FISHERY MANAGEMENT PLAN, REGULATORY IMPACT REVIEW, AND FINAL ENVIRONMENTAL IMPACT STATEMENT FOR CORALS AND REEF ASSOCIATED PLANTS AND INVERTEBRATES OF PUERTO RICO AND THE UNITED STATES VIRGIN ISLANDS

CARIBBEAN FISHERY MANAGEMENT COUNCIL

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IN MEMORIAM

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ABBREVIATIONS USED IN THIS DOCUMENT

AP	Advisory Panel
CFMC	Caribbean Fishery Management Council
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPUE	Catch-per-unit-effort
COE	Corps of Engineers
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Program
DAH	Domestic Allowable (Annual) Harvest
DNER	Department of Natural and Environmental Resources (Puerto Rico) (Previously known as Department of Natural Resources - DNR)
DPNR	Department of Planning and Natural Resources (U.S.V.I.)
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency
EQB	Environmental Quality Board
FMFC	Florida Marine Fishery Commission
FMP	Fishery Management Plan
FMU	Fishery Management Unit
FRL	Fisheries Research Laboratory of the DNRE
FWS	Fish and Wildlife Service
GIFA	Governing International Fishery Agreement
GMSAF	Gulf of Mexico and South Atlantic Fisheries
IDEA	International Diving Education Association
MCD	Marine Conservation District
MMS	Minerals Management Service
MPRSA	Marine Protection, Research, and Sanctuaries Act
MSY	Maximum Sustainable Yield
NAUI	National Association of Underwater Instructors
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
OCRM	Office of Coastal Resource Management
OY	Optimum Yield
PADI	Professional Association of Diving Instructors
PMP	Preliminary Management Plan
P.R.	Puerto Rico

RIR	Regulatory Impact Review
RTSC	Recreational Training SCUBA Council
SAFE	Stock Assessment and Fishery Evaluation
SAS	Special Aquatic Sites
SCUBA	Self Contained Underwater Breathing Apparatus
SIA	Social Impact Assessment
SSC	Scientific and Statistical Committee
SSI	Scuba Schools International
STPs	Secondary Treatment Plants
TALFF	Total Allowable Level of Foreign Fishing
USCG	United States Coast Guard
USGS	United States Geological Service
U.S.V.I.	United States Virgin Islands

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 <u>Ecological Relationships</u>

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 <u>Current Recreational Use</u>:

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 <u>Overfishing:</u>

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 <u>Inadequate Information Base:</u>

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 <u>Limited Public Information/Education:</u>

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 <u>Habitat Loss and Degradation:</u>

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 <u>Management Measures Proposed</u>:

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.

<u>Discussion</u> - 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.

<u>Discussion</u> - 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.

<u>Discussion</u> - 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.

<u>Discussion</u> - 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;

- Ë identify habitats of special concern or ecological importance;
- Ë 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;
- Ë develop a comprehensive mapping of coral and rock reef areas over the insular platform;
- Ë harmonize local laws with federal laws;
- Ë ensure compliance with discharge and dredging laws;
- Ë permit no discharges in identified coral areas of special ecological importance or concern;
- Ë 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;
- Ë 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;
- Ë cooperate with NMFS to ensure consistent and integrated permitting and data collection systems;
- Ë regulate diving activities to reduce damage to reef areas through direct physical damage and casual collecting;
- Ë emphasize the importance of the reef ecosystem for the development of tourism (eco-tourism);
- Ë introduce a permitting system for those who collect and market live marine organisms;
- Ë develop management regulation for seagrass habitats;
- Ë prohibit the release of exotic marine species into surrounding waters of Puerto Rico and the U.S. Virgin Islands;
- Ë 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 <u>Effect on Wetlands</u>:

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

9.2 <u>Vessel Safety</u>:

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 <u>Paperwork Reduction Act</u>:

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).

11.0 REFERENCES

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TABLE 1: Species included in the fishery management unit (FMU) of the Fishery Management Plan for Corals and Reef Associated Plants and Invertebrates of Puerto Rico and the U.S. Virgin Islands. (References: Barnes, 1987; Sadovy, 1991; Goenaga and Buolon, 1992; Greenberg, 1992; Grana, 1993; Humann, 1992; 1993.)

Scientific Name	Common Name	Nombre Común
PHYLUM PORIFERA		
Class Demospongiae		
Niphates digitalis	Sponges	Esponjas marinas
N. erecta	Pink vase sponge	
Aphimedon compressa	Lavander rope	
Spinosella policifera	Erect rope sponge	
S. vaginalis		
Geodia neptuni		
Chondrilla nocula	Leathery barrel	
Cynachirella alloclada		
Tethya crypta		
Myriastra sp.		
Haliclona		
PHYLUM CNIDARIA		
Class Hydrozoa		
Order Hydroida		
Order Milleporina	Hydroids	
Millepora spp.	Fire corals	Corales de fuego
Order Stylasterina		
Stylaster roseus	Lace corals	
Class Anthozoa	Rose lace coral	
Order Antipatharia		
Antipathes spp.	Black corals	Coral negro
Stichopathes spp.	Bushy black coral	
Subclass Octocorallia	Wire coral	
Order Alcyonacea		
Family Anthothelidae	Soft corals	Coral suave
Erythropodium caribaeorum		
Iciligorgia schrammi	Encrusting gorgonian	Gorgonaceo
Family Briareidae	Deepwater sea fan	Abanico del alto
Briareum asbestinum		
Family Telestacea	Corky sea finger	Dedos de asbestos
Telesto riisei		
Order Gorgonacea	Telesto	
Family Gorgoniidae	Gorgonians	Gorgonaceos
Gorgonia mariae		
G. ventalina	Wide-mesh sea fan	
G. flabellum	Common sea fan	Abanico común
Pseudopterogorgia acerosa	Venus sea fan	Abanico de Venus
P. americana	Sea plume	
P. bipinnata	Slimy sea plume	
P. rigida	Bipinnate plume	
P. albatrossae		

TABLE 1 (cont.)

Pterogorgia anceps	Angular sea whip	
P. citrina	Yellow sea whip	Varillas de mar
Family Plexauridae	Sea rods	
Eunicea mammosa	Swollen-Knob	
E. succinea	Shelf-knob sea rod	
E. laxispica		
E. fusca	Doughnut sea rod	
E. laciniata		
E. touneforti		
E. clavigera		
E. knighti		
E. calyculata	Warty sea rod	
Muricea atlantica		
M. muricata	Spiny sea fan	Abanico
M. pinnata	Long spine sea fan	Abanico
M. laxa	Delicate spiny sea fan	
M. elongata	Orange spiny sea fan	
Muriceopsis sp.		
M. sulphurea		
M. flavida	Rough sea plume	
Plexaura flexuosa	Bent sea rod	
P. homomalla	Black sea rod	
Pseudoplexaura porosa	Porous sea rod	Varillas
P. flagellosa		
P. wagenaari		
P. crucis		
Plexaurella dichotoma	Slit-pore sea rods	
P. nutans	Giant slit-pore	
P. grandiflora		
P. grisea		
P. fusifera		
Family Ellisellidae		
Ellisella spp.	Sea whips	
Order Scleractinia		
Family Astrocoeniidae		
Stephanocoenia michelinii	Blushing star	Coral sonrojado
Family Pocilloporidae		
Madracis decactis	Ten-ray star coral	Coral cacto verde
M. mirabilis	Yellow pencil	Coral cerillas
Family Acroporidae		
Acropora palmata	Elkhorn coral	Coral orejón
A. cervicornis	Staghorn coral	Coral candelabro
A. prolifera	Fused staghorn	Coral prolífero
Family Agaricidae		
Agaricia agaricites	Lettuce leaf coral	Coral hoja
A. fragilis	Fragile saucer	Coral platillo
A. tenuifolia	Thin leaf lettuce	Coral de cintas
A. lamarcki	Lamarck's sheet	Coral laminado
Leptoseris cucullata	Sunray lettuce	

TABLE 1 (cont.)

Family Siderastreidae		
Siderastrea siderea	Massive starlet	de estrellas liso
S. radians	Lesser starlet	Coral rugoso
Family Poritidae		
Porites astreoides	Mustard hill coral	Coral colinoso
P. porites	Finger coral	Digitado romo
P. branneri	Blue crust coral	
P. divaricata	Small finger coral	de deditos
Family Faviidae		
Favia fragum	Golfball coral	Cupulita de coral
Diploria clivosa	Knobby brain coral	Cerebro tuberoso
D. strigosa	Symmetrical brain	Cerebro liso
D. labyrinthiformis	Grooved brain	Cerebro surcado
Manicina areolata	Rose coral	Coral rosa
M. mayori		
Colpophyllia natans	Boulder brain	Cerebro gigante
Cladocora arbuscula	Tube coral	de tubitos
Montastrea annularis	Boulder star coral	Coral montañoso
M. cavernosa	Great star coral	Coral cavernoso
Solenastrea bournoni	Smooth star coral	Coral liso
Family Rhizangiidae		
Phyllangia americana	Hidden cup coral	
Astrangia solitaria	Dwarf cup coral	
Family Meandrinidae		
Meandrina meandrites	Maze coral	Cerebro ondulado
Dichocoenia stokesi	Elliptical star	Cálices largos
D. stellaris		
Dendrogyra cylindrus	Pillar coral	Coral de columnas
Family Mussidae		
Mussa angulosa	Large flower coral	Coral florido
Scolymia lacera	Solitary disk	Coral solitario
S. cubensis		
Isophyllia sinuosa	Sinuous cactus	Cacto sinuoso
Isophyllastrea rigida	Rough star coral	Estrella áspero
Mycetophyllia lamarckiana	Fungus coral	Coral hongo
M. aliciae	Thin fungus coral	Hongo fino
M. danae	Fat fungus coral	Hongo gordo
M. ferox	Grooved fungus	Hongo surcado
Family Caryophyllidae		
Eusmilia fastigiata	Flower coral	Coral ramillete
Tubastrea aurea		
Family Oculinidae		
Oculina diffusa	Ivory bush coral	Arbusto de marfil
Order Actiniaria	Anemones	Anemonas
Condylactis gigantea	Giant anemone	
Bartholomea annulata	Corkscrew anemone	
Hereractis lucida	Knobby anemone	
Aiptasia tagetes	Pale anemone	
Lebrunia spp.		

TABLE 1 (cont.)

Stichodactyla helianthus	Sun anemone	
Order Zoanthidea		
Zoanthus spp.	Zoanthids	Zoantidos
Order Corallimorpharian		
Ricordia florida	Florida carallimorph	
Discosoma spp. (formally Rhodactis)		
Phylum Mollusca		
Class Gastropoda		
Order Mesogastropoda	Winged conchs	Carruchos
Family Strombidae		
Strombus spp. (except Queen Conch (S. gigas)		
Family Ovulidae		
Cyphoma gibbosum	Flamingo tongue	Lengua de flamenco
Family Ranellidae		
Charonia tritonis	Atlantic trumpet	Fotuto
Order Neogastropoda		
Family Olividae		
Oliva reticularis	Netted olive	Aceituna tejida
Order Sacoglossa		
Family Elysiidae		
Tridachia crispata	Lettuce sea slug	Lapa de lechuga
Class Bivalvia		
Orden Limoida		
Family Limidae		
Lima spp.	Fileclams	Limas
L. scabra	Rough fileclam	Lima áspera
Order Ostreoida		
Family Spondylidae		
Spondylus americanus	Atl. thorny oyster	Ostra espinosa
Class Cephalopoda		
Order Octopoda		
Family Octopodidae	Octopuses	Pulpos
Octopus spp. (except the Common Octopus (O. vulgaris)		
Phylum Annelida		
Class Polychaeta	Tube worms	Poliquetos
Family Sabellidae	Feather duster	
Sabellastarte magnifica	Magnificent duster	
Sabellastarte spp.	Tube worms	
Family Serpulidae		
Spirobranchus giganteus	Christmas tree	
Phylum Arthropoda		

TABLE 1 (cont.)

Sub-phylum Crustacea		
Order Decapoda		
Family Stenopodidae	Coral shrimp	
Stenopus hispidus	Banded shrimp	
S. scutellatus	Golden shrimp	
Family Hippolytidae		
Lysmata spp.	Peppermint shrimp	
Thor amboinensis	Anemone shrimp	
Family Palaemonidae		
Periclimenes spp.	Cleaner shrimp	
Family Alpheidae		
Alpheaus armatus	Snapping shrimp	
Family Diogenidae		
Paguristes spp.	Hermit crabs	Cangrejos hermitaños
P. cadenati	Red reef hermit	
Family Majidae	Coral Crabs	
Mithrax spp.	Clinging crabs	
M. sculptus	Green clinging	
M. cinctimanus	Banded clinging	
Stenorhynchus seticormis	Yellowline arrow	
Family Grapsidae		
Percnon gibbesi	Nimble spray crab	
Family Squillidae	Mantis	
Lysiosquilla spp.		
Gonodactylus spp.		
Phylum Bryozoa (Ectoprocta)	Bryozoans	Briozoarios
Phylum Echinodermata	Echinoderms	Equinodermos
Class Stelleroidea	Starfish	Estrellas de mar
Oreaster reticulatus	Cushion sea star	
Linckia guildingii	Common comet star	
Ophidiaster guildingii		
Astropecten spp.	Sea stars	
Ophiocoma spp.	Brittle stars	
Ophioderma spp.	Brittle stars	
Ophioderma rubicundum	Ruby brittle star	
Astrophyton muricatum	Giant basket star	
Davidaster spp.	Crinoids	
Nemaster spp.	Crinoids	
Analcidometra armata	Swimming crinoid	
Class Echinoidea	Sea urchins	Erizos
Diadema antillarum	Long-spined urchin	Erizo negro
Echinometra spp.		Erizo rojo
Lytechinus spp.		Erizo blanco
Eucidaris tribuloides	Pencil urchin	
Tripneustes ventricosus	Sea egg	
Class Holothuroidea		

TABLE 1 (cont.)

Holothuria spp.	Sea cucumbers	Pepinos de mar
Phylum Chordata		
Subphylum Urochordata	Tunicates	Tunicados
Phylum Chlorophyta	Green algae	Algas verdes
Halimeda spp.	Watercress alga	
Penicillus spp.	Neptune's brush	
Caulerpa spp.	Green grape alga	
Ventricaria ventricosa	Sea pearls	
Udotea spp.	Mermaid's fan	
Phylum Rhodophyta	Red/coralline algae	Algas rojas
Phylum Angiospermae		
Thalassia testudium	Turtle grass	Yerba de tortuga
Syringodium filiforme	Mantee grass	Yerba de Manatí
Halophilia spp.	Sea vines	Enredaderas
Halodule wrightii	Shoal grass	Yerba del bajo
Ruppia maritima	Widgeon grass	Yerba de pato

TABLE 2

REPORTED NUMBERS OF INDIVIDUALS OF DIFFERENT INVERTEBRATE SPECIES/SPECIES GROUPS EXPORTED FROM PUERTO RICO THROUGH THE LUIS MUÑOZ MARIN AIRPORT, SAN JUAN BETWEEN JAN 1990 AND AUG 1992

Source: Export Shipping Lists submitted to the Puerto Rico Department of Natural Resources [Set 1 - January 1990 to October, 1991 (81 lists); Set 2 - December 1991 to August, 1992 (133 lists)], and company trade lists (see Sadovy, 1991).

NAME	**NUMBER**		**PRICE US$**
	SET 1	**SET 2**	**(SET 2)**
PORIFERA			
Haliclona (orange tree sponge)	45	12	
(red sponge)	146	154	2.00-3.50
(elephant ear sponge)	50		2.00
COELENTERATA (for other stony corals and octocorals see below MISC. INVERTS.)			
Octocorals (gorgonians/seafans/ sea whip algae)		72	3.50-6.00
Tubastrea aurea (orange polyp - coral)		24	3.95
(open brain coral)		6	4.00
Condylactis (pinktip/Haitian pinktip)	382	5064	0.50-1.50
Bartolomea annulata (curlique/ringed anemone)	150	679	1.10-2.50
Stoichactis helianthus (carpet anemone)	105	280	1.95-4.00
**Ricordea florida (green/blue/green anemone/ false coral rock/florida false coral)		202	1.75-2.50
**Phymanthus crucifer (anemone rock)	10		
Lebrunia (staghorn/antler anemone)		26	2.50-3.50
**Zoanthus spp. (sea mat/colonial anemone/ anemone colone rock)	45	77	8.00
ANNELIDA			
Sabellastarte magnifica (solo feather duster)	75	1245	1.45-3.50
Sabellastarte spp. (colonial/cluster duster)	61		
CRUSTACEA			
Periclimenes spp. (anemone shrimp)		32	1.50-1.75
Stenopus spp. (red-banded/coral shrimp)	102	244	1.00-2.00
Stenopus scutellatus (gold shrimp)		2	
Alpheus spp. (pistol/snapping shrimp)	162	166	0.65-3.00

NAME	NUMBER SET 1	NUMBER SET 2	PRICE US$ (SET 2)
CRUSTACEA (continued)			
Lysmata spp.			
(peppermint shrimp/scarlet/lady)	15	1	3.95
(unspecified hermit crabs)	10		
Mithrax sculptus (green/emerald crab)	20	100	0.25-1.00
(decorator/sponge crab)		4	
Stenorhynchus spp. (arrow crab)	78	322	1.00-3.50
MOLLUSCA			
Cyphoma gibbosum (flamingo tongue)			2.00
Lima scabra (flame scallop)	280	195	1.00-2.50
Spondylus americanus (spiny/thorny oyster)		123	8.00-15.00
Tridachia crispata (nudibranch)		11	1.25
Octopus		8	4.00-4.50
ECHINODERMATA			
Astropecten (flat/sand star)	76		1.75
Oreaster reticulatus			
(red Bahama/West Indies starfish)	83	224	1.75-4.50
(comet star)			4.00-6.00
(brittlestar)	180		
Ophioderma/Ophiocoma			
(red/burgundy brittlestar)	481	750	0.50-3.00
Ophioderma (red serpent star)		11	5.00-12.00
Astrophyton (basket star)		144	3.00-3.50
(feather/star/crinoid)		34	3.50-4.50
Diadema antillarum (long spine urchin)			1.50
Lytechinus spp. (pin cushion urchin)			3.00
Eucidaris tribuloides (pencil urchin)	103	313	0.80-3.00
Holothurians (red sea cucumber)		1	4.00
MISCELLANEOUS INVERTEBRATES	135		
**(tunicates)			
**(bryozoa)			
TOTALS	2,796	10,524	

** denotes LIVE-ROCK categories

TABLE 3

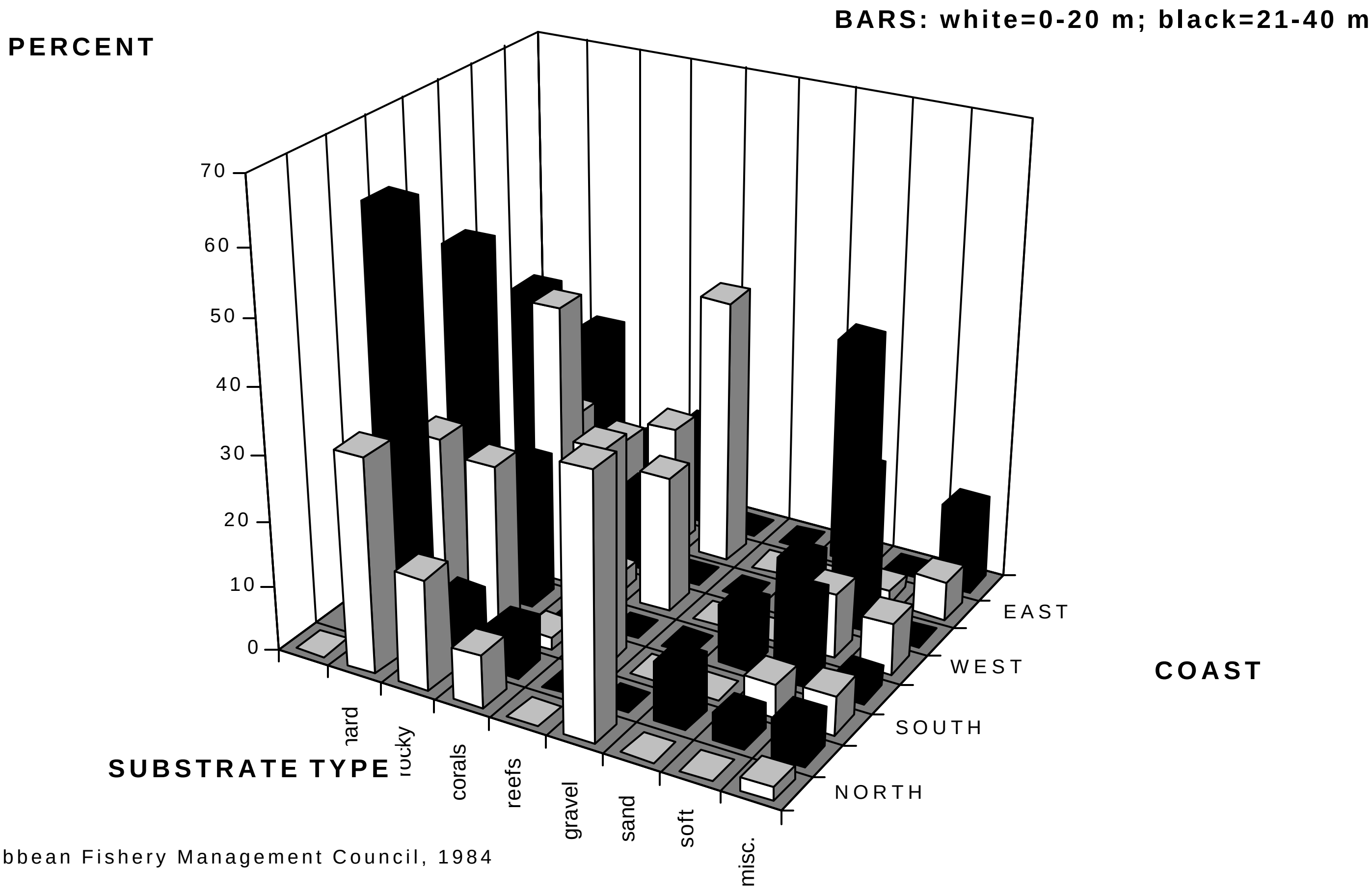
REPORTED NUMBERS OF BOXES OF MARINE FISH AND INVERTEBRATE SPECIES EXPORTED FROM PUERTO RICO THROUGH THE LUIS MUÑOZ MARIN AIRPORT, SAN JUAN, PUERTO RICO BY MONTH FOR 1990-1992.

Source: Export Shipping Lists submitted to the Puerto Rico Department of Natural Resources, and Office of the Puerto Rico "Cuerpo de Vigilantes" (see Sadovy, 1991).

MONTH	1990	1991	1992
JANUARY	11	218	77
FEBRUARY	36	218	49
MARCH	0	98	145
APRIL	0	243	85
MAY	86	1,291	237
JUNE	332	0	160
JULY	239	0	154
AUGUST	146	0	165
SEPTEMBER	125	145	139
OCTOBER	177	235	0
NOVEMBER	135	128	61
DECEMBER	114	111	147
TOTALS	1,401	2,687	1,419

FIGURE 1

DISTRIBUTION OF SUBSTRATE TYPE BY COAST AND BY DEPTH
(east coast includes USVI)

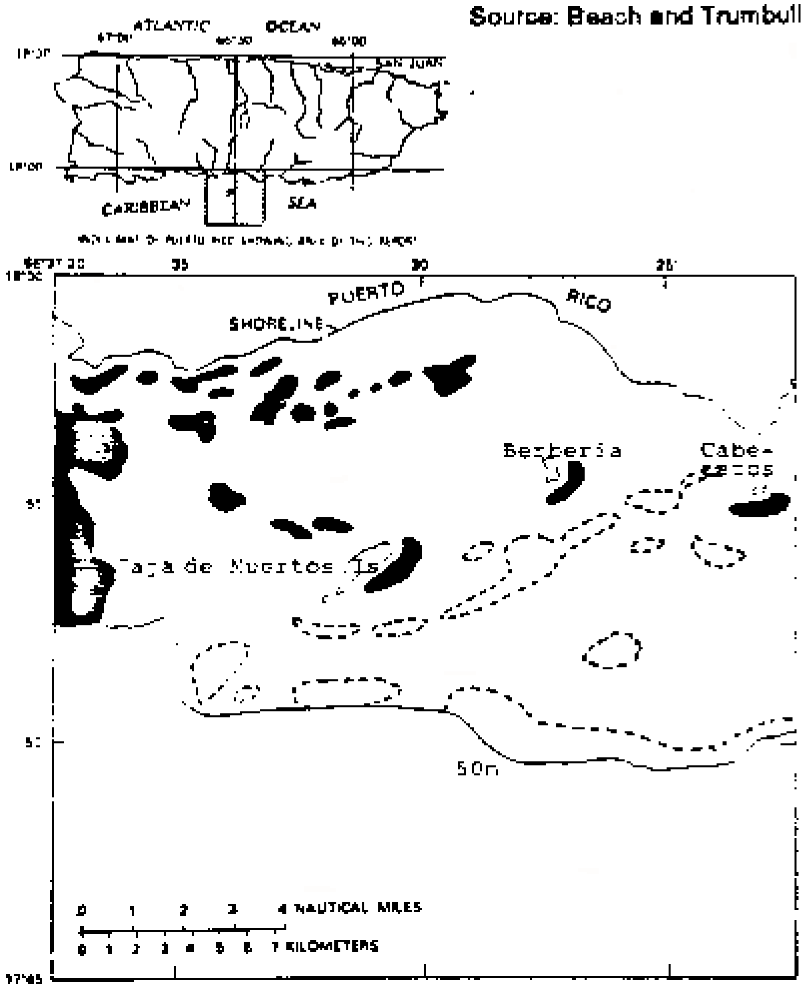


Source: Caribbean Fishery Management Council, 1984

FIGURE 2

DISTRIBUTION OF LIVE AND SUBMERGED REEFS ON THE INSULAR SHELF (to 50 m), CAJA DE MUERTOS AREA, SOUTHERN PUERTO RICO

Source: Beach and Trumbull, 1981

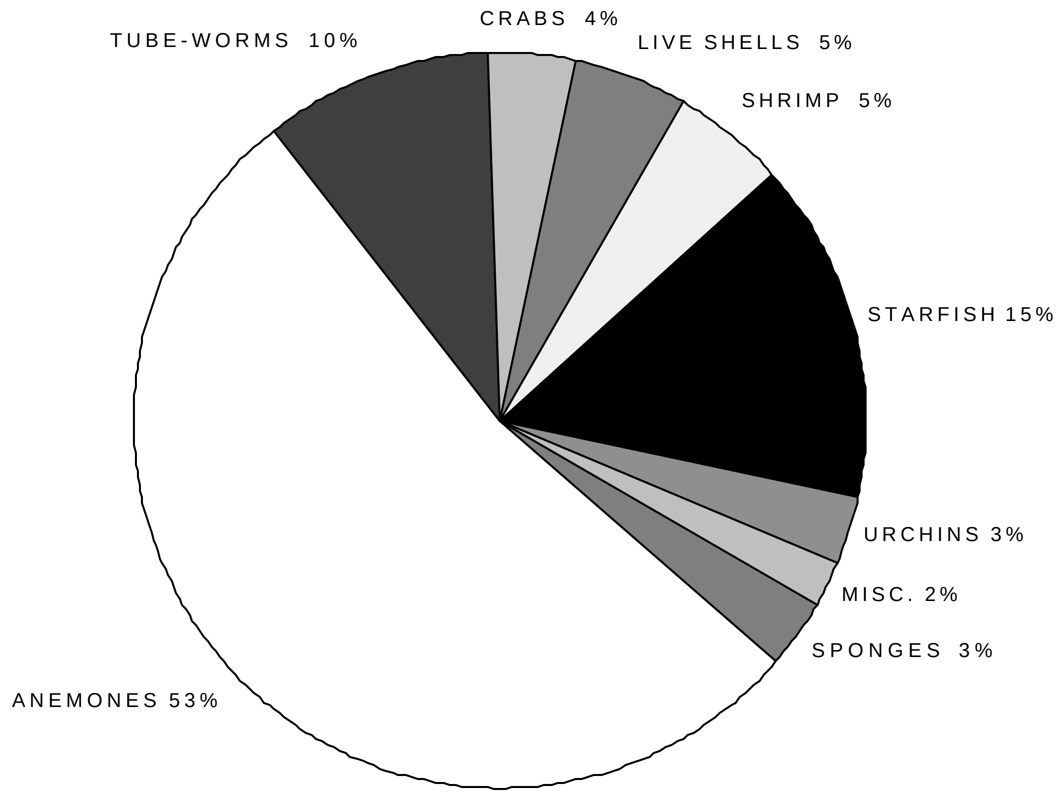


SUBMERGED REEFS—Drowned reefs, biologically constructed of intergrown and cemented calcareous (predominantly coral and coralline algae) skeletal material. No active reef framework coral growth but this abundant growth of gorgonians, sponges and small encrusting corals.

LIVE REEFS—Biologically constructed reefs with active reef framework coral growth. Includes fringing reefs east and south of the Cayos Cabezazos, Cayo Berberia, and the northern end of Isla Caja de Muertos, numerous patch and fringing reefs in the Ponce Basin and the Bajo Tasmanian Platform reef and its southern extension.

FIGURE 3

LIVE INVERTEBRATES EXPORTED FROM PUERTO RICO 1990-1992



Source: Sadovy, 1991, unpubl. data

FIGURE 4

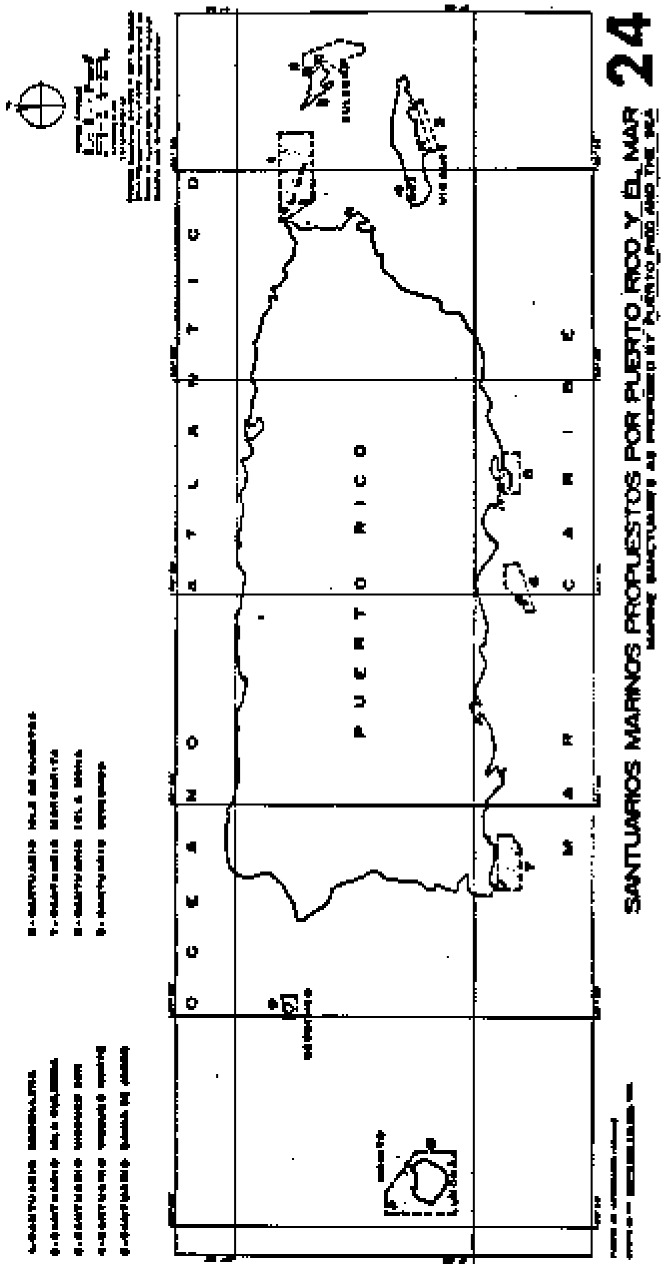

SANTUARIOS MARINOS PROPUESTOS POR PUERTO RICO Y EL MAR
24
O C E A N O   A T L A N T I C O
P U E R T O   R I C O
M A R   C A R I B E

FIGURE 5

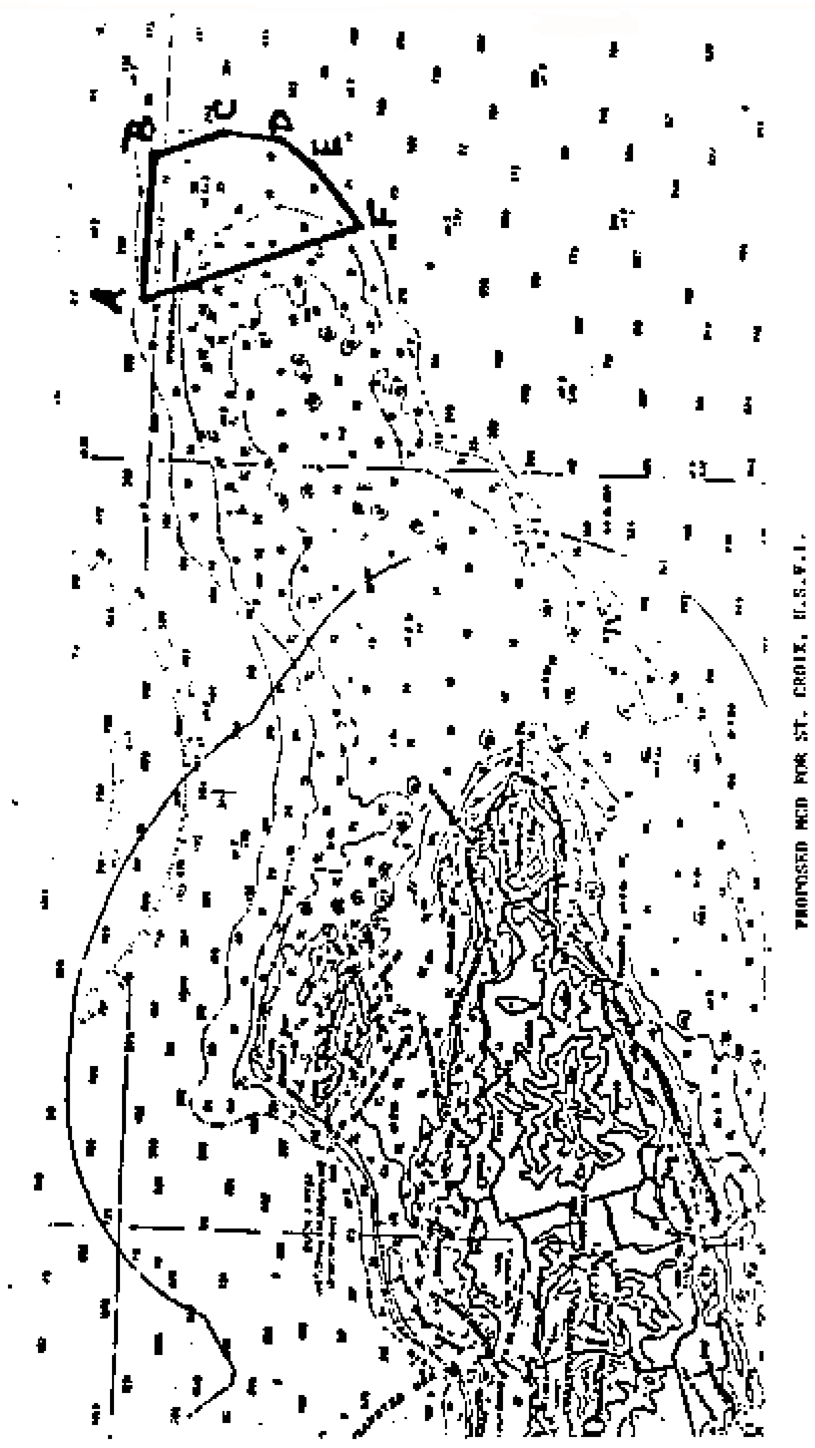


FIGURE 2. PROPOSED RED HIND AREA CLOSURE -- LANG BANK

APPENDIX A

The following species are not included in the Coral fishery management unit. These are species not usually taken for other purposes except for food. Some of these species are under management (Spiny lobster FMP) or are under consideration for management.

Phylum Mollusca	Moluscos	Mollusks
Class Gastropoda	Gastrópodos	Gastropods
Strombus gigas	Carrucho	Queen conch
Cittarium pica	Burgao,bulgao	Whelk
Class Cephalopoda	Cefalópodos	Cephalopods
Octopus vulgaris	Pulpo	Octopus
Phylum Arthropoda	Artrópodos	Arthropods
Class Crustacea	Crustáceos	Crustaceans
Panulirus argus	Langosta	Spiny lobster
P. guttatus		Spotted lobster
P. laevicunda		
Scyllarides spp.		Spanish/slipper lobster
Carpilius corallinus	Juey dormido	Batwing coral crab
Mithrax spinosissimus	Obispo	Clinging crab
Callinectes spp.	Cocolías	Blue crabs
C. sapidus		
C. danaee		

APPENDIX I

THE STATE OF PUERTO RICAN CORALS: AN AID TO MANAGERS

Report
Submitted to
Caribbean Fisheries Management Council
Suite 1108, Banco De Ponce Building
Hato Rey, Puerto Rico

By

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February 1992

THE STATE OF PUERTO RICAN CORALS: AN AID TO MANAGERS

V. Abundance and present condition of the coral reef resource in Puerto Rico and the U.S. Virgin Islands

- A. Species distribution
- B. Present condition
    - 1) Puerto Rico
    - 2) offshore islands
        - a) Vieques
        - b) Culebra
        - c) Mona and Monito
        - d) Caja de Muertos
    - 3) U.S. Virgin Islands
        - a) St. Croix
        - b) St. Thomas
        - c) St. John
- C. Habitat threats
- D. History of exploitation
- E. Habitat requirements
- F. Habitat information needs

VI. Management recommendations

- A. Identification of critical areas
- B. Most susceptible species
- C. Collection
    - 1) commercial
    - 2) touristic
    - 3) scientific
- D. Cultivation
- E. Monitoring
- F. Probable future condition

VII. References

I. Introduction

A. Background

This work attempts to give an overview of the biology, taxonomy, distribution and state of corals in Puerto Rico, the U.S. Virgin Islands and adjacent islands. It is intended for the general public interested in corals, for managers that wish to evaluate proposed development within the context of the presence of the important ecosystems created by particular types of corals and for the beginning student that will hopefully soon contribute to the better understanding of these interesting animals. This document does not pretend to review all the literature on any of the topics discussed but will hopefully provide the raw material from which a management program for corals will be prepared.

B. Phylogenetic division of corals

Strictly speaking all extant corals belong to the Order Scleractinia of the Class Anthozoa (Phylum Cnidaria). Flexible usage of the word "coral", however, also includes other taxa within and in addition to Anthozoa. Octocorals (O. Gorgonacea and O. Alcyonacea) and black corals (O. Antipatharia) are other anthozoan orders including "corals". Hydrocorals, instead, belong within Class Hydrozoa. In this report the word "coral" will refer only to the Scleractinia and the rest will be noted as: a) octocorals, b) black corals or antipatharians and, c) hydrocorals or calcium secreting Hydrozoa. Details of the most common species are given below.

1) Class Hydrozoa (Cnidaria)

Hydrocorals (Phylum Cnidaria; Class Hydrozoa) are distantly related to the rest of the skeleton forming cnidarians and fall within two orders: the Milleporina and the Stylasterina. The Milleporina (commonly known as fire corals) are colonial and more than one type of polyp inhabits a single colony with specialization for feeding (gastrozooids) and defense (dactylozooids). These polyps protrude through cupless pores that can be easily seen in the skeleton with a magnifying glass and their digestive cavities are interconnected, as in other colonial, skeleton forming cnidarians. They posses stinging cells (nematocysts), generally more powerful than those of other Cnidaria, that enable them to paralyze and capture prey. Hermatypic hydrocorals play a significant role in coral reef construction, particularly in shallow, windward substrates, and their importance will be considered within this context when coral reefs are discussed. In brief, hydrocorals are capable of growing in shallow waters (being emergent during low tides) and, because of their buffering effect, contribute substantially to the protection of coastal lands during times of high seas. The Stylasterina are also colonial but do not contain zooxanthellae. They form small, fragile and cryptic colonies that are usually colorful (pink, purple or red) and branch in one plane. Stylasterines have been used frequently as ornamental pieces and as such may deserve fisheries management. Common species of both orders are included in Appendix 1. and brief descriptions are given in Colin (1978), Cairns (1982) and Kaplan (1988). It is emphasized that these tables do not necessarily include all species but only those usually encountered.

2) Antipatharia (Cnidaria; Anthozoa)

Black corals are typically deep sea, colonial anthozoans usually occurring under ledges possibly because their larvae is negatively phototactic (Grigg, 1965). The axial skeleton is black, spiny and scleroproteinaceous and is secreted in concentric layers around a hollow core. The polyps overlay the horny skeleton, are interconnected and possess six non retractile, unbranched tentacles. They usually contain a diverse array of internal and external unstudied "commensals" that include palaemonid crustaceans, lichomolgid copepods and pilargiid polychaetes (Goenaga, 1977; Humes and Goenaga, 1978).

Black corals are slow growing and their entire colonies are harvested for artisanal purposes in some regions of the Caribbean. In 1970 the local precious coral jewelry industry (black and pink coral) was estimated to have a retail value of more than 4 million dollars. Their axial skeleton is polished and attains considerable thickness in some species, rendering them commercially valuable in the jewelry trade to humans. Species that do not branch are bent for making necklaces.

The ecology and life history of these organisms is, for the most part, unknown but the available evidence suggests that recruitment is infrequent (Grigg, 1976). Therefore, populations of commercially important species can decline rapidly if overharvested. Their taxonomy, to a large extent, is also unknown.

In Puerto Rico and the Virgin Islands commercial harvesting is apparently uncommon but is known to occur. Thick stemmed, branched and large (i.e., potentially important economically) black corals (e.g., Antipathes spp.) occur in water depths below 50 m in La Parguera, Puerto Rico (Goenaga, 1985) although unbranched, thin stemmed species (e.g., Stichopathes spp.) are present at depths of 20 m (Goenaga, 1977). Both genera can also occur sparsely in very shallow, turbid waters off Mayaguez, western Puerto Rico and in La Parguera, southwestern Puerto Rico. The same situation has been observed in Jamaican individuals of Antipathes pennacea (Oakley, 1988). I have observed an individual of Antipathes sp. above depths of 8 m south of Arrecife La Gata, La Parguera, indicating that adult colonies of these species do not require deep waters. In the Virgin Islands, these species are most common at depths exceeding 30 m but can be found on the north shore of St. Croix and north of St.John (e.g. Haulover Bay) at depths of less than 20 m. Some of these colonies have been observed to have been harvested over a several year period which would indicate either cautious harvesting (some of these areas being within the V.I. National Park) or personal collecting for low level jewelry production. Antipatharians commonly settle on sloped surfaces, on the underside of plate-like scleractinians or in crevices, suggesting that the larval stages are susceptible to sediment bed load, to settling sediments, and/or to competition by encrusting organisms that require high light levels such as scleractinians.

Black corals may prove to be important as sclerochronological tools. As stated above they are known to produce growth rings although their periodicity is not well known. If the temporal cycle is defined they may be important assets in the elucidation of environmental variations in deeper habitats (i.e., below the thermocline) where hermatypic corals are absent or rare.

Appendix 1 includes species reported from the Caribbean. For the most part it is likely that most will be present in Puerto Rico and the U.S. Virgin Islands. The source for each record is included.

3. Octocorallia (Cnidaria; Anthozoa)

These cnidarians form soft, flexible colonies that may be bushlike, fanlike or rodlike, depending on the species. The polyps occupy cups within the skeleton and have 8 branched tentacles that are easily seen upon close inspection. In addition to the number of tentacles per polyp these plant-like animals differ from the also plant-like black corals in their capacity to retract the polyps within their skeletons. Their skeleton is internal as in hydrocorals and antipatharians and consists of a central axis composed of a collagenous protein (i.e., gorgonin) and of an abundant meshwork of calcium carbonate spicules embedded within a mass of tissue (i.e., coenenchyme) that surrounds the axial skeleton. This axial skeleton is absent in some species.

Soft corals include members of two orders within the Subclass Octocorallia: Gorgonacea and Alcyonacea. Alcyonacea includes species with skeletons consisting of spicules but no axial skeleton; Gorgonacea includes octocorals with axial skeletons composed of gorgonin (Muzik, 1982). Appendix 1 includes species observed in Puerto Rico and the U.S.V.I.. Reports are based on Yoshioka and Yoshioka (1989a) and personal observations.

Gorgonians are conspicuous members of coral reef ecosystems in the West Indies and can be very abundant in some sites where scleractinian corals apparently are unable to proliferate. The causes for these wide variations in population densities, however, remain to be answered. Valuable insight suggesting water motion and substrate relief as important factors is given by Yoshioka and Yoshioka (1989a and 1989b).

Gorgonians contain large amounts of chemical compounds (e.g., prostaglandins) with no obvious functions (Cierezco and Karns, 1973; Tursch et al., 1978; Fenical, 1982). The hypothesis that these compounds may be used for chemical defense against predators has been postulated by Bakus (1974). This hypothesis has been supported by experimental studies (Gerhart, 1984). This feature of gorgonians has made them the subject of intense collection in southwestern Puerto Rico and to a lesser extent in some areas on the south side of St. Thomas. The ecological effect of this extraction remains unassessed.

4. Scleractinia (Cnidaria; Anthozoa)

Scleractinians are calcium secreting, anemone-like animals that can form colonies comprised of many physically and physiologically linked polyps or else can be solitary or consisting of one polyp. Tentacles occur in multiples of six and the digestive cavities are divided by partitions (sclerosepta and sarcosepta) that radiate from the center of the 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 coral species possess annual growth bands, related to variable skeletal densities, that can be used to infer past environmental variations.

Corals can be divided ecologically into those that are capable (hermatypic corals) and those that are not capable (ahermatypic corals) of forming reefs. Reef building corals differ from non reef building species in that the former, and not the latter, contain algal endosymbionts (Dinoflagellata) commonly referred to as zooxanthellae. Zooxanthellae promote fast growth rates 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. Coral reefs are an important asset to nations that possess them. Their socioeconomic importance will be discussed below.

The fact that reef corals are capable of forming coral reefs sets them apart from the other types of corals. Reef forming corals are habitat generating organisms and this aspect poses important management considerations. While management of the first three skeleton forming cnidarians may focus on the individuals, management of the reef building corals will need to focus on the habitat. In other words, a valid management practice for black corals may be to control their collection or to culture them, because it is through collection that they are mainly affected. To effectively manage reef corals it is essential to control all the numerous human activities that are capable of damaging them, either directly or indirectly. This means the control of upland deforestation with its resultant soil destabilization and sediment input into the ocean, sewage outfalls, industrial outfalls, military activities, anchoring practices, and others. In summary, it means managing the coral reefs themselves.

We are of the opinion that the four groups should be included in a management plan but this report refers mainly to the principal coral reef builders, the Scleractinia. This order contains the most endangered corals in Puerto Rico and the U.S.V.I.. For reasons that will be mentioned below this group also contains some of the most fragile or sensitive taxa.

II. Socioeconomic and ecological importance of corals

The importance of hydrocorals, black corals and gorgonians to Homo sapiens has been mentioned in the section Phylogenetic division of corals. As stated above the emphasis of this manuscript is on reef building corals and their importance will be discussed in more detail. First, a brief background on the main products of reef corals: coral reefs.

Coral reefs are tropical and subtropical ecosystems that flourish at temperatures between 25 and 29 degrees centigrade in insular and continental platforms. Within the Wider Caribbean they occur from the Gulf of Mexico south to Panama and Tobago and north to the Bahamas and represent 9 % (1,000 km2) of the total area covered by these ecosystems in the world (Smith, 1978). Bermuda and northern Brazil (Recife) contain the northernmost and southernmost coral reefs, respectively, in the Atlantic Ocean. These regions are related biogeographically to Caribbean reefs but are impoverished in terms of reef related species. The reefs off Brazil exhibit relatively high endemicity (Margarida, 1982).

The principal building blocks of coral reefs are reef corals that accumulate through many centuries. These ecosystems are mainly known for their natural beauty and high biological diversity. The biological diversity in coral reef ecosystems has no parallel on Earth except for tropical rain forests (Connell, 1978). The ecological and socioeconomic importance of coral reefs is given in what follows.

A. Ecological importance

Coral reefs shelter a wide array of plants and animals and, at the same time, generate the oceanographic conditions that permit the establishment of other ecosystems. Seagrass meadows and mangrove forests, for example, occur in waters that are sheltered by the presence of coral reefs. These associated habitats shelter, in turn, many organisms that include commercially important as well as endangered species many of which contribute to the biodiversity of coral reefs as adults. Given this diversity of habitat and biota, coral reefs are important scenarios or natural laboratories where ecological hypotheses concerning or related to the coexistence of species can be tested.

B. Socioeconomic importance

1) Production of pharmacological compounds

A large diversity of chemical compounds may have resulted as a consequence of complex interactions between species in the coral reef. Some of these substances are highly active biocompounds whose applications in medical research are just now being discovered. These include antimicrobial, antileukemic, anticoagulant and cardioactive properties (Fenical, 1982; Rinehart et al., 1981; Salm and Clark, 1982). 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)(Angeles, 1981).

2) Prevention of coastal erosion and storm damage

This is particularly important for regions with low lying coastal plains. Coral reefs also contribute to the formation of sandy beaches and sheltered harbors. Beaches of touristic importance in Puerto Rico, such as Luquillo Beach, and many beaches in the U.S.V.I. are protected by offshore coral communities from direct wave action. These communities, although not necessarily structural coral reefs (i.e., do not contain a solid, structural framework formed by corals) are inhabited by corals and other sessile, benthic organisms that protect the underlaying structure, possibly eolionite, and contribute to its growth. The structural complexity of the surface of these reefs produces a baffle effect, which acts to reduce the wave energy.

The importance of the maintenance of healthy coral reef growth to reduce coastal erosion is underscored by the observed sea level rise in the last decades (Etkins and Epstein, 1982; Gornitz et al., 1982). Coastal erosion is likely to be felt more in areas where coral reefs are degenerated since large waves are capable of penetrating more easily in the absence of these natural barriers (Cubit et al., 1984).

3) nutrition

Coral reefs are among the most productive habitats of the world (Lewis, 1977). Fisheries in the Caribbean can be defined, with few although significant exceptions (e.g., upwelling zones and shrimp fisheries), as coral reef fisheries (Munro, 1983). Reef fishery products are often the primary source of dietary protein for coastal and island people. According to the Caribbean Fisheries Management Council (National Ocean and Atmospheric Administration, U.S. Department of Commerce) 59 % of the total fisheries consumed in Puerto Rico and the Virgin Islands come from coral reefs. The fisheries potential of many Caribbean reefs has been impaired in the last decades partially due to overfishing (e.g., Appeldorn and Lindeman, 1985) and, possibly, to habitat degradation (e.g., Bouchon-Navarro et al., 1985).

4) recreation

Tourism on many Caribbean islands is based on reef related activities and on the aesthetic and recreational value of reefs. An example is the underwater trail in Trunk Bay, St. John, 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). This trend in visitation and impact is seen throughout the Caribbean (Rogers, 1985). Likewise, thousands of residents don masks, fins and/or SCUBA gear and dive on nearshore coral reefs for recreation. Tourism and recreation thus can provide powerful economic arguments for management and can play an important role by educating users about the nature of reef environments and their sensitivity, thus creating a large basis of informed support for continuing reef protection (Kenchington, 1988; Robinson, 1982). This type of development, however, requires close supervision and a parallel educational process about the fragility of component reef organisms. Without these considerations touristic activities can be detrimental to these fragile ecosystems (e.g., Salm, 1985).

5) extraction of atmospheric carbon dioxide

Coral reefs constitute about 0.17 % of the world ocean area and about 15 % of the shallow sea floor within the 0-30 m depth range (Smith, 1978). These ecosystems play an important role in the marine carbon budget primarily through the deposition of aragonitic calcium carbonate. Surface tropical waters, which are stratified by a permanent thermocline, are supersaturated with respect to calcium carbonate. The inorganic transfer of atmospheric CO_2 across the air-sea interface is, therefore, limited. By extracting $CaCO_3$, coral reef organisms provide a way of bringing more CO_2 into the ocean system. Reported rates of $CaCO_3$ deposition by coral reefs demonstrate that these ecosystems are an important buffer in the Earth's CO_2 cycle (Barnes et al., 1986). Coral reefs may contribute about 0.05% of the estimated net CO_2 fixation rate of the global oceans (Crossland et al., 1991). This aspect of coral reefs means that their importance transcends the national level and escalates to aspects of global significance.

C. Age of Puerto Rican and U.S.V.I. coral reefs

Modern coral reefs have deposited on Pleistocene erosional surfaces that flooded when sea level rose after the end of last glaciation. Sea level was about 100 m below present at the peak of the last glaciation and started rising about 18,000 years before present (ybp). At about 8,000-9,000 ybp, Caribbean shelves flooded and reef construction began over topographic highs of the platform. This means that the oldest reefs on our shelves, namely those at the insular shelf edge, are about 8-9,000 years old with those further inshore being younger (i.e., about 4-5,000 years old). In conclusion, even though corals arose as a group in the Triassic (200-230 million ybp; Rosen, 1981)) present coral reefs are relatively young. These assumptions are based on the work of Adey (1978) for St. Croix, U.S. Virgin Islands.

III. General biology

A. Reproductive biology

Corals can reproduce sexually and asexually. Sexual reproduction, usually hermaphroditic (of which several possibilities exist; for a review see von Moorsel, 1983; Szmant, 1984; Szmant, 1986), always result in the formation of minute larvae (called planulae) that spend a variable amount of time in the water column as plankton (from days to weeks) and eventually settle on an appropriate substrate (or die if one is not found). Alternatively, larvae can be brooded within the gastric pouch of its parent and let loose when ready for settling. Larval capacity for substrate selection is unknown for most species but is likely to vary among them. After settling, larvae develop a skeleton and, if colonial, start budding additional polyps that will eventually form an adult colony. Natural selection probably acts more intensely during initial larval recruitment (Crisp, 1977) and is probably the reason for production of vast numbers of gametes. Individuals of some species delay sexual reproduction and use the their available energy for asexual growth until a colony size safe from predation has been attained (Szmant, 1985).

Forms with branching morphology and high growth rates (e.g., Acropora palmata and A. cervicornis) can disperse through breakage during storms (e.g., Highsmith, 1982). Resulting fragments can, although not always do, recruit onto the substrate and form a new colony.

Most corals have well defined seasonal patterns of sexual reproduction (Szmant, 1986). Energy allocated to reproduction can be considerable even in those species in which sexual recruitment is rare. For example, even though Montastrea annularis is one of the most abundant corals off La Parguera and in many reefs off Mayaguez, I (CG) have never observed juvenile colonies of this species. The same can be said for other sites in the Caribbean (e.g., Bak and Engel, 1979; Hughes, 1985). Very small colonies of this species can be frequently observed in La Parguera. Upon close inspection, however, it can be seen that these are remnants of larger colonies that have undergone partial mortality and the rest of their skeleton have been covered by other organisms such as filamentous algae. While this is generally true for the V.I. as well, very small, apparently juvenile colonies have been observed in certain localities (e.g. Salt River submarine canyon (Boulon, 1979; Beets, pers. comm.)).

Different coral species have different colony turnover (Loya, 1976) but, as a whole zooxanthellate corals are more like trees, tortoises and elephants in being remarkable for their longevity (Rosen, 1981). In the La Parguera area, for example, there are corals of the species Montastrea annularis, which form colonies that can reach more than 5 m in diameter and height. Considering growth rates of slightly less than one cm per year (Goenaga and Winter, unpublished data), these corals are many hundreds of years old.

Rosen (1981) has remarked that "there is no real information on what constitutes the life span of most coral species, nor even how this concept applies to corals".

B. Feeding

Cnidarian, skeleton forming animals are well equipped to capture and eat living animal prey. They possess tentacles loaded with batteries of nematocysts. These are stinging cells that serve to paralyze and kill zooplankton. Hermatypic corals (scleractinians and, possibly, hydrocorals and gorgonians), however, are considered polytrophic organisms (Muscatine and Porter, 1977). This means that they can feed at multiple levels in the food web. These modes of feeding include: a) dissolved and suspended organic matter (auxotrophic), b) photosynthetates from zooxanthellae (primary consumers) and, c) zooplankton (secondary consumers). In addition, their capacity to photosynthesize, as a symbiotic unit with zooxanthellae, makes them a very special case of primary producer in which production exceed consumption in many cases.

Hermatypic gorgonians have abundant zooxanthellae in their tissues. The extent to which different species depend on their zooxanthellae for nutrition is, to a large extent, unknown (Muzik, 1982).

Black corals do not contain zooxanthellae. Their tentacular muscles are not well developed and tentacular contraction and retraction are slow. Even so, when presented in the laboratory with living zooplankton they exhibit an efficient preying response. Living food is rapidly engulf with the aid of ciliary currents inflowing through the pharynx into the gastrovascular cavity.

C. Biological interactions and ecological relationships

Reef corals represent a peculiar situation since, in most cases, they are the main constructors of their own habitat, the coral reef. Therefore, their condition reflects the condition of their habitat. If corals are dead or dying, the coral reef is likely to degenerate sooner or later.

Many other organisms, however, do depend to different extents on the condition of the coral reef. These include commercially important species that utilize corals, directly or indirectly, for shelter, food and as spawning sites.

Although the vertical structure (i.e., habitat created by the upward and lateral growth of corals that is capable of sheltering fish, molluscs, crustaceans, among others) of a coral reef is retained for some time after the death of the reef corals, as is the case of Arrecife Algarrobo off Mayaguez, ultimately, bioerosion, formerly counteracted by construction, will possibly flatten the habitat thereby diminishing the available shelters. The associated biota is likely to migrate elsewhere or die.

The biological composition of organisms living in and on the surface of coral reefs depends on many factors, many of which are still not well understood. Littler and Littler (1985) have proposed a model, based on prevailing nutrient concentration, wave energy and grazing pressure, to describe the predominant organisms living on coral reefs. The model fits many of our observations for Puerto Rico and the Virgin Islands and is discussed briefly here. Although Littler and Littler refer mainly to variations among reefs, the concepts can also be applied to trends observed to occur within reefs. Under this model corals gain primacy where there is: 1) intensive herbivory, 2) moderate levels of wave shear, and, 3) low nutrient concentrations. With an increase in the amount of nutrients, the growth of short lived filamentous and leafy algae is favored. Coralline algae, another important component in coral reefs, are generally not inhibited by moderate to high levels of nutrient enrichment but predominate in areas of moderate to heavy grazing, as in shallow, reef front habitats of La Parguera reefs prior to the 1984 Diadema antillarum die off (Vicente and Goenaga, 1984). These also predominate under heavy wave shear. The latter conditions are unknown in Puerto Rico but result in extensive algal ridges or algal crests elsewhere in the Caribbean. Adey and Burke (1976) have described algal ridges and boiler reefs from southeastern St. Croix. Eutrophic waters, where grazing and wave ripping are low, tend to favor large standing stocks of frondose macroalgae that can overgrow and kill both coralline algae and corals. Areas in which nutrient levels are low and grazing activity low to moderate are usually dominated by microfilamentous algae with greater surface area to volume ratios. However, these also appear opportunistically in any system where physical disturbances make space available.

We have also observed that the lower bathymetric limit of predominant photosynthetic reef organisms is, to a large extent, correlated with average water turbidity. Thus, major reef building coral species, such as Montastrea annularis are capable of growing down to 60 m in clear, shelf edge habitats off both north and south coasts of our islands but are limited to depths above 4-5 m in nearshore, turbid waters off Mayaguez. As it is well known, light accelerates calcium carbonate deposition in hermatypic corals and this light enhancing effect results from zooxanthellar photosynthesis. In the absence of adequate solar energy, corals are likely to be under competitive disadvantage.

D. Capacity for reef formation

Coral reefs are marine promontories or mounds that: 1) are capable, in part, of resisting wave action, 2) bind sediments, 3) grow vertically and horizontally by biological and physical processes, 4) are capable of generating hydrodynamic and chemical environments different from adjacent ones, and, 5) provide shelter for a large diversity of vertebrate and invertebrate taxa. The surface or outer layer of coral reefs is colonized and veneered by organisms of many phyla, the most notable ones being corals, octocorals, hydrocorals, anemones, sponges, and algae. Coral reef frameworks, however, are built mainly by reef corals (and infilled by coralline algae, calcareous algae, foraminiferans and molluscs).

The formation of coral reefs is a result of the relationship between scleractinians and zooxanthellae. This relationship allows the symbiotic unit to grow faster and, possibly more important, to grow uninterruptedly over long time periods. In these organisms, as in other colonial organisms, the probability of dying decreases with age (Jackson, 1979). Therefore, coral colonies accumulate over time in the tropics and generate the largest calcium carbonate buildups known in our planet.

The extent to which these buildups are a product of coral growth, however, is not uniform. Many generations of reefal organisms can build significant portions of the relief over which they live (in which case a coral reef is termed "structural" or, "true coral reefs"). In contrast they can overlie topographic highs unrelated to biogenic growth, such as cemented sand dunes (formed during lower sea stands in Pleistocene times). The former is probably the case of many reefs in the Puerto Rican southern coast while the latter is probably the case of many coral communities on the north coast and in the Virgin Islands. This is speculative and confirmation of the dominant process will be possible only after drilling through reef frameworks, determination of framework thickness and dating the underlying substrata.

IV. Stressors

A. Natural stressors

Damage to Puerto Rican and Virgin Island coral reefs due to natural phenomena has been documented on several occasions. Mass mortality of Millepora complanata was observed during heavy rains on the east coast (Goenaga and Canals 1979). Heavy mortality of echinoids and other reef flat organisms was found to be related to extreme low water exposure at mid-day (Glynn 1968).

Hurricanes can modify substantial portions of shallow reefs. Hurricane Edith caused extensive destruction of branching corals in 1963 (Glynn et al. 1965; see account for La Parguera). Two tropical storms in 1979 (David and Frederic) caused extensive damage on the outer east coast and southern coastal reefs. Damage was most obvious in the shallow Acropora palmata zone where colonies were ripped off and overturned causing damage to adjacent massive corals (Goenaga and Cintron 1979). These hurricanes caused damage to the reefs off the eastern point of Vieques (Raymond and Dodge 1980). The more exposed south coast was most severely affected, with most Acropora palmata stands destroyed and Porites beds affected. On the north coast, A. palmata was damaged in the fore reef area and some Porites beds were crushed by broken A. palmata branches, Long Reef experiencing the greatest effect.

Storms have undoubtedly caused the greatest destruction to coral reefs off the south side of St. John in the Virgin Islands (Rogers and Teytaud 1988). Hurricanes David and Frederic (1979), are known to have caused considerable damage to reefs off St. Croix (Rogers et al. 1980) and are most likely responsible for the widespread fragmentation of the dominant branching coral species seen in Fish Bay, Reef Bay, Coral Bay and other southside beaches on St. John. Tropical storm Klaus (1984) caused considerable physical damage to corals in Fish Bay (Rogers and Zullo 1987). Hurricane Hugo caused a significant reduction in total living cover by scleractinians on coral reefs on the south side of St. John (Rogers, et al. In Press). No measurable recovery of live corals occurred in the 12 months following the initial post-storm survey.

Based on frequency of hurricanes in the last decades it has been suggested that the so called "Acropora palmata zone" may not be the prevailing biota in shallow reef fronts in Jamaica (Woodley, 1989) and Puerto Rico (Goenaga, 1990). Instead, if Acropora spp. takes several decades to repopulate these areas, it is likely that this zone is more frequently devoid of branching coral species.

It must be mentioned that although hurricanes appear to be detrimental to coral reefs the opposite seems to be true (in the absence of additional stresses). By displacing large numbers of fast growing, predominant branching coral species that monopolize the substrate, large amounts of space is freed and made available for slower growing, massive species. The net effect appears to be an increase in species diversity (see Connell, 1978). These climatological phenomena have been also postulated to be important in terms of reef growth. Highsmith et al (1980), for example, postulated that hurricanes redistributed large amounts of calcium carbonate from reef corals that were incapable of further vertical growth because of their nearness to the water surface.

As elsewhere in the Caribbean, coral diseases, borne about by different pathogens, are known to attack reef corals in Puerto Rico and the Virgin Islands. The white band disease, for example, has caused drastic population declines in A. palmata. Peters (1983) has suggested that bacteria may be responsible but no causal agent has been specifically identified. The vector of this disease is yet unknown and its incidence in St. Croix is thought to be related to human activities (Gladfelter, personal communication). Vast stretches of living and healthy A. palmata observed in Cayo Largo, Fajardo, in 1979, have been severely decimated possibly as a consequence of this disease. A large portion of the affected colonies remain in growth position. This disease has affected over 5 ha of the A. palmata reef at Buck Island National Monument, St. Croix (Gladfelter 1982) and various other reef areas on St. Croix. Davis et al. (1986) has recorded a rate of advance of 4-5 mm/day for the disease. Many cases of white band disease have been reported from St. Thomas and St. John as well.

The black band disease, caused by a cyanobacteria (Peters, 1984), has been observed to affect corals in Puerto Rico (Peters, 1984) but it is still not as abundant as, for example, in Looe Key, Florida. This disease generally attacks massive, hemispherical corals, mainly Diploria spp. and Montastrea spp. I have observed a limited number of affected colonies in reefs of La Cordillera, Fajardo, and at the El Negro reef off the west coast of Puerto Rico. This disease has also been observed on corals in the Virgin Islands National Park on St. John and Buck Island, St. Croix (Rogers and Teytaud, 1988).

The recent, massive die offs of the black sea urchin, Diadema antillarum, throughout the Caribbean has also contributed to modify corals and the coral reef habitat. Individuals of this species act as bull dozers cleaning the substrate of fast growing fleshy and filamentous algae where coral larvae can settle and grow. Algal biomass within coral reefs has increased after the urchin die offs and other hervibores have not appeared to increase concomitantly. The increase in algal biomass, in turn, is likely to increase the availability of algal propagules that can settle on injuries inflicted to reef corals by various organisms such as fish (e.g., scarids) and molluscs (e.g., Coralophyllia sp.). This situation is possibly worse in artificially eutrophied areas (i.e., where nutrients are dumped into the ocean) where algal growth is likely to be further stimulated.

Another source of stress are the recent, massive coral bleachings (i.e., expulsion of zooxanthellae or their in situ degeneration) in which growth rates are slowed down and their capacity to heal from wounds is possibly impaired. Events of this nature have occurred Caribbean wide in 1987 and 1990 (Williams et al., 1987; Goenaga et al., 1989; Goenaga and Canals, 1990). Studies elsewhere in the Caribbean suggest that bleachings were more severe in polluted areas. National Park staff on St. John observed bleaching of several hard coral species and Palythoa in October of 1987 but not as severe as reported for Florida. D. labyrinthiformis and D. strigosa were most affected and Agaricia lamarki colonies as deep as 27 m were observed bleached (Rogers and Teytaud, 1988). M. annularis colonies were observed bleached at 60 m on the south shelf edge of St. Thomas (R. Boulon, pers. obser.).

B. Anthropogenic

Tropical shallow water communities are subject to many of the same anthropogenic stresses as communities from high latitudes (Hatcher et al., 1989), but the relative importance of these differ and attempts to extrapolate the results of studies from higher latitudes to the tropics have been unsuccessful. For example, dissolved nutrient concentrations are usually much lower in tropical surface waters than in temperate waters. The elevation of phosphate concentrations by 0.75 uM in New England waters would result on the average in doubling of phosphate concentration there, whereas in the eastern Caribbean it would constitute an approximately 40-fold increase (Hatcher et al., 1989).

For these reasons it is essential that we develop tropical guidelines to manage our marine resources. In this section we review the impact of human activities on coral reefs. Included are only those activities that are known to have impacted Puerto Rican and Virgin Island coral reefs at one time or another. Those activities that are capable of damaging coral reefs but that are unlikely to happen in our islands are not discussed. For a brief review of anthropogenic activities that damage coral reefs elsewhere in the Caribbean the reader is referred to Goenaga (1991).

1) Oil pollution

Oil pollution has been known to impact coral reefs in Puerto Rico several times. One instance was when the Zoe Colocotrini ran aground southwest of La Parguera, near Margarita Reef in the early 1970's. Recently (1991), a oil cargo ship sunk in the eastern Caribbean and, after a few days, the oil plume impacted coral reefs in eastern Puerto Rico, particularly those of Isla Culebra. The extent and nature of the impact, however, remains unassessed. Oil spills resulting from leaking oil barges and sunken vessels have impacted coral reefs around all three Virgin Islands and offshore cays at one time or another. An oil spill from a sunken barge off St. Martin reached St. John in early 1991 and affected reefs on the east end of the island. The long-term affects of these oil spills remains unknown.

Although the effects of oil on reef corals in their natural environment is controversial and poorly understood (Loya and Rinkevich, 1980; Brown and Howard, 1985) many coral reef scientists have expressed their apprehension concerning the harmful effects of oil spills (e.g., Bak and Elgershuizen, 1976). Degradation of some Caribbean coral reefs have already been attributed to chronic oil pollution. Chavez et al. (1985), for example, noted that the reef biota at Cayo Arcas, a group of islands off Yucatan (Mexico) that hold an oil pumping station, has been subjected to considerable environmental stress. Specifically, they attributed the disappearance of dense Acropora cervicornis thickets at this site to "activities related to the oil industry".

Bak and Elgershuizen (1976) have suggested that the water soluble fraction of oils in seawater is more harmful to corals than their direct contact with oil. Rutzler and Sterrer (1970) suggested that corals escaped observable damage from an oil spill in Panama because they were continuously submerged. Detergents, however, can disperse oil and its toxic fractions into deeper waters affecting the biota that otherwise would not come in contact (Cerame-Vivas, 1969; Cintron, 1981). Nevertheless, direct field evidence of these effects are generally wanting.

Data from laboratory experiments show that colonies of the scleractinian Madracis mirabilis were more affected by mixtures of various crude oils and Shell dispersant (LTX type) than by either the crude oils or the dispersant separately (Elgershuizen and de Kruijf, 1976). These investigators hypothesized that the observed non additive effects were related to a higher solubility of the toxic oil fraction in sea water after emulsification by the dispersant. Active ingestion of oil drops by corals do not occur and it is unlikely that oil is adsorbed to living coral tissue (Bak and Elgershuizen, 1976).

Mucus produced by corals, however, can trap drops of oil that may be incorporated into the reef food web via the mucus-eating fish and crustaceans (Elgershuizen et al., 1975). Zooxanthellae from the Caribbean scleractinian Diploria strigosa exhibit reduced photosynthesis after eight hour exposure to dispersed oil in concentrations of 19 ppm (Cook and Knap, 1983). Although recovery was rapid, long term effects were not looked at. Also, most of these experiments simulate the effect of episodic, acute oil spills. The effect of chronic, long term oil pollution remains unassessed to our knowledge.

Shinn (1972) observed that the scleractinian Montastrea annularis can survive two hours total immersion in Louisiana crude oil and that Acropora cervicornis, exposed for two hours to a mixture of seawater containing one part crude to 6-12 parts seawater, caused immediate retraction of polyps although recovery was complete after 24 hours. Based on these observations he remarked that "it would seem safe to conclude then that crude oil spills do not pose a significant threat to Atlantic reef corals". However, as Johannes (1975) has noted, this statement is premature since Shinn reported no subsequent observations on these corals. Dodge et al. (1985) determined experimentally that corals treated with chemically dispersed oil at concentrations of 20 ppm showed no depression in calcification. Once again, it is unknown whether long term impairment of vital functions, such as reproduction or maintenance, had occurred in individuals of these species. Also, Shinn's own experiments illustrate the importance of interspecific response to oil. Evidence of pathological responses, including impaired development of reproductive tissues, atrophy of mucous secretory cells and muscle bundles, has been observed in colonies of the shallow water Caribbean coral Manicina areolata during exposure to water accommodated fractions of No. 2 fuel oil (Peters, et al., 1981). This atrophy may help explain the decreased capacity of corals to recover from injuries after subject to oil pollution reported in Panama by Guzman and Jackson (1989). Gooding (1971) also documented an extensive destruction of reef associated biota, other than corals, by an oil spill in Wake Island. Guzman, et al. (1991) studied the short term effects of a major oil spill on the Caribbean coast of Panama in 1986. Their results showed that a large, nearshore oil spill can adversely affect individuals and communities of subtidal reef-building corals, and suggest that the effects may be long lasting.

Other effects of oil and the use of dispersants on coral reefs are the alteration of the physical properties of the reef surface (which inhibits larval settlement), the impairment of oxygen exchange across the air-water interface (Blumer, 1971; Kinsey, 1973) and the interruption of light penetration by surface oil films (Mergner, 1981). These have not been documented in the Caribbean.

A long-term, chronic situation may exist where corals and other shallow water marine invertebrates are increasingly being exposed to oil in the marine environment. This situation is occurring wherever boats are pumping their bilges. Most bilge water contains various amounts of oil and these slicks can be observed wherever the increasing numbers of pleasure and commercial vessels are anchored or moored. I (RHB) have observed up to half a dozen slicks moving downwind from Francis Bay on St. John at any one time from the dozens of boats anchored there. These slicks end up along the north shore of St. John where many reefs are found. The long-term effects of this low level but chronic exposure to oil will be hard to assess.

2) Siltation from upland vegetation clearing

Together with eutrophication this is probably the most significant anthropogenic activity in Puerto Rico and the Virgin Islands having a long term, detrimental effect on reef corals and their associated biota. It is noteworthy that despite recurrent warning to governmental authorities of the effect of upland deforestation on coral reefs (by coral reef scientists including ourselves) and despite multiple examples of the effect on our islands there is apparently little perception of the problem. To say the least, no action is taken. Abundant literature (and abundant examples in our islands and elsewhere) reveal the detrimental effects of the removal of upland vegetation without considering appropriate land conservation practices (e.g., utilization of siltation ponds, stabilization of unconsolidated sediment, reforestation programs and others). Similar problems exist in the Virgin Islands but resource management agencies and the public seem to understand the correlation between upland clearing and loss of sea life due to sediment runoff. This results in less problems of this nature than exist on Puerto Rico.

Siltation of coral reefs results from upland vegetation clearing and is generally considered an important factor controlling reef corals. It can limit reef corals by: 1) increasing water turbidity (Jerlov, 1968) and, thus, affecting the photosynthetic output of zooxanthellae, 2) causing energy expenditure in particle rejection (Lasker, 1980), 3) increasing the potential for bacterial infection (Ducklow and Mitchell, 1979; Peters, 1984), 4) abrasion (Wein, 1962; Storr, 1964), 5) creating conditions unsuitable for larval settlement (Maragos, 1972), 6) reducing feeding periods (personal observations) and/or altering heterotrophic and autotrophic feeding efficiencies (Dodge and Szmant, in press), 7) affecting planktonic food supply (Bak, 1978), and, 8) shifting the relative abundance of fish and promoting the survival of those that graze on the benthos (Galzin, 1981). The removal of mangrove stands, generally accompanying upland deforestation on developed coastal areas, magnifies the problem of siltation. These stands act as natural barriers for runoff due to precipitation. In the Puerto Rican southwestern coast it is not uncommon to observe large sediment plumes after heavy rains where the mangroves have been removed and replaced with stilt houses (CG, pers. obser.). These are located within the coastal zone and many dump raw sewage into the water.

Although coral reefs are known to occur under silt laden and/or eutrophic waters (Goenaga, 1988), it is unknown whether these are in the process of disappearing or whether the component biota is or will be capable of adapting to these conditions. The available evidence suggests that at least some of the biotic components which depend more upon sunlight die in deeper, although are able to persist in shallower, portions of reefs (Morelock et al., 1979; Acevedo, 1986; Goenaga, 1988).

3) Sewage discharge

Reef corals live in waters that are usually oligotrophic or with generally low nutrient concentrations. It has been suggested that the predominance of symbiotic relationships in coral reefs, such as that between zooxanthellae and corals, has evolved in response to low nutrient concentrations (Muscatine and Porter, 1977; Taylor, 1981). This symbiosis has resulted in an efficient recycling of nutrients between host and hostess. Under eutrophic conditions (high nutrient concentration in the water column) organisms with faster growth rates and capable of rapid transformation of nutrients into biomass, such as fleshy and filamentous algae, will usually outcompete or displace the slower growing corals (Johannes, 1975). High nutrient concentration in the water column is also known to stimulate bioerosion (i.e., the biochemical erosion of the vertical, calcium carbonate structure produced by corals by boring sponges, boring annelids and sipunculids) (Highsmith, 1981). The dynamic interplay between CaCO3 accretion (i.e., by coral growth) and destruction (i.e., by bioerosion) of coral reefs is, therefore, strongly influenced by nutrient availability. Examples illustrating this relationship are known from the fossil record (Hallock, 1988). In addition, cnidarian larval settlement, including those of corals, is precluded where the substrate has dense algal growth (Sammarco, 1980). Coral planulae need clean substrates that are free of algae to develop. The most probable outcome in eutrophic areas, as observed elsewhere around Puerto Rico (e.g., Ponce; C. Goenaga and V.P. Vicente, personal observations) and in the Caribbean, is a relict reef in which the vertical CaCO3 structure may, for some time, be preserved but in which the main reef building organisms, namely corals, become an inconspicuous element of the new community. This new community, dominated by fleshy and filamentous algae, is incapable of producing the structure necessary to maintain reef growth.

Sewage discharge into coastal waters may affect coral reef communities by 1) causing nutrient enrichment and enhancing the growth of algae at the expense of corals (Marszalek, 1981), 2) depressing oxygen levels (Wade et al., 1972), and 3) by introducing toxic substances such as chlorine (cf. Muchmore and Epel, 1973). Coral morbidity and mortality under experimental conditions is apparently the result of competition for space with algae and light and not directly related to effluent toxicity (Marszalek, 1981). Sewage is known to stress reefs in Barbados, Curacao, Florida Keys, Guadeloupe, Jamaica, Martinique, St. Kitts and British and U.S. Virgin Islands (Rogers, 1985).

The classical example of the effects of eutrophication on coral reefs is Kaneohe Bay in Hawaii. Twenty six to ninety nine percent of the local coral reefs here were destroyed by overgrowth of corals with the green alga Dictyosphaeria cavernosa due to cultural eutrophication (Maragos, 1972). Partial regeneration of the reef habitat has occurred six years after diversion of sewer discharges from the ocean (Maragos et al., 1985). In Puerto Rico, coral reefs growing close to sanitary discharges also show proliferations of green algae, namely, Ulva sp., Enteromorpha sp. and Dictyosphaeria sp. (V. Vicente and C. Goenaga, personal observations). These tend to colonize corals from their bases, eventually overgrowing them. Recent mass mortalities of the black sea urchin, Diadema antillarum, in the Caribbean make the situation worse. This urchin is a voracious omnivore that continually grazes on fleshy and filamentous algae covering the substrate. The head of the Environmental Protection Agency in the Caribbean, Pedro Gelabert, has recently stated that "...45% of the Puerto Rican coasts are too polluted to swim in them..." (El Nuevo Dia, 13 March, 1991; page 29) and point to raw sewage discharge as one of main pollutants. In the Virgin Islands, the proliferation of residential septic tanks has resulted in high soil loading which, during large rainfall events generates nutrient rich runoff into the sea. This has caused short term eutrophic conditions in various bays around St. Thomas and St. Croix. Faulty ocean outfalls from municipal sewage plants have resulted in severe eutrophication in several areas, notably off the airport in St. Thomas and the south shore on St. Croix. In these areas, algal overgrowth is very evident (RHB, pers. obser.).

4) Dredging

Dredging is a common practice in many embayments of our island. It is usually carried out to increase the depth of ship routes close to shore and for the construction of marinas. While options to minimize the effect to marine ecosystems are available (e.g., screens) these are not always nor thoroughly utilized. Supervision of dredging activities by appropriate government agencies is usually wanting. Dredging of inland lagoons and the devastation of a coral reef community near San Juan is discussed later.

The impact of dredging on coral reef communities are of three basic types: 1) mechanical damage (resulting in breakage of coral and octocoral colonies, many of which subsequently die), 2) sediment loading or siltation (i.e., rapid deposition of coarse silt and sand size sediments resulting from sediment laden water leaking from the dredge pumps) resulting in burial and death of colonies, and, 3) increased turbidity resulting in bleaching, excessive mucus secretion or death in scleractinians. Also, waters over dredged areas have significantly more bacteria than neighboring seawater (Galzin, 1981). This seems related to the suspension of fine sand particles that are utilized as a substratum by the bacteria and may result in the elimination of certain benthic faunal and floral species and the proliferation of tolerant species. Galzin (1981) also found that sand dredging in Guadeloupe, French West Indies, resulted in a decline of the abundance of the fish fauna and a reduction of species equitability.

An additional, usually ignored effect is the resuspension of toxic materials into the water column during dredging. 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). This can be the case when dredging near marinas or boat haulout facilities (e.g. Benner Bay, St. Thomas) where toxic metals from antifouling paints have leached into the water and adsorbed onto bottom sediments.

5) Thermal pollution

Activities generating thermal pollution, mainly related to the energy industry, are known to be maintained in the vicinity of Caribbean coral reefs. The effect of this type of pollution on reef corals has not been documented for the Caribbean but it is known that increased water temperatures retard growth or cause mortality in scleractinians and also prevent larval recruitment into thermally enriched areas of reefs of Guam (Neudecker, 1981). Maximum ambient temperatures were found to be close to lethal temperatures for corals in Guam (Mayor, 1918). Mayor noted that the temperature at which the feeding reactions and normal metabolic processes cease are more significant than death temperatures. For example, three species of coral ceased to feed at temperatures 1.5-3.0_C lower than their lethal temperatures. The effect of thermal stress has been thoroughly studied in Hawaii (Jokiel and Coles, 1977; Jokiel and Coles, in press).

It is becoming increasingly important to assess the effect of thermal pollution in light of the proposed coal plant in Mayaguez. The thermal outfall will discharge in the vicinity of coral communities that are already stressed by organic enrichment and siltation. It is plausible that thermal pollution may be the "touche" for these communities. While it has been stated that reef fish proliferate in these stressed coral reefs (suggesting that the integrity of the structural reef components are not essential to the maintenance of, at least, some associated biota) this may turn out to be an understatement. Many reef fish utilize the structure generated by coral growth as shelter. When corals die this calcium carbonate structure (i.e., the coral skeletons) remains in growth position for some time. After a time period which is likely to vary according to prevailing physical and chemical factors the structure collapses due to bioerosion. It is then that reef associated biota will probably migrate elsewhere or die.

6) Anchoring

Anchoring on top of coral reefs can represent considerable disruption to coral reef communities. Davis (1977), for example, estimated that this activity has damaged nearly 20 % of staghorn communities in the Fort Jefferson National Monument, Florida. Tilmant and Schmahl (1981) found a significant linear correlation of reef use and incidence of physical damage. Standing and walking over coral and coral collecting can also ruin large portions of reefs (Goenaga, personal observations). Although this damage appears to be localized and inconsequential in the long run its' cumulative effects may not be so, especially where usage is intense.

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% were anchored in coral with the rest on sand, mud or pavement. With an estimated 30,000 anchors being dropped in Park waters each year, this can result in considerable damage. Anchor chains can do more damage than the anchors as they drag across the bottom when the boat swings to wind and current shifts. In 1989 a 440 foot sailing cruise ship, the "Wind Spirit" dropped its anchor on a reef off northern St. John and destroyed some 300 m^2 of coral reef. The case is still pending as the V.I. National Park is seeking $350,000 in damages from the company for reef damage.

However, touristic sightseeing of coral reefs, if well planned and with adequate supervision, seems to be highly compatible with the preservation of these ecosystems and can be highly productive in terms of education and in terms of the employment generated. The economy of many Caribbean islands depend to a large extent on external tourism. The promotion of this activity for internal tourism seems equally important since it is likely to create an awareness of this important natural resource on islanders.

7) Scientific activities

Curiously, scientists are capable of inflicting considerable, although localized, damage to coral reefs. This is particularly so whenever, for example, collection is done carelessly. Reef corals are vulnerable to tissue injuries and these represent sites where algal infection can proceed.

8) Military activities

Military maneuvers near coral reefs are practiced in Vieques, off eastern Puerto Rico. The results from this activities can be quite significant. It seems particularly important to discuss the impact of military activities given that several authors (consultants to the armed forces) have stated that military activities are inoffensive to coral reefs and this notion may be utilized to justify further maneuvers elsewhere.

In 1982, Antonius and Weiner concluded that the "military impact of the Viequen reefs was negligible when compared to natural damage caused by storm- generated wave action". These conclusions are based on comparisons made between the reefs from Vieques and those in the eastern coast of St. Croix (presumably not subject to military activities) with which they found no differences. A close look at their section on Materials and Methods, however, reveals that, in their work, "the emphasis was on shallow water communities". It is widely known and has been extensively documented (e.g., Woodley et al., 1981; Graus et al., 1984; among many others) that damage to coral reefs by storms occurs mainly in shallow waters. It is at these depths that corals with the highest growth rates predominate (e.g., Acropora palmata and A. cervicornis). This is one reason why hurricanes have minimal long term effects on coral reefs (Graus et al., 1984). Deeper portions of coral reefs, where slower growing, massive corals predominate, are not affected as heavily by storms. However, military activities do not discriminate between shallow and deeper portions of the reef and bombs drop in shallow and in deep substrates affecting them equally. It seems reasonable, therefore, to question why Antonius, a consultant for the U.S. Navy, did not investigate the deeper portions of the reefs in Vieques. The same criticism applies to the work by Raymond and Dodge (1980).

In another work, Dodge (1981) also concluded that "...a general similarity between (bombing) range and control stations..." in Vieques, together with "...quantitative coral abundance and diversity data of others (namely, data by Antonius and Weiner, 1982) indicate a lack of anomalous and adverse sedimentation/turbidity conditions affecting coral on reefs near the range area". However, several comments must be made. Reef corals, as well as other organisms, need energy for processes other than growth, namely reproduction and maintenance. The effects of the presence of the range on these two other processes were not assessed. Coral colony fragmentation, a process acknowledged by Antonius and Weiner (1982) and Dodge (1982) to occur in Vieques, is, in fact, known to severely limit the reproductive potential of some species (Szmant-Froelich, 1985). An example of one of this species is Montastrea annularis, the very same species utilized by Dodge (1981) in his study.

Aerial photographs of eastern Vieques do show extensive cratering resulting from bombing activities on land as well as in the sea. Craters range in diameter from 5 to 13 m and the effects extend beyond the extent of direct disruption (Rogers et al., 1978). These reefs are littered with artillery and air-delivered exploded and unexploded ordnance (metal fragments, flare casings, parachutes) which have caused extensive damage. Damage to reefs in Vieques has been categorized by Rogers et al. (1978) as follows: 1) damage by direct hits and by shock waves which shear colonies near the site of impact, 2) damage due to abrasion by steel and rock fragments generated by the blasts, 3) damage by fragments that come to rest on top of living coral tissue, 4) fracturing and weakening of reef structure by blasts and direct hits, 5) dislodgement of colonies which can be transported by heavy seas causing greater damage, 6) deposition of coarse sediments on top of living corals, 7) damage by flare parachutes which drape around soft and stony corals, and others.

Large numbers of unexploded ordnance in these reefs limit their future utilization as fishing and/or touristic centers. It is hard to estimate the costs involved in the restoration of such damage. We can only hope that leaching substances from oxidizing and degenerating ordnance do not further pollute marine life in these areas.

9) Ship grounding

Ship grounding in coral reefs can abrade, fracture or overturn reef biota and hull breakage can result in the spill of hazardous substances. Also, alteration of the hydrodynamic regime while the ship is grounded over the reef can generate sediment plumes that increase water turbidity and smother corals downcurrent. Direct damage by ship grounding is more localized than that of storms but may alter the reef contour and relief to a much greater extent (Smith, 1985).

Curtis (1985) described how portions of Molasses Reef, Florida, was crushed and resembled a "graded roadbed covered with a veneer of coralline debris" when the M/V WELLWOOD grounded. He found that the damage was significant but that it depended on depth, location and afflicted taxa. Additional consequences of this grounding included damage by cable drag, propeller wash scour and shading. In Bermuda, ship groundings have obliterated topographical features of coral reefs creating flat, barren areas with deposits of boulders and rubble and sparse surviving corals (Smith, 1985). Damage to coral reefs by ship grounding has also occurred on other important marine reserves such as Mona Island, Puerto Rico (H. Ferrer, G. Cintron and R. Martinez, Department of Natural Resources, Commonwealth of Puerto Rico, personal communication).

In the Virgin Islands there are few known cases of large ship groundings on coral reefs. Of more widespread concern are the many groundings of pleasure craft, primarily by bareboat (no licensed captain aboard) charter boats. One case is that of Windswept Reef on the north shore of St. John. For several years, before the Park Service installed marker buoys, an average of five boats per week (from 10 to 60 feet in length) were striking this reef (RHB, pers. obser.). The reef was covered with shattered coral heads and fragments of branching corals. Live corals had numerous scars and patches of antifouling paint. Since bouy emplacement, observed groundings have been reduced to less than one per month. Reef recovery will take many years, if it occurs at all. This reef is an extreme example due to its location but similar groundings occur every day in some part of the Virgin Islands.

10) Overfishing and commercial collection of reef biota for aquaria

The manner in which overfishing may affect coral reefs is uncertain but it is likely that the community structure is modified. For example, overfishing of predator species in St. Croix was suggested to be the cause of unusual abundances of the echinoid Diadema antillarum in 1973 (Ogden et al, 1973). Diadema antillarum can locally overgraze bottom vegetation and corals and its abundance has been directly linked to the frequency of recruitment of reef corals (Sammarco, 1980). The community structure of coral reef fish has been dramatically altered as a result of intensive overfishing and this is believed by many scientists to have caused imbalances in the coral reef communities as well.

Massive collection of juvenile fish for aquaria is an established practice in Puerto Rico, particularly in the southwestern and western coast. While the effect of this activity is unknown it is conceivable that there are significant changes in the community structure after selective and intense removal of fish species, many of which are juveniles of commercially caught species. The aquarium trade is usually accompanied by the removal of additional taxa. The removal of, for example, the banded cleaning shrimp (Stenopus hispidus), a species widely collected in southwestern and western Puerto Rico, may have important consequences. This species is a well known parasite cleaner of fish and the effect of lowering its population densities may be important. Furthermore, these collectors usually utilize chemicals to collect fish whose effect on benthic life is unknown or uncertain. It is urgent and of outmost importance to analyze the aftermath of these activities so that they can be regulated.

C. Tolerance of corals to stressors

Degraded reef corals can recover by regeneration of partially damaged colonies or fragments or through recolonization by larval settlement. Factors which can influence coral recolonization include the extent of damage and its location, the availability of coral larvae, the requirement for a "conditioning" period of the substratum before corals can settle, the availability and diversity of microhabitats for settlements and survival, the role of grazers, and competition with other organisms such as algae and soft corals (Pearson, 1981).

The available evidence suggests that coral communities may recover from major natural disturbances after several decades but are likely to suffer irreversible changes from man-made disturbances (Weiss and Goddard, 1977). Full recovery from man-made disturbances may be prolonged or prevented altogether because of permanent change to the environment or a continuation of chronic, low level disturbances (Pearson, 1981). In 1975 Johannes reviewed the known effects of pollution on coral reef communities. He pointed out that reef corals are central to the integrity of the reef community and when these are selectively killed, migration or death of much of the other reef fauna ensues. Accordingly, the environmental tolerance of the reef community as a whole cannot exceed that of its corals.

At this point it is necessary to mention that non-structural coral communities have the same practical importance as coral reefs in terms of coastal protection, nutritional importance, and others. Coral communities differ from coral reefs essentially in the thickness of the biogenic framework. The former form thin veneers over preexisting structures, such as cemented sand dunes, that drowned after sea level rose during the last glacial period. Coral reefs, in contrast, have a thicker framework which, to a larger extent, have been the product of biogenic (i.e., versus physicochemical) activity. Non-structural coral communities give integrity to the underlying structure and prevent its physical or chemical erosion and eventual destruction.

The importance of habitats neighboring coral reefs, such as seagrass beds and mangrove forests, has been stressed by Ogden and Zieman (1977). Seagrass beds are important feeding grounds for nocturnal feeding fishes, such as grunts and snappers, which shelter on reefs by day. When they return to the reef these fishes deposit organic compounds in the form of feces that become available to detritivores and are introduced to the reef food web. Mangroves provide nurseries for juveniles of certain reef fish (chaetodontids, scarids, lutjanids)(Boulon, 1991) and are also feeding grounds for fish that shelter on reefs; mangroves also introduce fixed nitrogen and organic detritus into the trophic system of reefs as do reef flats and seagrass beds. Consequently, damage to these neighboring communities can potentially have an effect on nearby coral reefs. Fishermen on the south shore of St. Croix tell of the marked decrease of fish caught on reefs after the dredging and filling of Kraus Lagoon, an extensive mangrove nursery area. This can only have had serious consequences for the ecological balance of the reefs.

V. Abundance and present condition of the coral reef resource in Puerto Rico and the U.S. Virgin Islands

A. Species distribution

Coral abundance in Puerto Rico, the Virgin Islands and elsewhere is highly variable and dependent on the local conditions. As stated above, the relative abundance of coral species vary naturally both within and among coral reefs. Generally, along many portions of the Puerto Rican north coast reef forming corals are represented by small, sparse colonies with low vertical relief. Coral diversity is also low with tolerant species, such as Siderastrea siderea and Montastrea cavernosa, predominating. In turbid, silted reefs under the influence of river discharge reef corals may be dying or dead below depths of a few meters. For example, at Escollo Rodriguez, Mayaguez, corals below 4 m are scarce and many heads over 100 yrs. old of Siderastrea siderea are over 80% dead with only small patches of living tissue remaining. Colonies living in shallower waters, however, are surprisingly healthy, at least until 1988. Generally, the further offshore, the more healthy and abundant are corals. Similar species distributions occur in the Virgin islands with the exception of coral mortality due to rivers and the heavy discharge of upland sediments. In general north coast reefs in the Virgin Islands are adapted to the annual periods of heavy wave energies during the winter months. South shore reefs are generally more protected but have suffered from the passage of tropical storms and hurricanes, which have a higher frequency of passage to the south of our islands.

Species within all taxa that have been observed in Puerto Rico and the Virgin Islands are listed in Appendix 1. Species that have been observed elsewhere in the Caribbean are expected to occur in Puerto Rico and the Virgin Islands since they belong to the same biogeographic province. These are marked with an asterisk. It should be noted that Brazilian species do not necessarily occur in the Caribbean and are, therefore, not included.

With few exceptions the distribution of stony corals is homogeneous among the coral reefs of Puerto Rico and the Virgin Islands (i.e., most species occur in most reefs) although their relative abundance may differ among reefs. Some species are distributed in relation to physical factors prevailing in different reefs or different coastlines. For example, the hydrocoral Millepora squarrosa tends to have a higher relative abundance where water movement, related to wave energy or currents, is high and may be absent where water movement is low. This species is common on the outer, exposed reefs off La

Parguera and also in the north coasts of our islands. As another example, the scleractinian Agaricia lamarcki and the antipatharian Stichopathes spp. occur in reefs that possess deep or turbid waters. Substrate below turbid waters, as well as that of deep waters, receive reduced solar radiation. The shelf edge reefs off of La Parguera and St. Croix, for example, contain abundant individuals of both species below depths of 20 m. These species, however, also inhabit inshore, shallow (i.e., less than 10 m deep) reefs off Mayaguez.

Differential species distributions also occur within reefs along physical gradients (e.g., depth). Factors such as wave energy, water currents, light intensity and light quality, covary with depth and their effects upon the coral reef biota are difficult to separate. Differential species distribution along physical gradients is often called "zonation" and is exhibited by several species inhabiting the coral reef. The elkhorn coral, Acropora palmata, for example, inhabits only the shallow portions of coral reefs and are rarely found below 5 m. Likewise, in many reefs off of La Parguera, Stephanocoenia michelini is generally (although not always) restricted in the deeper reef substrates. More often, however, coral species are distributed throughout the depth gradients and it is their shape or relative abundance that may differ among microhabitats. The epitome of this situation, called phenotypic plasticity (or variation in growth form according to habitat), are individuals of one of the major coral reef building species: Montastrea annularis (star coral). Colonies of this species vary both in shape and size in relation to the depth gradients. Whereas in shallow, well lit environments it may form colonies that exceed 5 m in diameter and in height, in deep (or turbid) waters it forms plates that rarely exceed 1 m in diameter and few centimeters in height. The latter is also true for sloped surfaces.

In addition to variations related to the depth gradient, conditions are markedly different between areas windward and leeward of the shallowest region of emergent coral reefs: the reef crest. The reef crest, generally but not invariably with abundant colonies of Millepora spp., breaks and baffles wave energy and promotes calm water conditions on the leeward portion of coral reefs. Branching species of Porites generally form extensive, quasi monospecific, beds in the reef lagoon, just leeward of the reef crest. These so called Porites biotopes shelter a large number of other invertebrates and algae. For reasons that are not clear but that may be related both to natural (i.e., storms) and anthropogenic (e.g., eutrophication) causes, the extent of these biotopes has declined sharply within the last two to three decades in the La Parguera embayment and in the outer channels of the Mangrove Lagoon in St. Thomas.

B. Present condition

1) Puerto Rico

The information that follows provides information on the distribution of coral reefs and, therefore, of reef corals and associated biota. It is extracted in part from the coral reef inventory by Goenaga and Cintron (1979) and additional information by Wells (1988). Additional information from unpublished information by V.P. Vicente and myself is included. Information by other observers is credited as such. At present I am gathering additional data that will form part of a more extensive document on the coral reefs of Puerto Rico.

Many reefs in Puerto Rico have suffered considerable damage from human activities. Extensive coral reef degradation has been observed at the following sites: 1) all reefs from San Juan to Las Cabezas de San Juan, 2) inshore Fajardo reefs, 3) Humacao reefs, 4) annular reef off Puerto Yabucoa, 5) inshore Ponce reefs, 6) all reefs off Bahia Guayanilla and Bahia de Tallaboa, 7) all reefs off and fringing Guanica, 8) all west coast inshore reefs from Boqueron to Rincon, 9) reefs off Arecibo, and 10) reefs off Dorado.

Corals grow in most Puerto Rican coasts but differing physical conditions among platform segments result in localized reef formation. Reef development in this document is defined in terms of: 1) biotic cover, 2) cover of the major reef builders, namely reef corals, and 3) vertical structure or substrate heterogeneity.

In general, reef development on the western two thirds of the north coast is limited, except for patchy coral growth. This is possibly due to the presence of large river discharges that generate turbid water and promote unstable substrate unfavorable for larval settlement. As stated earlier siltation is an important factor affecting the distribution of corals.

East of San Juan lies a discontinuous chain of poorly developed and heavily stressed coral communities trending in an east-west direction and extending 1.5 km offshore. These probably consist of thin coral veneers over shallow, eolianitic platforms which, in some cases (e.g. Isla Piedra and Isla Cancora), rise above water (Kaye 1959). Mound-like patch reefs off Punta Las Marias rise to within a couple of meters of the surface. The tops of these mounds contain head corals with Acropora palmata, the elkhorn coral, on the periphery. Gorgonians tend to increase in abundance in the lower slopes.

A well-developed reef system laid in clear waters northwest of Boca de Cangrejos with extensive coral growth from the surface to 10 m depth was virtually destroyed by sedimentation from extensive dredging, and organic pollution from sewage treatment plants in Torrecilla Lagoon (Cintron, personal communication). Currently, almost no living coral is found deeper than 1.5 m. However, an apparently well developed reef occurs northeast of Boca de Cangrejos (Goenaga and Vicente, unpublished observations). Montastrea annularis, the small star coral, has a high estimated relative abundance in these reefs. Although this area is frequently subjected to the inflow of silt laden waters derived from the Torrecillas-San Jose lagoon system, prevailing Atlantic swells apparently do not permit the outflow of these waters over the reef (local fishermen, personal communication).

Off Punta Vacia Talega, stony corals veneer beach rock platforms mainly as encrusting forms. Millepora complanata is the most abundant coral near the surface, and Diploria spp. and Isophyllia rigida are common in deeper areas. Soft corals tend to be more abundant in sheltered areas. Scattered patch reefs that break the surface occur between Punta Iglesias and Punta San Agustin; these do not form a continuous barrier, but provide an effective wave energy absorbing structure. Water visibility is usually low and patches adjacent to the shore are dead, probably as a result of siltation. Water visibility improves offshore but corals are common only in depths of 1-3 m on the outermost reefs.

To the east, fringing coral communities, about .5 km wide, are found on the north and west side of Punta Miquillo and on the north and east side of Punta Picua. Punta Miquillo and Punta Picua were probably once sand cays, but are now connected to the mainland by a broad marsh, the former now severely decimated by construction activities. Both reefs, especially that at Punta Miquillo, have low coral cover. Benthic communities on the Punta Miquillo reef were damaged after a channel was dredged parallel to the shoreline in the 1960's. Punta Percha, farther east, had a slightly higher living coral cover in 1979. Ensenada Comezon has numerous, small patch reefs (about 2 m high) that lack distinct biotic zonation. Algae are dominant there but a number of small coral colonies also occur. Two roughly circular (300-500 m diameter) patch reefs occur offshore from the mouth of Rio Mameyes, each with a periodically exposed shoal of coarse sand. Coral diversity is low, probably due to siltation from the river.

East of this reef system is a complex of bank barrier, fringing and patch coral communities that protect and probably nourish Luquillo Beach at Punta Percha. The fringing reefs surrounding the northern and eastern end of the beach show degradation on the seaward edge where growth is limited to shallow waters. East of Luquillo, water transparency increases gradually and the reefs exhibit slightly higher living coral cover. East of Rio Juan Martin are a series of patch and fringing reefs with low coral diversity, that have been described by Torres (1973). Siltation appears to be the main factor limiting coral growth.

Reef development increases towards the east as river discharge diminishes east of Rio Espiritu Santo. Well developed reefs are common in Siete Mares (Fajardo). The only gross difference between these and other north coast coral communities appears to be the absence of the influence of river discharge in Siete Mares. M. annularis, as well as other scleractinians, are abundant (cover above 16%) in the reef front of the reef outside and west of the northernmost tip of Bahia Las Cabezas. This reef is emergent on its eastern portion and submerged to the west. Gorgonians are more abundant in deeper waters where there are large incrustations of the sponge Anthosigmella varians. The sands at the reef base is coarse and apparently well oxygenated. The brown alga, Dictyota sp., is moderately abundant at the shallow reef portion and unidentified red macroalgae forms dense algal carpets that cover most of the available hard substrates not colonized by benthic organisms. "Isoyake" surfaces (i.e., bare hard substrate) caused probably by grazing are common in shallow waters.

High reef development on the northeast coast occurs in the fringing reef system around the islets situated on La Cordillera but these have never been studied systematically, except for Icacos (Pressick, 1970) and an effort to preliminarily characterize the area by the DNR (Goenaga and Vicente, 1990 unpublished report available upon request). In general these reefs contain patchy, but diverse and abundant coral cover, particularly on their leeward sections. Between these offshore islands and the mainland there are other islets with high reef development on their windward shores (Mckenzie and Benton, 1972). Reef development is apparently directly related to distance from the mouth of Rio Fajardo. Isleta Marina and Cayo Ahogado have been formed by wave deposited sand and coral fragments atop the reef platform, and have a maximum altitude of less than 3 m. They undergo wave erosion periodically.

On the mainland, south of Las Cabezas de San Juan, an extensive but dying reef fringes the coast from northeast Cabo San Juan to the north end of Punta Sardinera, protecting the entrance to Bahia Las Croabas. From Playa Sardinera to Punta Barrancas there are no coral reefs, presumably because of the influence of Rio Fajardo. Narrow coral reefs, however, project eastward about 450 m from Punta Barrancas and Mata Redonda. There is a shallow reef in the northern Bahia Demajagua, but reef development is not extensive (McKenzie and Benton 1972).

Further south on the east coast, Isla Pineros, off Media Mundo, Ceiba, has moderate coral growth on its north and east coasts. Cabeza de Perro, an islet in the same area, was used by the U.S. Navy for bombing practice and lacks marine benthic life. South of this point to Punta Lima, the coast is mainly fringed by Thalassia testudinum beds with occasional small fringing and patch reefs. Some of these east coast fringing reefs probably rest near sand or mud formations, judging from their location at the edge of swamps (Kaye, 1959). Most of them have formed on a 6-7 m deep platform. Many patch reefs that do not reach intertidal level occur off this stretch of coast.

Southwest of Punta Lima coastal waters become turbid as a result of sediment laden rivers and creeks. Several islets such as Cayo Santiago and Cayo Batata occur here and have some coral growth especially in shallow waters and in south facing areas open to the sea. Surprisingly dense 90% living A. palmata stands intermingle (in 1979) with gorgonian and head corals close to the surface. Submerged shoals with sparse coral growth also occur occasionally off Humacao, such as Bajo Parse which consists of numerous gorgonians, small head corals and extensive patches of an encrusting sponge (Anthosigmella varians).

There is little coral growth in Yabucoa Bay (further south) apart from an annular reef in the southern part of the bay with few living corals possibly due, in part, to river runoff (Diaz-Piferrer 1969; Seiglie 1969). About 5.5 naut. mi. east of Yabucoa Bay is the reef La Conga, probably part of the submerged barrier reef bordering a large portion of the southern shelf of Puerto Rico.

A fringing reef extends almost continuously for four miles along this coast between Cabo Mala Pascua to Puerto Patillas which is exposed at low tide and protects a low sand apron at the foot of the Sierra de Guardarraya. A similarly stressed reef is responsible for the seaward protection of Punta Figueras. Arrecife Guayama, lying 0.6-0.9 km off Punta Figueras and nearly 5 km in length, is well developed, but now affected by siltation. The A. palmata zone has low coral cover and many dead colonies. West of this reef are the Corona and Algarrobo patch reefs which appeared relatively healthy and little affected by siltation in 1979.

Arrecife Las Mareas, south of Las Mareas, Guayama, is almost devoid of living coral and extensively colonized by fleshy algae. Southwest of Punta Pozuelo, a fringing barrier reef, Cayos Caribe extends for about 2.5 km. Cayos de Barca and Cayos de Pajaros are part of the same system although shallow channels divide them. The system forms an arc that protects the entrance of Bahia de Jobos. On the lee side of the reefs are a number of narrow sand cays fringed by mangrove vegetation. Living coral cover is moderate and tends to increase westward.

Numerous offshore keys occur off Salinas, Santa Isabel and Ponce (e.g., Unitas). About 2.5 km south of Ponce, an area of prolific gorgonian growth, particularly in shallow waters, is found at Bajo Tasmanian. This consists of a two-tiered platform, the northern level 6-12 m deep, and the southern level 18-24 m deep. Acropora cervicornis is common on the deeper portions. Large shingle-like growths of various massive corals occur in the shelf edge (Beach 1975). Las Hojitas reef, east of Punta Cucharas, is a perfect example of a dead coral reef. There are extensive dead coral colonies in the reef front whose outline can be easily seen but that are covered by extensive algal and sponge cover possibly due to increased nutrient content of the waters originated by the discharge of sewage treatment plants. South of Punta Cuchara lies Arrecife Ratones. Its deep reef front consists of an irregular bottom with silty sand at the base of the reef and among depressions. Topographic relief is high and generated primarily by scleractinian corals. Cover of sessile benthos is dominated by this taxa with Agaricia agaricites, M. annularis and M. cavernosa being the most abundant species (living coral cover about 5%). Large dead scleractinians, however, are often observed. Gorgonians are common to abundant. The surface of dead corals and substrate not colonized by zoobenthic organisms is covered by a thin, coralline algal tuft overlain by fine sediment.

Further west off Tallaboa living coral cover and diversity are low, due possibly to the industrial development of the area. Isolated heads of Acropora palmata and Millepora complanata occur on the seaward side of Arrecife Guayanilla. The reef off Punta Verraco has an extensive Thalassia and Syringodium bed on its reef flat. Stony coral cover in the shallow front reef is very reduced. The deeper fore reef has an extensive communities of gorgonians. Arrecife Unitas, northeast of Arrecife Guayanilla, exhibits low scleractinian cover and low gorgonian density. Off Punta Ventana, southwest of Guayanilla, is a submerged reef with moderate cover by scleractinians. Gorgonians are abundant and the reef, in general, seems to be well developed, in relation to those off Guayanilla and Tallaboa bays.

An extensive submerged reef surrounds the coast east of Punta Ventana to Punta Vaquero, where it breaks the surface. This reef protects Playa Tamarindo, Bahia de la Ballena and Playa de Cana Gorda on the coast of Guanica and has low living coral and huge carpets of the fast-growing colonial anemones Zoanthus and Palythoa lie over the predominately dead coral framework of the reef front. Patchy coral growth, with occasionally large colonies, occurs on the more protected, leeward reef sections.

West of Punta Jorobado, reefs become more prolific and complex in the area of La Parguera. This region is considered to have highest development of coral reefs in Puerto Rico. The coral reefs of La Parguera as well, as those elsewhere, are undergoing modifications mainly by proliferation of filamentous and fleshy alga (Vicente, 1987; Goenaga, 1988). The causes are unclear and may be related both to anthropogenic and natural causes.

Off La Parguera is a submerged (i.e., it does not break the water surface) barrier reef at the edge of the insular shelf. This reef is diverse and biological cover of benthic organisms is high in many areas (Boulon, 1980; Weinberg, 1981). The reef extends to the east towards Guanica and Guayanilla, where cover and diversity are reduced, and also towards the west. The geology of a portion of this system was studied by Quinn (1972) who concluded that, as other submerged shelf edge reefs of the Caribbean, it had been formed when sea level was low about 12,000 years ago after the end of the last glaciation.

Bahia Sucia, east of the Cabo Rojo lighthouse, contains a submerged coral reef, Rock-ola, with large colonies of M. annularis and abundant fish. In Bahia Salinas, west of the Cabo Rojo lighthouse, patches of coral alternate with Thalassia testudinum grass beds, and are described in Almy and Carrion-Torres (1963). Nearshore, between Cabo Rojo and Mayaguez there is high water turbidity, unusually slight wave action and heavy land drainage. The broad bank that lies immediately offshore minimizes wave action and probably limits water circulation and the removal of land drainage pollution. The coral patches and assemblages generally have few stony corals but dense stands of gorgonians occur there. Living stony corals are partially covered by mats of macro algae in some areas (Kolehmainen, 1974).

Offshore reefs include Escollo Negro and Arrecife Tourmaline, Las Coronas, Escollo Rodriguez, Cayo Fanduco, Manchas Interiores, Manchas Exteriores, Arrecife Peregrina and Gallardo and many other submerged banks with coral communities. These reefs are distinct from those of La Parguera and others in the south coast in that generally there is no well developed reef front. The substrates have reduced slopes and patchy coral growth with abundant gorgonians. North of El Negro, near but south of the shelf edge, there are deep reef sections that have abundant cover of platelike colonies of M. annularis over a medium relief substrate that results in an extensive and complex system of crevices and caves inhabited by abundant fishes. This habitat is quite unique and has been observed only off southern Vieques (I. Sadovy, personal communication), in addition to the Mayaguez platform. Las Coronas is a shallow (2-4 m) sand shoal colonized principally by large sized gorgonians and occasional massive corals. Manchas Interiores, Manchas Exteriores and Arrecife Peregrina have low relief spur and groove systems sloping more or less abruptly westward where inhabited by black coral (Antipatharia) and deeper water fauna. Encrusting coral growth with large pillar corals and gorgonians dominate the shallow depths. Escollo Rodriguez, about 1.6 km west of Cano Corazones consists of a series of elongated patch reefs. There is abundant fish life but the reefs appear to be affected by siltation from the Guanajibo River (Schneidermann and Morelock 1973; Goenaga, 1988). Much of the scleractinians inhabiting waters below 4 m are dead or dying. Shallow waters, however, contain surprisingly healthy and large colonies of M. annularis. Bajo Gallardo is a well-developed, relatively untouched reef about 13 km west of Punta Aguila, Cabo Rojo, with luxuriant elkhorn coral growth and abundant fish life. Other reefs in Mayaguez Bay exhibit signs of eutrophication and are described by Goenaga (1991, unpublished report).

North of Arrecife Peregrina to Punta Higuero, the insular shelf is less than 1 km wide and has coral communities on the outer edge where the bottom slopes steeply. Stony corals, unusual gorgonians, and black corals are abundant at depths of 15+ m but water transparency is quite variable, being influenced by river discharge. Poorly developed fringing reefs, consisting mainly of partially dead Acropora palmata and scattered gorgonians occur on the north side of the Rincon peninsula from Punta Higuero to Punta del Boqueron. There are a series of submerged coral communities about .3 km north of the Culebrinas river mouth, west of the town of Aguadilla. A large portion of the substrate of these reefs are covered by dense algal mats dominated by the articulated coralline algae Jania sp. and Amphiroa sp. Coral cover is generally low but can be higher than 10% in some patches. Coral colonies are generally small but abundant locally. Off Punta Tamarindo there are exceptionally large colonies of Acropora palmata in shallow waters. These colonies are approximately round in outline and inhabit a substrate where other corals are small and uncommon.

An underwater cave system occurs off Bajura, Isabel, which has dense coral growth, mainly agariciids, on the outer walls and ledges. The biota in these caves, about 1 to 6 m deep, has never been studied in detail. Some inner portions contain what appears to be fossilized A. palmata colonies. Surfaces of inner walls often contain extensive patches of the ahermatypic coral Tubastrea aurea.

Submerged patch reefs occur off Camuy and Puerto de Tortuguero and several minor coral assemblages are present in Arecibo. North of Dorado, is an extensive but highly stressed reef fringing the shore. The reef flat (1-3 m deep) has abundant gorgonians (e.g., Gorgonia spp.), and the predominant corals are Diploria strigosa and D. clivosa (brain corals). The reef front has many dead corals overgrown by algae and other corals and very high densities of Gorgonia flavellum (?). Seaward of this reef are small patch reefs at 25 m with abundant fish life.

2) offshore islands

a) Vieques

Numerous reefs are found around the coast of Vieques. Reefs off the eastern end are well known as a result of series of studies carried out in relation to a law suit by the government of Puerto Rico to the U.S. Navy in relation to environmental damage by military activities there (see discussion on the effect of Military activities in the section on Anthropogenic stressors). The area is used as a practice range for air dropped bombs and ships gunnery, but includes reefs at Punta Este on the eastern point, Penasco Fosil, Punta Gato, Gato Afuera, Isla Yallis and Punta Icacos on the north coast and Cerro Indio, Pena Roja, Bahia Salinas, Punta Salinas, Cerro Matias and Roca Alcatraz on the south coast.

Raymond and Dodge (1979) carried out an ecological survey of the shallow reefs fringing the promontories on the eastern, western, and northern shores of Bahia Salinas del Sur. The fringing reef off the west side of the bay consists of a well-developed Acropora palmata community. Banks and mounds of Porites porites have developed around two distinct promontories on the north coast (MacIntyre et al. 1983). The fringing reef on the eastern side of the bay consists of coral heads of the genera Montastrea, Siderastrea and Diploria. Another reef with a shallow reef front dominated by A. palmata and deeper head corals extends out from the promontory. The seaward slope levels off at 8 m, grading into the sediment floor of the bay. The back reef shoreward of the reef crest is composed of large colonies of M. annularis on rubble and pavement. MacIntyre et al. (1983) describe the results of core drilling and give estimates of accumulation rates for this reef. Roca Alcatraz, an island 1 km south of the bay is surrounded by A. palmata colonies.

b) Culebra and Culebrita

Ensenada Honda on Culebra has been described by Cintron et al. (1974). Communities of Porites furcata are found along the southeast coast (Glynn, 1973) and are extensive off Puerto del Manglar off the eastern coast (Goenaga, 1983). These corals form extensive monotypic stands that extend from the leeward reef through the reef crest and into the reef front. This is quite uncommon in other reefs where large, monotypic stands of this coral are restricted to the leeward reef sections.

c) Mona and Monito

Coral reefs or coral communities fringe most of the southeastern, southwestern and western sections of Mona. These lie at the zoogeographic center of the Caribbean Basin and contain maximum species richness for Caribbean coral reefs.

Cintron et al. (1975) described coral community zonation for Playa de P†jaros, Punta Caigo o No Caigo, Playa Uvero, El Capitan to Punta Arenas, Cabo Barrionuevo and the east and southeast cliffs of Monito. They conclude that the main coral communities habitat types were: 1) spur and groove, 2) the "drop off" at Carabinero, 3) the submarine caves at Carmelitas and, 4) the submarine cliffs of the north coast. They observed a total of 22 species and one hydrozoan. Coral abundance was said to be minimal along the vertical faces of the cliffs on the northern shore of the island where sponges and gorgonians are predominant zoobenthos. Coral communities are abundant from Cabo Barrionuevo on the northwest side to Punta Este on the east coast. Encrusting and solitary coral colonies scattered over hard bottom occur on the Carabinero and Playa Uvero shelf. Weinberg (1980) made a quantitative study on the "drop off" at Carabinero and he found a general impoverishment of species along the fore reef and down the drop off. Canals et al. (1983) report percent living coral cover at Playa de Pajaros, Playa Sardinera and Las Carmelitas. These range from 2.2% to 90.0%.

d) Caja de Muertos

Canals et al. (1980) describe the coral reefs of Caja de Muertos. Reef development is highest in the northeast coast of this island. The southern and western coasts contain patchy coral growth. These are small and underdeveloped reefs. Goenaga and Cintron (1978) documented the complexity and diversity of the lagoon of the eastern fringing reef.

3) the U.S. Virgin Islands

a) St. Croix and Buck Island

The St. Croix shelf is very different from the northern islands' shelf in that it is much narrower and shallower, which produces a compression of reef types and also allows less extensive areas of deep reef communities.The proximity and shallowness of the north shore shelf edge reefs has enabled them to be studied relatively extensively whereas the shelf edge reefs on the north sides of St. Thomas and St. John have not been studied at all. The shelf edge reef on St. Croix's north shore is similar in structure and community composition to the shelf edge reef described south of La Parguera, P.R.. This reef system runs fairly continuously from Butler Bay on the west coast to the western end of Long Reef on the north coast. The shelf edge reef along this shore ranges from several hundred meters to a little over a half a kilometer from the coastline. Just seaward of the coastline along this shore lies a zone of hard carbonate pavement followed by mostly dead reef patches encrusted with living coral (Multer, 1974). These have produced an irregular and broken series of wave resistant spurs. The dominant coral on these structures is A. palmata with scattered growths of A. cervicornis, P. astreoides, P. porites, D. strigosa, M. complanata and others. The shelf edge reef is dominated by M. annularis with varying amounts of A. agaricites, P. astreoides, P. porites, M. cavernosa and other species of hard corals. This reef has developed spurs made up of M. annularis sometimes also having shingle-like layers of A. agaricites. These spurs alternate with sediment chutes floored with coarse sand which is being transported off the shelf via these chutes. Coral growth ends at 60 to 70m and framework builders are replaced by sclerosponges such as Ceratoporella nicholsoni. The main stress on the shelf edge reef is the frequent anchoring of dive vessels. Several dive operations and sport divers come here to see the well developed reef, the many fish and experience the spectacular wall dive.

Near the eastern end of this system is Salt River submarine canyon. The two walls of the canyon differ markedly in coral cover, possibly the result of differences in vertical profile and substrate type (Boulon, 1979). The east wall ranged from less than one percent coral cover in the inner portion to 25 percent coral cover near the shelf edge. The most common species were Mycetophyllia sp., M. Annularis, D. strigosa, Agaricia sp. and M. cavernosa. The west wall is much steeper with solid substrate and ranged from 22 to 59 percent coral cover with the most common species being M. cavernosa, Agaricia sp., Porites sp. and S. siderea. Increases in sedimentation from upland sources have undoubtedly decreased coral growth and cover since this survey was made.

Long Reef extends eastward to Fort Louise Augusta and is described as an emergent bank barrier reef with an extensive back reef lagoon. The reef is dominated by A. palmata, M. annularis, Millepora sp., P. porites and others (Diamond Development, 1988). The reef is covered by high densities of algae probably due to eutrophication from human activities in Christiansted. This and channel dredging activities have reduced the living reef to less than 30% of the surface. Seaward of this reef the shelf slopes out to the edge with Agaricia lamarki in large formations perpendicular to the reef and separated by sand channels. The eastern part of Long Reef and Round Reef are described as in a less than “healthy” state (VIPA, 1983). Live coral cover is low (6 - 23%) as compared to other reefs in the area (18 - 65%). The authors were unable to ascertain whether this is the result of a less than optimal natural physical environment or human impact. Although, the combination of extremely low live coral coverage, the prevalence of small colonies and large amounts of sediment on the deeper reef at the edge of the Christiansted Canyon all suggest that sedimentation is a major factor limiting reef growth in this area.

Most of the shoreline east of Long Reef to Teague Bay is fringing reef with scattered bank reefs dominated by M. annularis. The Teague Bay reef is about 5km long and is considered the most extensive bank barrier reef on St. Croix (Ogden, 1974). The reef encloses a lagoon about .25 mile wide and averaging 5m deep. The back reef is dominated by M. annularis, P. porites and A. palmata. The reef crest receives heavy wave energy and has a distinct zone of M.complanata mixed with A. palmata. The fore reef slopes to the sand channel separating St. Croix from Buck Island. The fore reef is primarily composed of P. porites, A. cervicornis, M. annularis and Diploria spp. Main impacts to this reef system are from coastal and upland development and the increase in sediment input into the ocean. Anchor damage and boat groundings have also caused reef degradation.

Due to the prevailing wind and wave directions, the east end of St. Croix receives abundant clean water. This has resulted in producing well developed coral reefs with little human impact except for overfishing. Nearshore are numerous fringing reefs dominated by A. palmata and M. annularis. Offshore the shelf extends eastwards for about 20km and averages 20-30m deep. A submerged reef complex rises to about 10m in depth along the seaward edge and is known as Lang Bank. The bank is mostly cemented pavement with scattered sponges, gorgonians and coral heads. Dominant corals here are Porites spp., Diploria spp., Montastrea spp. and A. cervicornis.

The southeastern shore from East Point to Vagthus Point contains discontinuous bank barrier reefs enclosing shallow bays between rocky points. To the west of Vagthus Point large buttresses, as much as 5m in height, stand near to shore and reach to just below the surface (Palm Shores, 1987). These buttresses contain large D. labyrinthiformis heads with diameters over one meter. A. palmata is also found along with M. alcicornis, M. complanata, M. annularis, P. astreoides,P. porites, D. cylindrus and A. agaricites. Offshore of these structures lie a series of rubble reefs. All of the above listed corals with the addition of A. cervicornis occur on these rubble reefs.

The southwestern shore from Hess Oil to Sandy Point once contained relatively good reef development but the dredging of Krauss Lagoon and numerous dredgings of ship channels have killed most of the nearshore and bank reefs. The shelf is widest at this part of the island and there are numerous, scattered large patch reefs on the outer portions dominated by M. annularis.

The west end of St. Croix is a sand plain with scattered inshore areas of raised pavement supporting communities of hard corals mixed with gorgonians and sponges. North and west of the Frederiksted pier are scattered patches of corals dominated by M. annularis. The shelf edge reef system starts off Butler Bay and extends north towards Hams Bluff.

The Buck Island National Monument is located 2km north of Teague Bay on St. Croix. A barrier reef starts near shore at the southernmost point of Buck Island

(Anderson, et al., 1985). This reef forms an arc around the east end of the island, roughly paralleling the north shore. The crest of this reef is dominated by Millepora spp. The reef then grades into a contiguous series of patch reefs to the northwest of the island. This system of patch reefs extends approximately 2km northwest of the west tip of the island. A. palmata is a major constituent of this reef system. North and east of the barrier reef system is an extensive coral/gorgonian flat, nearly continuous to the shelf edge. Several massive A. palmata reefs are emergent at low tide. Although these reefs are composed of 100% A. palmata, less than 20% of the coral is actually alive. The evidence of impact from white band disease on this species is strong (Davis, et al., 1986), having reduced once world famous reefs to literal skeletons of their former selves.

While the types of communities surveyed by Davis, et al. (1986) have not changed since the original descriptions in 1977 (Gladfelter, et al., 1977), the condition of many of the communities has been dramatically altered. The lagoon area behind the barrier reef had a rich, live A. prolifera population in 1977 and now is consolidated A. prolifera rubble with an algal veneer. The A. palmata reefs show a reduction in live coral cover from nearly 100% in 1977 to only 20% in 1985. The cause or causes resulting in these dramatic changes are still not well understood.

b) St. Thomas and offshore cays

St. Thomas and St. John have extensive shelf habitats with the shelf being approximately 8 miles wide on the south and 20 miles wide on the north. Little to no work has been done on the shelves or the shelf edge. Observations from the Johnson Sea-Link have shown significant shelf edge reef development on the south side where the shelf edge is better defined. On the north, the shelf gradually slopes off into deep water. The shelf edge south of Saba Island was observed to occur at approximately 60m and at one site it was comprised of 80 to 100 percent living coral cover (R. Boulon, pers. obser.). The predominant coral appeared to be M. annularis. On this particular dive (Jan. 1990) a number of colonies exhibited varying degrees of coral bleaching. From benthic charts, the shelf edge south of St. Thomas and St. John appears to be similar to the shelf edge off southwestern Puerto Rico but at a slightly greater depth.

Saba Island and Flat Cay are small uninhabited islands SSW of the St. Thomas airport. Flat Cay has very good reef development off its windward (eastern) shore (Rogers, 1982). Saba Island has a coral reef off its eastern shore. From 1978 to 1981 a monitoring study indicated a significant decrease in living coral cover at Flat Cay, probably due to filling activities at the airport runway extension and Hurricanes David and Frederic (August 30 - September, 5, 1979). Extensive physical damage to A. palmata was observed about two weeks after these storms.

Around Range Cay and along the eastern shore of Brewers Bay are found scattered corals on pavement. The western shore has a fringing coral reef and an extensive coral reef is found in the western and central portions of the bay. Seaward of the grass bed in eastern Brewers are sparse coral communities on areas of raised pavement. Brewers Bay has been stressed by sand extraction, dredging and some sewage effluent from the treatment plant located near the airport. The runway extension for the new airport partly closed the bay and has resulted in reduced flushing rates.

Perseverance Bay is to the west of Brewers Bay and is the largest bay on the southwestern coast of St. Thomas. Fringing coral reefs exist along the western shore and extreme eastern shore near Black Point (Nichols and Towle, 1977). The seaward reefs faces are dominated by A. palmata, Diploria, Montastrea, Porites, Meandrina and Agaricia. Signs of stress and attrition were evident in 1977 in the shallower reef platforms and shoreward portions of all the reefs. The lowered water quality observed by Nichols and Towle (1977) has improved with stabilization of bottom sediments in Brewers Bay and may presently be allowing for healthier communities.

To the west of Perseverance Bay and around the west end of St. Thomas, including Kalkun Cay, West Cay and Salt Cay, coral communities occur predominantly as scattered corals on submerged rocks or nearshore carbonate pavement. Most corals in these communities are small head corals like Montastrea, Diploria, Siderastrea, etc.. Savanna Island has several fringing reefs along its shoreline and probably also has some deeper reef formations.

From Botany Point to Stumpy Point on the northwest coast of St. Thomas there is considerable development of both fringing and deeper bank reefs. Little to no work has been done here so descriptions of these reefs is limited to knowledge of the present conditions and what stresses may be impacting them. The primary natural controlling agent on reef structure in this area is the occurrence of large swells during the winter months. This level of energy limits coral growth to encrusting and head forms. Little human induced stresses in this area allow for relatively healthy reef communities.

Most of the bays along the north coast of St. Thomas contain varying amounts of fringing reefs and hard bottom communities with scattered corals. The rocky coastlines between the bays support scattered corals growing on the submerged rocks. Varying degrees of exposure to wave energy from the north determine the coral types and growth forms present at different sites along this coast. Many of the inshore reefs along this coast are suffering from sediment runoff and/or nutrient loading from septic runoff during large rainfall events. The wide insular shelf along this coast can be characterized as being mostly composed of algal and sand plains with occasional raised carbonate ridges containing coral/gorgonian communities.

Inner Brass Island has been relatively well studied as a result of potential development on the island (Williams, et al., 1990). Much of the island is surrounded by either hard bottom with sparse, mixed coral zones comprised of A. palmata, Diploria P.

astreoides and Millepora. The northwest part of the island has several areas of good coral development where the slope is steep and deep water forms of Montastrea, Diploria and others are abundant. The east side of the island receives considerable wave energy. Tyre Bay contains a mostly dead A. palmata reef that most likely was killed when the Navy blasted a channel through this reef in the 1940’s. Outer Brass Island is surrounded by deep water and coral growth is limited to subtidal rock surfaces and some hard bottom.

To the east, Hans Lollik Island has received considerable attention due to a very large proposed hotel/residential resort development (Tamarind Resort Assoc., 1991). Reefs surrounding this island include deep water, fringing and patch reefs. An extensive fringing reef system borders almost the entire eastern shoreline, while the inner portion of Tamarind Bay contains small patch reefs. Along the eastern shore of the island, the fringing reef has created a channelized deep reef and reef wall, with a narrow lagoon inshore that is full of patch reefs and A. palmata flats. The northwest side of the island is mostly corals growing on subtidal bedrock and mixed coral/gorgonian flats. Deep bank reefs occur along the outer edge of the gorgonian flats on the southwest portion of the island. They also occur extensively on the fringe of the eastern gorgonian flats and extend to the north tip of Little Hans Lollik and Pelican Cay. Around the island, subtidal bedrock communities are dominated by Diploria spp., Favia and Millepora spp.. The patch reefs are comprised of M. annularis, M. cavernosa, P. porites, Agaricia spp., Diploria spp., I. sinuosa, Favia, S. radians, and D. stokesi. The deep bank reefs here are described as being mostly composed of gorgonians with few hard corals (Diploria spp., Montastrea spp., Favia and A. cervicornis). Little Hans Lollik and Pelican Cay are surrounded primarily by coral encrusted subtidal bedrock and gorgonian flats.

Magens Bay on the north coast is a deeply indented bay. Extensive buttressed fringing reefs on the south side of the bay are mostly dead (RHB, pers. obser.). This is most likely due to sediment runoff and septic loading of the soil which leaches into the water during large rainfall events. Residential development on the north shore of St. Thomas has skyrocketed during the past twenty years. The north side of Magens Bay has scattered reef development on carbonate benches along the shore. Some of these reef areas are very healthy with the predominant corals being M. annularis, Diploria spp., Porites spp. and some A. cervicornis. These areas do not appear to have been affected much by the water conditions on the other side of the bay.

Mandahl Bay, to the east of Magens Bay, has suffered some of the consequences of dredging and groin construction in the late 1960’s. Present day reefs include a hard bottom area off the mouth of the channel created by the groins. This area has scattered A. palmata, A. cervicornis, Montastrea spp. and others (Mandahl Bay Villas, 1990). The western part of the bay contains scattered small corals on rocky ledges. We can only speculate that coral development was quite good in this bay prior to dredging and groin construction based on what is left.

Most of the shoreline east of Mandahl Bay to Sapphire Bay is composed of rocky coastline with a few beaches. Coral communities along this stretch are limited to growth on subtidal bedrock or scattered corals on carbonate pavement. Several Porites patch reefs in southern Water Bay were destroyed by dredging activities in the 1960's and 1970's (D. Hubbard, pers. comm.).

A line of islands stretch to the northeast and include Thatch, Grass, Mingo, Lovango and Congo Cays and Carvel Rock. The north sides of these islands are bordered by deep water and only support scattered coral colonies on the subtidal bedrock. The south sides have several deeper fringing reef areas and scattered corals on carbonate pavement. A submerged rock formation to the east of Lovango Cay has a relatively healthy veneer of corals growing on it. Strong currents here provide clean, food rich water for these benthic organisms.

Sapphire Bay (Red Bay) once had a very healthy reef around Prettyklip Point but was destroyed by dredging and removal of beachrock which has resulted in increased water turbidity. Broken shafts of A. palmata up to eight feet long are now cemented into the existing reef (Sapphire Beach Hotel and Marina, 1984). Small Acropora spp. and Diploria spp. occur offshore on submerged bedrock outcrops.

Red Hook Bay on the east end of St. Thomas has fringing reefs along the north side of the bay. These reefs are composed of M. annularis, D. labyrinthiformis, Porites spp., A. agaricites, S. siderea and A. cervicornis. Many dead Montastrea and Diploria skeletons are found here with live coral cover being less than 10% (V.I. Port Authority, 1988).

A long history of dredging in this bay and heavy vessel traffic have taken a serious toll on these reefs. The south side of Red Hook Bay has coral growth on subtidal bedrock around Cabrita Point. Great Bay on the south side of Cabrita Point has scattered fringing reefs which are relatively healthy but increasing development in this bay will almost certainly have an effect on them. The south side of the bay near Current Cut has extensive reef growth on pavement. Large colonies of M. annularis and Diploria spp. predominate. The channel between St. Thomas and Great St. James Island is composed of dense coral/gorgonian communities due to strong tidal currents flowing between the islands. Most of the coral communities around The St. James islands and Dog Island are scattered corals on subtidal bedrock with some hardbottom areas. Whelk Rocks to the east of the channel between the St. James islands and Cow and Calf Rocks south of Deck Point, St. Thomas are boulder piles with encrusting corals.

Except for the barrier reef areas between Cas Cay and Patricia Cay and Patricia Cay and Long Point, most of the south shore of St. Thomas is scattered coral communities on carbonate pavement. Most of these occur adjacent to shore but some occur as raised patches off Benner Bay and south and east of Dog Island. Coral encrusted boulder reefs occur at Triangle reefs east of Charlotte Amalie harbor. Several small fringing reefs occur at Bolongo Bay and around Green Cay. The barrier reefs which form the southern arm of the Benner Bay Mangrove Lagoon have suffered storm damage but still have relatively high live coral cover. The reef crests are emergent at low tides and extensive backreef habitat is present. The upper fore reefs are composed primarily of A. palmata. The channel between Patricia Cay and Long Point has the remains of once healthy Porites reef flats. Dredging for sand extraction in the 1960’s may have killed this reef.

Buck Island is mostly surrounded by coral encrusted subtidal bed rock. The north side of the island has some relatively well developed deeper fore reef. This area is used by the Atlantis Submarine for its underwater tours. It is not known what effect, if any, this may be having on the reefs here.

Charlotte Amalie Harbor has nothing in the way of reef development. If it ever did, it would be long dead due to dredging, sewage disposal, cruise ships, etc.. There are some deeper coral communities along the south and west shores of Hassel Island which appear to be just out of the turbid water conditions inside the harbor.

Water Island has little in the way of coral reefs around it. Most of the coastline is rocky with scattered hard coral attached to the subtidal portions of the rocks. However, along the southeastern shoreline, from approximately five meters to 20m in depth, there is a deep, buttressed reef formation with high living coral cover (V. Vicente, pers. comm.). The dominant coral on the buttresses is M. annularis.

c) St. John and offshore cays

Approximately 56% of St. John’s land area is a National Park (Dept. of the Interior). Along with this, 5,650 acres of submerged lands are also owned and managed by the National Park. While this has provided some protection for the marine resources, inholdings and nearby development have produced sedimentation in several of the bays under NPS jurisdiction (Hubbard, et al., 1987). Continued fishing, diving and heavy boating activities, including anchoring and groundings, have resulted in continued degradation of NPS marine resources. Until the NPS takes serious, drastic measures to protect its resources, the decline will continue. From 1983 to 1985 the NPS contracted with a number of local agencies to survey the marine resources within NPS waters. These projects resulted in fairly detailed reports on the benthic invertebrate and associated fish assemblages (Beets, et al., 1986; Boulon, 1986). Descriptions for coral reefs and communities within the NPS will rely considerably on these reports along with personal observations by RHB.

Cruz Bay is the principal harbor and port of entry for St. John and as such is the most heavily utilized bay on the island. A shallow, mostly dead reef extends from the southern point (Gallows Point) and provides considerable protection for the bay. This reef has been killed due to sedimentation and vessel groundings. Thirty years ago, this reef was very healthy and good for snorkeling. Remains of A. palmata stands can still be seen. The north side of the bay contains some coral growth on subtidal bedrock with live cover <5%.

Solomon and Honeymoon Bays have subtidal bedrock off the points with coral cover of 5-10%. The predominant corals are P. porites, A. palmata, A. cervicornis, S. radians, S. siderea, M. annularis, C. natans, D. clivosa and D. strigosa. A small patch of dead upper fore reef is off the southern point of Honeymoon Bay. A few small patches of A. palmata are surviving among many dead ones. Other corals are present with a live coral cover of 20-25%.

Caneel Bay and Scott Beach have patches of subtidal bedrock with low coral cover (<5%). Towards the northern point of Scott Beach the coral cover increases to 40-50% with Millepora sp. becoming dominant. Turtle Bay has a similar distribution of coral cover on subtidal bedrock with coral cover increasing towards the points.

The Durloe Cays (Henley, Ramgoat and Rada) have varying amounts of coral cover around them on subtidal bedrock. The exposed northeast parts have higher cover (40-60%) which then decreases towards the southern parts. Some large colonies of A. palmata exist and D. cylindrus is unusually common around these cays. Other corals here include D. strigosa, D. labyrinthiformis, D. clivosa, C. natans and P. porites. Southeast of Henley Cay are carbonate ridges with high coral cover (60-80%) with M. annularis being dominant. Surrounding all the Cays in deeper water is a zone of gorgonian/coral pavement with coral cover around 5%.

Hawksnest Bay is a deeply indented bay with several types of coral assemblages. The eastern and western shores are dominated by subtidal bedrock with low coral cover (5-10%). Four large patches of upper fore reef exist in the southern part of the bay. These are dominated by A. palmata which provides about 10% live cover. These reefs have been impacted by sediment runoff from the St. John clinic at the top of the watershed and boat groundings. The western part of the bay has areas of pavement with low coral cover (5-10%). These areas are bordered on the seaward side by lower fore reef having coral cover of 25-30%.

Dennis Bay and Perkins Cay have considerable reef development between them and off the beach. Large stands of A. palmata exist on the east and west sides of the beach with many of the colonies dead and low coral cover (5-10%). To the west and northeast of Perkins Cay the coral cover is higher(15-20%) with the dominant corals being P. astreoides and A. palmata. There is a narrow lower fore reef zone dominated by M. annularis and 20-30% coral cover.

Jumbie Bay has moderate sized patches of A. palmata dominated upper fore reef on the east and west sides of the bay. There is high mortality of A. palmata in this reef which has resulted in low live cover (5-15%). White band disease is evident here which may explain the mortality. A band of head coral colonies stretches between the upper fore reef patches and is dominated by M. annularis.

Trunk Bay and Trunk Cay have little coral growth. Most of it is present on subtidal bedrock around the cay and eastern point. An underwater trail is located on the western side of the cay and has suffered from breakage and abrasion from swim fins and collection of “souvenirs” by tourists. This trail is an example of the cumulative impact of many individuals over a long period of time.

Johnson’s Reef is an extensive nearly emergent bank reef complex located north of Trunk Bay. The reef crest is dominated by Millepora sp. (30-40% coral cover) with small dead colonies of A. palmata, probably from storm damage. The upper fore reef is impressive with 40-50% coral cover dominated by moderate to large colonies of A. palmata. White band disease has been observed but not common. P. astreoides is abundant in patches. This reef sustains considerable damage from boat groundings. The lower fore reef is a narrow band around the platform with M. annularis being dominant and coral cover of 30-40%.

Windswept Beach is located on an exposed point protected by a large fringing reef. The reef is dominated by A. palmata in relatively good condition. Storm and vessel damage is evident. During the years from 1982 to 1985 an average of 3 boats per week were grounding on this reef. After the NPS installed buoys marking the reef, fewer than one boat per month were observed to hit this reef. Total coral cover here is 30-40% with many small colonies of A. palmata growing in the nearshore parts of the reef.

The bays east of Windswept to Mary’s Point (Peter, Little Cinnamon, Cinnamon, Maho, Little Maho and Francis) have little in the way of reef development. Peter Bay has a small patch of healthy A. palmata reef at the western end but other coral growth in these bays is on subtidal bedrock or carbonate pavement with low coral cover (<5%). Mary’s Point to Leinster Bay is all subtidal bedrock with low coral cover except for one area of carbonate ridges off the central part of the north shore of Mary’s Point that has higher coral cover (probably 20-30%). Whistling Cay off the west end of Mary’s Point has a small pavement area off the south side with scattered corals. The rest of the cay is mostly subtidal bedrock with corals growing on it.

Mary’s Point Creek has several small reef areas at its mouth that have small stands of A. palmata and scattered other corals. Leinster Bay and Waterlemon Cay have several areas of carbonate pavement with scattered corals. Waterlemon Cay has several large colonies of A. palmata and P. porites on its northwestern side with 10-20% coral cover. The coast east to Brown Bay is mostly subtidal bedrock with encrusting corals. Just east of Threadneedle Point and just east of Brown Bay are small, narrow patches of fringing reef dominated by A. palmata and Millepora spp..

Mennebeck Bay has fringing reefs extending from both points and forming a semi-enclosed bay. Reef development is diverse and healthy. The reef crests are dominated by Millepora spp. and the upper fore reef by A. palmata with 25-30% coral cover. The lower fore reef is dominated by M. annularis and P. porites with 35-40% coral cover. Haulover Bay has well developed reefs on the western side and a series of deep (22m+) patch reefs in the middle of the bay. These patch reefs have high scleractinian diversity and large numbers of antipatharians with Antipathes atlantica, an unidentified species and Stichopathes lutkeni being present. The unidentified species forms large colonies of 3-4m in crown diameter. There is evidence of some collection of these corals.

From the eastern point of Haulover Bay around East End to Red Point are some of the best developed, healthiest reefs left in the Virgin Islands. This stretch of coast includes Newfound Bay, East End Bay, Privateer Bay and several small unnamed bays. These bays all have well developed fringing reefs and extensive areas of lower fore reef seaward of them. The fringing reefs are dominated by A. palmata, Millepora spp. and Porites spp.. The lower fore reefs are dominated by Montastrea spp., Diploria spp., Agaricia spp. and others. Some of these reefs were affected by the oil spill that originated off St. Marten in 1991 but are not known to have suffered any mortality. Recent subdivision work in Privateer Bay threatens to produce sediment runoff which could affect these relatively pristine coral reefs. Flanagan Island, southeast of Privateer Point, is fringed by subtidal bedrock with encrusting corals.

Round Bay has little in the way of coral reefs. The shoreline has varying amounts of subtidal bedrock with encrusting corals. Out in mid-bay are a number of raised patches of carbonate pavement with scattered corals and other organisms. From Hurricane Hole to Lagoon Point coral growth is limited to growth on subtidal bedrock at the points. These bays are deeply indented with substantial amounts of red mangrove development. Lagoon Point was once a well developed fringing reef with an extensive backreef lagoon. There are still some stands of A. palmata but storm damage and a few boat wrecks have reduced much of this reef to rubble. The lower fore reef is still relatively healthy with fairly high coral cover composed of Montastrea spp., Diploria spp., Agaricia spp. and others.

John’s Folly Bay has a fringing reef extending off both points. This reef has also suffered considerable storm damage and has few large stands of A. palmata left. There is a relatively expansive lower fore reef seaward of this bay with good coral cover. Le Duck Island east of John’s Folly is mostly subtidal bedrock and carbonate pavement, both of which have only scattered corals. Eagle Shoal lies south of Le Duck Island and comes to about 2m from the surface. This shoal contains many grottos and caves in the boulders that create this structure. Coral cover is good with head corals predominating. To the west of Eagle Shoal lies Drunk Bay. This bay is mostly cobble and large subtidal bedrock boulders. However, there is a fringing reef along the north side of the bay dominated by A. palmata and having 25-30% coral cover. The east side of Ram Head is predominately subtidal bedrock and carbonate pavement with some lower fore reef along the edge.

The west side of Ram Head is mostly cobble bottom inshore with a lower fore reef having spur and groove formations offshore. Saltpond Bay has low coral cover (<5%) in the bay with high Millepora cover (30-35%) on the rocks at the mouth of the bay. Booby Rock has an extensive, tiered lower fore reef northwest of it with high coral cover (30-40%). Many large colonies of M. annularis and C. natans are present.

Coral communities in Kiddle and Grootpan Bays are primarily on carbonate pavement with generally low coral cover (<5%). The west side of Grootpan Bay has an area of higher cover (up to 20-25%) with several large colonies of M. annularis, C. natans and D. cylindrus. Kiddle Bay has a patch of lower fore reef in the middle of the bay with 20-30% coral cover of which M. annularis predominates. Off the western point of Kiddle Bay is a bank patch reef with low relief and total coral cover of 20-50%. M. cavernosa is the dominant coral.

Little and Greater Lameshur Bays contain considerable amounts of subtidal bedrock with coral cover ranging from <5% inshore to 10-20% near the points. Millepora spp. dominate near the points. Shallow carbonate pavement areas in both bays contain low coral cover (<5%). Little Lameshur has a small area of lower fore reef on the western side with a coral cover of 15-20% dominated by P. porites and M. annularis. In Greater Lameshur a large area of lower fore reef occurs on the eastern side near the sites of the Tektite I and II programs during 1969-1971. Coral cover is 15-20% and is primarily M. annularis. The west side of Yawzi Point, which separates the two bays, coral cover is from 20-25% in mid reef and 30-40% near the edge with M. annularis dominant. The east side of the point is a coral garden with coral cover of 35-40%. M. annularis predominates with large colonies often forming continuous complexes. Several large colonies of C. natans and P. porites are also present. Greater Lameshur Bay had extremely high abundances of Diadema antillarum prior to the 1983 die-off.

Europa Bay is mostly subtidal bedrock on the points with low coral cover (<5%). Some small colonies of A. palmata are present but this species is the main contributor to the storm rubble present throughout this bay. There is a narrow reef crest composed of eroded carbonate mounds with few corals on their tops. The sides are colonized by Diploria spp., Montastrea spp., Colpophyllia spp., Porites spp. and F. fragum. A patch of lower fore reef is off the western shore and is dominated by M. annularis.

Reef Bay is the largest bay on the south side of St. John. Both sides of the bay have exposed reefs which form an incomplete barrier for the shore and back reef zones. All reef zones in this bay are in relatively good condition except for reef crest and upper fore reef zones which were severely damaged during hurricanes David, Frederick and Hugo. The reef crests are ramparts of A. palmata fragments, the amount of which suggests a previously extensive A. palmata zone. The western side of the bay is currently experiencing sedimentation due to residential development using improper construction methods. The back reef on the eastern side of the bay is wide and contains large, healthy stands of P.

porites which have grown to low mean water. The western back reef is very narrow but healthy with high coral cover (30-40%) of P. porites and P. astreoides. The fore reef zones in this bay are primarily carbonate pavement with mounds containing large colonies of M. annularis, D. strigosa and S. siderea. A. palmata rubble is abundant. There are several large offshore bank patch reefs in this area. Just south of White Cliffs is a large patch reef that rises to about 15m from the surface from a sand plain at about 25m. This reef has scattered corals on top with good coral cover near the edge. Large head corals predominate. South of the western end of Reef Bay lie several smaller bank patch reefs having low vertical relief but high coral cover (50-60%). A. agaricites is predominant with scattered large colonies of M. annularis and C. natans. Numerous other species are also present in small amounts.

Eastern Fish Bay is an extension of the western Reef Bay fringing reef system. The reef crest and upper fore reef exhibit similar types and amounts of storm damage as at Reef Bay. The upper fore reef is barren pavement with all A. palmata having been stripped off. A few large M. annularis colonies are still present.The lower fore reef is oriented as a series of spurs and grooves with high coral cover (40-60%). The western side of Fish Bay has an extensive lower fore reef with high coral cover (30-40%) dominated by A. agaricites.

Rendezvous Bay extends from Dittlif Point on the east to Bovocoap Point on the west. Most coral communities in this bay occur as scattered corals on carbonate pavement or on subtidal bedrock with low coral cover. The western side of Rendezvous Bay has a considerable amount of lower fore reef with moderate coral cover dominated by M. annularis. This zone extends around Bovocoap Point to Devers Bay. Extending southwest from Bovocoap Point are a series of raised carbonate ridges with extensive ledges around the edges. These ridges have low coral cover (<5%), most of which is composed of plate-like colonies of several species of head coral.

The shoreline from Devers Bay to Cruz Bay is mostly subtidal bedrock and nearshore carbonate pavement with low coral cover. Off Moravian Point are several patches of subtidal bedrock which are emergent at low tide. They contain scattered corals with Millepora spp. predominating. There is some lower fore reef associated with these patches. Stevens Cay to the west has extensive carbonate pavement surrounding it and a wide zone of lower fore reef further offshore. The lower fore reef has moderate coral cover with varying amounts of M. annularis, A. cervicornis and Agaricia spp..

C. Habitat threats

Possibly the most important threat to corals in Puerto Rico and the Virgin Islands is inland deforestation, particularly (although not necessarily restricted to) that adjacent to fringing and platform coral reefs. Sediments derived from inland deforestation are detrimental to reef corals and, therefore to coral reefs, in ways mentioned above (see section on Anthropogenic stressors). Additionally our coral reefs are also stressed, although to generally unknown extents, by chemical pollutants, indiscriminate and careless commercial and scientific collection of living corals, collection of "live rock" (coral reef portions frequently containing endolithic biota as well as living postlarval, juvenile and/or adult corals) and commercial collection of both juvenile and adult reef fish. The latter is largely responsible for unbalances in our reef systems resulting in low or no recruitment and a gradual degradation of these once productive systems.

The corals most likely to be affected are those inhabiting fringing reefs (i.e., those closest to shore) which are generally under the direct influence of human activities (Goenaga, 1986). Those that presumably are least affected by anthropogenic effects are those farthest from land (e.g., shelf edge reefs). Shelf edge reefs and bank barrier reefs (those in mid portions of insular platforms) are also subject to siltation by dredging and by fishing activities as well as by ocean outfalls.

D. History of exploitation

Collection for commercial purposes of reef corals and hydrocorals is presently uncommon in our islands. In the past, it was a common activity particularly off the east coast of Puerto Rico (Fajardo). Most vendors, mainly local fishermen, were stopped from their activities by implementing the regulation for the extraction of corals prepared by the PRDNR. The CZM Act of 1978 prohibits the taking of coral and sand in the U.S.V.I..

More importantly, has been the collection of corals and associated biota by scientists. This activity, sometimes as destructive or even more destructive than commercial extraction, is, to my knowledge (CG), unregulated (although according to Miguel Canals, forest keeper of the Guanica Forest Biosphere, coral extraction for any purpose within a natural reserve is restricted and regulated). In the U.S.V.I. this is regulated by Act 5665 which requires permits for any collection of indigenous species, marine or terrestrial.

Black corals, to our knowledge, have not been systematically harvested for commercial purposes in the past nor in the present. Gorgonians, on the other hand, are intensively collected, at least in the La Parguera, PR area, for scientific/commercial purposes, namely for the assessment of pharmacologically important compounds. Similar, though not as intensive, collections have been made off the southwest coast of St. Thomas. The impact of this activity, intensive only for short time spans, is unknown and needs to be assessed, particularly in relation to the abundance and ecology of target species.

As stated elsewhere, commercial collection of reef associated biota (e.g., juvenile reef fish, anemones, brittle stars, cleaning shrimps and others) is common and intense in the west and southwest Puerto Rican coast and to a lesser extent in the VI and its effect on reef corals and other biota needs to be assessed urgently. It is at this moment unknown whether irreparable damage is being done to the environment.

E. Habitat requirements

Generally, optimum development of reef corals occurs in clear, oligotrophic sea water that is unpolluted, relatively free of terrigenous sediment input and not subject to temperatures above or below that in which they originally developed. Wide shelves are apparently also important or correlated to the formation of extensive and complex reef habitats. In Puerto Rico and the VI these conditions (except that related to the width of the insular shelf) are met with increasing frequency as distance increases from the coast or on offshore islands. A high incidence of dead or dying reef corals is usually observed on inshore habitats. Examples of this situation are Mayaguez, Guanica, Guayanilla, Yabucoa, many sites along the north coast of PR and numerous sites around the VI.

F. Habitat information needs

It is essential that the appropriate government agencies, namely the Puerto Rico Department of Natural Resources, the Virgin Islands Department of Planning and Natural Resources and others, update coral reef inventories so that careful evaluation of unexplored sites is made possible. Inventories need to focus on particularly critical sites. For example, very old, unusual colonies of Montastrea annularis (possibly around one thousand years old) inhabit submerged banks southeast of La Parguera. It is extremely important to characterize this area and give it special protection. Assessment of shelf edge reefs east of La Parguera, north of St. Croix, south of St. Thomas/St. John and of offshore islands also needs to be made. Shelf areas also need to be surveyed for the presence of bank reefs and other habitat critical for the survival of coral reef fish and the source of recruitment for many of our inshore reefs.

V. Management recommendations

A. Identification of critical areas

The following areas are considered critical because of the presence of extensive coral reefs and abundant reef corals and need to be assessed in detail. It must be emphasized that there is urgent need to update inventories and detailed descriptions of many of these areas. Further information of interest in this context is given in Wells (1988).

1. Puerto Rico

a. La Cordillera (the coral reefs of La Cordillera have been assessed recently by DNR personnel) -northeast coast from east of Cabezas de San Juan to nearCulebra

b. Bahia°a de Jobos and adjacent platform reefs-south coast; south of the municipalities of Salinas and Guayama

c. Cayo Ratones-south coast; about 1 km south of Ponce

d. Caja de Muertos and Cayo Berberia -south coast; south of Ponce

e. La Parguera -south coast; off the municipality of Lajas

f. Sergeant Ree -southeast coast; 0.3 km southeast of Punta Tuna

g. Tourmaline and El Negro reefs -west coast; approximately 10 km west of Punta Ostiones

h. Reefs south of La Cancora, near Punta Boca de Cangrejos -north coast; north of San Juan

i. Submarine caves off Jobos, Isabela -north coast; north of the municipality of Isabela

j. Vieques -18 km east of eastern Puerto Rico

k. Culebra-north of Vieques

l. Mona and Monito -halfway between Dominican Republic and western Puerto Rico in the Mona Passage

m. Caja de Muertos

2. U.S. Virgin Islands

a. Buck Island -north of St. Croix

b. Shelf edge reefs north of St. Croix -from Hams Bluff east to Christiansted on north shore

c. St. Croix barrier reefs -south coast from East Point to Vagthus Point -north coast from Teague Bay to East Point

d. Shelf edge reefs south of St. John/St. Thomas -from south of the east end of St. John west to south of Sail Rock

e. Reefs associated with the Mangrove Lagoon, St. Thomas -Long Point to Deck Point and including Cow and Calf Rocks

f. All reefs within the V.I. National Park on St. John -north and south coasts of St. John

g. East end reefs on St. John -Haulover Bay to Red Point, St. John

h. Stevens Cay and Moravian Shoal -west end of St. John

B. Most susceptible species

The most susceptible species is probably Acropora palmata given the high incidence of the disease known as "white band disease" caused by an unknown agent. Populations of this species and its congeneric A. cervicornis have been drastically reduced within the last decade. Collection of this species should be completely banned and scientific studies requiring handling of specimens should be made under close supervision of competent personnel. Species that are subject to intensive scientific collection, be it whole or portions of the colonies, are also in need of urgent regulation.

C. Collection

1) commercial and touristic

Commercial collection of skeleton forming cnidarians should be strictly prohibited at least until information on growth rates are thoroughly analyzed in the context of possible exploitation. This includes collection of reef rock (i.e., "live rock") which, in addition to generating disturbance in the coral reef, is likely to contain larvae or juvenile coral recruits that are not visible to the naked eye. Tourists should neither be allowed to collect until sustainable yield data are available.

2) scientific

Bonafide, justifiably scientific collection of skeleton forming cnidarians or portions of them, should be regulated. It is necessary that government agencies supervise the collection or extraction of these animals. As mentioned earlier this activity can cause extensive damage to coral reefs. Collection methods that are damaging to corals and associated biota should be banned.

D. Anthropogenic reduction of water quality

Efforts must be made to educate the general public, government officials, developers and special interest groups on the effects of terrigenous sediment input and the discharge of untreated sewage and petroleum products into our coastal waters. These inputs and discharges must be eliminated to the most practical extent possible.

E. Fishing

Fishing effort on coral reef fish must be reduced to allow for a restoration of naturally balanced reef systems which will result in stony coral recovery.

F. Anthropogenic destruction of habitat

Education and enforcement must target the problems of anchor and vessel grounding damage to coral reefs. The provision of moorings in popular anchoring sites and marking of reefs with buoys will significantly reduce damage to corals.

G. Cultivation and transplantation into degraded habitats

Cultivation of skeleton forming cnidarians is a possibility that could be explored considering the commercial demand for this resource. Cultivation is possible from "nubbins" and, possibly, from sexually produced larvae. There is ample, available literature from which this issue could be assessed and resolved.

Transplantation to degraded habitats is also an option to be considered. Its implementation, however, would be fruitful only if factors producing the degradation are simultaneously curbed (i.e., in those cases where these are recurrent). There is existing literature also that would help in the assessment of this possibility.

H. Monitoring

Monitoring of degraded and healthy habitats need to be implemented, particularly near recent sources of pollution and or other detrimental activities. Photographic documentation of selected reefs can lead to very valuable information on short to medium term changes in the community structure. The resources needed and the time to be spent to carry on this activity are minimum for the quality of the information obtained.

I. Probable future condition

The future condition of reef corals depends on the: 1) extent that concerned government agencies (i.e., PR Department of Natural Resources, VI Department of Planning and Natural Resources, PR Environmental Quality Board, PR Planning Board, Environmental Protection Agency, Corps of Engineers) decide to properly manage the coastal zone of PR and the VI in benefit of these valuable resources and, 2) frequency of further "natural" disturbances. The second we cannot control if, in fact, these disturbances are Homo-independent. The first is up to government authorities and is to a large extent related to education beginning in the lower grades (the Departments of Education are largely responsible for this). In the absence of quick changes in the policies related to coastal zone management coral reefs will most likely undergo further degradation. It is not unreasonable to state that this degradation will be irreversible in terms of human generations. Aspects related to the recovery of coral reefs are discussed above (section on Tolerance of corals to stressors and capacity to recover from disturbances).

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Appendix 1.

Phylum Cnidaria
Class Hydrozoa
Order Milleporina
Millepora alcicornis Linnaeus
Millepora complanata Lamarck
Millepora squarrosa Lamarck
Order Stylasterina
Stylaster roseus (Pallas)

Class Anthozoa
Order Antipatharia
Antipathes pennacea Pallas @, @@
A. tanacetum Pourtales @
A. furcata Gray @
Stichopathes spp. @@@

Subclass Octocorallia
Order Alcyonacea
Family Anthothelidae
Erythropodium caribaeorum (Dushassaing and Michelotti)
Family Anthothelidae
Iciligorgia schrammi Duchassaing
Family Briareidae
Briareum asbestinum (Pallas)
Family Telestacea
Telesto riisei (Duchassaing and Michelotti)

Order Gorgonacea
Family Gorgoniidae
Gorgonia mariae Bayer
G. ventalina Linnaeus
G. flabellum Linnaeus
Pseudopterogorgia acerosa (Pallas)
P. americana (Gmelin)
P. bipinnata (Verrill)
P. rigida (Bielschowsky)
P. albatrossae Bayer
Pterogorgia anceps (Pallas)
P. citrina (Esper)
Family Plexauridae
Eunicea mammosa Lamouroux

Appendix 1 (cont.)

E. succinea (Pallas)
E. laxispica (Lamarck)
E. mammosa Lamouroux
E. succinea (Pallas)
E. fusca Duchassaing and Michelotti
E. laciniata Duchassaing and Michelotti
E. touneforti Milne Edwards and Haime
E. clavigera Bayer

Family Plexauridae
E. knighti Bayer
E. calyculata Ellis and Solander
Muricea atlantica (Kukenthal)
M. muricata (Pallas)
M. pinnata Bayer
M. laxa Verrill
M. elongata Lamouroux
Muriceopsis sp.
M. sulphurea (Donovan)
M. flavida (Lamarck)
Plexaura flexuosa Lamouroux
P. homomalla (Esper)
Pseudoplexaura porosa (Houttuyn)
P. flagellosa (Houttuyn)
P. wagenaari (Stiasny)
P. crucis Bayer
Plexaurella dichotoma (Esper)
P. nutans (Duchassaing and Michelotti)
P. grandiflora Verrill
P. grisea Kunze
P. fusifera Kunze
Family Ellisellidae
Ellisella spp.

Order Scleractinia
Family Astrocoeniidae
Stephanocoenia michelinii Milne Edwards and Haime
Family Pocilloporidae
Madracis decactis (Lyman)
M. mirabilis (Duchassaing and Michelotti)

Appendix 1 (cont.)

Family Acroporidae
- Acropora palmata (Lamarck)
- A. cervicornis (Lamarck)
- A. prolifera (Lamarck)

Family Agaricidae
- Agaricia agaricites (Linnaeus)
- A. fragilis Dana
- A. tenuifolia Dana
- A. lamarcki Milne Edwards and Haime
- Leptoseris cucullata (Ellis and Solander)

Family Siderastreidae
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- S. radians (Pallas)

Family Poritidae
- Porites astreoides Lamarck
- P. porites (Pallas)
- P. branneri Rathbun
- P. divaricata Lesueur

Family Faviidae
- Favia fragum (Esper)
- Diploria clivosa (Ellis and Solander)
- D. strigosa (Dana)
- D. labyrinthiformis (Linnaeus)
- Manicina areolata (Linnaeus)
- M. mayori Wells
- Colpophyllia natans (Houttuyn)
- Cladocora arbuscula (Lesueur)
- Montastrea annularis (Ellis and Solander)
- M. cavernosa (Linnaeus)
- Solenastrea bournoni Edwards and Haime

Family Rhizangiidae
- Phyllangia americana Milne Edwards and Haime*
- Astrangia solitaria (Lesueur)*

Family Meandrinidae
- Meandrina meandrites (Linnaeus)
- M. meandrites forma brasiliensis (Edwards and Haime)
- Dichocoenia stokesi Milne Edwards and Haime
- D. stellaris Edwards and Haime
- Dendrogyra cylindrus Ehrenberg

Family Mussidae
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Appendix 1 (cont.)

Isophyllia sinuosa (Ellis and Solander)
Isophyllastrea rigida (Dana)
Mycetophyllia lamarckiana Milne Edwards and Haime
M. aliciae Wells
M. danae Milne Edwards and Haime
M. ferox Wells

Family Caryophyllidae

Eusmilia fastigiata (Pallas)
Tubastrea aurea (Quoy and Gaimard)*

Family Oculinidae

Oculina diffusa Lamarck

* ahermatypic
@ source: Opresko, 1974
@@ source: Oakley, 1988
@@@ source: Noome and Kristensen, 1976; Goenaga, 1977

A PRELIMINARY ASSESSMENT OF THE EXPORT TRADE IN MARINE AQUARIUM ORGANISMS IN PUERTO RICO

Report Submitted to the

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by

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INTRODUCTION

There has been concern in Puerto Rico over the last 2-3 years regarding what is perceived to be a growing export trade in marine organisms marketed for the aquarium industry. This trade characteristically involves the collection and sale of a wide range of tropical marine vertebrate and invertebrate organisms, as well as plant species, to private and, to a lesser extent, public aquaria. Concern has been expressed both by those active within the aquarium trade and those familiar with Puerto Rico's marine resources over the potential negative impact that increasingly intensive collection could have on fish and invertebrate populations, and the habitat with which they are associated.

There is no published information or database currently available in Puerto Rico regarding either the volume or nature of this trade, the species and areas exploited, the gears employed, or the number of businesses involved. Such information is essential for issues to be addressed concerning the exploitation and preservation of marine resources marketed for the aquarium industry. The purpose of this report is 4-fold:

1. to summarize what is known from tropical areas worldwide regarding the growth and possible impact of the aquarium trade;
2. to provide a first assessment of the nature and extent of this trade in Puerto Rico by documenting the number of people involved islandwide, by determining the species involved and by identifying the principal areas and methods of collection;
3. to describe the biology of key exploited species, or species complexes;

4. to identify information required for monitoring and assessing the trade on a continual basis, with suggested actions for the compilation of the appropriate biological and socio-economic data;

5. to provide recommendations for regulating the industry to enable commercial exploitation commensurate with conservation of the resource base.

WORLD TRADE IN MARINE AQUARIUM ORGANISMS

Trade in ornamental marine fishes began in the early 1950's (Wood, 1985). Since 1965, there has been a steady increase in international trade in coral reef organisms for private aquaria (Lubbock and Polunin, 1975). By 1979, the world trade in marine and freshwater ornamental fishes had an annual wholesale value of $600 million, with a 10-15% estimated annual growth. Marine species had a relatively small share of the market (Wood, 1985) although this proportion is increasing. Growth in the marine side of the industry has come about because of a combination of the widespread use of biological filters, improvements in the treatment of disease, the development of silicone seals enabling easy construction of aquaria, and the manufacture and marketing of synthetic salts allowing salt water to be available countrywide (Hess and Stevely, no date).

Marine organisms are predominantly exported from the Philippines, Hawaii, Taiwan, Hong Kong, Thailand, Singapore, Java, Queensland, Sri Lanka, Ethiopia, Saudi Arabia, Kenya, Mauritius, Florida and some Caribbean Islands (Lubbock and Polunin, 1975), although from a number of these locations fish are re-exported rather than actually collected (see below). The majority of marine organisms in world trade is exported from the Philippines, with 16% from Hawaii and Florida (this would include re-export from Caribbean countries). Major importers are the U. S. A., Hong Kong, western Europe, Japan, Canada and Australia. The cost, insurance, freight (c.i.f.) value of world trade in ornamental marine fish and invertebrates was estimated at $U.S. 24-40 million annually (Wood, 1985). This does not include international trade in dead coral and shells used for jewelry and ornamentation which may be substantial (Wells, 1981).

The majority of marine fish are tropical coral reef species which are largely collected from the wild, rather than cultivated, as is the case for 50-60% of freshwater ornamental species (Anon, 1979). All invertebrates are wild-caught (Wood, 1985). Imported animals are small species, or juveniles of larger species, usually less than 20 cm in length, although more commonly between 2-8 cm (Lubbock and Polunin, 1975). Since the mid-1980's, national and international trade has increasingly included "live rock". "Live rock" is a broad term used to describe several types of substrate colonized by marine organisms - four main types are distinguished; 1. rubble rock, 2. algae or plant rock, colonized by algae 3. false coral or anemone rock covered with anemones of the genera Ricordea and Rhodactis, and 4. sea mat or gravel rock colonized by anemone-like organisms, usually of the genus Zoanthus (Wheaton, 1989). The increased demand for live invertebrates that comprise "live rock" has developed with the increasing popularity of "living reefs" or "mini-reefs", private aquarium systems which generally include few fish species.

There is considerable variation in the manner in which collectors and exporters of marine aquarium organisms operate, and regarding the licencing and regulation of harvest practices and trade (Conroy, 1975; Anon., 1979). Collectors may themselves be exporters, or may sell to exporting middlemen. The diverse nature of the marine aquarium industry worldwide, and perceptions regarding its potential impact in exploited areas, are best illustrated by the following individual country accounts.

Southeast Asia

Philippines

A major supplier of tropical fish worldwide. In 1975 more than 80% of U. S. imports originated in the Philippines (Randall, 1984). More than 90% of exported fish are marine species (Lubbock and Polunin, 1975). From 1970-1979 the export value increased 20-fold and today aquarium fishes are within the top ten fishery products being exported. More than 40 companies export fish (Albaladejo and Corpuz, 1981). The Philippines has a reputation for poor quality fish because of the collection techniques employed which include the use of sodium cyanide and explosives (Dawson-Shepherd, 1977; Albaladejo and Corpuz, 1981). The average volume and destination of fishes exported every month is monitored with the assistance of the Fisheries Unit Personnel, National Export Coordinating Center (NECC). It was concluded that, without proper resource management, the supply of aquarium fishes would rapidly dwindle and extensive destruction of reefs would result (Albaladejo and Corpuz, 1981). There is high mortality of fishes between the time of collection and the time of export because of the limited experience of many people engaged in the industry, the collection methods used, fierce competition and low market prices.

Singapore

There is much re-export to the U. K. and other locations through Singapore from Thailand, Malayasia, Indonesia, Sri Lanka and the Philippines (Wood, 1985).

Indian Ocean

Kenya

Kenya is the largest supplier to the U. K. in East Africa. Collection is strictly regulated and demand exceeds supply (Wood, 1985).

Sudan

Export of native marine species for the ornamental trade is prohibited (Wood, 1985).

Red Sea

Little is exported because of strict regulations on collecting (Wood, 1985).

Sri Lanka

Between 25,000 and 30,000 boxes are exported annually containing approximately 200,000 fish and 400,000 invertebrates.

This is the largest exporter to the U. K. with 139 species appearing on exporters' trade lists. Many collectors believe that aquarium fish species are less abundant now than prior to the development of the aquarium trade. Fish from Sri Lanka are generally considered to be of acceptable quality (Wood, 1985). There is concern for the vulnerability of certain endemic or rare species to overcollection. Also, nothing is known of the secondary consequences of removing large numbers of fish or invertebrates from an ecosystem. It has been suggested, for example, that population explosions of coral-eating starfish, Acanthaster planci, in Sri Lanka, could have been caused by removal of fish that eat its larvae (Wood, 1985).

Maldives

Export of aquarium fish from the Maldives began in about 1980, and by 1988 exports had doubled (Edwards, 1988). The Maldives is now considered to be an attractive base for this industry because of an international airport with direct flights to Europe and abundant reefs. Two business are involved with 25 people. Holding facilities are good with central filtration, protein skimmer and sterilization capacity. Packaging techniques and practices are good. One hundred species are exported, although just 20% of species contribute to 70% of exports. Quality of fish is perceived to be good because of sound collection practices.

Fish are either exported directly from the Maldives or via Sri Lanka. Collection is regulated and the trade carefully monitored (Edwards, 1988). There is concern over possible conflicts between the collection of fish and the tourist industry, as well as the potential for negative environmental and ecological impacts resulting from overexploitation. No collecting is permitted within approximately 1000 m of tourist islands (Wood, 1985). Quotas of 100,000 (fish plus invertebrates) have been introduced to prevent expansion of the trade and these are strictly enforced (Edwards, 1988). However, it is considered to be difficult to select which species should be subject to export quota. Some species are believed to be more likely to experience high levels of mortality if removed from the reef and thus need specific protection. For example, certain butterflyfishes do not feed well in captivity and their mortality is high. Other species are rare or live in limited or specialized habitats and are considered to be vulnerable to overcollection (e.g. Amphiprion spp.), or are important for reef health such as 'cleaners' (species of fish or invertebrate, commonly shrimp, that clean the ectoparasites from the bodies of other fishes).

Djibouti

The potential for developing an export trade in marine aquarium fishes in Djibouti was recently investigated to draft a preliminary management policy for the exploitation of marine ornamental fish. Evaluated were the nature of the resource base, the potential impact of collecting on the ecology of the area and on the artesenal fishery. If this trade were to be developed it would likely represent a major export. Djibouti has no national product or export and relies largely on foreign aid (Barratt and Medley, 1990). Recommendations developed from initial assessments recognized that exploitation should be based on resource availability and that there could be successful trade provided there is sufficient management and protection of resources from overexploitation. Certain species such as Amphiprion spp. were perceived to be particularly vulnerable to heavy exploitation because of easy capture and specialized habitat i.e. association with anemones.

Pacific

Australia

Australia's principal export trade is with the U. S. A. where some species may be held temporarily before re-export (Wood, 1985). Trade to the U. K. is limited largely because of long travel times. The size and nature of the aquarium fish industry is economically and ecologically important, and is expanding fast. However, little information is available on target species involved or on acceptable collection levels (Whitehead et al., 1986). Collectors must have prior written permission from the Government to use chemicals or explosives for collection. Permits and licences exist depending on whether collection is recreational or commercial, or whether it takes place in zoned (protected) or unprotected areas, to ensure reasonable collecting, to reduce user conflict, and to conserve reefs (Whitehead et al., 1986).

Hawaii

Hawaii is an important exporter of marine ornamental species. The fish are reputed to be of high quality and mortality is low because collection with chemicals and explosives is prohibited (Poollen and Obara, 1984; Wood, 1985). The trade is of economic importance but considered to be of potential damage to reef ecosystems. Collection is prohibited in marine conservation areas. Collectors need permits to use nets and are required to maintain fish, prior to export, in reasonable health and in adequate holding facilities, which are periodically inspected (Wood, 1985). They must also submit monthly catch reports (Walsh, 1978). Businesses are small and the collector is usually the exporter. More than 60 licenced collectors were involved in the early 1980's (Randall, 1984), with an estimated total of 89 people participating in the industry at all stages, including packing and shipping (Poollen and Obara, 1984). The most important single fish species exported is the yellow tang (*Zebrasoma flavescens*) followed by a number of butterflyfish, angelfish and other tang (acanthurids). Some of these species were noted to have declined in collections between 1976-1982 (Poollen and Obara, 1984) and many fish collectors recognize the need for management of the industry to prevent overexploitation.

Western Atlantic

Florida

Attention was focused on the aquarium trade in Florida in 1975 (Robins, 1976) when it was recognized that information on the biology and socio-economics, as well as possible user conflicts, was needed to characterize the industry. Florida exports both wild-caught as well as a small proportion of tank-bred species (mainly anemonefish). Mandatory landings figures have been collected from 1989 onwards from wholesalers. For April 1990 - March 1991, approximately 200 species, or species groups, were reported in landings data collected on trip tickets (Florida Marine Research Institute, Florida Department of Natural Resources (FDNR) data). Nearly two-thirds of the marine life fishermen live in Florida Keys (Januzzi, 1991). Because of many problems in the business, fishermen throughout Florida consider that some form of limited entry arrangement into the fishery is necessary (Januzzi, 1991).

The most frequently collected species reported were invertebrates (Condylactis gigantea - 316,000 organisms; sand dollars (several genera) - 211,000; various crabs - 120,000; turbinellid snails - 76,000; Lima scabra - 60,000, and substantial quantities of "live rock", recorded in pounds). The most frequently collected fish species were angelfish, wrasses, and damselfish (Holacanthus bermudensis - 28,000; Holacanthus tricolor - 27,000; Pomacanthus arcuatus - 17,000; Thalassoma bifasciatum - 16,000; Chromis cyaneus - 14,000). Considerably more invertebrates than fish were reported and there is concern particularly over the substantial numbers of anemones and volume of "live rock" being taken. Collection of "live rock" is to be phased out over the next three years. The economic importance of aquarium fishes has been reported to be high. For example, the U. S. dollar value from FDNR landings statistics in 1976, prior to the recent growth in the industry, indicated that aquarium fishes ranked eighth in economic importance in Florida (following grouper and king mackerel).

The taking of organisms for the aquarium trade is regulated in Florida State and Federal waters. As of January 1st, 1991, regulations (Chapter 46-42 - Marine Life) were in effect to protect and conserve Florida's tropical marine life resources and assure use of non-lethal methods of harvest. The taking of several species of vertebrate, invertebrate and plant is restricted. Longspine urchin, Diadema antillarum cannot be harvested. Some species are subject to maximum or minimum size limits. Bag limits or quotas are in force and there are permitting requirements for collection of plants and animals, or the use of certain collection methods. Quinaldine use requires a permit which allows up to a 2% quinaldine concentration in solution in seawater, mixed with isopropyl alcohol or ethyl alcohol (acetone may not be used as a solvent).

Curaçao

In 1970, four licenced exporters were known to be exporting marine ornamental fish and invertebrates, including "live rock", for the aquarium trade. Data on the export of fishes and invertebrates from Curaçao between 1972 and 1977 indicate that all fish were collected using quinaldine (Kruijf, 1978). After 1976 the taking of stony corals was prohibited. Principal species exported to the U. S. and Europe over this period were *Gramma loreto* - 48,185; *Condylactis giganteus* - 41,530; *Sabella* spp. - 34,586; *Centropyge argi* - 24,751; *Opistognathus aurifrons* - 24,244; *Holacanthus tricolor* - 14,272; *Myripristis jacobus* - 13,219; *Pomacanthus paru* - 10,693). Exports after 1975 declined for two reasons; collectors around Miami came to supply an increasingly large proportion of the U. S. market, and the opening of reef areas in Haiti produced supplies of organisms for the U. S. market at very low prices. Concern was expressed that two of the most commonly collected species, *H. tricolor* and *P. paru*, might require collecting limits because of their relatively low abundance (Kruijf, 1978). *Holacanthus ciliaris* - the queen angel - is a rare species which cannot be collected (Lubbock and Polunin, 1975).

Barbados

This is the principal Caribbean source of aquarium trade fishes to the U. K. and accounts for 2% of total U. K. imports (Wood, 1985). Use of quinaldine is not permitted.

U. S. Virgin Islands

Some export of marine organisms occurs. Licensing is required for the export of indigenous and endangered species (Jim Beets, pers. comm.) and a 10% export tax is in effect. Principal species exported are *Gramma loreto*, *Opistognathus aurifrons*, angelfish species and a number of invertebrates.

Hispaniola

Exports from Haiti increased in the mid 1970's (Kruijf, 1978). Fish prices were low and labor was cheap. Haiti is believed to be a principal shipper to the U. S. A. (Mark Derr, pers. comm.). Reports indicate that alcohol and quinaldine are used extensively to capture fish and that the resulting fish quality is poor. Substantial export activity has also been reported to occur from the Dominican Republic although specific information was unavailable.

Bahamas

Use of bleach for fish capture has been reported from the Bahamas (Hess and Stevely, no date).

Puerto Rico

Export of organisms for the aquarium trade began in about 1970. In the early 1970's, Lubbock and Polunin found Puerto Rico listing 49 species available for export (Lubbock and Polunin, 1975). In 1983, Puerto Rico supplied 0.1% of total U. K. imports, representing approximately 123,000 kg in weight. The U. S. is the principal import market. Until recently the number of collector/exporters has been small but over the last 2-3 years there has been an increase in collecting and export activity on the Island. Possible reasons for this are the excellent air transport facilities, the increased restrictions on Florida-based collectors, and increased demand for marine aquarium organisms in general. Listings of exported species are provided to Puerto Rico's Department of Natural Resources personnel at the Luis Muñoz Marín airport where shipments must be inspected. Summaries of these data are not compiled. The aquarium fish trade is not specifically regulated, although collection of a number of marine species (e.g. lobster with carapace length less than 3.5" and removal of corals including sea fan/gorgonian) is prohibited, as is the use of poisonous substances in Puerto Rico waters (regulated under Law No. 83, May 13, 1936, known as the "Ley de Pesca", and amendments), and the taking of "live rock" (Law No. 132, June 25, 1968, amended). The treatment of animals maintained in captivity is also regulated (Ley, 67 May, 1973, known as the "Ley para Protección de Animales"). Exporters do not have to be licenced and collectors are not legally recognized as commercial fishermen.

THE MARINE AQUARIUM TRADE IN PUERTO RICO (1990-1991)

Collection of Data

Information on the aquarium trade in Puerto Rico was obtained from conversations with knowledgeable contacts both within and outside the aquarium trade in Puerto Rico and in Florida, as well as officials of the Florida and Puerto Rico Departments of Natural Resources. All individuals known to be active in the export trade for a number of years were either visited at their business facilities or interviewed by telephone. Information was summarized on species, or species complexes, indicated on company trade lists as available in Puerto Rico, species, or species complexes, actually exported (by number of organisms), and numbers of boxes of organisms imported and exported per month, for 1990-1991. Export information was obtained from export packing lists of individual shipments (shipping lists) from a total of 92 (species composition of exports data) and 81 (boxes exported data) shipping lists, respectively (11 shipping lists had species composition data but did not show numbers of boxes exported). The shipping lists utilized do not constitute a random subset of all island exporters as some, not necessarily the biggest shippers, are more frequently represented than others.

Collectors/Exporters

Most collectors are exporters, although some collectors also sell their catch to an exporting middleman, or, less frequently, to Island pet shops. There are at least 6 export businesses on the Island. These are based in western and southern Puerto Rico and also out of San Juan. Three of these businesses have been established in the export trade for a number of years, others are relatively recent: several collectors started by selling locally and then later began to export. One recently established business is reportedly initiating a breeding program for Indo-West Pacific anemonefish (clownfish). Combined, the businesses depend on about 40 regular collectors working on a full- or part-time basis, with additional individuals collecting on a more casual basis. I would estimate that less than 100 people are involved in all phases of the aquarium trade, from collectors and their assistants, to biologists, packers and shippers. Most exporters depend for the majority of their income on the export trade, but often have other means of income outside of the aquarium industry.

Methods Used for the Harvest of Marine Organisms

Major collectors have their own boats, diving and collecting gear. Boats are in the order of 7 m in length. Collecting trips may be made 7 days a week if weather permits and demand is high, otherwise collecting trips may be made 3-4 days weekly. Demand tends to be highest in the winter and lowest in the summer months (Wood, 1985; pers. comm.). Collectors visit specific collecting areas depending on species being sought and indicate that they are careful to rotate the area of collection to avoid fishing too heavily in any one location. 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 is by net (barrier, gill, drop or cast, and hand or dip nets), fish trap (1/4 - 1/2" mesh, and specialized traps - for example to catch Gramma loreto), chemicals such as 'Quinaldine', and slurp gun (not common). Cast nets are small circular nets with weights attached along the outer edge, and hand or dip nets are generally comprised of 1/8" monofilament mesh and may incorporate plastic panels. There are also reports that bleach, formalin and gasoline have been used on occasion, especially in the area of La Parguera. Quinaldine (2-methyl-quinoline) is mixed with isopropyl or ethyl alcohol or acetone, diluted with seawater and dispensed from bags, small plastic bottles or pressure sprayers. It is derived from coal tar and used in the manufacture of dyes and explosives (Hess and Stevely, no date). There is considerable debate regarding the short- and long-term effects of this chemical on fishes and invertebrates, although it is clear that it is toxic to certain species (see below). Many wholesalers are reluctant or refuse to purchase fish collected with quinaldine because they believe that mortality rates are higher than with net-caught fishes. Some collectors interviewed indicated that quinaldine-caught fish may be detected visually by damage to gills which come to look "burned" or pinker than the gills of fish not exposed to this chemical. Many locations prohibit the unpermitted use of quinaldine because of its perceived detrimental effects on marine organisms (e.g. Hawaii and Florida).

Areas Collected

Collection areas are north and south of the Rincón peninsula, Punta Arenas in Cabo Rojo (for sea mat - *Zoanthus*), and along the northwest coast to Arecibo for certain species such as angelfish and blennies (Fig. 1). The island of Desecheo 20 km west of Rincón is especially suitable for yellowhead jawfish (*Opistognathus aurifrons*), royal gramma (*Gramma loreto*) and pygmy angelfish (*Centropyge argi*). Collecting is also carried out extensively around the reefs and mangrove islands of La Parguera, especially for invertebrates and queen angelfish, as well as southeast of Ponce, especially off the island of Caja de Muertos, 8 km offshore, for angelfish and triggerfish, and between Ponce and Salinas. No collection sites could be confirmed off eastern Puerto Rico although collection has recently been proposed for Fajardo and Isla Cabra, and has been reported to occur sporadically in Culebra.

Species Collected

Species composition, as determined from trade lists and exporters' shipping lists, of 5 different shippers between 1990 and 1991, is shown in Table 1. A total of 155 species (plus a few "miscellaneous" invertebrate species which could not be identified to genus), or species groups, appeared on traders' lists, as available in Puerto Rico, 104 fish species and 51 (+ miscellaneous) invertebrates. Of these, 83 fish species and 23 (+ miscellaneous) invertebrates were noted as exported. Examination of a subsample of 92 shipping lists from 4 different shippers indicated that 6 species, or families, made up 70% of the total fish export: Gramma loreto; Opistognathus aurifrons; Holacanthus tricolor; Pomacanthus paru; Balistes vetula, and assorted blennies. Principal fish families exported were Grammidae, Opistognathidae, Pomacanthidae, Chaetodontidae, Pomacentridae, Holocentridae, Blenniidae, Labridae, and Balistidae. Individuals are taken between 3.5 - 13 cm depending on the species.

A wide variety of invertebrates was exported, in particular anemones, shrimps, crabs, flame scallop, and various echinoderms, e.g. brittlestars. There were difficulties in identifying to species a variety of species. Often, common names were used which are not species-specific or names of species not present in Puerto Rico, or even in tropical waters, were applied. Several species were listed as available on company trade lists (although not recorded as shipped) the taking of which is not permitted (e.g. lobster, gorgonian/sea fan). Removal of certain species would require removal of substrate and hence come under the definition of "live rock" (e.g. Ricordea florida). I believe that the volume of invertebrates exported is grossly under-represented in shipping lists. It has been reported, for example, that in a single day collectors take many hundreds of anemones from La Parguera.

Handling and Shipping of Marine Organisms

Animals are taken to holding facilities and generally retained for a few days prior to packing and export. Facilities vary from a small number of plastic "paddling pools" fed by a simple flow-through water system, to a series of glass and concrete tanks, under-gravel and ultra-violet filters, and protein skimmers. On several occasions I observed small numbers of unhealthy fish (pale in color, fins torn, listless) in holding facilities. Some collectors report that fish considered to be in less than good health are returned to the sea.

For shipping, animals are packed in single or double plastic bags. These are filled with oxygen by some shippers, and the bags closed and placed in boxes for shipping. Boxes vary in dimension from 30 x 43 x 43 cm (12 x 17 x 17") to 53 x 53 x 53 cm (21 x 21 x 21") and may or may not be lined with insulating material for stabilization of temperature, depending on shipper, destination and season. The majority of marine organisms is currently shipped out of San Juan (Luis Muñoz Marín airport) to the east and west coasts of the U. S. A., Canada, and to Europe, particularly to the U. K. and Germany. However, some export also occurs out of

Aguadilla, and reportedly on occasion through the postal system (Federal Express) and United Parcel Service (U.P.S.).

Listings of exported species are provided to Department of Natural Resources personnel at the Luis Muñoz Marín airport where shipments are inspected. Shipments must also be checked by the U. S. Division of Fish and Wildlife, who charge a $25 inspection fee, if for export outside U. S. territory

Estimates of mortality from the time of capture to the time of export reportedly varies between 10% and 20% depending on capture and handling methods, the level of skill of collectors and conditions of holding facilities. This estimate of mortality is high compared to mortality rates reported for net-caught fish in Hawaii (Poollen and Obara, 1984) and relative to the most commonly cited level in the industry of 10% (Wood, 1985). Some fish importers consider that mortality rates of more than a few percent are unacceptable (pers. comm. Richard Sankey).

Estimated Export/Import Volume (1990-1991)

From the shipping lists, it was determined that an average shipment of fish and invertebrates comprised 12 boxes (range 2 - 29) and that each box on average contained 31 organisms (range 7 - 100, depending on the species involved and their size). It was estimated from interviews with exporters that an average of at least 9 shipments a week leave Puerto Rico. This provides a monthly estimate of 432 boxes exported per month (9 x 12 x 4), and 5184 boxes per year, containing an annual total of 160,704 organisms (9 x 12 x 4 x 12 x 31). This does not include U. S.

mail or U. P. S. shipments. Exporters vary in the number of shipments from 1-3 per week. Boxes were estimated to weigh between 8-14 kg, if not containing coral or "live rock". To put into perspective the current volume involved in this trade, the estimated number of organisms exported is approximately equivalent to the total number of grouper reported landed annually by the comemrcial fishery of Puerto Rico (Fisheries Research Laboratory, PRDNR, unpubl. data). Grouper are among the most frequently landed fish categories on the Island.

The number of boxes exported appearing in Department of Natural Resources records (2448 for 10 months) (Table 2) is clearly a gross underestimate of true exports. This conclusion is supported in part by reports of zero boxes in June, July and August, 1991, during which months export shipments were made according to interviews with collectors/exporters. Furthermore, Department figures did not include shipments out of the Aguadilla airport where airport inspection activity is reported to be minimal. Substantial imports of marine organisms were also noted (Table 2).

SPECIES DESCRIPTIONS OF COMMONLY EXPLOITED MARINE ORGANISMS

Fish Species

For the majority of species exploited, there is little life history information available. Only data on the most commonly exported species, as determined from shipping lists, are summarized. However, other species of importance for the industry are damselfish, such as blue chromis, Chromis cyanea, the pygmy angelfish, *Centropyge argi*, and a number of squirrelfish species and blennies, in particular the red-lipped blenny, *Ophioblennius atlanticus*.

Gramma loreto - royal gramma, fairy basslet (Grammidae)

A violet/yellow colored fish commonly found in groups of 2-3 to dozens or more in clear waters down to about 60 m although generally in shallower water (Böhlke and Chaplin, 1968; Randall, 1983). Its range extends from Bermuda and the Bahamas throughout the Antilles to islands off Venezuela. It is apparently absent from Florida (Böhlke and Chaplin, 1968). It is found in high vertical relief habitat, in caves and under ledges in restricted home ranges where residency has been reported up to 76 weeks (Luckhurst and Luckhurst, 1978). It is mainly planktivorous (Luckhurst and Luckhurst, 1978), although it has been reported to feed on the ectoparasites of other fish (Eibl-Eibesfeldt, 1955). It attains just over 8 cm in total length and shows little sexual dimorphism other than a somewhat larger male mean size (Thresher, 1984). Reproduction in Puerto Rico occurs between January and June (Amador, 1982), and in Curaçao recruitment was noted through much of the year, with peaks in September and May (Luckhurst and Luckhurst, 1978). Information on the biology of this species is scattered and fragmented and there is some debate over its sexual pattern, which has been proposed to be hermaphroditic (Corsten and Corsten, 1974). This is considered to be a common western Atlantic species (Randall, 1983). It is captured predominantly using quinaldine with which 300-500 individuals may be captured in a day. Occasionally a specially designed hand trap may be used but catch rates are reported to be substantially lower than with quinaldine. Several aggregations of this species were monitored after partial or total removal (Kruijf, 1978). Replacement occurred within 1-4 weeks and was dependent on levels of recruitment into the area.

Holacanthus tricolor - rock beauty (Pomacanthidae)

A pomacanthid (angelfish) found in the western Atlantic from Georgia, Bermuda and the Bahamas to Brazil and in the Gulf of Mexico (Böhlke and Chaplin, 1968; Randall, 1983). It occurs to depths of approximately 10 m and forages solitarily during the day, feeding on algae and sponges, and occasionally ascidians, fish eggs, gorgonians and zooantharians (Neudecker and Lobel, 1982). It has been reported to attain 34 cm in length (Munro, 1983), although it is not generally of value to the aquarium trade at lengths greater than 13 cm. The young up to about 2.5 cm are yellow in color with a black spot on the upper side of the body posterior to the mid-point. This spot later grows to become the large dark area covering most of the body, and dorsal and anal fins (Randall, 1983). Juveniles may feed on the cutaneous mucus of larger cave-dwelling fishes (Thresher, 1984). Spawning has been observed at dusk in triplets or small groups of one male and several females, throughout much of the year (Moyer et al., 1983; Munro, 1983). The smallest mature female was recorded at 10 cm total length (Munro, 1983), and the eggs are planktonic. Individuals are relatively sedentary. Females have overlapping home ranges and males defend large territories with a mean area of approximately 1,000 m^2 which encompass a number of female home ranges (Hourigan and Kelley, 1985). The sexual pattern of this species is unclear and protogynous hermaphroditism has been proposed (Hourigan and Kelley, 1985). The species is sexually monomorphic. Rock beauty are caught using large hand nets, and with quinaldine.

Holacanthus ciliaris - queen angelfish (Pomacanthidae)

This angelfish is colored blue/green and yellow. There is no sexual dichromatism. It is distributed in the tropical western Atlantic from the Gulf coast of Florida and the southern Gulf of Mexico, through the Bahamas down to Brazil (Böhlke and Chaplin, 1968; Randall, 1983). It has been collected to a maximum length of 43 cm (Randall, 1983), and is often found in triplets or small groups (Thresher, 1984). Ripe fish have been reported in all months of the year except November and December (Munro et al., 1983). Individuals tend to stay in the same general area (Randall, 1962). This species is taken with nets and quinaldine. Its capture is banned in Curaçao because of its rarity (Lubbock and Polunin, 1975).

Pomacanthus paru - french angelfish (Pomacanthidae)

The adults of this species are grey and the juveniles are black with vertical yellow bands. Juveniles are known to pick the skin of various fish species and have been observed cleaning the teeth of large needlefish (Böhlke and Chaplin, 1968). It is distributed in the western Atlantic from the Bahamas and Florida to Brazil. Ripe individuals were collected from May to November in Jamaica (Munro, 1983). French angelfish have been reported to reach 41 cm (Randall, 1983), although only individuals up to about 13 cm are used for the aquarium trade. They are taken with hand nets and quinaldine.

Bodianus rufus - spanish hogfish (Labridae)

A red/violet/yellow fish with a black spot on the anterior portion of the spinous dorsal fin. It is recorded in the western Atlantic from Bermuda, the Bahamas and Florida to Brazil, including the Gulf of Mexico, the coast of Central America and Venezuela (Böhlke and Chaplin, 1968; Randall, 1983). This is a reef-associated species found down to about 40 m. The young pick parasites from larger fishes. Individuals have been reported to reach about 40 cm (Randall, 1983) and feed on crabs, sea urchins, brittlestars and mollusks. The social structure is characterized by stable dominance hierarchies that are linearly organized according to sex and relative size. Males are generally larger and dominate groups of up to 12 females in permanent territories (Hoffman, 1985). Females mature at about 10 cm and spawning occurs daily at sunset through much of the year. Eggs are planktonic and the species is protogynous (Hoffman, 1985). Individuals are predominantly caught by hand net and quinaldine.

Thalassoma bifasciatum - bluehead wrasse (Labridae)

This is one of the most abundant West Indian reef fishes and is distributed from Bermuda and the Bahamas, southern Florida, southern Gulf of Mexico, throughout the Caribbean Sea to the islands of the north coast of South and Central America (Böhlke and Chaplin, 1968; Randall, 1983). The species has several different color phases, exhibiting marked sexual dichromatism, and its name derives from the largest phase, that of the adult male. It feeds on small benthic animals and zooplankton, and the juveniles feed on the ectoparasites of other fishes (Randall, 1983). It spawns through much of the year in pairs or groups at about midday, is a diandric protogynous hermaphrodite, and produces planktonic eggs (Thresher, 1984). Some males defend territories and females have home-ranges. It is reported to reach about 15 cm (Randall, 1983). Only blueheads are caught for the aquarium trade in Puerto Rico resulting in differential male removal from exploited populations. Individuals are generally taken by hand nets to which they are attracted by bait such as crushed sea urchin.

Halichoeres radiatus - puddingwife wrasse (Labridae)

The puddingwife wrasse is known from Bermuda and North Carolina to Brazil (Böhlke and Chaplin, 1969), and is recorded to reach a length of 46 cm (Randall, 1983). It is found in areas of coral cover where individuals are often seen singly, and is somewhat secretive. The species exhibits sexual dichromatism and is reported to be hermaphroditic. The smallest mature female recorded was 16 cm in standard length (Warner and Robertson, 1978).

Opistognathus aurifrons - yellowhead jawfish (Opistognathidae)

A yellow/white colored jawfish which is found in the

Florida Keys and throughout the West Indies (Randall, 1983). It usually lives in sandy areas in vertical burrows lined with small stones or shell fragments above which it is most commonly seen to hover as it feeds on zooplankton (Randall, 1983; Thresher, 1984). It occurs in relatively shallow water and attains a length of about 10 cm (Randall, 1983). Its abundance has been reported to vary seasonally and it is often found in large groupings (Kruijf, 1978). Spawning occurs in the burrow and males incubate eggs in their mouth. Eggs hatch within 7-10 days and settlement occurs at about 10-15 mm (Thresher, 1984). The species is sexually monomorphic and is a popular aquarium fish (Thresher, 1984). It is caught predominantly by using quinaldine, although this species is reported to be particularly sensitive to quinaldine and is easily killed by overdosing (Colin, 1975).

Balistes vetula - queen triggerfish (Balistidae)

Distributed from Massachusetts to Brazil, this is a common species on reef or rocky areas, but ventures to adjacent sand rubble or seagrass areas (Randall, 1983). Adults are solitary diurnal feeders on a great variety of invertebrates but particularly on sea urchins, such as Diadema (Randall, 1983). It may also be found in schools and has been reported to occur down to 100 m (Munro, 1983), although smaller individuals are generally found in shallow water. The queen triggerfish is reported to attain a fork length of 57 cm (Randall, 1983) and to mature sexually at about 17 cm (Munro, 1983). Ripe individuals have been collected between January and August in Puerto Rico (Erdman, 1976). This species is commercially exploited and rated number 16 of the 33 most economically-important fish groups in Puerto Rico in 1990 (Matos and Sadovy, 1991). Individuals are taken with quinaldine at about 5 - 7 cm length - only juveniles of this species are apparently exploited for the aquarium trade.

Invertebrate Species

A wide range of invertebrate species are taken, in particular brittlestars, cleaner shrimps, flame scallops and anemones (Table 1). Reports indicate that several hundred individuals of the anemone Condylactis may be taken in a single day from La Parguera, a location particularly popular for collection of invertebrate species. A number of species reported as being available on traders' lists are in reality what should most accurately be described as "live rock". For example, Ricordea florida must be removed with its rocky substrate and is considered one type of "live rock" in Florida. Certain species such as the flame scallop, some feather dusters and the christmas tree worm are typically removed with accompanying substrate and should likewise be considered "live rock". Collection of brittlestars and some tube worms may necessitate the lifting or displacement of rock or coral substrate. Some organisms are extracted individually from sandy substrates. Cleaner shrimp are removed from host anemones. The effect of the removal of cleaners (fish or shrimp species) on the general health of reef fish is unknown. The long- and short- term effects of using quinaldine both on individuals captured, or impacted when other species are being taken, or on associated habitat at time of capture are not clear. However, its effect is clearly toxic in some cases. This chemical has been shown to cause no damage to certain scleractinian corals during preliminary studies but was found to have a detrimental effect on two coral species, *Agaricia agaricites* and *Meandrina meandrites* (Jaap and Wheaton, 1975). Jellyfish may be killed instantly by quinaldine (Ireland and Robertson, 1974), and crustaceans and cephalopods showed signs of irritation at quinaldine concentrations used to anesthetize fishes, although it is unclear if it was the alcohol associated with the quinaldine or the quinaldine which causes the reaction (Hess and Stevely, no date). This chemical has also been shown to induce significant histopathological changes in the thyroids of mice, and thyroid abnormalities have also been encountered in people exposed to quinaldine (Dr. F. Khafagi, Director of Nuclear Medicine, Royal Brisbane Hospital, Herston, Brisbane, 4029, Australia).

BIOLOGICAL AND SOCIO-ECONOMIC DATA NEEDS

In order to monitor and evaluate the volume, nature and potential impact of the marine aquarium trade in Puerto Rico, information is needed, on an annual basis, on the number of individuals collecting and exporting organisms, the numbers and types of animals collected and exported, and the extent of trade in aquarium organisms within Puerto Rico i.e. non-export trade. Also, some means of measuring catch per unit effort (perhaps on a per trip basis) should be established.

Species identification of a number of invertebrate organisms needs clarification by direct examination of specimens, if possible, and the principal collection areas should be assessed regarding their significance, if any, as critical habitats. The capture methods employed need to be evaluated to ascertain to what extent these may impact detrimentally either targeted or non-targeted species and associated habitat. In particular, the short- and long-term impact of using quinaldine to collect vertebrate and invertebrate species must be addressed if limited use of this chemical is to be permitted.

The potential for user conflict between aquarium industry collectors, commercial fishermen and the tourist/recreational industry needs evaluation. Stock analyses of species exploited by more than one user group (such as the queen triggerfish, Balistes vetula) should be made to determine the combined impact of removal of individuals at distinct life history phases, by different user groups, on the overall condition of the stock. The impact of collection activities on areas programmed for tourist development, such as Caja de Muertos, should be evaluated.

Biological data on the life history of principal species exploited is inadequate, particularly with respect to reproductive biology, and special habitat requirements, vulnerability to collecting methods, if any, and abundance on a local and island-wide level. Assessment of commonly collected organisms regarding their suitability as aquarium species would enable formulation of recommendations concerning species considered appropriate for exploitation by the industry. For example, if mortality in aquaria is high (such as determined for certain butterflyfishes, see above), exploitation for the aquarium industry should be discouraged. It is necessary to assess the holding and shipping techniques utilized by collector/ exporters to ensure that mortality is minimized, the animals treated humanely, and hence that best use is made of exploited resources.

The time required for recolonization of an area following heavy collection should be assessed. For example, areas heavily collected in the Bahamas using rotenone and subsequently monitored were found to exhibit disturbances in population balance for at least 4 months following collection. Between 4-9 months were required to re-establish the pre-collection population equilibrium (Smith, 1973). The time required for recolonization by Gramma loreto was found to be dependent upon availability of recruits (Kruijf, 1978). A study by Taylor and Nolan carried out over 2.5 years in Hawaii on the 5 most frequently exploited fish species indicated that more heavily collected areas did not show greater reductions when compared to non-collected areas but did indicate population fluctuations in certain species for both collected and uncollected areas (Taylor and Nolan, 1978). Populations of heavily fished species (e.g. royal gramma, yellowhead jawfish, angelfish species, and a number of invertebrates) should be monitored to determine the impact of heavy collection, and how this may vary seasonally. Recommendations regarding appropriate periods for collection, or for protection of collected areas or species, based on biological knowledge of population responses to collection, could be made to reduce the possibility of over-exploitation.

MANAGEMENT OPTIONS AND CONSIDERATIONS

1. Collectors and exporters of marine organisms for the aquarium trade should be licenced to collect and export marine organisms, and the number of licences limited according to availability and suitability for exploitation of fish and invertebrate resources. To prevent further expansion of the industry until the necessary studies and evaluations are available, licences could be restricted to those individuals who can clearly demonstrate current and substantial activity in the industry in Puerto Rico. Licence applications should include socio-economic details of applicants.

2. Licenced collectors/exporters should be required to submit monthly reports on numbers of each species captured, as well as exported or sold in Puerto Rico, and location and method of capture. Listings should include both common and latin names.

3. 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. Exporters should demonstrate knowledge of Commonwealth and Federal laws pertaining to the capture, treatment and shipping of marine organisms.

4. The use of quinaldine to capture fishes should be unequivocally prohibited on the basis of its proven toxicity to certain fish and coral species, pending further study of its effects, if this should be determined as necessary. The use of any other

capture method determined to be damaging to organisms harvested, or to the coral reef environment, should be prohibited, or carefully regulated.

5. Inspections of export shipments should be thorough and made on all shipments from both San Juan and Aguadilla (or others as necessary) airports, or any other shipment points. Inspectors need to be trained to recognize marine species of fish and invertebrates. Any box weighing over approximately 14 kg should be carefully inspected for coral or "live rock". Shipment weights should be noted, and monthly figures showing export volume (by number of boxes and by weight should be made available in summarized form.

6. Consideration should be given to the possibility of introducing annual quotas for the capture of certain vulnerable or uncommon species (possible candidates are sea horses and swiss-guard basslets), species which do not survive well in captivity, or species which may be of particular importance to the reef ecosystem, such as fish and invertebrates which clean ecto-parasites off other species. Global annual catch quotas, in addition to limited entry (item 1), should be introduced to prevent expansion of collection activity while the resource base and other biological questions are being assessed.

7. Consideration should be given to the imposition of size limits (minimum and/or maximum) to protect life history phases deemed to be particularly vulnerable to overexploitation.

8. A summary of laws which relate to all phases of the collec-

tion, handling, maintenance, and sale and export of organisms for the aquarium trade should be developed and pertinent regulations clarified and communicated to the industry.

9. Collectors and exporters of marine organisms marketed for the aquarium trade should be encouraged to participate fully in the development of a management policy for the fishery.

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TABLE 1:

Fish and invertebrate species, or species groups, exported from Puerto Rico, or indicated on company trade lists available for export, according to trade lists and shipping lists for 1990/1

FISHES:

Elasmobranchs	SHARKS, SKATES, RAYS	
Gymnothorax miliaris	GOLDENTAIL MORAY	44
Gymnothorax funebris	GREEN MORAY	
Myrichthys oculatus	GOLDSPOTTED SNAKE EEL	4
Echidna catenata	CHAIN MORAY	
Muraenids	MORAY "EELS"	8
Plectrypops retrospinis	CARDINAL SOLDIER	183
Holocentrus ascensionis	LONGJAW SQUIRRELFISH	5
Myripristis jacobus	BLACKBAR SOLDIERFISH	242
Holocentrids	SQUIRRELFISH	3
Apogon maculatus	FLAME/FISH/CARDINAL	98
Astrapogon stellatus	CONCHFISH	1
Priacanthus arenatus	BIGEYE	24
Priacanthus cruentatus	GLASSEYE	26
Chromis cyanea	BLUE CHROMIS	439
Chromis insolatus	SUNSHINE DAMSELFISH	20
Abudefduf saxatilis	SERGEANT MAJOR	12
Stegastes partitus	BICOLOR DAMSELFISH	
Stegastes leucostictus	BEAUGREGORY	49
Stegastes planifrons	YELLOW DAMSELFISH	20
Stegastes dorsopunicans	DUSKY DAMSELFISH	
Microspathodon chrysurus	YELLOWTAIL/JEWEL DAMSEL	299
Pomacentrids	DAMSELFISH	8
Thalassoma bifasciatum	BLUEHEAD WRASSE	612
Clepticus parrae	CREOLE WRASSE	43
Halichoeres cyanocephalus	LIGHTNING WRASSE	20
Halichoeres radiatus	PUDDING WIFE	587
Halichoeres maculipinna	CLOWN WRASSE	34
Halichoeres garnoti	YELLOWHEAD/NEON WRASSE	122
Xyrichtys splendens	RAZORFISH/GREEN WRASSE	26
Bodianus rufus	SPANISH HOGFISH	462
Labrids	WRASSES	
Sparisoma chrysopterum	REDTAIL PARROTFISH	
Scarus taeniopterus	PRINCESS PARROTFISH	
Scarids	PARROTFISH	20
Centropyge argi	PYGMY ANGELFISH	345
Pomacanthus paru	FRENCH ANGELFISH	882
Pomacanthus arcuatus	GRAY ANGELFISH	7
Holacanthus ciliaris	QUEEN ANGELFISH	114
Holacanthus tricolor	ROCK BEAUTY	1552
Pomacanthids	ANGELFISH	7
Chaetodon capistratus	4-EYE BUTTERFLYFISH	133
Chaetodon ocellatus	SPOTFIN BUTTERFLYFISH	
Chaetodon striatus	BANDED BUTTERFLYFISH	338

FISHES continued:

Chaetodon aculeatus	LONGSNOUT/NOSE BUTTERFLY	111
Chaetodontids	BUTTERFLYFISH	98
Gramma loreto	ROYAL GRAMMA	11124
Serranus tabacarius	TOBACCO FISH	57
Serranus tigrinus	HARLEQUIN BASS	76
Serranus annularis	ORANGEBACK BASS	1
Serranus baldwini	LANTERN BASS	13
Serranus tortugarum	CHALK BASS	54
Serranids	BASSES	14
Liopropoma rubre	SWISSGUARD BASSLET	6
Hypoplectrus nigricans	BLACK HAMLET	
Hypoplectrus indigo	INDIGO HAMLET	
Hypoplectrus unicolor	BUTTER HAMLET	
Hypoplectrus puella	BARRED HAMLET	
Hypoplectrus guttavarius	SHY HAMLET	1
Hypoplectrus gummigutta	GOLDEN HAMLET	
Hypoplectrus aberrans	YELLOWBELLIED HAMLET	
Serranids	HAMLETS	12
Paranthias furcifer	CREOLE FISH/ANTHIAS	135
Epinephelus fulvus	CONEY/GOLD CONEY	53
Epinephelus guttatus	RED HIND	12
Serranids	GROUPER	47
Rypticus saponaceus	SOAPFISH	1
Equetus punctatus	SPOTTED DRUM	21
Equetus lanceolatus	JACKKNIFE FISH	22
Pareques acuminatus	CUBBYU/HIGH-HAT	205
Chaetodipterus faber	SPADEFISH	6
Amblycirrhitus pinos	REDSPOTTED HAWKFISH	31
Anisotremus virginicus	PORKFISH	17
Ophioblennius atlanticus	REDLIP BLENNY	451
Blenniids	BLENNIES	948
Gobiosoma spp.	NEON GOBY	
Quisquilius hipoliti	RUSTY GOBY	
Gobiids	GOBIES	
Opistognathus aurifrons	YELLOWHEAD JAWFISH	2631
Opistognathus whitehurstii	DUSKY JAWFISH	126
Scorpaenids	SCORPIONFISH (STONEFISH)	8
Bothus lunatus	PEACOCK FLOUNDER	
	FLOUNDER	23
Symphurus arawak	CARIBBEAN TONGUEFISH	
Dactylopterus volitans	FLYING GURNARD/SEA ROBIN	437
Hippocampus spp.	SEA HORSE	24
Sygnathids	PIPEFISH	3
Acanthurus coeruleus	BLUE/YELLOW TANG	367
Acanthurus chirurgus	SURGEON TANG/DOCTORFISH	50
Balistes vetula	QUEEN TRIGGERFISH	920
Xanthichthys ringens	SARGASSUM/REDTAIL TRIGGERFISH	74
Canthidermes sufflamen	OCEAN TRIGGERFISH	1
Melichthys niger	BLACK TRIGGERFISH	76

FISHES continued:

Aluterus scriptus	SCRAWLED FILEFISH	
Cantherhines macrocerus	WHITESPOTTED FILEFISH	22
Monacanthids	FILEFISH	28
Lactophrys, Acanthostracion	TRUNKFISH, COWFISH	
Canthigaster rostrata	SHARPNOSE PUFFER	36
Diodon hystrix	PORCUPINEFISH	2
Antennarius spp.	FROGFISH	70
Ogcocephalus spp.	BATFISH	6
Synodus intermedius	LIZARDFISH	1
Mullids	GOATFISH	9
Aulostomids	TRUMPETFISH	60

INVERTEBRATES:

Haliclona spp.	ORANGE TREE SPONGE	45
	RED SPONGE	146
	ELEPHANT EAR SPONGE	50
	GORGONIANS/SEA FANS	
Tubastrea aurea	ORANGE POLYP (CORAL)	
Condylactis	CLUSTER ANEMONE/PINKTIP	382
Bartolomea annulata	CURLIQUE ANEMONE	150
	COLONY ANEMONE	45
Stoichactis helianthus	CARPET ANEMONE	105
Ricordea florida	GREEN ANEMONE	
Phymanthus crucifer	ROCK ANEMONE	10
Heteractis lucida	STINGING ANEMONE	
Aiptasia tagetes	ANEMONE	
Zoanthus spp.	ORANGE TUNICATE(?)/SEA MAT	
Sabellastarte magnifica	SOLO FEATHER DUSTER	75
Sabellastarte spp.	COLONIAL/CLUSTER DUSTER	61
Spirobranchus giganteus	CHRISTMAS TREE WORM	
Panulirus argus	SPINY LOBSTER	
Periclimenes spp.	ANEMONE SHRIMP	
Stenopus hispidus	RED-BANDED CORAL SHRIMP	102
Stenopus scutellatus	GOLD SHRIMP	2
Alpheus armatus	PISTOL SHRIMP	162
Lysmata spp.	PEPPERMINT SHRIMP/ SCARLET/LADY	15
Thor amboinensis	BUMBLEBEE SHRIMP	
Pseudosquilla	MANTIS SHRIMP	
Other hermits		10
Paguristes cadenati	RED LEG HERMIT	
Mithrax sculptus	GREEN/EMERALD CRAB	20
Percnon gibbesi	SALLYLIGHT/URCHIN CRAB	
	DECORATOR/SPONGE CRAB	
Stenorhynchus seticornis	ARROW CRAB	78
Mithrax cinctimanus	ANEMONE CRAB	

INVERTEBRATES continued:

Cyphoma gibbosum	FLAMINGO TONGUE	
Lima scabra	FLAME SCALLOP	280
	SPINY OYSTER	
Charonia variegata	TRITON	
Oliva reticularis	MEASLE COWRIE/OLIVE SHELL	
Tridachia crispata	NUDIBRANCH	
	OCTOPUS	
Astropecten	SAND STAR	76
Oreaster reticulatus	RED BAHAMA/WEST INDIES STARFISH	83
Subclass OPHIUROIDEA	BRITTLESTAR	180
Ophioderma	RED/SERPENT/BURGUNDY BRITTLESTAR	481
Astrophyton	BASKET STAR	
	CRINOID	
Diadema antillarum	LONG SPINE URCHIN	
Lytechinus spp.	PIN CUSHION URCHIN	
Eucidaris tribuloides	PENCIL URCHIN	103
Echinometra spp.	PURPLE/ROCK URCHIN	
Valonia ventricosa	SINGLE CELL	
Pencillus capitatus	NEPTUNE SHAVING BRUSH	
MISCELLANEOUS INVERTEBRATES		135

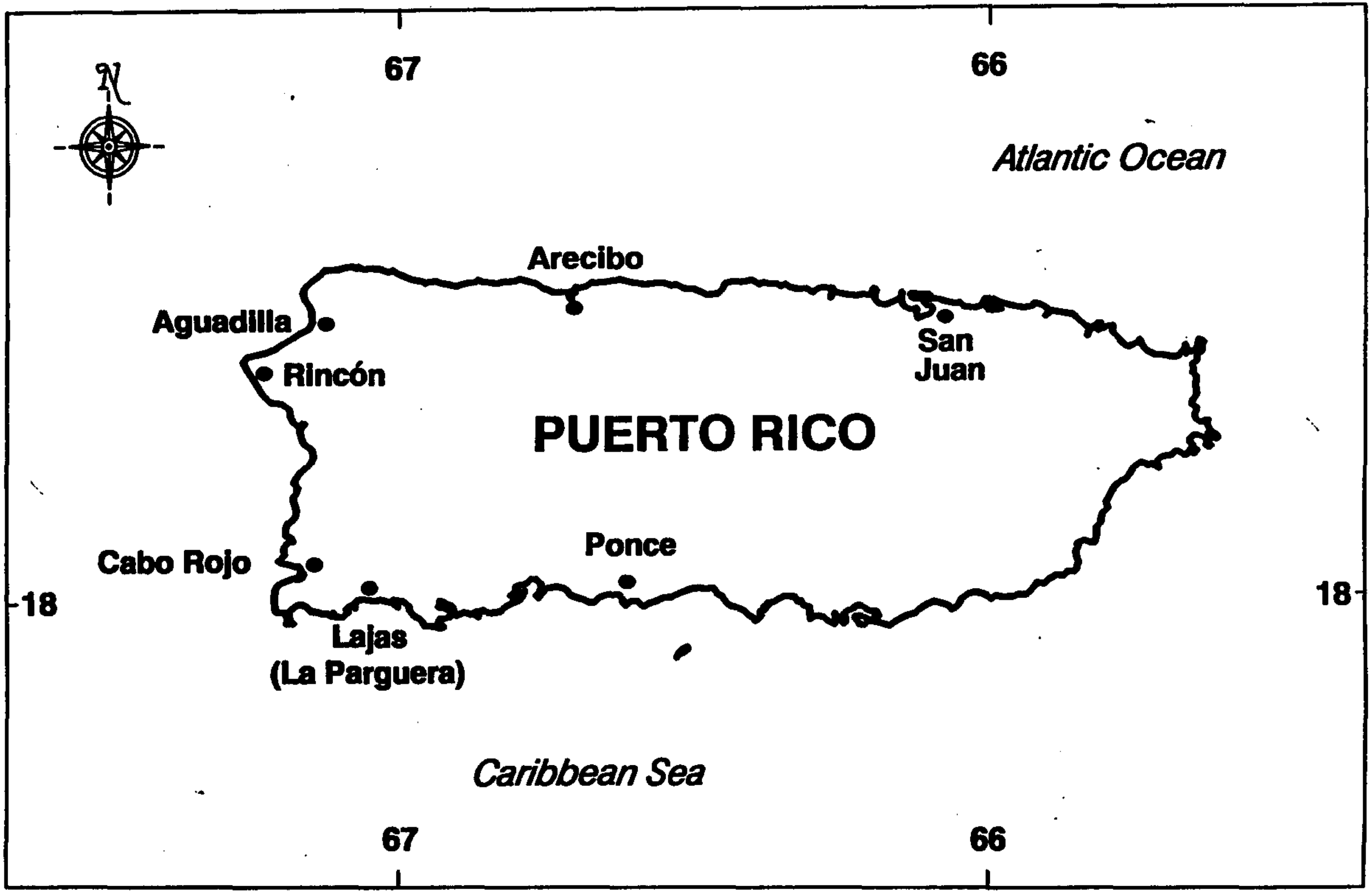
TABLE 2:

Numbers of boxes of marine fish and invertebrate species exported from and imported to Puerto Rico through the Luis Muñoz Marín airport by month for 1990 and 1991 (Source: Puerto Rico Department of Natural Resources)

	1990		1991	
MONTH	EXPORT	IMPORT	EXPORT	IMPORT
JANUARY	11	359	218	172
FEBRUARY	36	453	218	145
MARCH	0	0	98	192
APRIL	0	470	243	108
MAY	86	701	1,291	213
JUNE	332	637	0	154
JULY	239	726	0	149
AUGUST	146	0	0	87
SEPTEMBER	125	153	145	N/A*
OCTOBER	177	177	235	N/A
NOVEMBER	135	124	N/A	N/A
DECEMBER	114	167	N/A	N/A
TOTALS	1,401	3,967	2,448	1,220

* N/A - information not available

FIGURE 1: Collection areas discussed in text



APPENDIX 3

DRAFT REGULATORY IMPACT REVIEW AND INITIAL REGULATORY FLEXIBILITY ANALYSIS FOR THE DRAFT FISHERY MANAGEMENT PLAN FOR CORALS AND REEF ASSOCIATED PLANTS AND INVERTEBRATES OF PUERTO RICO AND THE U. S. VIRGIN ISLANDS

July 1994

Caribbean Fishery Management Council

and

National Marine Fisheries Service

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I. INTRODUCTION

Executive Order (E.O.) 12866 "Regulatory Planning and Review" was signed on September 30, 1993 and established guidelines for promulgating new regulations and reviewing existing regulations. While the E.O. covers a variety of regulatory policy considerations, the costs and benefits of regulatory actions are a prominent concern. Section 1 of the E.O. is repeated in its entirety:

Section 1. *Statement of Regulatory Philosophy and Principles*.

(a) The Regulatory Philosophy. Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American people. In deciding whether and how to regulate, agencies should assess all costs and benefits of available regulatory alternative, including the alternative of not regulating. Costs and benefits shall be understood to include both quantifiable measures (to the fullest extent that these can be usefully estimated) and qualitative measures of costs and benefits that are difficult to quantify, but nevertheless essential to consider. Further, in choosing among alternative regulatory approaches, agencies should select those approaches that maximize net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts, and equity), unless a statute requires another regulatory approach.

(b) The Principles of Regulation. To ensure that the agencies' regulatory programs are consistent with the philosophy set forth above, agencies should adhere to the following principles, to the extent permitted by law and where applicable:

(1) Each agency shall identify the problem that it intends to address (including, where applicable, the failures of private markets or public institutions that warrant new agency action) as well as assess the significance of that problem.

(2) Each agency shall examine whether existing regulations (or other law) have created, or contributed to the problem that a new regulation is intended to correct and whether regulations (or other law) should be modified to achieve the intended goal of regulation more effectively.

(3) Each agency shall identify and assess available alternatives to direct regulation, including providing economic incentives to encourage the desired behavior, such as user fees or marketable permits, or providing information upon which choices can be made by the public.

(4) In setting regulatory priorities, each agency shall consider, to the extent reasonable, the degree and nature of the risks posed by various substances or activities within its jurisdiction.

(5) When an agency determines that a regulation is the best available method of achieving the regulatory objective, it shall design its regulations in the most cost-effective manner to achieve the regulatory objective. In doing so, each agency shall consider incentives for innovation, consistency, predictability, the costs of enforcement and compliance (to the government, regulated entities, and the public), flexibility, distributive impacts, and equity.

(6) Each agency shall assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.

(7) Each agency shall base its decisions on the best reasonably obtainable scientific, technical, economic, and other information concerning the need for and consequences of the intended regulation.

(8) Each agency shall identify and assess alternative forms of regulation and shall, to the extent feasible, specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt.

(9) Wherever feasible, agencies shall seek views of appropriate State, local, and tribal officials before imposing regulatory requirements that might signicantly or uniquely affect those governmental entities. Each agency shall assess the effects of Federal regulations on State, local and tribal governments, including specifically the availability of resources to carry out those mandates, and seek to minimize those burdens that uniquely or significantly affect such governmental entities, consistent with achieving regulatory objective. In addition, as appropriate, agencies shall seek to harmonize Federal regulatory actions with related State, local and tribal regulatory and other governmental functions.

(10) Each agency shall avoid regulations that are inconsistent, incompatible, or duplicative with its other regulations or those of other Federal agencies.

(11) Each agency shall tailor its regulations to impose the least burden on society, including individuals, businesses of differing sizes, and other entities (including small communities and governmental entities), consistent with obtaining the regulatory objectives, taking into account, among other things, and to the extent practicable, the costs of cumulative regulations.

(12) Each agency shall draft its regulations to be simple and easy to understand, with the goal of minimizing the potential for uncertainty and litigation arising from such uncertainty.

In compliance with E.O. 12866, the Department of Commerce (DOC) and the National Oceanic and Atmospheric Administration (NOAA) require the preparation of a Regulatory Impact Review (RIR) for all regulatory actions which either implement a new Fishery Management Plan (FMP) or significantly amend an existing plan, or may be significant in that they reflect important DOC/NOAA policy concerns and are of public interest.

The RIR is part of the process of preparing and reviewing fishery management plans and provides a comprehensive review of the changes in net economic benefits to society associated with proposed regulatory actions. The analysis also provides a review of the problems and policy objectives prompting the regulatory proposals and an evaluation of the major alternatives that could be used to solve problems. The purpose of the analysis is to ensure that the regulatory agency systematically and comprehensively considers all available alternatives so that the public welfare can be enhanced in the most efficient and cost effective way.

The Regulatory Flexibility Act (P.L. 96-353) has the purpose of relieving small businesses, small organizations, and small governmental entities from burdensome regulations and record keeping requirements. The Small Business Administration (SBA) defines a small business in the commercial fishing activity, classified and found in the Standard Industrial Classification Code, Major Group, Hunting, Fishing and Trapping (SIC 09), as a firm with receipts up to $2.0 million annually. Additionally, the SBA defines a small business in the charter boat activity to be in the SIC 7999 code, Amusement and Recreational Services, not elsewhere classified, as a firm with receipts up to $3.5 million per year.

To meet the basic objective of the Regulatory Flexibility Act, federal agencies are required to determine if proposed regulations will have a significant economic impact on a substantial number of small business entities. The process of making such determinations requires the preparation of an Initial Regulatory Flexibility Analysis (IRFA) and the RIR serves as the source of most of the information for the IRFA. However, certain information required for IRFA determinations is not necessarily available in the RIR. For example, if the RIR does not contain an estimate of the number of small businesses affected, a description of the small businesses affected or a discussion of the nature and size of impacts, then the IRFA would be expanded to include such information.

II. PREVIOUS MANAGEMENT REGIME

There are no federal regulations that currently govern the take of corals and reef-associated plants and invertebrates in the EEZ around Puerto Rico and the U.S. Virgin Islands.

Commercial harvest and export of reef-associated organisms is allowed under permit in the U.S. Virgin Islands. Of the 28 permits that have been issued on St. Thomas since 1990, 26 were for "private use" and 2 were considered commercial. The private use category included public aquariums and research facilities. St. Croix issued 25 permits, mostly for small numbers of organisms, for both private and commercial use. Detailed information on the species composition of permitted collections is not available. In the U.S. Virgin Islands, collection and export of reef-associated plants and invertebrates for use in aquariums is regulated by permit.

In Puerto Rico, commercial harvest of black coral and octocorals is allowed under permit but export is prohibited. No information is available regarding the number of permits issued. Collection of reef-associated plants and invertebrates for use in aquariums is not regulated in Puerto Rico.

III. PROBLEMS IN THE FISHERY

1. **Overfishing:**

Some species in the fisheries management unit (stony corals, sea fans, gorgonians and live-rock) are overfished. This situation is by definition since optimum yield (OY) for these species is established as zero except for scientific collection, education and restoration programs and there is some documented take beyond the defined OY's. The historical and present take is more fully described by Sadovy (1991) and Goenaga and Boulon (1992); their descriptions are summarized later in the RIR.

The usual economic implication of an overfished resource is that total value from the resource will be increased if the overfishing problem is resolved. Even though the "overfishing" situation addressed by this FMP is quite different from the usual case of being unable to maintain a positive OY from fish or shellfish resources, the economics of the situation becomes analogous if the determination is made that OY is correctly established at zero. A great deal of the balance of the RIR will be involved with such a discussion.

2. **Lack of Management:**

Coral reefs, reef-associated invertebrates, 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 these species to land-based and sea-based activities, 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 if certain species are selectively removed. As a hypothetical example, suppose that management policy results in overfishing of reef-related carnivores. The absence of carnivores could in turn result in an excessive number of herbivores and lead to a situation of excessive grazing on sessile reef organisms. If the reef system depends on these organisms, then a situation could develop whereby the reef ecosystem and all or a major part of the value associated with the ecosystem is lost.

It has been documented that there is a growing market for reef organisms from the U.S. Caribbean. Because of dwindling world supplies and the imposition of management regimes in other nations, this recently observed growth is expected to continue and perhaps intensify and this situation also indicates the need for management throughout the range of state and federal waters occupied by these resources.

The obvious economic implication of this problem is that if management is indeed necessary, then the development of an appropriate management regime could lead to more valuable use of the resources and if the increased use value exceeds the costs associated with management then net national benefits can be increased.

3. **Lack of Effective Environmental Policies/Enforcement**:

There is serious concern over the lack of monitoring and enforcement of human activities that are actually or potentially detrimental to coral reefs and associated organisms, but do not involve direct harvest or other direct physical damage. For example, a major cause of mortality of corals and associated invertebrates worldwide is sedimentation and pollution related to land-based or nearshore activities such as agricultural, mining or forest operations and discharge of municipal or manufacturing wastes. 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 sediment input from upland sources, the elimination of discharge of untreated/partially treated sewage and the release of petroleum products into coastal waters should be addressed. Additionally, 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).

Enforcement of existing laws is likewise a concern to the Council. Some examples of recent or current illegal activities include the use of quinaldine for the collection of live organisms, nearshore ship tank cleaning and nighttime discharging of bilges.

Regardless of the importance of this problem, the solution is largely outside the authority of the Caribbean Fishery Management Council. Hence there are no management measures to analyze via this RIR.

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 and the disturbance of substrate while collecting are considered damaging to the coral reef habitat. Some conditions encountered in the holding and shipping of live organisms are considered likely to result in unacceptably high rates of mortality. To the extent that current regulations are not sufficient, the assumption is that some resource value is lost. This FMP proposes regulations to address the harvest techniques, but not the holding facilities problem.

5. **Inadequate Information Base:**

There is insufficient scientific and fishery information on reefs, reef-associated invertebrates and plants regarding growth rates, life span, colonization patterns, distribution, abundance, landings, catch, effort and mortality. In particular, there is a lack of information on which to base appropriate levels of OY, MSY and allowable harvest for reef-associated invertebrates. Additionally, the interaction of reef community species and the roles of the various species are not well understood, although these associations are known to be of importance to the long-term health and productivity of the reef system. Information on water quality in the U.S. Virgin Islands, and on the impacts of onshore and nearshore human activities on offshore areas of both Puerto Rico and the U.S. Virgin Islands is needed.

6. **Limited Public Information/Education:**

There is a general lack of public understanding of the importance of reef ecosystems. While the FMP does not contain measures to address this problem, there are recommendations for public education.

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 legal and illegal human activity, as well as uncontrollable natural phenomena, reduces the productivity and value of these ecosystems. Loss of coral reef and seagrass habitats directly affects a wide range of organisms that are heavily dependent on reef habitats for food and shelter. Some of these organisms are the basis for fisheries of considerable commercial and recreational significance in the region while the organisms collectively provide the basis for the recreational diving industry. 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 harvest by scientists or commercial collectors. While some of these effects can be mitigated by appropriate management action, the FMP does not attempt to regulate all activities that affect the coral habitat.

8. **User Conflicts:**

Given the importance of coral reef habitats for commercial and recreational fisheries, for tourism-related activities, and for other uses, it is clear that there is much potential for user conflicts. While the FMP discusses possible approaches to resolve conflicts, there are no measures proposed at this time.

IV. OBJECTIVES OF THE FMP

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.

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.
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.

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.

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 provide more conscientious resource use.

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.

7. To provide a flexible management system that 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.

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

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.

V. ANALYTICAL APPROACH

Most of the measures in the amendment are specifically designed to help meet the primary objective of the FMP regarding optimizing the benefits to the Nation from the management of the species contained in the fishery management unit. The main approach suggested by the FMP is to maintain the stocks at their present level and thus resolve the primary problem, which is overfishing as defined by any take other than for scientific or restoration project purposes. In the case of the coral and associated stocks the overfishing is discussed largely in terms of a combination of legal and illegal commercial and recreational harvest as discussed in the FMP. However, the FMP also has extensive discussions about the effect of human activities not directly related to harvesting. For example, the FMP indicates that degradation by onshore activities such as agricultural production are important as are the effects of releasing untreated or partially treated sewage effluent, the effects of dredge and fill activities, damage caused by anchoring and other effects. With the exception of anchoring, for which limited management is proposed, the FMP cannot directly address these effects because the Council does not have the statutory ability to control them. Hence, the RIR analysis is largely limited to a determination of whether or not the measures designed to manage the direct harvest are expected to contribute to an increase in net benefits to society. It is obvious that changes in net economic benefits derived from the management of the fishery depend heavily on the effect that the implementation of a zero-take management strategy will have on the biological well being of the stocks and hence on values derived from non-consumptive use. The measures will be looked at separately to determine whether or not they contribute, in a positive manner, to the RIR condition of realizing a net positive economic benefit (benefits net of public and private costs).

Those proposed measures that restrict fishing practices will involve an analysis that provides a contrast of short term losses with long term gains, a procedure which is common with management schemes designed to rebuild overfished stocks.

The net economic benefits (which can be negative or positive) include the sum of (1) expected changes in producer surplus and consumer surplus for landings from the commercial fishery, (2) potential changes in consumer surplus derived from recreational and other non-use sources and (3) management costs (plan preparation and review, enforcement, additional data collection and public burden in terms of reporting costs).

The analysis used in this RIR will involve a combination of qualitative and quantitative approaches. In other words, the RIR analysis will attempt to discover how the proposed management measures affect net societal benefits but in some cases there will be no attempt to place estimated dollar values on the gains or losses discussed. There are some basic reasons for this. The first and major reason is that data on the biology and economics of the fisheries is insufficient even though the biological and economic decline of the fisheries is well established (see section 5.5 of this FMP). The second reason is that it may be more important at this stage to see if there are plausible benefits vs. trying to place exact dollar values on benefits. In this approach, some dependence will be placed on relating the results of quantitative studies on other reef systems to the situation in Puerto Rico and the U.S. Virgin Islands.

The analyses and discussions that follow contain two extremely important assumptions. First, it is assumed that all the measures that are implemented as regulations will be fully adopted by the Governments of Puerto Rico and the United States Virgin Islands. Second, it is assumed that the level of compliance with any resulting regulations will be high enough so that the potential benefits (to the extent that they exist) can actually be achieved. **IF THESE ASSUMPTIONS ARE VIOLATED THEN EVERYTHING THAT FOLLOWS WILL BE IRRELEVANT. THE OUTCOME OF THE MANAGEMENT EFFORT WILL BE A NET ECONOMIC LOSS BECAUSE THERE WILL BE NO BENEFITS WHILE GOVERNMENT AND PRIVATE COSTS ARE INCURRED.**

VI. SYNOPSIS OF THE USE OF CORAL REEFS

Corals, coral reefs and associated species occur worldwide in the tropical-semitropical belt and have a number of competing uses in most places they are found. Spurgeon (1992), in his article "The Economic Valuation of Coral Reefs," provides a fairly exhaustive list of uses and functions of coral reefs (and associated organisms) deemed to have value. In order to provide a means of approaching the valuation question he describes three classifications, namely direct use, indirect use and non-use values.

Direct use includes fisheries production, aquarium trade, curio trade, pharmaceutical and other industrial uses, construction, tourism, research and education. Indirect uses are considered to be biological support of other ecosystems, coastal zone extensions (measuring exclusive economic zones using fringing coral reefs versus shorelines as the starting point), physical protection, global life support and social services (described as foregone cost of the provision of social welfare services that may be necessary if the reef did not exist). Finally, the non-use category encompasses existence (the value of "knowing that it is there"), option (the value to be able to use something at a future date) and what he terms intrinsic use. The latter is attributed to the proposition that all organisms have some right to exist (he agrees that this type of non-use is beyond valuation in any monetary sense).

In contrast to uses of value, there are some costs to society associated with coral reefs. Particularly because of their rock-like structure and because they tend to be subsurface, coral reefs pose hazards to navigation. While there is a tendency to think of ship groundings in terms of damages to the reef, the damage to human life and property can be significant in some instances. Beyond the direct costs associated with groundings, there are costs associated with the avoidance of reefs. In general these costs consist of the extra time, fuel and other costs incurred when ship traffic has to detour to ensure that a reef grounding is avoided. The costs can also include the provision of navigational aids designed to warn shipping traffic of the location of reefs and the costs of removing reef structure to provide shipping access to inside waters.

With the exception of intrinsic non-use value, all the other values and costs described by Spurgeon (1992) are capable of being valued if the data were made available. Unfortunately, most of the data are not available for the U.S. Caribbean or anywhere else in the world and it is indeed possible that the cost of collecting all the relevant data could easily exceed the total value of certain categories of use.

Spurgeon (1992) explicitly covered several classes of what might be termed "intended" uses of corals. There is another class of uses that will be labeled as "unintended use" for the purpose of this RIR. This class includes unintended damage or removal of coral by a variety of human activities, some related to the uses described by Spurgeon (1992) and some that are not. Most or all of these uses comprise section 5.7 in the FMP. While the RIR notes that the FMP does not provide for management of most of the unintended uses at this time, this class of uses will be referenced later because of their value relative to the value of other uses.

Most of the uses of coral resources as described by Spurgeon (1992) occur in the U.S. Caribbean and Section 3.0 of the FMP contains a useful synopsis of the known historical and current information on these uses. The following information is freely taken from that section with certain editorial changes to meet the needs of the RIR.

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 Rolon, 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. In 1979, Puerto Rico implemented a regulation that essentially prohibited the harvest of most coral species from state waters. In the U.S. Virgin Islands, the taking of coral is regulated by permit. In addition to commercial and recreational take, the harvest of coral and associated invertebrates has been important for scientific and educational purposes in both Puerto Rico and the U. S. Virgin Islands.

The taking of reef-associated organisms for the aquarium trade is a relatively new activity that began in about 1970 in Puerto Rico and since then has expanded from a handful of harvesters, dealers and exporters to an industry that employs about 100 people (Sadovy, 1991). This activity has remained relatively undeveloped in the U. S. Virgin Islands and has been regulated by permit since 1990. The expansion of the aquarium trade in Puerto Rico over the last two decades is attributable to three factors. The demand for live marine organisms has shifted with technology that enables more people to successfully maintain these species in home aquariums. 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, a reduction in supply from competing sources (restrictions on the collection of organisms in Florida waters, declines in abundance in the Philippines and a recent trade embargo against Haiti) has made Puerto Rico an increasingly important source of these rganisms.

As previously stated, commercial harvest of reef-associated organisms is allowed in U.S. Virgin Islands state waters under permit and 53 collection/retention/transit permits have been issued since the implementation of permits in 1990. Information on the species composition of the harvest is not available although inspection of permit applications indicated that typical collections include low numbers of a variety of vertebrate and invertebrate species. Commercial harvest of black coral and octocorals is allowed under permit in the state waters of Puerto Rico, but there is currently no known legal harvest of other corals in Puerto Rico. However, gorgonians and at least one stony coral species (Tubastrea aurea) are listed as available for the aquarium industry and shipments of corals to the U.S. mainland 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, and that occasional undetected shipments are made from the airport in San Juan. For example, a recent export shipment of 300 live corals was recently intercepted and this suggests that harvest and export occur, but with unknown frequency and volume.

In early 1993, approximately six companies were known to export live invertebrates from Puerto Rico for the aquarium trade and an additional seven businesses serve the domestic (Puerto Rico) market. While the majority of the marine aquarium trade is in fish species, in 1992 an estimated 25% of the trade involved invertebrates, live-rock and some corals.

Some reef-related species are collected and prepared for the curio trade. 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 dead organisms at the shoreline, but the quality of some intact gorgonian colonies indicate that animals were harvested and preserved with marketing in mind (Yvonne Sadovy, pers. obs.). A wide variety of other species, some of which may eventually be regulated under this FMP, are a part of the curio trade. These include seashells, starfish, cured sea urchins and spines of the slate pencil urchin. However, the majority of organisms sold as curios and used in craftwork are imported. Trade figures from The Puerto Rico Planning Board indicate that there were no recent exports for the curio trade while imports of between 20,000 and 37,000 kg of these products were recorded and most of these probably came from Florida dealers. A random survey of 30 companies from a list of 200 marine life dealers in Florida indicated that 11 of them export marine products (mainly originating in the Philippines) to Puerto Rico.

The discussion above indicates that most of the existing commercial value of reef species is related to the harvest of live organisms for the aquarium trade, while the trade in coral species and live-rock is relatively minor. This conclusion is supported by the survey completed by Sadovy. On the basis of an analysis of 214 export shipping lists covering the period 1990-1992, she found that the combined exports of live-rock, gorgonians and corals constituted only 3.7% of all organisms recorded.

The principal direct recreational importance of coral reefs is related to the tourism and diving industry. Recreational use includes viewing as well as harvest of reef species for use in home aquariums or as curios. The volume of this harvest is unknown but is probably rising over time. One indicator of an expanding personal use harvest is that diving and snorkeling has grown rapidly over the last decade. For example, the number of businesses that teach recreational diving in Puerto Rico has grown from about 3 or 4 in the 1970's to about 35-45 today. 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 tourists. Another indicator of the growth of recreational diving and personal use harvest is that the Puerto Rico Board of Tourism is promoting eco-tourism and part of the promotion involves positioning Puerto Rico as a diving destination. Further, commercial fishers in a number of areas are increasingly providing services for recreational divers and fishers as income from traditional commercial fisheries enterprises continues to diminish (Ruperto Chaparro, pers. obs.).

The U.S. Virgin Islands currently rank ahead of Puerto Rico as a diving destination for tourists and the 25-30 dive businesses in the U.S. Virgin Islands predominantly cater to tourists (George Mitcheson, Ralf Boulon, pers. obs.). An indicator of the growing importance of diving-related activities in the U.S. Virgin Islands is that attendance at Trunck Bay beach, located in the national park on St. John, has increased from 20,000 people in 1966 to 170,000 people in 1986 (Rogers and Teytaud, 1988).

In addition to having well known commercial and recreational uses, certain gorgonian species are a source of chemical compounds of medical interest or use. As a result, gorgonians have been harvested in the La Parguera area of Puerto Rico and the southwest coast of St. Thomas, U.S. Virgin Islands for scientific research and testing for commercial feasibility as sources of these compounds. The impact of this activity on the gorgonian stocks is unknown and needs to be assessed (Goenaga and Boulon, 1992). Periodic harvest of other soft corals, sponges and macroalgae also has occurred for similar reasons and with unknown frequency and volume of harvest. It is not known to what extent harvesting activities on these species may change in the future or what additional compounds are yet to be discovered.

Education and research regarding the importance and significance of the reef environment is another use of the reef resource and some harvest of reef organisms for scientific and bona fide teaching purposes occurs in both Puerto Rico and the U. S. Virgin Islands.

VII. ANALYSIS OF MANAGEMENT MEASURES

MANAGEMENT MEASURE 1: Prohibit the harvest or possession of stony corals, wheter dead or alive, except for legally permitted research, education, and restoration programs.

In Puerto Rico and the U.S. Virgin Islands, stony corals have a number of the uses discussed above and the significance of the measure is to eliminate the uses and value associated with the harvest of stony corals (with the exceptions for research, education and restoration noted). Following Spurgeon (1992), this would involve eliminating the aquarium trade, the curio trade, other industrial uses, construction and that portion of tourism that involves harvesting (personal use would be assigned a value of the consumer surplus derived from the use of collected species). Of these, the information derived from the FMP contains no information indicating current use in the other industrial or construction categories. Hence, the significance of the measure is to eliminate the commercial and recreational take for aquarium and curio purposes. Uses not eliminated by the measure therefore include fisheries production, tourism, research, education, biological support, coastal zone extensions, physical protection, global life support, social services, existence, option and intrinsic.

Because stony corals grow at a slow rate, the FMP has concluded that stony corals cannot be viewed as renewable resources. If this is true (the operating assumption is that the FMP is correct), then coral resources must be treated like mineral resources or petroleum when considering the value of the consumptive uses. In economic terms, the annual value of the consumptive uses is the one-time sum of producer and consumer surplus in any given year and the total present value is the sum of discounted annual values.

Not only do the stony corals represent a unique fishery in that they are considered as non-renewable from a biological and hence economic perspective, their role in creating the value of the non-harvest uses once again makes them somewhat unique among fishery or marine resources. Specifically, as they are harvested over time, the value derived from the other uses diminishes in some (unfortunately unknown) proportion to the remaining stock of coral. Taken to the extreme, if all the stony corals were to be harvested at some annual rate, it is clear that the value from all other uses of stony corals would decline over time and would reach zero at some point. Although that scenario is not very realistic because management would surely change before that point was reached, the general notion is correct. The general notion is that while the harvest-related uses have a one-time value that is realized at the point of harvest, the other uses have a value that is not generally eroded over time if the coral resource remains intact but approaches zero as the remaining stock of coral approaches zero.

The significance of the point made in the previous paragraph can be illustrated by a hypothetical example. Using fishery management jargon, assume that there is an annual fixed quota for stony corals and that the quota is equal to five percent of the beginning stock of coral. By simple math, the life of the "fishery" is fixed at 20 years (all the coral will have been harvested) and regardless of the beginning annual value of the fishery, it is zero for year 21 and thereafter. Now consider the value of all the other uses combined and assume that the value of the other uses is proportional to the amount of coral in the water. On a ceteris paribus basis the first year value is the maximum annual value (even before discounting the values accruing in later years) and values after the first year will steadily decrease over time and will be zero in the 21st year and thereafter. The opposite conclusion is that if there is no harvest then, on the same ceteris paribus basis, the non-use value can be considered as an annuity, i.e., the value does not decline over time (except for the discounting to calculate the present value). In the case of the hypothetical example, the value of the other uses under the no harvest scenario extends beyond the 20th year and into perpetuity.

Regardless of the economic uniqueness of coral resources, the task of the RIR is to determine the economic effect of the management measure on net benefits to society and this determination involves calculating the net present value of the stony corals in their harvest uses versus the decline in value from the other uses. Note that the last sentence indicates another unique aspect of the coral fishery. In the usual fishery case, the notion of competing uses almost always refers to the distribution (allocation) of Total Allowable Catch (TAC) from the fishery and the question concerns the way to distribute the harvest rights in a fashion that will tend to maximize the economic benefit derived from the quotas assigned to the competing groups. The operating principle in this usual case is to allocate the TAC among competing user groups so that the marginal benefit is equal for all users. If marginal benefits are not equal then total benefits can be increased by increasing the quota assigned to those users having the higher marginal benefit. However, in the case of stony corals, the entire harvest quota would be allocated to the users that have to harvest coral to create benefits. The other users (competing non-harvest users) get their benefits from the coral which is not harvested and the "competition" occurs because their future benefits decline if the total stock of coral declines. Further, the non-harvest users are not concerned so much with the harvest (quota) for any given year but are instead concerned with the cumulative effect of a continuing annual harvest.

In the case of the harvest uses, the FMP provides information that indicates the current commercial harvest may be small. However, there are a number of world-wide supply and demand factors that point to making the commercial uses increasingly valuable over time with the obvious outcome of an increasing harvest over time. Summarized, the supply factors largely involve the fact that some Indo-Pacific and other resources may have been harvested to a degree that the cost of harvest from those areas has risen significantly and in other areas management regimes to limit or eliminate the harvest are in effect. On the demand side, the increasing use of home aquariums as well as an increasing interest in these types of natural products as curios probably provides the major demand shift.

The FMP provides the only known information on commercial harvest in the U.S. Caribbean. Sadovy's survey of exports during 1992 indicated that less than one percent of all marine organisms were classified as corals of all types and would number less than 1,000 valued at about $4,000. This admittedly very rough estimate of minimum export value is not economic value defined as the sum of producer and consumer surplus and that true value would be some relatively small fraction of the export value. While the estimates provided by Sadovy are very conservative for a number of reasons, the data nonetheless indicate that exports of stony corals are small. More recently, Sadovy (pers. comm.) reported that there appears to be little or no current harvest of stony corals for the curio trade or jewelry manufacturing and that Puerto Rico imports corals, principally from Florida. In spite of the small reported commercial harvest there appears to be an unknown level of illegal harvest that enters commercial channels. In addition to the small commercial take for export, there is an unknown amount of harvest for domestic markets and this amount is likewise small. Additionally, there is undoubtedly some recreational take for personal use but once again there is no information on the volume. Despite the lack of information on direct harvest the supposition based on available information is that the current harvest is relatively small but increasing. The consequence in terms of the RIR is that the stony coral harvest and value are small at present and that the value of all the other uses of stony corals combined is declining (or more accurately rising at some reduced rate since the demand for the other uses is rising) due to the small directed commercial harvest.

The observation that current harvest is probably relatively small can be interpreted in two ways. One line of thought is that there is no need for a harvest restriction because the harvest is small and the other is that eliminating a small harvest has only a minor negative economic impact. While the latter appears to be correct, it should be recalled that the effect of direct harvest on the value of the other uses is not reflected by the annual take, but that value derived from the other uses declines as a result of the cumulative harvest over a number of years. In addition, it has been noted previously that a decline in the world supply of stony corals and a demand that appears to be increasing over time indicates that the harvest of stony corals in the U.S. Caribbean will undoubtedly increase in the absence of management controls. This indicates that the decline in the value from other uses in future years will proceed at a faster rate than the present rate.

The FMP contains some information that indicates the value of the other stony coral uses combined may be quite large. However, that information tends to concentrate on the expenditures associated with recreational diving experiences and expenditures are not the correct measure of the contribution of stony corals to the value of the other uses. Measurement of the correct values emanating from the existence of stony corals have been attempted in a few cases. For example, Hudloe (1990) used contingent valuation methodology to determine that Australian citizens valued the existence and option use of the Great Barrier Reef at over $29 million or about $36 per resident adult. That value would not include the consumer surplus derived from resident and tourist recreation diving, fishing and viewing on the Reef. In another study, Hudloe (1990) estimated that the resident population that actually used the Reef gained a total consumer surplus of about $4 million annually or about $5 per adult user (tourist consumer surplus would have to be added to this amount). The results of these studies provide an indicator of the recreational use value of the coral reefs of the U.S. Caribbean. With an adult population of about 2.1 million, the existence and option value of the reefs would be about $76 million if the reef system has a value similar to that of the Great Barrier Reef. The extent to which lower per capita values in the U.S. Caribbean (due to relative per capita incomes and perhaps an overall lower reef quality) are offset by the larger population in the U.S. Caribbean versus Australia makes it difficult to estimate the true value. Nonetheless, the existence and option value to adult residents is substantial and does not include the actual resident or tourist direct use value. As a caution against misinterpreting this large value, note that it represents the total value lost for all time if the entire reef system were to disappear and readers should avoid comparing this value with annual values related to other uses.

Fish production is another value of coral reefs and Munro and Williams (1985) estimated that coral reefs produce an average maximum sustainable yield of 15 metric tons per square kilometer and Munro (1984) estimated that the productivity of coral reefs is responsible for about one-eighth of the world's fish harvest. Most of the fisheries production of the U.S. Caribbean depends on the existence of the coral reefs and in 1991, Puerto Rico recorded landings of 2.5 million pounds valued at $4.3 million (Fisheries Research Laboratory, PRDNR, 1992) while the U.S. Virgin Islands reported projected landings of 1.9 million pounds valued at $4.8 million (Department of Planning and Natural Resources U. S. V. I., 1992). While landed value overstates the true economic value of the fisheries and hence the contribution of coral reefs, a crude estimate that the true value amounts from 10% to 40% of landed value (author's estimate), results in a rough estimate of the annual economic value of fisheries production of about $0.9 to $3.6 million.

There is no information available to infer the value of the other uses which include research, education, biological support of other ecosystems, coastal zone extensions, physical protection, global life support (Note: The RIR guidelines preclude counting values that accrue to non-U.S. citizens) and social services. Although no information is available, these uses do have value and should be considered when attempting to determine any loss in value that is related to loss of reefs.

Another entirely different approach to the valuation of coral reefs is to refer to court settlements involving governments and parties responsible for ship groundings on coral reefs. Some examples include a settlement of $600,000 involving the destruction of 340 square meters of coral in the Strait of Tiran (Spurgeon, 1992), $1.5 million for a grounding involving 1,610 square meters in the Florida Keys and $2.8 million involving 3,073 square meters of coral also in the Florida Keys (Finch, Julious and Lopez, 1992). Averaging these examples, the value of coral reefs is determined to be $975 per square meter. Once again, this value is for all time and hence should be viewed with caution. Nonetheless, this independent valuation method points to a considerable value that the courts place on coral reefs.

Finally, there are the costs associated with reefs (ship groundings, coral reef avoidance costs and avoidance systems such as navigational aids). Although some information is undoubtedly available for the U.S. Caribbean, the RIR has made no attempt to research these costs.

Recall (perhaps redundantly, but for emphasis) that the issue is weighing the annual direct harvest value against the increasing loss in value for all other uses in all future years. It should be evident that the small annual harvest values previously reported will be exceeded by the lost value that would be associated with the cumulative loss of coral reef material over time.

The entire discussion above depends heavily on the notion that enforcement and compliance will be good enough to ensure that the current and future direct harvests are kept at a reasonably small level. Although it is not possible to estimate that threshold level, it exists and if it is exceeded, then the losses in future value would make management moot. Related to the need for an effective compliance rate is the need to have consistent regulations throughout the range of the corals. The RIR recognizes the implication that current U.S. Caribbean regulations and permitting systems will have to be altered and operated at some cost and these costs are discussed further in the "Management Cost" section of the RIR.

Another potentially important part of this option is the allowance of some harvest for research, education, and restoration purposes. For the research and education exemption, it may be necessary to create some incentives or procedures to ensure that the harvest for these purposes is kept to a minimum. Information in the FMP indicates that the removal of corals for research and education purposes can be particularly destructive and there may be a plausible explanation rooted in economics. Quite a lot of research, education, and testing of various types involves what is termed "destructive sampling" and a well-known example is the crash-testing of cars. In the usual case, such as in the example, the researchers have to incur the cost of the destruction as a part of their research budget and therefore have an incentive to minimize their costs. However, in the case of research involving corals, the researchers presumably do not pay for the lost use value associated with their destruction of coral for research and education purposes. In economic terms, this situation could lead to the creation of marginal costs to society that exceed the marginal value associated with the research and education requiring the destruction of coral. The way to correct the situation is to ensure, through some <u>effective</u> process, that the research and education community consider the societal costs and use only the very minimum amount of material possible. Further, there should be some mechanism available to ensure that the destruction of the <u>first</u> piece of coral is justified by the value of research results before permits are issued. The exemption for transplanting or laboratory production of corals is less of an issue, but it is clear that some reasonable probability of success of such experiments should be determined before permits are issued.

The RIR concludes that the measure has a (perhaps large) net benefit to society.

<u>Option 1A</u>: Permit the regulated harvest of stony corals.

It is recognized that the supposition that all stony corals are non-renewable is countered by information in the FMP that some species grow fast enough that a sustainable harvest may be possible. However, the FMP also suggests that there is not enough information available to support a reasonable management measure and states that when such information becomes available, then the Council intent is to amend the plan accordingly.

If this option was exercised, it would be expected that the current small level of harvest would increase by a small but unknown amount because this option is less restrictive than current state law. Accordingly, current direct use values from commercial and recreational harvest would increase slightly. With some level of harvest, the non-use values would tend to decline over time. A regulated harvest would also imply some level of public and private costs associated with permits or similar documents. Assuming that most of the stony corals can be considered as non-renewable resources, the RIR conclusion is that this option would have a small negative impact on net national benefits.

Option 1B: Prohibit all harvest of stony corals.

Referring to the discussion and analysis for the preferred option, this option would prohibit commercial and recreational take and would also disallow take for scientific and restoration purposes. The RIR conclusion is that this option would have a positive net benefit to society but would be inferior to the preferred option if reasonable controls on scientific and restoration take are implemented for the preferred option. Given the historical take for such purposes, the outcome of the option is less clear if appropriate controls are not instituted. Refer to the previous discussion on the exemptions provided by the preferred option.

Option 1C: No Action.

Refer to the discussion and analysis for the preferred option. While the status quo generally has no impact (nothing changes), the unique status of the coral fishery implies that the status quo would have a negative economic effect on societal benefits in the long run. This conclusion is predicated on the cumulative loss in other coral uses with a given annual harvest for direct use.

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.

Following the categories of use described by Spurgeon (1992), octocorals have most of the same uses as stony corals with the addition of uses as pharmaceutical compounds, but do not have use in terms of other industrial, construction and physical protection. Their main uses and value probably derive from fisheries production and from uses related to recreational diving. They have some use as commercial and personal use in home aquariums and as curios and it is this use that would be eliminated by the measure.

Information in the FMP indicates that the soft corals (octocorals) differ from the stony corals in their rate of growth to the extent that many of the species can be considered as renewable resources from both a biological and economic perspective. If this is true, and if it is feasible to enforce harvest regulations at a reasonable level of compliance, then a measure that totally eliminates all harvest for commercial and recreational use should result in a negative change in net societal benefits. The reasoning is straightforward and essentially indicates that soft corals can be considered in the same manner as other renewable fishery resources, i.e., some level of harvest is allowable and the objective is to set the harvest at the level corresponding to maximum economic yield (MEY). Even though the stocks can be considered to be renewable, the level of MEY for soft corals would be below that level which maximizes the direct harvest value over time. This is the case because the harvest of soft corals will decrease the values in other uses, although not to the degree shown previously for stony corals. Unfortunately, the available biological information has not been assembled and analyzed in terms of determining the acceptable level of harvest of the various species of soft corals. The RIR notes that the Council is on record as agreeing that at least some soft coral species may be treated as renewable resources and has indicated an intent to consider an amendment to the FMP when more information becomes available.

Information in the FMP indicates that the current harvest level is minor as judged from the Sadovy report on the export of marine aquarium species that indicated less than 4% of all exports involved corals and live rock and most of the volume was in live rock. Since the current harvest appears small, the RIR concludes that the portion of the measure that refers to soft corals will have a small net negative impact on benefits to society.

The measure also addresses any species in the FMU if attached or existing upon live-rock and for the purposes of the RIR, live-rock is deemed to have the growth characteristic of stony corals, i.e., live-rock is judged to be a non-renewable resource. For essentially the same reasons as making the determination that prohibiting the harvest of stony corals will have a net positive benefit to society, the same conclusion is reached for live-rock.

In summary the RIR concludes that it is economically sound to prohibit all commercial and recreational harvest of live-rock, but not necessarily economically sound to prohibit all commercial and recreational harvest of soft corals.

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.

For clarification, the reference to aquaculture operations is specifically meant to refer to live-rock.

Recalling the discussion on the outcome for the preferred measure, the portion of the option which refers to traditional commercial and recreational harvest is expected to have a small negative impact on net benefits to society.

In the case of live-rock aquaculture, the measure has no impact since there is no live-rock aquaculture in the EEZ of the U.S. Caribbean at this time. It is noted in the FMP that the Council may reconsider this part of the management of live-rock if aquaculture systems are successfully developed (presumably in jurisdictions outside the U.S. Caribbean).

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

As mentioned above, octocorals rejuvenate removed portions and grow faster than stony corals. Thus, limited harvest of certain octocoral species probably would generate net benefits to society. Since the measure does not specify the level of harvest, e.g., allow harvest at present levels, it is not possible to be more explicit. The FMP indicates that some level of managed harvest may be possible in the future based on appropriate scientific findings that could help establish sustainable harvest levels.

A sustained regulated harvest of live-rock is expected to reduce economic benefits because of the expected decline in non-use value over time. See the discussion of the preferred option.

Overall, the option is expected to have a negative impact on benefits in the case of the octocorals, but a positive impact for live-rock. It is not possible to predict the overall outcome of the two effects combined.

Option 2C: Prohibit all take of octocorals and any species if attached or existing upon live-rock.

This option imply that take of octocorals for scientific, education and restoration programs would not be allowed. Assuming adequate controls on scientific, education and restoration permits under the preferred option, this option would have a small negative impact resulting from presumed lost research values. Referring to the discussion on the outcome of prohibiting commercial and recreational harvest of octocorals under the preferred measure, this part of the option is also expected to have a small negative impact on net benefits to society.

Option 2D: No Action.

The status quo option does not alter current net societal benefits.

MANAGEMENT MEASURE 3: Prohibit the sale or possession of any species whose harvest is prohibited unless the specimen entered the management area in interstate commerce and is fully documented as to point of origin.

No sale provisions which accompany no harvest provisions have been deemed to have a positive effect on benefits in a number of other FMP's because such actions help ensure compliance with regulations. It is assumed that the record-keeping requirements are already met since invoices accompany shipments at present. The only potential additional cost would be to maintain such invoices and that cost would be very small or zero (most businesses probably maintain such records for normal business purposes).

Option 3A: No action.

The status quo option does not alter current net societal benefits.

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.

Synthetic chemicals, natural products derived from plant species, and explosives, including powerheads on spear guns, would be prohibited. Chemicals currently being used to harvest reef-associated organisms include quinaldine, gasoline, and bleach. These substances are known to be detrimental to both fish and invertebrate species, including the target species. In the case of the target species the use of chemicals in harvesting is known to result in relatively high mortality during holding and shipping (Sadovy, pers. comm.).

Since other harvest methods are available to successfully harvest these organisms, the proposed prohibition on the use of chemicals would not preclude harvest of the majority of commercial organisms. However, the measure would presumably increase the harvest cost to an unknown degree because the harvester would have to revert to use of the next most efficient and legal harvest method. On the other hand, benefits should accrue to the first and subsequent buyers via reduced mortalities of the organisms being purchased. Additional benefits would accrue through reduced mortality of non-target species. In the absence of definitive information, the measure is expected to have a net positive impact on benefits to society.

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

Referring to the discussion on the outcome for the preferred measure, this option is expected to have a small negative impact on net benefits to society.

Option 4B: No action.

The status quo option does not alter current net societal benefits.

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.

Gear methods commonly used to harvest marine aquarium invertebrates include hand-held dip nets, by hand, chemicals such as quinaldine, and slurp guns. A crow bar or similar instrument is sometimes used to remove live-rock or to overturn corals and coral heads to allow access to organisms being harvested. Some of these methods can damage the reef habitat and are a source of incidental mortality for other reef-associated organisms. Of the traditional gear employed in the harvest of marine aquarium organisms, only hand-held dip nets and slurp guns represent no threat to coral reefs and associated organisms and are effective for the majority of commercial organisms. While most invertebrates may be collected with dip nets and slurp guns, certain collections for scientific or restorative purposes may require the use of chemicals (such as anesthetics) or nets such as cast nets. Accordingly, an exemption for certain permitted activities is proposed. The measure apparently has almost no current economic impact in the case of the use of chemicals since chemicals will be prohibited if Measure 4 is adopted. However, the measure will outlaw the use of crowbars and similar instruments. As was the case with the discussion on the use of chemicals, the scant evidence available results in the RIR finding of a small net positive benefit to society.

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.

There is insufficient information to allow evaluation of OY for reef-associated invertebrates managed by the FMP. Although an estimate of current harvest levels could be based on reported exports, this may be an underestimate due to the substantial but unquantified domestic market. Given the available information, the Council does not believe that any of these species are in current danger of being overfished, with the possible exception of Condylactis sp. which constitutes over 50 percent of the export trade, by number. When additional information becomes available the Council will re-evaluate this option.

The present level of information is insufficient to make a solid determination on the change in net benefits to society if invertebrate harvest were limited to current levels. If the majority of the resources are not overfished and if there are no overcapitalization problems in the fishery, then a restriction of harvest at present levels would result in a small net loss in benefits to society. This result would occur because there would be losses in consumer and consumer surplus and additional management costs associated with monitoring the necessary quotas.

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

Maximum protection of invertebrate species would be afforded by a total prohibition of harvest. However, because the majority of reef-associated invertebrates are thought to be currently harvested in low numbers and may be able to sustain limited harvest at least at current levels, a total prohibition is not justified at this time. If harvest levels increase or certain species are considered to be particularly vulnerable to harvest, the Council intends to reconsider this option.

The RIR determination is that the measure would have negative impacts on benefits to society because of an expected loss of all current producer and consumer surplus associated with current harvests of what appear to be underfished resources (see the RIR discussion and conclusion regarding the preferred option).

Option 5C: No action.

The status quo option does not alter current net societal benefits.

MANAGEMENT MEASURE 6: Require a permit (up to a year) to harvest or possess organisms in the fishery management unit in the EEZ.

MANAGEMENT MEASURE 7: Require hervesters, 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.

These two preferred measures are discussed jointly because of their relationship and because both need to be implemented for each to be effective.

A permit would be required to harvest, maintain, and/or sell reef-associated invertebrates and the permit system would be operated by local governments, with the assistance of the National Marine Fisheries Service (NMFS). The measures also implies that permit applicants would have to supply information regarding species, quantities, unit value, harvest areas, and gear used. A permit would be denied anyone with an outstanding violation in any state or federally regulated fishery. Potential permit holders would have to agree to follow minimum standards of maintenance, handling, and transport of live marine organisms. An appropriate fee would be charged to recover costs of administering the permit system.

The stated reason for a permit system is to collect data on effort in the fishery and to identify the participants. A permit system would also facilitate introduction of a limited entry system in the event such a system is warranted and could be an aid in ensuring adequate compliance with regulations. Special permits also would be available for research, education and restoration purposes for other components of the FMU (stony corals, octocorals, and live-rock). Research, education and restoration permits would be awarded on a case-by-case basis following submission of a research plan, including species and quantities to be harvested, and area of collection.

The appropriate RIR analysis involves the determination as to whether or not the benefits of data collection and other implied uses of the permits system exceed the combined public and private costs of implementing and maintaining the system. Information in the FMP suggests that about 100 permits may be issued and the administrative costs are estimated at $35 per permit or a total of $3,500 (refer to "Management Costs" section of the RIR). These costs would accrue to the state governments or to the permit holders, but the details are not yet available. Costs of associated data collection have not been estimated in the FMP because the details of a proposed regular reporting system have not been fully addressed. However, the FMP indicates that the burden hours would "not be onerous." If the notion of regular dealer reporting via a mail-in system (to include appropriate harvest data) is followed, then the costs would be minimized. The proposed option is similar to logbook reporting systems used on the U.S. mainland except that the state governments would administer the program. For these similar programs, the reporting burden is estimated to be 15 minutes for each monthly report. In the case at hand, the annual burden would be 3 hours per permit holder or 300 total hours. If time is valued at $10/hour then the total private cost is estimated to be $3,000. The sum of administrative and reporting costs becomes $6,500.

It is not possible to determine the dollar value of the benefits associated with the permits system. In the case of a number of existing FMP's it has been determined that the provisions of the FMP cannot be implemented without a permits or similar system. In such cases, it can generally be demonstrated that the benefits exceed costs if the costs are reasonably small. However, in the case of this FMP, the other management measures can be implemented in the absence of the permits system and this situation makes the net benefit determination more difficult. A number of the options in the FMP are stated as being subject to change if better data becomes available and that scenario provides the basis for the value (in the future) of the permits system. In particular, the FMP indicates that the complete prohibition on harvest of all corals and live-rock may be relaxed if information regarding potential harvests (along with an analysis of existing biological data) indicates the possibility of a managed sustained harvest of certain species. In such a case the value of the permits system would probably exceed the cost. To the extent that permits aid compliance, there is some benefit but it cannot be quantified without further information.

Given the information available, the qualitative determination is that a case exists for the net benefits from a permit system and associated data collection system to be positive.

<u>Option 6A</u>: No action.

<u>Option 7A</u>: No action.

The status quo options do not alter current net societal benefits.

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.

VIII. MANAGEMENT COSTS

Major categories of management costs typically include administrative costs incurred by the Council and NMFS, enforcement costs borne by the states, NMFS and Coast Guard, public burden costs associated with data collection and costs of developing and maintaining permits and data collection systems.

The Caribbean Fishery Management Council has provided detailed information on their administrative costs broken down into the categories shown below. In December 1989, at its 68th regular meeting, the Caribbean Fishery Management Council received information on the trends in the use and exploitation of live-rock. Input on the live-rock issue was furnished by the Southeast Regional Office of NMFS, the NMFS General Counsel, interested organizations, Council Members, the scientific community and the general public. At the 69th regular meeting held April 1990 in St. Thomas, U.S.V.I., more and broader information was presented on live-rock. The Scientific and Statistical Committee (SSC) and the Advisory Panel (AP) considered the live-rock issue and the possibility of the development of a Fishery Management Plan for Corals at their meeting on July 17, 1990. Recommendations for the management of live-rock were presented to the Council by the SSC and the AP at its 70th regular meeting in July 1990. At that meeting, a motion was presented by Mr. D. Moore (Council member representing the Government of the U.S.V.I.) and seconded by Ms. Ana Olivencia (Council member representing the Government of Puerto Rico) requesting the Council to initiate the process for the development of this FMP that includes aquarium trade fish, live-rock, corals and soft corals.

The Council contracted with the late Dr. Carlos Goenaga to assess the state of corals around Puerto Rico and with Mr. Ralf Boulon to do the same in the U.S. Virgin Islands. At a later date Dr. Yvonne Sadovy was contracted to assess the state of the aquarium trade fishery in Puerto Rico. The reports from these contractors served as source documents in the process of developing the FMP.

Scoping meetings on the Plan were held by the Council during 1992. Proposed management measures were considered by the SSC, AP, and HAP and recommendations were presented to the Council by the end of 1993. After Council recommendations, a draft FMP was prepared and presented at public hearings during the first quarter of 1994. It is expected that the FMP will be completed during 1994.

STATEMENT OF ESTIMATED COUNCIL COSTS - AS OF JUNE 30, 1994

I. Consideration at the Council Meetings

Estimated Cost of Council Members Compensation for One Council Meeting	$4,519
Estimated Travel Expenses for Council Members to One Council Meeting	$3,430
Total Cost of Compensation and Travel Expenses for One Council Meeting	$7,949

Using the estimated total cost of a Council meeting shown above, the costs of meetings related to the FMP are as follows. The Council meetings are estimated to last 16 hours, of which at least an average of 2.5 hours were devoted to the FMP for Corals and associated organisms during the 70th to the 78th meetings (9 meetings).

Estimated Cost from 70th to 78th Meetings

2.5 hours divided by 16 hours = 15.6%
$7,949 x 15.6% x 9 meetings = $11,160

The Council considered the draft of the FMP at its 79th, 80th, and 81st Regular Meetings. These meetings were dedicated almost entirely (90%) to the development of the FMP. The estimate is as follows:

Estimated cost of Council Members for One Council Meeting	$4,519
Estimated cost of Compensation at the 79th, 80th, 81st Meetings $4,519 x 90% x 3 =	$12,201
Estimated Travel Expenses for Council Members for Three Meetings	$10,020
Estimated Compensation and Travel Expenses for these Regular Meetings	$22,221

II. Time Devoted by the Staff

It is estimated that the Fishery Biologist has devoted 90% of the time to the development of the FMP since October 1992.

Salary for the Period October-December 1992	$14,095
Salary for the Period January-March 1993	14,571
Total	$28,666
Estimated Cost of Staff - $28,666 x 90%	$25,799

It is estimated that the Special Assistant for FMP Development devoted 80% of the time to the development of the FMP during the period July-September 1993 and October 1993 - June 1994.

Salary for period July-September 1993	$12,858
Salary for the period October 1993-June 1994	40,409
Estimated Cost of Staff - $53,267 x 80% =	$42,614

III. Scoping Meetings

Scoping meetings were held in Salinas, San Juan, Fajardo, Lajas, Naguabo and Aguadilla in Puerto Rico and in St. Thomas and St. Croix in the U.S.V.I.

Estimated Council Members Compensation	
1 member x 1 day x 7 scoping meetings	$2,072
Estimated Travel Expenses - Members (1)	800
Estimated Travel Expenses - Staff (2)	1,600
Estimated Cost of Scoping Meetings	$4,472

Estimated Cost of Other Related Meetings	
Coral Reef Symposium	$2,604
Meeting at the SERO/NMFS	1,188
Estimated Cost of Other Related Meetings	$3,792

IV. Public Hearings

The Council held public hearings on the FMP during the month of February 1994, in St. Thomas, St. John, St. Croix, U.S.V.I.; Cabo Rojo and Fajardo, Puerto Rico.

Estimated Cost of Council Members Compensation	
1 member x 2 days x 5 public hearings	$3,060
Estimated Cost of Travel Expenses - Members (1)	1,250
Estimated Cost of Travel Expenses - Staff (3)	750
Estimated Cost of Conference Rooms	500
Estimated Cost of Public Hearings on the FMP	$5,560

V. Contractors

Contract to Dr. Carlos Goenaga for the Assessment of the State of Corals Around Puerto Rico	$1,000
Contract to Mr. Ralf Boulon for the Assessment of the State of Corals in U.S.V.I.	950
Contract to Dr. Yvonne Sadovy for the Assessment of the State of the Aquarium Trade Fish in Puerto Rico	1,000
Estimated Cost of Contractors	$2,950

VI. Summary of Council Estimated Costs

Consideration at Council Meetings	$33,381
Time Devoted by Staff	68,413
Scoping Meetings	4,472
Other Related Meetings	3,792
Public Hearings	5,560
Contractors	2,950
Total Estimated Cost of Development of the FMP as of June 30, 1994	**$118,568**

The NMFS incurred administrative costs during the development of the FMP and these costs are as follows.

NMFS Administrative Costs

Fisheries Management Division	$ 9,000
Economics and Trade Analysis Division	10,500
Travel to meetings	4,000
Total NMFS Administrative Cost	**$23,500**

Enforcement Costs

National Marine Fisheries Service	$13,750
U.S. Coast Guard	31,096
Commonwealth of Puerto Rico	18,700
U.S. Virgin Islands	10,522
Total Enforcement Cost	**$74,068**

Cost of Public Burden for Reporting	**$3,000**
Cost of Permits	**$3,500**

SUMMARY OF COSTS OF FMP

Caribbean Council (Through June 30, 1994)	118,568

NMFS Administrative (One-time)	23,500
Enforcement (Annual)	74,068
Permits and Data Reporting (Annual)	6,500
TOTAL FIRST YEAR COST	**$222,636**

IX. SUMMARY OF IMPACTS OF MANAGEMENT MEASURES

Table 1 gives the summary of expected changes to net economic benefits if the preferred or alternative options were implemented. The "no action" options do not appear in the table because in most cases no action implies no impact.

The one-time costs of developing the FMP as well as continuing costs for permits, data reporting and law enforcement activities are shown in the preceding section. The one-time costs total $142,068 and the continuing costs have been estimated at $80,568 on an annual basis.

Table 1. Summary of Economic Outcome of Proposed and Rejected Management Measures for Major Use and Non-Use Values of U.S. Caribbean Coral Resources

	Measure	Commercial Harvest	Recreational Harvest	Fisheries Production	Viewing, Existence and Options Value	Private Cost	Overall Change in Net Benefits
1.	Prohibit stony coral harvest except for research, education and restoration purposes.	Small Negative	Small Negative	Positive	Positive	None	Positive (Perhaps Large)
1.A	Permit regulated harvest of stony corals.	Small Positive	Small Positive	Negative	Negative	Small (Permits)	Negative
1.B	Prohibit all harvest of stony corals.	Small Negative	Small Negative	Positive	Positive	None	Positive
2.	Prohibit harvest of soft corals and live-rock except for research, education and restoration purposes.	Negative	Negative	Small Positive	Small Positive	None	Small Negative (Octocorals) Positive (Live-Rock)
2.A	Prohibit the harvest of octocorals and live-rock, except for research, education and restoration purposes or for aquaculture of live-rock.	Negative	Negative	Small Positive	Small Positive	Small (Aquaculture Permits)	Small Negative
2.B	Permit regulated harvests of octocorals and live-rock.	Positive	Positive	Small Negative	Small Negative	Small (Permits)	Positive (Octocoral) Negative (Live Rock)
2.C	Prohibit all take of octocorals and live-rock.	Negative	Negative	Small Positive	Small Positive	None	Small Negative
3.	Prohibit sale of prohibited species.	Positive	Positive	Positive	Positive	None	Positive (Where Applicable).
4.	Prohibit use of chemicals and explosives.	Increase in Harvest Costs	None	Positive	Positive	None	Positive

Table 1.(cont.) Summary of Economic Outcome of Proposed and Rejected Management Measures[1] for Major Use and Non-Use Values of U.S. Caribbean Coral Resources

	Measure	Commercial Harvest	Recreational Harvest	Fisheries Production	Viewing, Existence and Options Value	Private Cost	Overall Change in Net Benefits
4.A	Permit regulated use of chemicals and explosives.	None	None	Negative	Negative	Small (Permits)	Small Negative
5.	Limit harvest of FMU organisms to hand-held dip nets and slurp guns, except for research, education and restoration purposes.	Increase in Harvest Costs	None	Positive	Positive	None	Positive
5.A	Limit harvest of FMU organisms to hand-held dip nets and slurp guns and limit harvest to current levels.	Negative and Increase in Harvest Costs	None	Small Positive	Small Positive	Small (Permits)	Negative
5.B	Prohibit harvest of FMU organisms.	Negative	Negative	Small Positive	Small Positive	None	Negative
6.	Require permits to harvest or possess legal species. Require harvesters, dealers and exporters to be permitted and to report harvests, shipments and unit costs.	None	None	Small Positive	Small Positive	$3,000 or $6,500	Positive

1 "No Action" alternatives are not present in the summary"

X. ANALYSIS FOR THE NEED FOR AN INITIAL REGULATORY FLEXIBILITY ANALYSIS

The Regulatory Flexibility Act requires a determination as to whether or not a proposed rule has a significant impact on a substantial number of small entities. If the rule does have this impact then an Initial Regulatory Flexibility Analysis (IFRA) has to be completed for public comment. The IRFA becomes final after the public comments have been addressed. If the proposed rule does not meet the criteria for "substantial number" and "significant impact," then a certification to this effect must be prepared. The determinations for this amendment are based largely on the RIR and partially on information in the FMP, both of which can be referenced for additional information.

The substantial number criterion is that 20% of the businesses engaged in the fishery must be affected by the action. There are about 16 small business in the U.S. Caribbean which are potentially involved in the collection, sale and export of coral reef organisms managed by this FMP. These firms employ a total of less than 100 workers in all phases of the businesses (mostly harvesters, biologists, packers and shippers). In addition to firms involved in the commercial aspects of harvest, there are an estimated 65 businesses which provide recreation diving services. Since the FMP will eliminate collecting for personal use, there is the chance that their businesses could be marginally affected by the actions contemplated by the FMP. However, of the total of about 81 businesses identified, less than 20% are expected to be affected by the actions because the volume of harvest is quite low.

The outcome of "significant impact" can be triggered if any of the following conditions are met:

- The regulations are likely to result in a reduction in annual gross revenues by more than 5 percent.

- Annual compliance costs (annualized capital, operating, reporting, etc.) increase total costs of production for small entities by more than 5 percent.

- Compliance costs as a percent of sales for small entities are at least 10 percent higher than compliance costs as a percent of sales for large entities.

- Capital costs of compliance represent a significant portion of capital available to small entities, considering internal cash flow and external financing capabilities.

- The requirements of the regulation are likely to result in a number of the small entities affected being forced to cease business operations. This number is not precisely defined by SBA but a "rule of thumb" to trigger this criterion would be two percent of the small entities affected.

For the commercial businesses, the FMP and RIR show that about 3 percent of their business involves the coral and associated species to be managed by the FMP and although the businesses would lose some sales and value via the action, the loss is expected to be less than 5% of sales. These small businesses will not have any compliance costs associated with the action and none of the businesses are expected to cease operations as a result of the rule.

Since neither the substantial number nor significant impact criteria are expected to be met, the determination is made that an IRFA is not required.

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APPENDIX 4
Fishery Management Plan for Corals and
Reef Associated Plants and Invertebrates of
Puerto Rico and the U.S. Virgin Islands

FINAL ENVIRONMENTAL IMPACT STATEMENT
FOR THE

Fishery Management Plan for Corals and Reef Associated Plants and Invertebrates of Puerto Rico and the United States Virgin Islands

Caribbean Fishery Management Council

July 1994

COVER SHEET

RESPONSIBLE AGENCIES: Caribbean Fishery Management Council
National Marine Fisheries Service

TITLE OF PROPOSED ACTION:
Fishery Management Plan for Corals and
Reef Associated Plants and Invertebrates
of Puerto Rico and the U.S. Virgin Islands

CONTACT FOR FURTHER INFORMATION:

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TYPE OF DOCUMENT: Final Environmental Impact Statement (FEIS)

ABSTRACT:

The Caribbean Fishery Management Council (Council) is proposing a Fishery Management Plan (FMP) for over 100 species of corals and over 60 species of reef-associated plants and invertebrates in Puerto Rico and the U.S. Virgin Islands. The FMP includes a fishery for live invertebrates, taken for the marine aquarium trade, and other coral reef and seagrass resources. The FMP is designed to address the impacts of man's activities on the condition of coral reefs and to respond to the rapidly expanding fishery for aquarium species, especially in Puerto Rico. Except for permitted research, education and restoration programs, the FMP prohibits the harvest of stony corals, sea fans, gorgonians and live-rock; limits harvest of other invertebrates to dip nets and slurp guns; and prohibits the use of chemicals and explosives. The FMP also addresses interstate or international commerce in prohibited species and requires permits and reporting to improve data collection. The FEIS explores the environmental consequences of the proposed actions, and alternative measures, and considers the possible economic impacts of limited harvests, restricted gear, and reporting requirements, on commercial harvesters of coral reef resources.

DUE DATE FOR COMMENTS: OCT. 10, 1995

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1.0 PURPOSE AND NEED

The FMP was developed for two reasons. The first is a general concern for effects of man's activities on coral reefs and reef-associated resources. The second is related to a new and rapidly expanding fishery for the marine aquarium industry, especially in Puerto Rico (See FIGURES 1 and 2). The Council is concerned about potential impacts of this fishery on both the targeted organisms and on the reef habitat from which they are collected, due to increasing demand and current harvest methods (e.g., chemicals and removal of reef substrate for "live-rock"). Although state laws regulate coral, there is no federal regulation of the taking of coral and coral reefs. No state or federal laws exist to protect reef-associated plants and invertebrates (except for spiny lobster and queen conch). The FMP, in association with state laws, is expected to provide consistent coral regulation in both state and federal waters off Puerto Rico and the U.S. Virgin Islands. Further, the FMP will provide a management scheme for currently unregulated reef-associated plants and invertebrates.

A major source of mortality of corals and associated seagrasses and invertebrates is sedimentation and pollution, caused predominately by land-based or nearshore activities such as deforestation and discharge of untreated sewage. The Council intends to use this plan to bring state and federal agencies together to work on these habitat issues. In particular the Council is concerned about the reduction of sediment input from upland sources, the elimination of discharge of untreated sewage and petroleum products into coastal waters, and higher standards for discharge permits.

Reef habitats surrounding Puerto Rico and the U.S. Virgin Islands are of special concern. Degradation from man-made and natural causes, despite current laws, is compromising these ecosystems. Anthropogenic stress on coral reefs not only directly compromises their condition, and that of the organisms that depend on them, but is also believed to undermine the reefs' ability to recover from natural stress. Loss of coral reef and seagrass habitats directly affects a wide range of organisms including fisheries of considerable commercial and recreational significance in the Caribbean. These resources are heavily dependent on reef habitats for food and shelter. Of particular concern is the loss or degradation of habitats critical for certain life history stages or phases of development.

Important sources of habitat degradation, other than land-based activities, are dredging and dumping, anchor damage, ship groundings, tourist and diver activities, and collection by scientists or commercial fishers. The Council believes that some of these effects can be mitigated by appropriate management action.

There is a potential for a rapid increase in the exploitation of components of the fishery management unit (FMU) and Puerto Rico may soon become 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. In addition, importation of marine exotic species by pet shops into Puerto Rico (1,220 boxes in 1991) introduces the potential for exotic introductions into marine waters through release or escape. Certain harvest techniques, such as the use of chemicals and the physical removal of live-rock and corals, or the disturbance of substrate in the course of collecting organisms, damage coral reef habitat.

There is insufficient scientific and fishery information on reefs, most reef-associated invertebrates, and seagrasses, regarding growth rates, life span, colonization patterns, distribution, abundance, landings, catch, effort and mortality, on which to base species-specific recommendations or to determine levels of optimum yield (OY), maximum sustainable yield (MSY), or allowable harvest levels. Little is known of the importance of interspecific associations in the distribution and general health of reef species, although these factors are thought to be critical to the integrity and diversity of the coral reef ecosystem. 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 a potential for user conflicts. If present trends continue, i.e., increasing coastal development and commercial exploitation, the condition of the coral reefs is expected to continue to deteriorate. The Council has agreed on a proposed set of management objectives to address the problems of coral resources.

MANAGEMENT OBJECTIVES

O 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.

O 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.

O 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.

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

O 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 provide more conscientious resource use.

O 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.

O 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.

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

O 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.

ISSUES TO BE CONSIDERED
OVERFISHING - How can we reduce direct and indirect harvests of slow-growing or non-renewable coral reef resources?
ECONOMIC IMPACTS - What are the effects of limiting harvests on commercial collectors and what are the benefits to non-consumptive users?
HABITAT LOSS - What is the effect of continued removal of reef resources on commercial fish stocks and threatened and endangered species?
MONITORING & ENFORCEMENT - How can we improve the opportunities for effective monitoring and enforcement of conservation rules?
INEFFICIENT UTILIZATION - How can we reduce capture and transport mortality of aquarium species?
INADEQUATE INFORMATION - How can we improve the data base for more effective management of coral resources?
REGIONAL MANAGEMENT - What is the best way to ensure a consistent management regime for the U.S. Caribbean?

2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

The following management measures (proposed actions) are intended to address the management objectives discussed above. Each management measure has a number of alternatives that have been considered by the Council.

MANAGEMENT MEASURE 1: **Prohibit the harvest or possession of stony corals, whether alive or dead, except for legally permitted research, education and restoration programs.**

Corals and coral reefs are distinctive habitats of limited distribution. Their principal value is non-consumptive. They provide essential habitat to shelter reef-associated fish and invertebrates, and have aesthetic significance for recreational users and tourists. Given the characteristically slow growth rates of stony corals, recovery and regeneration following harvest and other human perturbations are far slower than observed in most other living resources. Stony corals must therefore be considered as a resource that is non-renewable on a human time scale and harvest should be 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 research, education and restoration activities to allow data collection, study, and recovery of the depleted resource. Permits would be required for scientific and educational harvest, and restoration programs. Harvest of stony corals is prohibited in state waters of Puerto Rico and the U.S. Virgin Islands without a permit.

ALTERNATIVE 1A **S** Permit the regulated harvest of stony corals.

Although the majority of corals and coral reefs are non-renewable resources, it may be possible to allow commercial harvest of 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 information 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 management unit, this is not currently a viable management option. Once information becomes available that indicates that harvest may be resumed, the Council intends to amend the plan accordingly.

ALTERNATIVE 1B **S** Prohibit all harvest of stony corals.

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 habitat restoration activities is necessary to enhance our understanding and appreciation of coral resources and to allow for mitigation measures in damaged areas.

ALTERNATIVE 1C **S** No Action.

Stony corals receive no protection in waters under federal jurisdiction surrounding Puerto Rico and the U.S. Virgin Islands. While the resource does have commercial value, its principal worth is in non-consumptive uses. Regulations are needed to maintain and conserve corals and coral reefs and to prevent their damage and destruction. While this option could provide short-term benefits to those currently taking stony corals, ultimately status quo would negatively impact the resource and, in turn, any industries dependent on the healthy condition of coral resources and on the exploitation of coral-dependent organisms.

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.

Octocorals are most valuable as habitat for other organisms and as a source of biomedically active compounds. They have aesthetic, non-consumptive value for recreational divers and have a limited commercial use in the marine aquarium trade. Live-rock is an integral part of the reef community and is of value as habitat and as a product for the marine aquarium trade. These sessile reef resources are particularly vulnerable to natural and anthropogenic stress because of their sedentary nature and because, especially in the case of live-rock, their replacement rates are characteristically too slow to be considered a renewable resource. Moreover, especially in the case of gorgonians, population dynamics may make these resources less responsive to traditional fishery management approaches and, therefore, possibly more vulnerable to overfishing. Pressure to exploit octocorals and live-rock is expected to grow as market demand for live marine invertebrates increases and as regulations elsewhere (e.g., Florida) become increasingly restrictive. Octocorals and live-rock are believed to be of greater value to the Nation as habitat, for aesthetic use, and, in the case of certain octocorals, as potential sources of medically important compounds, than as a commercially harvested resource to supply the aquarium trade. Permits will be required for exempted research, education and habitat restoration purposes.

ALTERNATIVE 2A — Prohibit the harvest or possession of octocorals and live-rock, except for legally permitted research, education and restoration programs, or in the course of bona fide aquaculture operations.

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 enhance enforcement. Open-water aquaculture operations could affect marine ecosystems by changing species composition and distributions of natural communities. Without controls on allowable substrate in aquaculture operations, there is the potential to 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 basis. One 5-acre lease site off Florida's west central coast (Tarpon Springs) is expected to begin operations shortly. Land-based, closed systems for live-rock aquaculture would also require a permitting process for collection of "seed-stock", 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. The degree of interest in live-rock aquaculture in the U. S. Caribbean is unknown.

ALTERNATIVE 2B **S** Permit the regulated harvest of octocorals and live-rock.

Given the importance of octocorals and live-rock as non-consumptive resources and the lack of definitive information regarding growth and replacement rates and natural abundance, recommendations of sustainable harvest levels are not possible at this time. However, octocorals rejuvenate removed portions and grow faster than stony corals. Thus, limited harvest of certain octocoral species may be possible in the future based on appropriate scientific findings that could help establish sustainable harvest levels. Once information becomes available that indicates harvest of octocorals or live-rock can be resumed, the Council intends to amend this plan accordingly.

ALTERNATIVE 2C **S** Prohibit all take of octocorals and live-rock.

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

ALTERNATIVE 2D **S** No Action.

Octocorals and live-rock receive no protection in waters under federal jurisdiction in the U.S. Caribbean. While these resources have limited commercial value in the aquarium trade, their primary worth is in non-consumptive uses and as potential sources of biomedically active compounds. Regulations are needed to maintain and conserve octocorals and live-rock and to prevent their damage or destruction. While this option could provide short-term benefits for those currently harvesting octocorals and live-rock, ultimately, the status quo would negatively impact the resource and, in turn, the industries and other organisms dependent on them.

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.

It may be necessary to document the legal possession of prohibited species that were harvested from, or purchased, outside the area and arrived in interstate or international commerce. The burden of proof, however, should be upon the person possessing 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 could be considered prima facie evidence that the prohibited species was harvested from the management area and is in illegal possession.

ALTERNATIVE 3A **S** No action.

Without specified procedures to provide a "paper trail" documenting the origin of a specimen, a person in possession of a prohibited species would not be able to prove legal possession. Additionally, enforcement personnel should be able to assume, in the absence of specific documentation, that the prohibited species was taken from the management area and not imported legally.

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.

Synthetic chemicals, natural products derived from plant species, and explosives, including powerheads on spear guns, would be prohibited. Chemicals currently being used to harvest reef-associated organisms include the fish anesthetic, quinaldine, gasoline, and bleach. These substances are known to be detrimental to both fish and invertebrate species on both long- and short-terms bases. Since other, less damaging, methods are available to successfully harvest these organisms, this proposed prohibition would not preclude harvest of the majority of commercial organisms.

ALTERNATIVE 4A **S** Permit the regulated use of chemicals, including those derived from plant species, and explosives to harvest corals and associated invertebrates.

Under this option, the harvest of corals and associated invertebrates with synthetic chemicals, plant derivatives, and explosives would be allowed under permit. However, in the opinion of the Council, the toxic nature of quinaldine, the most commonly used chemical method of collection, and the destructive nature of explosives, combined with the availability of effective alternative methods, precludes the adoption of this alternative.

ALTERNATIVE 4B **S** No action.

Continued unregulated use of chemicals is expected to result in both short- and long-term detrimental effects on coral resources, especially sessile reef-associated organisms. It is widely understood that explosives have devastating effects on reef communities. Quinaldine, the most popular chemical collection method, is a coal tar derivative used in the manufacture of dyes and explosives. Although its effects on most species are inconclusive, quinaldine is known to be toxic to some organisms. The use of quinaldine is prohibited, along with the use of other chemical substances and explosives, under the Reef Fish FMP and by state laws of Puerto Rico and the U.S. Virgin Islands.

MANAGEMENT MEASURE 5: Limit harvest 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.

Gear methods commonly used to harvest marine aquarium invertebrates include hand-held dip nets, chemicals such as quinaldine, and slurp guns. A crow bar or similar instrument is sometimes used to remove live-rock and to overturn corals and coral heads to allow access to organisms sheltering underneath. Some of these methods can damage the reef habitat and are a source of incidental mortality for other reef-associated organisms. Of the traditional gear employed in the harvest of marine aquarium organisms, only hand-held dip nets and slurp guns represent no threat to coral reefs and associated organisms and are effective for the majority of commercial organisms. While most invertebrates may be collected with dip nets and slurp guns, certain collections for scientific, educational, or restorative purposes may require the use of chemicals (such as anesthetics) or nets such as cast nets. Accordingly, an exemption for certain permitted gear is proposed.

ALTERNATIVE 5A **S** Limit harvest of marine aquarium invertebrates to hand-held dip nets and slurp guns and to current levels of harvest.

There is insufficient information to allow evaluation of OY for reef-associated invertebrates in the FMU. Although an estimate of current harvest levels could be based on reported exports, this may be an underestimate due to the substantial but unquantified on-island trade. The Council does not believe that any of these species are in current danger of being overfished, with the possible exception of Condylactis sp. which constitutes over 50 percent of the export trade, by number. When additional information becomes available, this option will be re-evaluated.

ALTERNATIVE 5B **S** Prohibit harvest of reef-associated invertebrates.

Maximum protection of invertebrate species in the FMU would be afforded by a total prohibition of harvest. However, because the majority of reef-associated invertebrates are thought to be currently harvested in low numbers and may be able to sustain limited harvest activity at these levels, a total prohibition is not justified at this time. If, however, harvest levels increase or certain species are considered to be particularly vulnerable to harvest, the Council intends to reconsider this option.

ALTERNATIVE 5C **S** No action.

Reef-associated invertebrates, with the exception of spiny lobster, receive no protection in waters under federal jurisdiction in the U.S. Caribbean. 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 this option could provide short-term benefits for current harvesters, the potential exists for significant damage to coral resources from certain methods of harvest such as toxins and crowbars. Ultimately, status quo would negatively impact the resource and, in turn, the industries dependent on the exploitation of coral resources.

MANAGEMENT MEASURE 6: Require a permit (up to a year) to harvest or possess organisms in the fishery management unit in the EEZ.

An annual permit would be required to harvest, maintain, and/or sell reef-associated invertebrates in the FMU. The permit system would be operated by local governments, with the assistance of the National Marine Fisheries Service (NMFS). NMFS could screen and recommend approval or disapproval of any applications from the U.S. mainland. Permit applicants would have to supply information regarding species to be collected, quantities, unit value, collection areas, and gear used. A permit would be denied anyone with an outstanding violation in any state or federally regulated fishery. Issuance of a permit would be subject to acceptance by permittees of minimum standards of maintenance, handling, and transport of live marine organisms. An appropriate fee would be charged to recover costs of administering the permit system. A permit system is needed to determine present effort in the fishery and to identify participants. It would also facilitate introduction of a limited entry system, in the event such a system is warranted. Special permits would also be available for research, education and restoration purposes for other components of the FMU (stony corals, octocorals, and live-rock). Research, education and restoration permits would be awarded on a case-by-case basis following submission of a research plan, including species and quantities to be collected, and area of collection.

ALTERNATIVE 6A **S** No action.

Harvesters and exporters of invertebrates for the marine aquarium trade and other commercial users are not currently licensed in Puerto Rico and their activities are not regulated.
The U.S. Virgin Islands requires permits for both harvest and export; however, most commercial harvest occurs in Puerto Rico. A permit system for the entire management area is needed to establish area-wide participation in the fishery, to help limit access to the fishery should this become necessary, and for consistent management for the entire FMU.

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

Reports would be required by the permit agency to more accurately determine actual participation in the fishery, catch, and effort. This data would allow managers to assess the status of resources in the FMU and make informed decisions on future management measures. Permit data could also be used to estimate mortality of organisms collected by the aquarium trade between the time of capture and shipping. Permit data would also be used as the foundation for the development of a limited access system for the fishery, if necessary, and could help establish OY for invertebrate species. Reporting intervals and other requirements should be patterned after systems already tested and proven successful in other fisheries.

ALTERNATIVE 7A **S** No action.

No action would result in a continuing lack of information upon which to base management decisions and a growing potential for overharvest. A number of management actions and recommendations have already been deferred by the Council's 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 a permit and reporting system. Information on the number of participants and the amount of catch and effort is currently too incomplete to develop limited access programs should this prove to be necessary.

Establishment of Marine Conservation Districts (MCDs) -- Deferred Alternative.

The Council is considering the establishment of MCDs. An MCD is a discrete geographical area of special value and significance to the marine ecosystem that is to be maintained in its natural state. The purpose of the MCD is to conserve and manage representative samples of marine habitats and ecosystems and to maintain marine biodiversity. The expected effects of establishing MCDs under this FMP are (1) to provide refuge and replenishment areas to ensure continued abundance and diversity of reef resources; (2) to protect critical spawning stock and recruits from depletion and overfishing, thus increasing abundance of fishery resources; (3) to protect coral and coral habitat, and (4) to improve opportunities for eco-tourism.

Based on comments received on the draft FMP/EIS, the Council decided to defer the establishment of MCDs until more information is available and further consultation with the user groups is carried out.

TABLE I

Effects of Management Measures (1-7) and their Alternatives on the Issues:

1. STONY CORAL ALTERNATIVES				
ISSUES	**No Action**	**Limit Harvest**	**No Harvest w/exceptions**	**No Harvest**
Overfishing	Continuing adverse impacts.	Lessens adverse impacts.	Eliminates most impacts.	Maintains OY.
Economic Impacts	No effects on commercial users.	Minor effects.	Negative impact on harvesters.	Negative impact on harvesters.
Habitat Loss	Continuing adverse impacts.	Lessens adverse impacts.	Eliminates most impacts.	No "net" loss.
Monitoring & Enforcement	No effects.	Enforcement problems.	Enforcement problems.	Enforcement problems.
Inefficient Utilization	No effects.	No effects.	Lessens impacts.	Eliminates problem.
Inadequate Information	No effects.	No effects.	No effects.	No effects.
Regional Management	No effects.	Improves.	Improves.	Improves.

2. SOFT CORAL / LIVE-ROCK ALTERNATIVES				
ISSUES	**No Action**	**Limit Harvest**	**No Harvest w/exceptions**	**No Harvest**
Overfishing	Continuing adverse impacts.	Lessens adverse impacts.	Eliminates most impacts.	Maintains OY
Economic Impacts	No effects on commercial users.	Minor effects.	Negative impact on harvesters.	Negative impact on harvesters.
Habitat Loss	Continuing adverse impacts.	Lessens adverse impacts.	Eliminates most impacts.	No "net" loss
Monitoring & Enforcement	No effects.	Enforcement problems.	Enforcement problems.	Enforcement problems.
Inefficient Utilization	No effects.	No effects.	Lessens impacts.	Eliminates problem.
Inadequate Information	No effects.	No effects.	No effects.	No effects.
Regional Management	No effects.	Improves.	Improves.	Improves.

TABLE I (CONT.)

3. DOCUMENTATION ALTERNATIVES		
ISSUES	**No Action**	**"Paper-trail" Required**
Overfishing	No effect.	Discourages illegal possession.
Economic Impacts	No effect.	Minor to commercial interests.
Habitat Loss	No effect.	Discourages illegal possession.
Monitoring & Enforcement	No effect.	Major improvement.
Inefficient Utilization	No effect.	No effect.
Inadequate Information	No effect.	Minor improvement.
Regional Management	No effect.	Improves.

4. CHEMICALS/EXPLOSIVES ALTERNATIVES			
ISSUES	**No Action**	**Limit Use**	**Prohibit Use**
Overfishing	Continues adverse effects.	Lessens incidental taking.	Ends incidental taking.
Economic Impacts	None on commercial users.	Minor effects.	Minor effects.
Habitat Loss	Continuing adverse impacts.	Some improvement.	Major improvement.
Monitoring & Enforcement	No effects.	Enforcement intensive.	Enforcement needed.
Inefficient Utilization	Continues adverse effects.	Some improvement.	Eliminates incidental take.
Inadequate Information	No effects.	No effects.	No effects.
Regional Management	No effects.	Positive benefits.	Positive benefits.

TABLE I (CONT.)

5. GEAR RESTRICTION ALTERNATIVES

ISSUES	No Action	Limit Harvest by Gear	Limit Harvest by Gear/Quota	No Harvest
Overfishing	Unknown.	Expected benefits.	Expected benefits.	Positive effects.
Economic Impacts	None on commercial users.	Minor effects.	Moderate effects.	Major effects.
Habitat Loss	Continues adverse impacts.	Protects from nets, etc.	Protects from nets/overfishing.	Complete protection.
Monitoring & Enforcement	No effects.	Enforcement needs.	Enforcement needs.	Easier to enforce.
Inefficient Utilization	Continues adverse impacts.	Decreases capture mortality.	Decreases capture mortality.	Eliminates capture mortality.
Inadequate Information	No effects.	No effects.	No effects.	No effects.
Regional Management	No effects.	Positive effects.	Positive effects.	Positive effects.

6. HARVESTER PERMIT ALTERNATIVES

ISSUES	No Action	Permits Required
Overfishing	Unknown.	Unknown.
Economic Impacts	None.	Minor.
Habitat Loss	No effects.	No effects.
Monitoring & Enforcement	Continues adverse impacts.	Improves.
Inefficient Utilization	No effects.	No effects.
Inadequate Information	Continues adverse impacts.	Improves.
Regional Management	No effects.	Positive effects.

TABLE I (CONT.)

7. DEALER/EXPORTER PERMIT ALTERNATIVES		
ISSUES	**No Action**	**Permits/Reports Required**
Overfishing	Unknown.	Unknown.
Economic Impacts	None.	Minor.
Habitat Loss	No effects.	No direct effects.
Monitoring & Enforcement	Continues adverse effects.	Greatly improves.
Inefficient Utilization	No effects.	No effects.
Inadequate Information	Continues adverse effects.	Greatly improves.
Regional Management	No effects.	Positive effects.

POSSIBLE FUTURE ACTIONS

Several management measures were identified during the development of this FMP which merit consideration for future action. These measures were not included in the FMP because of insufficient data, but may be added by future amendment. The measures include:

< establishing marine conservation districts in the EEZ

< setting quotas for the harvest of reef-associated invertebrates

< limiting entry into the aquarium fishery, including establishment of a control date for possible use in determining historical participation

< establishing temporary closures (e.g., spawning season or area closures)

< prohibiting harvest of additional vulnerable or rare species

< developing maintenance, handling, and transportation standards to minimize mortality in the aquarium trade for reef-associated invertebrates

< prohibiting the introduction of exotic marine organisms

SPECIAL 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 effect of anthropogenic activities on nearshore reefs, especially in state waters, state cooperation is essential for effective management. Solutions to the problems of reef management may only be found through a combination of state and Federal action. One of the more critical issues is the elimination of discharge of untreated sewage and petroleum products into coastal waters.

The FMP provides the following recommendations to the governments of Puerto Rico and the U.S. Virgin Islands:

- Establish permitted anchoring sites in coral reef areas

- Identify habitats of special concern or ecological importance

- Create marine conservation districts to provide a monitoring baseline 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

Candidate areas include: Culebra (including the Península Flamenco area), Cordillera, Vieques Sur, Vieques Norte, Bahía de Jobos, Isla Caja de Muertos, Margarita, Islas Mona and Desecheo in Puerto Rico; south of St. John, and the reserve areas in St. Croix, as proposed by the U.S.V.I. Department of Planning and Natural Resources.

- Develop a comprehensive mapping of coral and rock reef areas over the insular platform

- Harmonize state and federal laws

- Ensure compliance with discharge and dredging laws

- Permit only tertiary water treatment standards for identified coral areas

- Develop a code of standards for the maintenance, handling, and transportation of fish and invertebrates traded live and ensure 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 pet shops, and airport monitoring

- Cooperate with NMFS to ensure consistent and integrated permit and data collection systems

- Regulate diving activities to reduce damage to reef areas from direct physical contact and recreational collecting

- Emphasize the importance of the reef ecosystem in the development of tourism (eco-tourism)
- Introduce a permit system for those who collect and market live marine organisms
- Develop management measures for seagrass habitats
- Prohibit the release of exotic marine species into island waters
- Enforce existing regulations to protect coral resources and habitats

3.0 AFFECTED ENVIRONMENT

Goenaga and Boulon (1992) provide a description of the corals and coral reefs of Puerto Rico and the U.S. Virgin Islands. This report is included as Appendix 1 of the attached FMP. In addition, Sections 2, 3, and 4 of the FMP contain a Description of the Resource, a Description of the Fishery, and a summary of Capacity Limits.

Description of the Resource

Species in the FMU

The FMU includes all corals, reef-associated invertebrates, and marine plants. Following is a list of the common names of the major groups. See Table 1 of the FMP for a more detailed description and species listings.

- Stony Corals
  - Reef-building corals (Scleractinians)
  - Fire Corals (Hydrocorals)
  - Black Corals
- "Live-rock"
- Octocorals
  - Gorgonians
  - Sea Fans
- Sea Anemones
- Sponges
- Tube Worms

Mollusks
- Snails
- Nudibranchs
- Clams, Scallops
- Oysters
- Octopus

Crustaceans
- Shrimp
- Crab

Echinoderms
- Starfish
- Brittlestars
- Feather Stars
- Sea Urchins

Bryozoans (moss animals)

Sea Squirts

Marine Algae
- Sargassum
- Watercress (Halimeda spp)
- Green Feather, Green Grape Algae (Caulerpa spp.)
- Mermaid's Fans and Cups (Udotea spp.)
- Coralline Algae

Seagrasses
- Turtle Grass
- Manatee Grass
- Sea Vines

Stony Corals

Coral reefs are among the most productive ecosystems on earth, supporting a higher biological diversity than any other system, with the possible exception of tropical rain forests. The structural complexity of the reefs produces a baffle effect, which acts to reduce wave energy. Stony corals buffer the shoreline and prevent erosion. The biodiversity of the reef system sustains coastal reef fisheries and has provided chemical compounds of medical significance. Their biodiversity and aesthetic value is also responsible for the rapid growth of recreational diving and other tourist activities. For example, the National Park Service reported an increase in annual visitors to the underwater trail in Trunk Bay, St. John, U.S. Virgin Islands from 20,000 in 1966 to 170,000 in 1986. A study in the Biosphere Reserve of St. John also noted an increase in the average daily number of boats using the park from 10 in 1966 to 80 in 1986.

Live-rock

"Live-rock" means any hard substrate (including dead coral or rock) to which is attached, or which supports, any living marine organism listed in the FMU. A market has developed for live bottom substrate found in tropical or semi-tropical areas to create "living reefs" or "mini-reefs" in home aquaria. About 400 tons are reported taken annually in Florida. Live-rock is collected by chipping off portions of the reef (presumably without stony corals present) or by removing substrate adjacent to the reef. This hard substrate is also an integral component of the reef habitat and important for the maintenance of reef-associated fish, invertebrates and plants. The sessile invertebrate communities that make up live-rock are an important food base for commercially important fish and shellfish. Furthermore, the physical and topographical complexity of live-rock provides critical shelter and habitat for a wide range or organisms. A number of studies have shown a positive correlation between increased habitat complexity and increased fish abundance and diversity.

Rock and dead coral surfaces are also vital substrates for the settlement of larval phases of benthic organisms which cannot settle on living coral. Suitability of substrate is one of the major factors controlling the distribution of many species. Little is 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. Any harvest is expected to result in net loss of this substrate.

Benthic Invertebrates and Algae

The benthic invertebrates and marine algae included in the FMU are a highly diverse group of organisms involved in the marine aquarium trade, either as individuals or as members of communities that comprise live-rock. Many of these organisms have only been identified to the level of family or genus. Identification to species is particularly difficult for gorgonians, sponges and brittlestars. Data are needed to document the distribution and abundance of harvested species and to evaluate their relative contributions to reef communities. One indication of the importance of benthic organisms in reef communities is the results of a study on a reef south of Ponce, Puerto Rico. In sample areas, researchers found 13-17 percent calcareous algae, 2-15 percent boring sponges, and 5-15 percent encrusting gorgonians among 11-22 percent live coral cover.

Seagrasses

Seagrass communities are highly productive and provide nutrients and habitat for many reef species of plants, fish, and invertebrates. They protect coral reefs by dampening wave action and slowing currents to enhance sediment stability and increase the accumulation of organic and inorganic material. While their distribution patterns in Puerto Rico and the U.S. Virgin Islands are poorly described, seagrasses are thought to be highly vulnerable to pollution, sedimentation, and other human activities in the U.S. Caribbean.

Description of Fishery

Section 3.0 of the Coral FMP provides a complete description of the fishery. Following is a summary of this information:

History of Exploitation

The taking of reef-associated invertebrates for the aquarium trade is a relatively new activity which began about 1970 in Puerto Rico. By the mid to late 1980s there began a rapid expansion from a handful of harvesters/dealers/exporters to an industry that employs up to 100 people. In the U.S. Virgin Islands, harvest and export of aquarium species is regulated by permit and this industry remains relatively underdeveloped. Harvest of aquarium species remains unregulated in Puerto Rico.

The expansion of the aquarium trade in Puerto Rico over the past two decades is attributable to three factors. First, there has been a general increase in demand for live marine organisms, especially in the U.S. and Western Europe, because improvements in technology have enabled more people to successfully maintain marine aquaria and "mini-reefs" in their homes.

Second, the excellent transport facilities in San Juan airport have made Puerto Rico a very attractive location for the harvest and export of Caribbean species. Finally, increasing restrictions on the collection of organisms in Florida waters, declines in abundance in the Philippines, and a recent trade embargo against Haiti, have all made Puerto Rico an increasing important source of Caribbean organisms.

Commercial Fishing

Commercial harvest and export of reef-associated organisms is allowed under permit in the U.S.Virgin Islands. Of the 28 permits that have been issued on St. Thomas since 1990, 26 were for "private use" and 2 were considered commercial. The private use category included public aquariums and research facilities. St. Croix issued 25 permits, mostly for small numbers of organisms for private and commercial use. Detailed information on the species composition of permitted harvests is not available.

In Puerto Rico, commercial harvest of black coral and octocorals is allowed under permit. No information is available regarding the number of permits issued. Gorgonians and at least one species of stony coral (Tubastrea aurea) are on export lists of local harvesters and shipments of corals by mail have been reported. Allegedly, boxes of corals and most live-rock are shipped from regional airports (e.g., Aquadilla and Ponce) where there are no inspections of shipments by the Puerto Rico Department of Natural Resources (PRDNR). A recent shipment containing 300 live corals was intercepted by PRDNR, suggesting that harvest and export of corals may occur in substantial quantities.

In early 1993, approximately 6 companies were known to export live invertebrates from Puerto Rico for the aquarium trade. An additional 7 companies are involved in intra-island trade, wholesale and retail, and also import Indo-west Pacific species. About 14 companies sell imported marine fish and invertebrates, largely of Indo-west Pacific origin. About 25 percent by number of the live exports from Puerto Rico are invertebrates (including corals) and live-rock . FIGURE 1 details species composition of 133 shipments of live marine invertebrates from Puerto Rico between December 1991 and August 1992 ("Set 2").

FIGURE 1 shows that the principal invertebrates species harvested for the export trade are anemones, starfish, fan worms, shrimp, crabs, urchins, and live-rock. The most heavily exploited species (>50 percent by number) is the sea anemone, Condylactis sp. Starfish, especially brittlestars, are also among the more heavily exploited species groups. Combined, live-rock, sea fans, and stony corals accounted for 3.7 percent by number of a random sample of reported exports. Principal harvest areas in 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. Harvesters indicate that they rotate areas of collection to avoid local depletion.

Recreational and Non-Consumptive Uses

The principal recreational value of coral resources involves tourism and the diving industries. In 1991, tourist expenditures were $708.1 million in Puerto Rico and $1,390.8 million in the U.S. Virgin Islands. In the 1970s, there were only 3-4 dive schools in Puerto Rico. Now there are 35-45 dive operations. The Board of Tourism is promoting Puerto Rico's underwater environment and sport fishing as part of a program of eco-tourism. Already, about 37 (17 percent) of the 221 marine recreational facilities in Puerto Rico and the U.S. Virgin Islands are dedicated partially or wholly to SCUBA training and equipment sales. In addition to spear fishing and possible collection of marine life for home aquariums or as souvenirs, sport divers want to see and photograph abundant, diverse and undisturbed coral resources.

The U.S. Virgin Islands is the major diving destination in the U.S. Caribbean. About 25-30 dive businesses are currently operating in the U.S. Virgin Islands, up from 20 in the 1980s. An underwater trail in Trunk Bay, St. John, is utilized daily by hundreds of tourists. The National

Park Service on St. John has documented annual increases of visitors to Trunk Bay beach from 20,000 in 1966 to 170,000 in 1986.

These figures give one indication of the value of the resource to the local economy. Other methods of assigning values to coral reef resources are based on interviews with coastal residents. The FMP's Regulatory Impact Review (see Appendix 3) contains a complete discussion of this subject. For example, Australian citizens valued the existence of their Great Barrier Reef at about $36 per resident adult. Using this figure, the recreational-use value of the coral reefs of the U.S. Caribbean would be about $76 million.

Medicinal Uses

Octocorals are a source of important biomedically active compounds. Prostaglandins, derived from the gorgonian, Plexaura homomalla, are among the most potent biological materials. They have been used to stimulate uterine contractions, reverse effects of cyanotic congenital heart disease, and hold much promise for medical research. Three species of Pseudoplexaura contain compounds that are active against human cancers of the nasopharynx and lymphocytic leukemia. Gorgonians have been collected in the La Parguera area of Puerto Rico and off the southwest coast of St. Thomas for scientific and commercial purposes related to their medical properties. The impact of these activities is unknown.

There are also collections of soft corals, sponges, and macroalgae for extraction of chemicals for pharmacological purposes. The frequency and extent of this activity are unknown but collections are thought to result in localized damage to reef and other coastal resources. Antimicrobial, antileukemic, anticoagulant and cardioactive chemicals have recently been isolated from a number of other reef-associated invertebrates. Section 3.4 of the FMP provides further information and references.

Commercial Landings and Fishery Habitat

From January 1990 to December 1992, an estimated 5,507 boxes of live marine aquarium fish and invertebrates (about 182,000 organisms) were exported from Puerto Rico through the San Juan airport (See FIGURE 2). This is considered to be an underestimate of harvest levels for the following reasons: (1) mail shipments are not included; (2) exports from regional airports are not included; (3) on-island sales are not included; (4) losses due to pre-shipment mortality (possibly 10-20 percent) are not included.

Of the total recorded shipped, about 25 percent were invertebrates (see Appendix 2 of the FMP). Wholesale unit prices range from $0.25 to $12.00, but average $2.00 to $3.00 a unit. The current value of invertebrates exported for the aquarium trade is probably in excess of $114,000 annually. If on-island trade is included the total value may be several times this estimate.

A primary economic value of reef and seagrass habitats lies in their importance to commercial fisheries, including reef fish, conch, and lobster. Since most of the fisheries production in the U.S. Caribbean is dependent on the existence of coral reefs, some of the economic value of the reef can be approximated by fishery landings data. The ex-vessel value of the commercial fisheries of Puerto Rico (employing about 1,219 fishers) was about $4.3 million in 1991. The U.S. Virgin Islands reported landings in 1991 totalling 1.9 million lbs worth $4.8 million.

Status of the Stocks

Stony Corals, Octocorals, Live-rock and Seagrasses

The FMP sets OY for stony corals, octocorals, live-rock and seagrasses at zero (0), except as may be authorized for research and habitat restoration. The Council believes that the greatest overall benefit to the Nation, and the most effective use of these resources is as habitat providing food and shelter for fish, conch, lobster, turtles, and manatees, the production of medically important compounds, and their aesthetic value to non-consumptive users. Given their restricted distributions and their typically slow growth and regeneration rates, these resources must be considered non-renewable, limited habitats of special concern.

Other Reef-associated Invertebrates

Little information is available regarding natural abundance, sustainable harvest levels, or actual level of current harvest for these organisms. Export figures provide only a minimum estimate of annual harvest. Because of insufficient data, the FMP does not set OY for these species. However, harvest levels are expected to increase and overharvest is known to cause depletion in certain species, e.g., the Bahama starfish in Florida. Thus, information is urgently needed to determine abundance, harvest levels, and capture-induced mortality, so that allowable harvest levels may be determined, especially for the more heavily exploited species in the FMU (e.g., Condylatis and brittlestars). Restrictions have already been placed on harvest of marine aquarium species in Florida in response to overharvesting.

TABLE II PROPOSED ACTIONS* AND THE FMP'S OBJECTIVES

OBJECTIVES	1	2	3	4	5	6	7
/ Optimize benefits to Nation	++	++	+	++	++	+	++
/ Minimize impacts on resources	++	++	+	++	++	+	+
/ Establish data collection systems						+	++
/ Establish marine reserves							
/ Educate users						+	+
/ Provide consistent rules	++	++	++	++	++	++	++
/ Provide flexible management	+	+	+	+	+	+	+
/ Reduce user conflicts	+	+	+	+	+	+	+
/ Recommend measures to reduce pollution							

***MANAGEMENT MEASURES:**

1- Prohibit harvest/possession of stony corals except for research, education and restoration.

2 - Prohibit harvest/possession of soft corals/live-rock except research/education/restoration.

3 - Require documentation of legal possession.

4 - Ban use of chemicals/explosives for reef-associated invertebrates.

5 - Restrict gear used for reef-associated invertebrates.

6 - Require harvester permits.

7 - Require harvester/dealer permits/reports.

4.0 ENVIRONMENTAL CONSEQUENCES

(A) Protection of habitat and non-renewable resources

Biological Effects

Corals, live-rock, and seagrasses are unique among fishery resources in that they serve as habitat for developmental stages of fish and invertebrates. For example, seagrass beds trap nutrients to feed reef species at some stage in their life cycles. Marine algae and invertebrates are the foundation of the food supply for all commercial fisheries. The structural complexity of coral communities including live-rock, and seagrass beds, provides shelter for juvenile fish and invertebrates, such as lobster. For the endangered West Indian manatee, and endangered and threatened sea turtles, reefs and seagrass beds are critical habitat. Sessile plants and animals are particularly vulnerable to pollution and sedimentation from upland sources and any additional harvest is likely to result in a net loss of habitat. Additionally, stony corals and live-rock, by virtue of their limestone structure, grow so slowly that they can be considered non-renewable resources on any human time-scale. Octocorals and perhaps other sessile invertebrates, have such unique population dynamics that they may not be amenable to current fishery management practices. Best available scientific information indicates that corals, live-rock, and seagrasses should not be harvested at any levels, unless necessary for medical research, habitat restoration, or other scientific purposes. Because many of these species, especially among the gorgonians, contain medically-active compounds, it is particularly important that we prevent depletion before researchers have had the opportunity to determine their usefulness in human medicine.

Socio-economic Effects

In Puerto Rico, about 40 fishers harvest live fish and invertebrates for the aquarium trade. By number, about 25 percent of exports are invertebrates. Less than 4 percent is live-rock and corals. Seagrasses are not commercially harvested in the U.S. Caribbean. The wholesale (ex-vessel) value of the approximately 45,500 live invertebrates reported exported annually is about $114,000 (assuming a $2.50 average cost per unit); therefore the reported export of stony corals, live-rock, and octocorals is valued at less than $5,000 annually. In the short-term, the prohibition of harvest of all corals, live-rock, and seagrasses is expected to have negligible economic impacts on current harvesters. Potential profits, especially from the export of live-rock, are expected to be in the millions, however, should demand continue to increase. Florida estimated that the ex-vessel value of the live-rock harvest off Florida would rise to $3.5 million by 1995, in the absence of protective regulations.

In addition to the value of the commercial and recreational fisheries that are dependent on reef and seagrass habitats, the non-consumptive value of these habitats needs to be assessed. Tourists visiting Puerto Rico and the U.S. Virgin Islands expect to see abundant, diverse, and undisturbed reef and seagrass habitats. The almost $2 billion in income from tourism needs to be weighed against the demands of aquarists and the current and potential incomes of island fishers. In the long-term, all segments of society may be better served by complete protection of reef and seagrass habitats for future generations.

(B) Limits on Allowable Fishing Gear

Biological Effects

A ban on the use of chemicals and explosives to take species in the FMU, and the specification of hand-held slurp guns and dip nets as the only allowable gear, are designed to increase survival of targeted species and protect non-targeted species from incidental mortality. Quinaldine, the most commonly used chemical agent, is a coal tar derivative used in the manufacture of dyes and explosives. Its stunning effect on reef fish, lobsters, and other invertebrates makes collection easier, but it also reportedly decreases the targeted organisms' survival and damages surrounding, usually sessile organisms, including corals. Hand-held dip nets and slurp guns should allow experienced fishers to harvest all allowable species without bycatch or increased capture mortality.

Socio-economic Effects

Marine aquarium fishers may experience increased costs of operation once proposed gear restrictions are in place. Using chemicals or large nets would be expected to increase harvesting efficiency but with concomitant bycatch and incidental mortality of surrounding organisms. In the long-term, users of these resources will benefit from the maintenance of stable and diverse reef populations. Continuing the use of poisons and explosives to harvest coral resources is probably inconceivable for most informed citizens and visitors to the U.S. Caribbean, regardless of the costs to affected fishers.

(C) Requiring Permits and Reports

Biological Effects

The FMP proposes a permit and reporting system for harvesters, dealers, and exporters of species in the FMU. A permit system can be used to determine present effort and identify participants in the fishery. It can also be used to introduce a limited entry system, if needed. Limited entry is one way to reduce participation and decrease capture mortality and bycatch in the fishery due to inexperience. Marine aquarium fishers in Florida are petitioning their state legislators to limit entry into their fishery. Required reports from collectors, harvesters, and exporters could be used to estimate capture-induced, maintenance, and transport mortality of invertebrates species. Permit data could allow the

Council to determine OY for a number of highly exploited species, such as anemones and brittlestars.

Socio-economic Effects

A fee would be charged to recover costs of administering the permit system. Up to 100 marine aquarium harvesters, dealers, and exporters are expected to apply for permits to harvest reef-associated invertebrates. The Regulatory Impact Review (Appendix 3) estimates the total administrative and reporting costs of this program at $6,500 or approximately $65 per applicant.

(D) Effects on Marine Mammals and Endangered Species

Marine mammals do not use coral reef and other hard bottom habitats, or seagrass beds; and they are not expected to be either directly or indirectly affected by the FMP. Of the endangered or threatened species under NMFS jurisdiction in the U.S. Caribbean, the hawksbill sea turtle (Eretmochelys imbricata) and the green sea turtle (Chelonia mydas) may use reef areas for foraging and shelter. The FMP's prohibitions on harvest of reef associated species including live rock, and the prohibitions on potentially damaging gear, are expected to benefit sea turtle conservation.

(E) MITIGATING MEASURES

The FMP's gear restrictions are designed to mitigate potential effects on habitat and species by gear used to take certain reef associated plants and invertebrates for the live aquarium trade.

(F) UNAVOIDABLE ADVERSE IMPACTS

Certain individuals and corporations (approximately 6 companies in Puerto Rico) are engaged in the harvest, sale and export of live marine invertebrates from the U.S. Caribbean. These entities will be adversely affected by the prohibitions on harvest and possession of corals, live rock and certain other species in the FMU.

(G) IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

There are not expected to be any irreversible or irretrievable commitments of resources in addition to increased costs of enforcement.

5.0 LIST OF PREPARERS

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6.0 LIST OF AGENCIES, ORGANIZATIONS, AND PERSONS TO WHOM COPIES OF THE STATEMENT ARE SENT

U.S. Department of Commerce, National Oceanic and Atmospheric Administration
  Office of Ecology
U.S. Department of State
U.S. Department of Agriculture
U.S. Department of the Interior
  U.S. Fish and Wildlife Service
  National Park Service
U.S. Department of Transportation
  U.S. Coast Guard
U.S. Environmental Protection Agency, Region II
Commonwealth of Puerto Rico
Government of the U.S. Virgin Islands

7.0 RESPONSE TO PUBLIC COMMENTS

This section summarizes testimony on the Draft FMP/RIR/EIS presented at 5 public hearings or submitted in writing to the Caribbean Fishery Management Council and/or the National Marine Fisheries Service during public comment period. Included, herein, are the written depositions and letters received, as well as Council's responses to comments on this FMP. (NOTE: THE MAJORITY OF THE DEPONENTS AND COMMENTS RECEIVED WERE IN FAVOR OF MANAGEMENT MEASURES 1 THROUGH 7 OF THE FMP. MANY OF THE COMMENTS ADDRESSED THE ORIGINALLY PROPOSED MARINE CONSERVATION DISTRICT, MOSTLY OPPOSITION TO ITS IMPLEMENTATION DUE TO LACK OF SCIENTIFIC AND SOCIO-ECONOMIC DATA. MANAGEMENT MEASURE 8 HAS BEEN RESERVED IN THIS FMP. THE COUNCIL DECIDED TO DEFER THE ESTABLISHMENT OF MCDs UNTIL MORE INFORMATION IS AVAILABLE AND

FURTHER CONSULTATION WITH THE USER GROUPS IS CARRIED OUT THUS, THE COMMENTS ON THE SUBJECT ARE NOT INCLUDED IN THIS SECTION). THE * DENOTES COMMENTS REGARDING MCD's WITHOUT RESPONSE AT THIS TIME). Editorial changes suggested and submitted by government agencies' officials have been incorporated already in the FMP.

Public hearings were held on the following dates and locations:

1. St. Thomas	(14)	February 1, 1994
2. St. John	(2)	February 2, 1994
3. St. Croix	(1)	February 3, 1994
4. Cabo Rojo	(6)	February 8, 1994
5. Fajardo	(9)	February 9, 1994

Numbers in parenthesis indicate number of persons who spoke at the hearings. In addition, nineteen (19) written comments were received and included herein.

1. Comment: Enforcement of the law has to be done at the "time and site" of harvest; and heavy fines should be established.

Response: The Council concurs that enforcement should be done at site of embarkment and at sea. The FMP calls for enforcement at "site and time" of harvest. The drafting of regulations should include the appropriate fines allowed under the Magnuson Act.

2. Comment: All licensed harvesters/dealers and exporters should pay revenue to export.

Response: At present, the Secretary of Commerce does not have authorization under the Magnuson Act to collect fees beyond the cost of issuing a permit.

3. Comment: Possession of prohibited species should be outlawed. There should be strict and "visible inspection" of people involved in the harvest of species in the FMU.

Response: Possession of prohibited species is already mentioned in the language of the appropriate management measures of the FMP. The Council also concurs that field inspections should be conducted as part of enforcement.

4. Comment: There should be a plan to provide education to the school systems and the general public about the FMP itself, so that people become aware of it.

Response: The FMP acknowledges the importance of education and makes allowance for permitting of institutions and persons involve in educating the public. In addition, the Council is involved in an education program that includes this and other implemented FMPs.

5. Comment: Regulate educators and investigators rather than exempt them from regulation in the FMP. Reasons for this comment include: (1) "these groups also damage the reef"; and (2) "this would allocate resources to educators and researchers while disallowing commercial fishers access to the resources."

Response: Exemptions to management measures are needed for future research and education that will assist in the conservation of the resource.

6. Comment: Suggests the establishment of a licensing system or a quota for the fisheries covered under this FMP.

Response: A permitting system is established in the FMP. Quotas have not yet been considered since the Council does not have enough information for establishing quotas.

7. Comment: Not only dealers, but every person harvesting species in the FMU should be required to have a permit.

Response: The intent of the Council is that anyone who harvests should have a permit (Management Measures 6 and 7).

8. Comment: Rules and regulations being developed for the industries should be stronger in terms of natural environment protection and should be enforced. "Oil spills are damaging not only the reefs and corals, but also the fishes, the environment, and tourism."

Response: The Council has included various recommendations to the local governments (Section 7.5.1 of the FMP) toward minimizing the negative effects caused by industries and other human activities.

9. Comment: Aquaculture should be allowed in the FMP.

Response: The Council, after careful consideration of the inclusion/exclusion of aquaculture in Management Measure 2, decided that in federal waters there is no need, at this time, to allow for aquaculture of live-rock. However, if the need arises, allowance could be considered for aquaculture of live-rock in federal waters.

10. Comment: Anchoring should be prohibited in all areas where corals could be damaged by this action.

Response: The Council is not allowed to include anchoring prohibitions in the FMP because of statute limitations under the Magnuson Act. However, recommendations in Section 7.5.1 of the FMP include the establishment of mooring buoys in pertinent coral areas.

11. Comment: Concern about the compatibility of the plans [regulations] made by the Council with those of the Puerto Rico government. "If this Plan is enforced in federal waters, the collectors and persons fishing for aquarium fishes could move to local waters, to be protected under the local government jurisdiction." This will increase the catch of the species in the FMU.

Response: The local government representatives have stated that their Agency (PRDNRE) will establish compatible regulations to preclude the above mentioned situation from occurring.

12. Comment: Coordination should be established with fishing groups and associations, to enhance enforcement capabilities.

Response: The Council endorses this idea and will include it as part of the agenda in the orientation meetings with other agencies and the public.

13. Comment: Opposed to allow legally permitted research, education and restoration programs (Management Measures 1, 2, 4, and 5) because of the damage it may cause to the coral and the coral reef resources.

Response: The Council considers that although the needed research could be destructive, it could assist in the conservation, monitoring and management of the resources.

14. Comment: Concern about encouraging depletion of corals and coral reef resources in Caribbean areas outside Council jurisdiction.

Response: The Council promotes pan-Caribbean management of the species included in FMPs (See Objective 6 of this FMP). Whenever possible, and so requested, the Council assists other countries in the development of management plans.

15. Comment: There is no SIA in this FMP.

Response: The Council understands the SIA is not a requirement under the Act for approval or disapproval of an FMP. Still, the Council believes that when the appropriate information is available, an SIA should be an integral part of any FMP. In the case of the present FMP there is no available information to prepare an SIA. However, since Management Measure 8 has been reserved, and this is the management measure that most likely will have a significant social impact, the lack of an SIA should not be hindrance to the approval of this FMP.

16. Comment: Concern about the permitting process and differences between federal waters in Puerto Rico and USVI.

Response: The intent of the Council is to have a uniform permitting system across the areas of jurisdiction (Federal waters, Puerto Rico and the U.S. Virgin Islands) following the Magnuson Act requirements and the compatible regulations to be established by the local governments.

17. Comment: Concern about the harvesting prohibitions when the fishery is so small and thus have an equally small effect on the ecology of the coral reefs.

Response: The Council believes that although, at the present time, the fishery for live-rock and other species in the FMU could be considered small, a conservative approach is warranted given the expansion of these activities in the past few years. The noted increase in the aquarium trade might significantly affect the habitat for the reef fish and other important species in the area.

18. Comment: There is lack of scientific data for this FMP.

Response: The best available data have been used in the preparation of this FMP, as per the Magnuson Act.

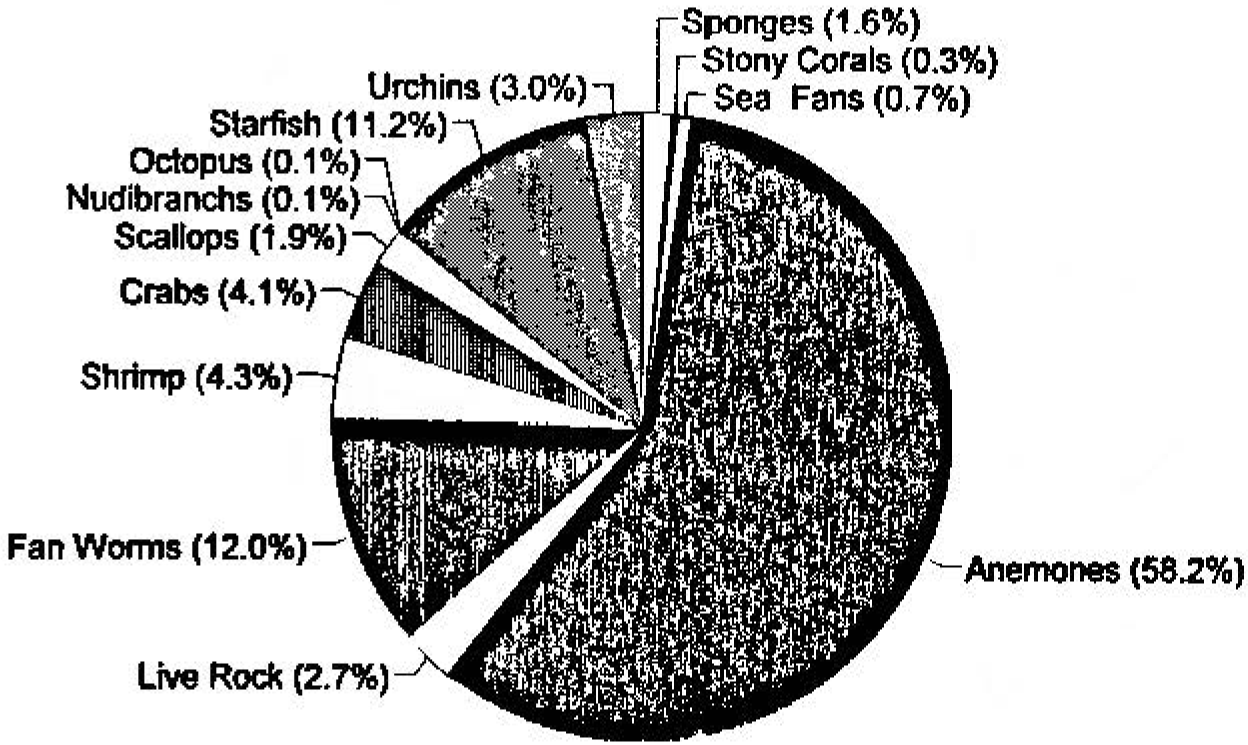

FIGURE 1. Live Invertebrates Exported from Puerto Rico

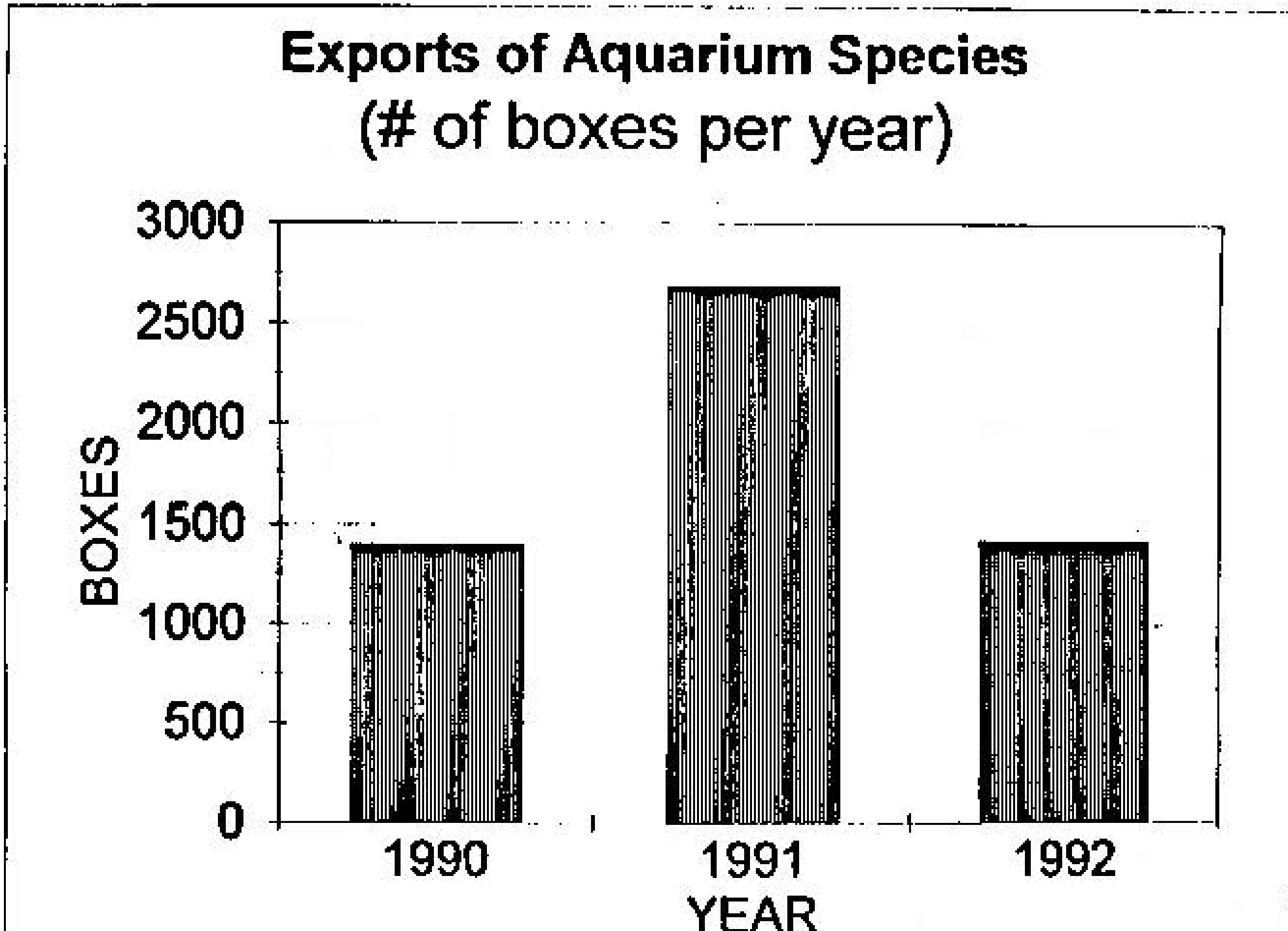

FIGURE 2. Minimum Estimated Exports from Puerto Rico