areas may need protection in addition to measures already provided in the FMP. MCDs are designed to direct protective regulations to only those specific areas requiring this protection. The establishment of MCDs will directly affect the activities of commercial and recreational fishers by causing them to move their activities to other potentially less favorable areas.
Short-term dislocations and loss of revenues could be avoided by choosing to take no action. However, long-term benefits of preserving habitats as well as species would be forgone.

7.3.2 Quotas, limited entry and harvest prohibitions

Given that the demand for marine aquarium organisms is growing and that the U. S. Caribbean is perceived as an attractive source of Caribbean fishes and invertebrates, consideration may have to be given to the introduction of quotas for species that are heavily collected (e.g., Condylactis). For example, concern has been expressed in Florida that overcollection may be occurring in the cases of Condylactis and Oreaster (communication to Ed Irby, Florida Dept. Nat. Res., Aug. 30, 1991); both species are in heavy demand by aquarists. For species which may be uncommon or rare locally, quotas or harvest prohibitions may be necessary. For species which are determined to have little chance of surviving shipment, or are unlikely to survive in captivity for a considerable proportion of their potential lifespan, the Ornamental Fish Industry in the United Kingdom is proposing that their trade be prohibited (Ornamental Fish Industry - UK - Briefing Doc. No. 1, Sept. 1991). Likewise, consideration should be given to identifying such species with a view to prohibiting their harvest in the U. S. Caribbean.

The option of limited entry may also be considered if harvest or biological data indicate this to be necessary. Priority to participate in the fishery will be afforded those fishers who can prove that a substantial portion of their income derives from this fishery, who have been longest active, who have participated in government programs of data collection and permitting that might be in effect and who have not violated any fishery regulations in Puerto Rico and the U. S. Virgin Islands.

7.3.3 Handling and transportation of live organisms

There is concern, in the case of organisms collected for trade in the aquarium industry, over post-harvest mortality induced by poor handling or shipping practices (Sadovy, 1991) (see Section 5.4). Holding facilities and packing materials and techniques used for shipment should meet certain specified standards to minimize mortality and to ensure the good health and welfare of live organisms. Under the Magnuson Act there is authority to regulate handling after harvest, through the hands of the harvesters or dealers, up to the point of shipping or first

sale. Such regulation may be rationalized under subsection 303(a)(1)(A) of the Magnuson Act which requires in each FMP, conservation and management measures which are:

> ... necessary and appropriate for the conservation and management of the fishery to prevent overfishing, and to protect, restore and promote the long-term health and stability of the fishery; 16 U.S.C. 1853(a)(1)(A).

Because organisms harvested for the aquarium trade are only valuable alive, their harvest has few analogies in commercial fishing. One possible analogy is the requirement for live wells for undersized spiny lobsters used as attractants in traps. The purpose of this requirement is to prevent mortality, thus reducing the number of undersized lobsters needed to meet the demand for attractants. Similarly, aerated live wells could be required to reduce the mortality rate of harvested species in order to reduce the number of animals needed to meet the demand for that species, and thereby, to conserve the species. Appropriate guidelines for handling and transporting need to be established.

7.3.4 Introduction of exotic marine organisms

With increasing commerce of tropical marine organisms around the world, there is also a growing possibility of releases of non-native species into local waters. Such species, or diseases they carry, could become established, possibly displacing/infecting local species or disrupting habitat, as has been noted for a substantial number of freshwater species in the Unites States. In Hawaii, deliberate introductions of non-native fishes were successful in a couple of cases with negative local effects (Oda and Parrish, 1981). Regulations are needed to prevent the introduction of non-native species into local waters through releases or through escapes from culture facilities. For example, viruses have been introduced to wild American shrimp stocks from shrimp species imported for culture from the Indo-Pacific region (Lightner and Redman, 1991). No regulations are in effect in the U. S. Caribbean which directly address release of marine exotics. The Council will recommend to local governments adoption of the necessary measures if warranted.

7.4 Data Collection and Research Requirements:

Based on the management measures set forth in Section 7.1, the following data collection activities are necessary to regulate exploitation of components of the FMU:

Biological - additional biological information on components of the FMU should address: a) long-term impacts of anthropogenic activities on reef communities inshore and offshore; b) growth, recruitment and replacement rates, especially of more heavily harvested species, with special emphasis on Condylactis; c) abundance of more heavily harvested species, with special emphasis on Condylactis; d) identification of particularly rare or vulnerable species; e) mapping of distribution of living coral and rock reefs over the insular platform; f) identification of habitats of critical importance or areas to designate as MCDs;

g) identification of species of critical importance for reef communities, their role in community health and stability (such as cleaners or algal grazers) and other significant ecological relationships; h) investigation of feasibility of live-rock mariculture in Puerto Rico and the U. S. Virgin Islands; i) investigation of impact of overfishing on coral reef communities.

Fisheries - to enable effective monitoring of the fishery, data on harvest and trade must be collected. Information is needed on species taken and their quantities, area, date and depth of collection, harvest method, and value of the catch. This information may be recorded by: a) a trip-ticket system that records the numbers of each species landed on each trip and the numbers and unit price of each species sold/exported; b) a port-sampling system to obtain size samples and species composition by gear type of a random subsample of trips and to complement trip-ticket data.

Assessment/Management - for effective management, additional information on the fishery is necessary: a) determination of catch and effort over time; b) assessment of mortality associated with harvesting, handling and shipping and development of means to reduce such mortality; fishery-independent monitoring of exploited areas for changes in abundance of exploited species; c) training of monitoring and enforcement personnel involved in the fishery to avoid misidentification that affects statistical reliability and undermines enforcement capabilities; d) monitoring of water quality and NPDES permits; e) evaluation of the applicability of standard fishery management approaches in the management of reef-associated invertebrates; f) evaluation of enforcement implications of live-rock culture.

Social and Economic - an organized effort to collect social and economic information on the recreational component of the fishery is needed and on the extent and nature of on-island trade. Continued monitoring of the number of persons fishing, the number of businesses, fishing sites, employees and value of the fishery is necessary especially since demand for certain components of the FMU, especially out of Puerto Rico, is expected to continue to grow.

7.5 Special Recommendations and Endorsement of State Actions:

7.5.1 Recommendations

It is the basic premise and goal of this FMP that management of component resources be carried out throughout their range. In particular, given the more intense impact of anthropogenic activities on nearshore reefs, and hence largely those in state waters, state cooperation is essential for effective management. It is recognized that solutions to the problems of reef management may only be accomplished through a combination of local and federal action and that one of the most critical issues is the elimination of discharge of untreated sewage and petroleum products into coastal waters. Specifically, it is recommended that states:

Ë establish permitted anchoring sites in coral reef areas;

- identify habitats of special concern or ecological importance;
- create marine reserves to provide a monitoring baseline, to protect special or important habitats, and to increase productivity by enhancing the spawning potential of individuals in the protected area with resulting benefits for both local fisheries and eco-tourism;
- develop a comprehensive mapping of coral and rock reef areas over the insular platform;
- harmonize local laws with federal laws;
- ensure compliance with discharge and dredging laws;
- permit no discharges in identified coral areas of special ecological importance or concern;
- develop a code of standards for the maintenance, handling and transportation of fishes and invertebrates traded live and compliance with existing regulations on the treatment of live animals;
- extend existing data collection programs to include data collection on the marine aquarium trade through port-sampling, inspections of maintenance facilities and island pet shops, and airport monitoring;
- cooperate with NMFS to ensure consistent and integrated permitting and data collection systems;
- regulate diving activities to reduce damage to reef areas through direct physical damage and casual collecting;
- emphasize the importance of the reef ecosystem for the development of tourism (eco-tourism);
- introduce a permitting system for those who collect and market live marine organisms;
- develop management regulation for seagrass habitats;
- prohibit the release of exotic marine species into surrounding waters of Puerto Rico and the U.S. Virgin Islands;
- enforce existing regulations.

7.5.2 Endorsement

The Council endorses the following actions concerning the designation of MCDs:

(1) endorse MCDs near the following areas within the territorial waters of Puerto Rico (Figure 4) - Cordillera, Isla Culebra, Vieques Sur, Vieques Norte, Bahía de Jobos, Isla Caja de Muertos, Margarita, Isla Mona, Desecheo;

(2) to endorse an additional MCD within Puerto Rican waters in the Peninsula Flamenco area of Culebra.

(3) to examine the Lang Bank area of St. Croix as a possible candidate for MCD status in the EEZ (Figure 5); and

(4) (4) to endorse MCDs in the territorial waters of St. Croix, as proposed by the U.S.V.I. DPNR.

7.6 Public Education and Awareness

A key factor in the management of resources is interest and understanding by the public and government officials empowered to implement and enforce management policy. Marine resources are particularly difficult to manage because degradation and depletion are rarely viewed directly. Moreover, there remains the widespread misconception that marine resources are essentially inexhaustible. Such problems of perception must be overcome for management to be successful and to receive full public support and cooperation. It is essential that education programs be aimed at increasing public awareness of the importance of reef ecosystems for the economy, for their medical potential and for aesthetic qualities and developed through:

1. extensive and comprehensive environmental instruction incorporated early in school education programs;

2. education of users of the reef environment such as fishers, boatmen, divers, etc., concerning laws in effect and the vulnerability of the reef environment, and linkage of demonstrated knowledge of laws to successful permit approval;

3. education of government officials and law enforcement officers concerning the laws in effect and the importance of protecting and managing reefs and reef-dependent natural resources;

4. provision of information sheets to island visitors with laws which relate to these resources;

7.7 International Considerations:

Given the high likelihood of the wide dispersal of larval phases of many of the components of the FMU across international boundaries, the most effective management of reef resources lies in international co-operation at the regional level. It is imperative, therefore, that pan-Caribbean integration and co-ordination of management policies be promoted.

8.0 RELATED MANAGEMENT JURISDICTIONS, LAWS, AND POLICIES

Until recently, reef-associated resources (other than coral) were of little concern to states or to the Federal Government, although warnings have been sounded in recent years. Over the last 5 years there has been a marked increase in the harvest of live reef-associated organisms for the marine aquarium trade and harvest is expected to continue to intensify. There is, therefore, concern that the fishery may become vulnerable to overfishing and that

management is necessary under the Magnuson Act and other federal and state laws. Harvested organisms within the FMU are marketed within Puerto Rico and the U. S. Virgin Islands, and are exported to the United States and internationally, largely to Canada and to western Europe. A number of state, federal and international laws apply to the harvest and trade of organisms in the FMU.

8.1 Federal Laws, Policies and Regulations

The following federal laws, policies, and regulations may directly or indirectly influence the management of reef resources. However, there are no known laws or policies that will constrain any of the measures in the FMP.

MAGNUSON FISHERY CONSERVATION AND MANAGEMENT ACT OF 1976 AS AMENDED: 16 U.S.C. 1801-1882

The Magnuson Act mandates the preparation of fishery management plans for important fishery resources within the EEZ. All FMPs and their respective management measures must be based on seven national standards as prescribed in the Magnuson Act.

MARINE PROTECTION, RESEARCH, AND SANCTUARIES ACT OF 1972 (MPRSA), TITLE III AS AMENDED: 16 U.S.C. 1431-1445

This Act provides for establishment of marine sanctuaries and may include regulation of the fishery resource within them. As of November 30, 1992, the following sanctuaries in the Atlantic Ocean or Gulf of Mexico were established: (1) Gray's Reef National Marine Sanctuary; (2) Flower Garden Bank National Marine Sanctuary; (3) Florida Keys National Marine Sanctuary; and (4) Monitor National Marine Sanctuary. The Looe Key and Key Largo Marine Sanctuaries
were recently combined with the Florida Keys National Marine Sanctuary. There are no National Marine Sanctuaries in the management area.

CLEAN WATER ACT (CWA) AS AMENDED: 33 U.S.C. 1251 et seq.

The CWA requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained before any pollutant is discharged from a point source into waters of the United States, including waters of the contiguous zone of the adjoining ocean. The disposal of drilling effluent and other drilling platform wastes is among the activities that require an EPA NPDES permit. Issuance of a permit is based primarily on the effluent guidelines found in 40 CFR Part 435. However, additional conditions can be imposed on permit issuance on a case basis to protect valuable resources in the discharge area.

MARINE PROTECTION, RESEARCH, AND SANCTUARIES ACT (MPRSA), TITLE 1 AS AMENDED: 33 U.S.C.1401-1421; 1441-1445

The transportation of materials for ocean dumping requires a permit. EPA issues the permits, except for transportation of dredged materials that is issued by the Corps of Engineers. Criteria for issuing such permits include consideration of effects of dumping on the marine environment, ecological systems, and fisheries resources.

COASTAL ZONE MANAGEMENT ACT OF 1972, AS AMENDED (CZMA): 16 U.S.C. 1451-1464

The principal objective of the Coastal Zone Management Act is to encourage and assist States in developing coastal management programs, to coordinate state activities and to safeguard the regional and national interests in the coastal zone. Under the CZMA states are encouraged, with federal funding, to develop coastal zone management programs that establish unified policies, criteria, and standards for dealing with land and water use in their coastal zone. Coastal states also can control activities in estuarine areas to protect particularly sensitive resources. The CZMA has been amended to include nonpoint source pollution from upland areas.

FISHERY MANAGEMENT PLANS

Management measures contained in this FMP are compatible with and complement those in other FMPs in the area. These plans include the Reef Fish Plan and the Lobster Plan. Given the probability for widespread larval dispersal of reef-associated fishes and invertebrates in the Caribbean and western Atlantic, this FMP also has the potential to complement other plans in the region (see below). Corals and coral reefs are also managed by the Gulf of Mexico and South Atlantic Councils and by the Western Pacific Council.

Fishery Management Plan

	Name of FMP	Lead Council or Office
1.	Coral and Coral Reefs FMP	Gulf of Mexico & South Atlantic Councils
2.	Precious Coral Fisheries of the Western Pacific Region FMP	Western Pacific Regional Fishery Management Council
3.	Gulf of Mexico Spiny Lobster Fishery FMP	Gulf of Mexico & South Atlantic Councils
4.	Gulf of Mexico Shrimp FMP	Gulf of Mexico Council
5.	Snapper-Grouper FMP	South Atlantic Council
6.	Reef Fish FMP	Gulf of Mexico
7.	Caribbean Reef Fish FMP	Caribbean Council
8.	Caribbean Spiny Lobster FMP	Caribbean Council

ENDANGERED SPECIES ACT OF 1973, AS AMENDED: 16 U.S.C. 1531-1543

The Endangered Species Act provides for the listing of threatened or endangered plant and animal species. Once listed as a threatened or endangered species, taking (including harassment) is prohibited. The process ensures that projects authorized, funded, or carried out by federal agencies do not jeopardize the species existence or result in habitat destruction or modification critical to species existence. Consultation under the ESA between the Council, NMFS and FWS, as appropriate, is required if the fishery affects, directly or indirectly, endangered or threatened species or any designated critical habitat. Federally listed endangered/threatened species of relevance to the Coral FMP are:

1. the endangered leatherback turtle - Dermochelys coriacea
2. the endangered hawksbill turtle - Eretmochelys imbricata
3. the endangered/threatened green turtle - Chelonia mydas*
4. the threatened loggerhead turtle - Caretta
5. the endangered manatee - Trichechus manatus

* Green turtles in U.S. waters are listed as threatened except for the Florida breeding population which is listed as endangered.

NATIONAL ENVIRONMENTAL POLICY ACT (NEPA), AS AMENDED: 42 U.S.C. 4321-4370a

NEPA requires that all federal agencies recognize and give appropriate consideration to environmental amenities and values in their decision-making. NEPA requires that federal agencies prepare an Environmental Impact Statement (EIS) before undertaking major actions that might significantly affect the quality of the human environment. Alternatives to the proposed action must be carefully assessed.

FISH AND WILDLIFE COORDINATION ACT, AS AMENDED: 16 U.S.C. 661-666c

Under the Fish and Wildlife Coordination Act, the FWS and the NMFS review and comment on aspects of proposals for work and activities sanctioned, permitted, assisted, or conducted by federal agencies that take place in or affect navigable waters. The review focuses on potential damage to fish and wildlife and their habitat, particularly in nearshore waters, and may, therefore, serve to provide protection to fishery resources from federal activities. Federal agencies must consider the recommendations of the two agencies.

FISH RESTORATION AND MANAGEMENT PROJECTS ACT, AS AMENDED: 16 U.S.C. 777-7771

Under this Act, the Department of Interior apportions funds to state fish and game agencies for fish restoration and management projects. Funds for protection of threatened fish communities located within state waters, including marine areas, could be made available under the Act.

NATIONAL PARK SERVICE ORGANIC ACT, AS AMENDED: 16 U.S.C. 1-4,22,43

The National Park Service under the Department of Interior may regulate fishing activities within park boundaries. There are many parks, monuments, and seashores along the Atlantic Ocean. In the management unit are located the St. John National Park and Buck Island National Monument (St. Croix, U. S. Virgin Islands).

LACEY ACT, AS AMENDED: 16 U.S.C. 1540, 3371-3378

The Act prohibits import, export, and interstate transport of illegally taken fish or wildlife. This Act strengthens and improves enforcement of federal fish and wildlife laws and provides federal assistance in enforcement of state and foreign laws.

MARINE MAMMAL PROTECTION ACT OF 1972, AS AMENDED 16 U.S.C. 1361-1407

This Act makes it unlawful (except for some native Americans) to kill, capture, or harass any marine mammal or attempt to do so; prohibits the importation of pregnant, nursing or illegally taken marine mammals; and prohibits whaling within U.S. areas of authority. If the fishery potentially affects marine mammal population(s), these impacts must be analyzed in the EIS. Councils must consider actions to mitigate adverse impacts.

8.2 Local Laws, Policies and Regulations

INDIGENOUS AND ENDANGERED SPECIES PERMITS ACT 5665, DECEMBER 1990 - GOVERNMENT OF THE VIRGIN ISLANDS, DEPARTMENT OF PLANNING AND NATURAL RESOURCES

This Act has the purpose of protecting, conserving and managing indigenous fish, wildlife and plants, and endangered or threatened species. The Act allows for the issuance of permits to collect and/or transit (export) indigenous or endangered species for commercial, private, educational or scientific use, and covers the collection of aquarium fish, invertebrates, or live-rock, maintenance in captivity or shipping of any indigenous or endangered species, or cutting or pruning or mangroves. Special permits may be issued for collectors from recognized museums, research organization, etc., bona fide scientists, and for recovery and propagation activities. Endangered or threatened animals of the U.S. Virgin Islands of relevance to this plan are the green turtle (Chelonia mydas), the hawksbill turtle (Eretmochelys imbricata), the leatherback turtle (Dermochelys coriacea), black coral (Order Antipatharia) and the jewfish (Epinephelus itajara).

LEY DE VIDA SILVESTRE DEL ESTADO LIBRE ASOCIADO DE PUERTO RICO ACT NO. 70, MAY 30, 1976; 12 L.P.R.A., # 81 et seq. (Wildlife Act of the Commonwealth of Puerto Rico

This Law also provides protection for federally and locally listed endangered/threatened species in Puerto Rico.

REGULATION TO CONTROL THE EXTRACTION, POSSESSION, TRANSPORTATION AND SALE OF CORAL RESOURCES OF PUERTO RICO OF OCTOBER 11, 1979, DEPARTMENT OF STATE REGULATION NO. 2577 OF NOVEMBER 5, 1979

This regulation covers the extraction, destruction, transportation, possession or trade of any coral living or dead with exemptions provided for scientific and educational activities, and for commercial extraction, on approval or permitting by the Secretary of the Department of Natural Resources. Included under this regulation is damage to corals caused by anchoring, trap deployment or other destructive activities. Corals included are stony coral (scleractinians), horny corals (octocorals), black corals (antipatharians), and hydrocorals (hydrozoans with a calcium carbonate skeleton).

LAW NO. 132 OF JUNE 25, 1968 AND AMENDMENTS (Article 5) (Puerto Rico)

This Law prohibits the expedition of permits for the extraction, removal, excavation or dredging of the earth's crust in the public domain when the intent is export outside of the authority of Puerto Rico. It also prohibits such activities when these are deemed to damage fishing and recreation activities, the integrity of reef systems or a reserve area. This Law includes prohibits the extraction of live-rock ('roca viva') from submerged lands (by Executive Order, October, 1990).

LEY ORGANICA DEL DEPARTAMENTO DE RECURSOS NATURALES, LAW 23 OF 20 JUNE, 1972, AND AMENDMENTS, 3 L.P.R.A., # 151 et seq. (Puerto Rico)

The Law created the Department of Natural Resources and established its authority over the protection and management of water and natural resources in Puerto Rico.

LEY DEL PROGRAMA DEL PATRIMONIO NATURAL DE PUERTO RICO, LAW 150 OF 4 AUGUST, 1988, 12 L.P.R.A., # 1225 et seq.

This Law provides number of mechanisms for the protection of biodiversity and threatened areas, its principal purpose. It covers the identification of areas where plants and animals are considered to be vulnerable or in danger of extinction. It also empowers the Department of Natural Resources to recommend Natural Reserve areas, and to acquire land to protect wildlife or habitats of concern.

LEY DE MINAS, LAW 9 OF 18 AUGUST, AMENDED IN 1975, 28 L.P.R.A., # 110 et seq. (Puerto Rico)

This Law establishes that the exploitation of mineral resources must be carried out in a manner compatible with the conservation of other resources of the Nation.

LEY DE VIGILANTES DE RECURSOS NATURALES DEL DEPARTAMENTO DE RECURSOS NATURALES, LAW 1 OF 1 JULY, 1977, 12 L.P.R.A., # 1201 et seq. (Puerto Rico)

The Ranger Corps is assigned to the Department of Natural Resources and is empowered to protect, supervise, conserve and defend natural resources. It is the principal body enforcing laws and regulations pertaining to natural resources in Puerto Rico. There is a Memorandum of Understanding (1991) concerning enforcement in state and federal waters currently in effect between the Coast Guard, NMFS and the Department of Natural Resources in the Puerto Rico/U. S. Virgin Islands area.

LEY DE CONSERVACION Y DESARROLLO DE CULEBRA, LAW 66 OF 22 JUNE, 1975, 21 L.P.R.A., # 890 et seq.

This Law was enacted to protect and conserve the ecological integrity of Culebra and surrounding waters.

THE FISHERIES ACT NO. 83 OF MAY 13, 1936, 12 L.P.R.A. # 41 et seq. (Puerto Rico)

The Fisheries Act was enacted to protect and promote fish life. The statute declares that all species of fish (which includes molluscs, crustaceans, aquatic mammals and plants), and all other species comprising the marine, lacustrine and fluvial fauna and flora are property of the Commonwealth of Puerto Rico. The Act allows for management measures to be implemented by the Secretary of the Department of Natural Resources (under amendment) and prohibits the use of poisons and explosives. It also covers the licensing of fishers although it specifically excludes as fishers those who trade live fish for aquaria, or ornamental purposes.

FISHING REGULATION OF JULY 11, 1984, DEPARTMENT OF STATE REGULATION NO. 3179 OF DECEMBER 6, 1984 (Puerto Rico)

The Secretary of the Department of Natural Resources may regulate commercial and recreational fishing with respect to gears, bag limits, sizes, and fishing areas.

LAW 67 FOR THE PROTECTION OF ANIMALS - PENAL CODE OF PUERTO RICO, MAY, 1973

This Law governs the handling and treatment of living animals and their maintenance while under captivity or undergoing transportation.

LEY DE ARENA, GRAVA Y PIEDRA, LEY 132 DE 25 DE JUNIO DE 1968, AS AMENDED, 28 L.P.R.A., # 207-220F

This Law regulates the extraction of components of the earth's crust on public and private land which have not been designated as economically valuable minerals, including sand, gravel, rock and earth. Extraction is only allowed under permit from the Department of Natural Resources which has interpreted this law to include Live-Rock. Extraction is unlikely to be permitted in reserves or reefs, or in swimming or recreational areas. The law has a citizen's clause which allows any citizen to denounce any other
citizen who has infringed the law or the Secretary of the Department of Natural Resources if he does not conform to the law.

8.3 Management Institutions

8.3.1 Federal Management Institutions

REGIONAL FISHERY MANAGEMENT COUNCILS

Management in the EEZ is based on FMPs developed by eight Regional Fishery Management Councils. Each Council prepares and amends plans for the fisheries in need of management within its geographical area. Plans are submitted to the Secretary of Commerce through NMFS and NOAA for approval and implementation through federal regulations.

The Councils' guidelines are standards that require, to the extent practicable, a fish stock shall be managed as a unit throughout its range and a stock shall be protected from overfishing while continuing to achieve Optimum Yield. As of October 23, 1992, there were 24 FMPs and PMPs in effect in the Atlantic Ocean, Gulf of Mexico and Caribbean Sea. While some involve a single species, others involve many species, such as the Snapper-Grouper FMP (33 species) and the Caribbean Reef Fish FMP (64 species). The present FMP has the potential to complement 8 other FMPs in the region (see above) because of the possibility that various life history phases of many of the species managed therein may utilize or depend on reef ecosystems in the US Caribbean.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA), NATIONAL MARINE FISHERIES SERVICE (NMFS)

The Secretary, acting through NMFS, has the authority to approve or disapprove all FMPs prepared by the Councils pursuant to the Magnuson Act. The NMFS has issued regulations and guidelines for the development of FMPs and the operation of the Councils. Where a Council fails to develop a plan, or correct an unacceptable plan, the Secretary may do so. The Caribbean Council, with authority over coral resources in federal waters of Puerto Rico and the U. S. Virgin Islands, recognizes the need to develop the Coral FMP because of

increased intensity of harvest on components of the FMU, likelihood of further increases, growing severity of anthropogenic stresses on reef communities, and the high non-consumptive value associated with many reef resources.

The NMFS also collects data and statistics on fisheries and develops stock assessments necessary to manage fisheries. The NMFS enforces regulations promulgated under an FMP and NOAA processes civil penalties for violations.

OFFICE OF COASTAL RESOURCE MANAGEMENT (OCRM), NOAA

The OCRM asserts authority over fisheries through National Marine Sanctuaries, pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA). By setting standards for approving and funding state coastal zone management programs, OCRM may further influence fishery management.

NATIONAL PARK SERVICE (NPS), DEPARTMENT OF INTERIOR

The NPS manages fish through the establishment of coastal and nearshore national parks and national monuments. Everglades National Park, St. John National Park and Buck Island (St. Croix) National Monument are examples of areas managed by the NPS. The system of national parks and monuments operated by the NPS preserves for all time the scenic beauty, wilderness, native wildlife, indigenous plant life and areas of scientific significance and antiquity.

FISH AND WILDLIFE SERVICE (FWS), DEPARTMENT OF INTERIOR

The ability of the FWS to affect fish management is based primarily on the Endangered Species Act and the Fish and Wildlife Coordination Act. Under the Fish and Wildlife Coordination Act, the FWS reviews and comments on proposals for work and activities in or affecting navigable waters that are sanctioned, permitted, assisted, or conducted by federal agencies. The review focuses mainly on potential damage to fish and wildlife, and to their habitats.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

The EPA has a general responsibility for controlling air and water pollution. Disposal of hazardous wastes and point-source discharge permitting are EPA functions. Environmental research relating to waste disposal and pollution are funded by EPA. The EPA provides protection to fish communities by managing National Pollutant Discharge Elimination System (NPDES) permits, or approving state programs to issue such permits, for pollutant discharges into ocean waters, and the conditioning of those permits to protect valuable resources. The EPA also has review and approval authority over the Corps of Engineers Section 404 permits. The CFMC is authorized to comment on NPDES and section 404 permits under the

Magnuson Act, and can hold public hearings on proposed actions if warranted by the potential effects on fisheries if the action is permitted.

CORPS OF ENGINEERS (COE), DEPARTMENT OF THE ARMY

The COE contracts and regulates coastal engineering projects, particularly harbor dredging and beach renourishment projects. The COE also reviews and is the permitting agency for coastal development projects and offshore structures. The COE authority over the disposal of dredged material, pursuant to both the Clean Water Act and the MPRSA, is to be exercised in a manner protective of fishery resources. Under the Rivers and Harbor Act, proposals to dispose of materials during the construction of artificial reefs are assessed to assure that materials do not physically alter the environment in a manner that endangers navigation.

U. S. GEOLOGICAL SURVEY (USGS)

The USGS has conducted considerable research in nearshore areas and has assisted or cooperated with other institutions and agencies to facilitate logistics and support of research. The USGS supervises mineral development on the outer continental shelf and must ensure that oil companies comply with regulations and lease stipulations once a lease is sold.

MINERALS MANAGEMENT SERVICE (MMS)

The MMS has authority over mineral and petroleum resources on the continental shelf. The MMS along with the USGS is charged with administering mineral exploration and development pursuant to the Outer Continental Shelf Lands Act, as amended in 1978 [43 U.S.C. (1331 et seq.)].

U. S. COAST GUARD (USCG), DEPARTMENT OF TRANSPORTATION

The 1978 Waterways Safety Act charges the USCG with marine environmental protection. The CG is the general enforcement agency for all marine activity in the federal zone including enforcement of sanctuary and fishery management regulations, managing vessel salvage and coordinating oil spill cleanup operations at sea. The USCG shares responsibility for enforcement of the NOAA -administered Acts with NMFS and may carry out cooperative enforcement with state governments, as currently with the Puerto Rico Department of Natural Resources.

8.3.2 State Management Institutions

There are 18 states bordering the Atlantic Ocean and Gulf of Mexico. In addition, the Commonwealth of Puerto Rico and the Territory of the U.S. Virgin Islands border the Caribbean Sea. Each of these entities has management authority over marine resources in state waters -- including coral resources. In 1992, the Marine Life Rule went into effect in

Florida state waters. The purpose and intent of this rule are to protect and conserve Florida's tropical marine life resources and to assure that harvesters use non-lethal methods of harvest and that the fish, invertebrates and plants so harvested be maintained alive for the maximum possible conservation and economic benefits. The rule regulates the fish and invertebrate species, the size limits and bag limits thereof and gear specifications for species that are taken for trade live in the marine aquarium industry. The rule includes the complete phase-out, over a period of years, of the take of live-rock. Florida also has a coral protection statute. Other states in the Gulf of Mexico and South Atlantic areas have several types of authorities which may provide indirect protection to coral resources, including: 1) authorities aimed primarily at other marine resources or the environment in general that may also relate to corals, e.g., fishing gear regulations or pollution control laws; 2) coastal zone management programs and related legislation; and 3) habitat management or protection programs. These authorities are summarized by state in the Coral and Coral Reefs FMP of the Gulf of Mexico and South Atlantic Fishery Management Councils, April, 1982.

The institutions responsible for the management of marine resources in the U. S. Virgin Islands and Puerto Rico are the Department of Planning and Natural Resources and the Department of Natural Resources, respectively.

8.4 International Treaties and Agreements:

Foreign fishing is prohibited within the EEZ and for continental shelf fishery resources beyond the EEZ unless: (1) it is authorized by an international fishery agreement that existed before passage of the Magnuson Act and is still in force and effect, or (2) it is authorized by a Governing International Fishery Agreement (GIFA) issued according to the Magnuson Act.

GIFAs resulting from the Magnuson Act are bilateral agreements in which participants agree to abide by the fishing laws and regulations of the other Nation when fishing their waters. A GIFA is required before a Nation can apply for fishing privileges in a particular fishery. Several nations presently have GIFAs with the United States. One international fishery agreement, between the United States and the United Kingdom, allows fishing at traditional levels in the EEZ around the U. S. Virgin Islands and the British Virgin Islands by British and US citizens.

Other relevant international agreements are those that protect marine and coastal flora in the wider Caribbean region, the 'Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region' (known as the SPAW Protocol to the Cartagena Convention), and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), which applies worldwide to signatory countries. These agreements impact international trade in certain molluscs, crustaceans, corals (hydrozoa and anthozoa) and seagrasses.

9.0 OTHER APPLICABLE LAWS AND REQUIREMENTS

9.1 Effect on Wetlands:

The proposed action has no effect on any flood plains, wetlands, trails, or rivers.

9.2 Vessel Safety:

Under provisions of Public Law 99-659, the Magnuson Act was amended to require that vessel safety considerations be evaluated in the prosecution of fishing as provided for in the FMP. Consultation with the Coast Guard is pending.

9.3 Paperwork Reduction Act:

The purpose of the Paperwork Reduction Act is to control the burden on the public, businesses, local, county, and state governments, and other entities of providing information to the federal government. The primary regulatory tool is the Information Collection Budget. The authority to manage information collection and record-keeping requirements rests with the Office of Management and Budget. This authority encompasses establishment of guidelines and policies, approval of information requests, and reduction of paperwork burdens and duplications.

9.3.1 Proposed Data Collection Program

Under this FMP, harvesters, dealers and exporters of managed species will be required to submit records regularly and report harvest, shipments, and sales and value. The information provided must include numbers of each species (using both common and latin species names) which are harvested (to include individuals lost through mortality prior to delivery to dealer or shipment and noted as such) and numbers exported or sold to island enterprises. The kind and amount of gear used, time fished, location fished, wholesale price by market category, and any other economic, sociological-anthropological information deemed appropriate or desirable, will be noted. These data will provide biological and catch-per-unit-effort (CPUE) information necessary for stock assessment and CPUE information necessary for stock assessment and other analyses. Those who fail to report or provide information in a timely and accurate manner may lose their permits. All information collected would be confidential. The permits would be issued, and data collected, by the local governments.

9.3.2 Estimate of Reporting Burden and Cost

It is unknown how many persons are likely to apply for permits to harvest species in the FMU. Approximately 100 harvesters, dealers and exporters may apply for the harvest of reef-associated invertebrates for the aquarium trade. Estimated burden hours are considered to be negligible for permittees since most of the information requested is included on shipping lists.

In addition to mandatory reporting by all permitted fishers, individual fishers may be selected to provide catch information via interview. Selected fishers will be required to provide information to a government field agent on species and size composition which are not provided from fishers-submitted reports. As commercial fishers already report to local governments, the additional estimated burden hours of collecting the additional data on fishers managed under this FMP are not expected to be onerous to local governments. As of March 31, 1993, the total estimated cost of development of this FMP to the federal government is $44,453.00.

9.3.3 Coastal Zone Management Consistency

This proposed action will be implemented in a manner that is consistent to the maximum extent practicable with the approved Coastal Zone Management Programs of Puerto Rico and the U.S. Virgin Islands. This determination has been admitted for review by these governments under Section 307 of the Coastal Zone Management Act.

9.3.4 Federalism

Executive Order 12612, effective October 26, 1987, requires that 'federalism' principles be considered in the formulation and implementation of federal policies. This proposed action does not contain policies with federalism implications sufficient to warrant preparation of a federalism assessment.

9.3.5 Social Impact Assessment

There is no information available for a social impact assessment. However, given the nature of the impact of management measures 1 through 7, the Council believes that these actions should not have a significant social impact.

A significant social impact might be expected, if MCDs are established. Therefore, the Council will attempt to gather the necessary information for a social impact assessment for the possible implementation of MCDs through future amendments to this FMP.

10.0 MAJOR ISSUES DISCUSSED AT PUBLIC HEARINGS

See Section 7.0 of EIS (Appendix 4).

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