UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
PROGRAM PLANNING AND INTEGRATION
Silver Spring, Maryland 20910

AUG 3 2010

Dear Reviewer:

In accordance with provisions of the National Environmental Policy Act (NEPA), we enclose for your review the National Oceanic and Atmospheric Administration (NOAA) *Final Programmatic Environmental Impact Statement (FPEIS) for Coral Restoration in the Florida Keys and Flower Garden Banks National Marine Sanctuaries* (FKNMS and FGBNMS).

This FPEIS addresses restoration techniques for physical injuries to coral reef resources within the FKNMS and FGBNMS. The purpose of this document is to present and analyze the current technologies available for effective implementation in these sanctuaries. Appropriate analysis of the technologies in this document will provide for efficient selection and implementation of action when needed.

This FPEIS is prepared pursuant to NEPA to assess the environmental impacts associated with NOAA proceeding with coral restoration efforts in the FKNMS and FGBNMS.

NOAA is not required to respond to comments received as a result of issuance of the FPEIS. However, comments will be reviewed and considered for their impact on issuance of a record of decision (ROD). Please send comments to the responsible official identified below via mail or email by September 13, 2010. The ROD will be made available publicly following final agency action on or after September 13, 2010.

Responsible Official:

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Sincerely,

for

Paul N. Doremus Ph.D.
NOAA NEPA Coordinator

Enclosure

FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT FOR CORAL RESTORATION IN THE FLORIDA KEYS AND FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARIES

July 15, 2010

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LIST OF ACRONYMS

ATBA	Area to be Avoided
CAD	Computer Aided Design
CE	Categorical Exclusion
CEQ	Council on Environmental Quality
DGPS	Differential Global Positioning System
EA	Environmental Assessment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FDEP	Florida Department of Environmental Protection
FKNMS	Florida Keys National Marine Sanctuary
FKNMSPA	Florida Keys National Marine Sanctuary and Protection Act
FGBNMS	Flower Garden Banks National Marine Sanctuary
FPEIS	Final Programmatic Environmental Impact Statement
FWCC	Fish and Wildlife Conservation Commission
GIS	Geographic Information System
IMO	International Maritime Organization
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MOU	Memorandum of Agreement
NAAQS	National Ambient Air Quality Standards
NAO	NOAA Administrative Order
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NMSA	National Marine Sanctuaries Act
NMSP	National Marine Sanctuary Program
NMSS	National Marine Sanctuary System
NOAA	National Oceanic and Atmospheric Administration
NRDA	Natural Resource Damage Assessment
ONMS	Office of National Marine Sanctuaries
PEIS	Programmatic Environmental Impact Statement
POL	Petroleum, Oil, or Lubricant
PSSA	Particularly Sensitive Sea Area
PVC	Polyvinyl Chloride
ROI	Region of Influence
SCR	Submerged Cultural Resources
SHPO	State Historic Preservation Officer
USC	United States Code
USCG	United States Coast Guard
USDOC	United States Department of Commerce
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

This Final Programmatic Environmental Impact Statement (FPEIS) addresses restoration techniques for anthropogenic physical injury to coral reef resources within Gulf of Mexico and Caribbean waters of the National Marine Sanctuary System (NMSS). There is a wide range of restoration techniques available for use, varying from those that are frequently used to those that are innovative and not commonly implemented. The purpose of this document is to present and analyze the current technologies available for effective implementation of restoration to address injury to coral reef resources in these areas of the NMSS; appropriate analysis of the technologies in this document will provide for efficient selection and implementation of action when needed.

This document does not cover restoration techniques for injuries to coral resulting from oil or hazardous substance releases. In addition, the Office of National Marine Sanctuaries (ONMS) does not typically undertake coral restoration after major storm events such as hurricanes, with the exception of removal of grounded or abandoned vessels and large marine debris such as lobster or stone crab traps, or where the storm may have exacerbated an anthropogenic injury.

The restoration techniques described in this document have varying degrees of beneficial and adverse impacts, but overall, the long-term benefit of re-establishing natural habitat outweighs short-term adverse impacts that may occur during implementation. In many cases, a combination of techniques (i.e., substrate stabilization followed by coral reattachment) may be used for a single restoration effort. The impacts from each technique are summarized in Table ES-1. Using the decision matrix in Section 2.3, ONMS believes that there will be minimal adverse effects from restoration implementation, and there will be a long-term cumulative benefit resulting from the minimization of coral reef resource degradation.

Although this FPEIS provides analysis of the impacts for typically expected restoration results, each injury site and circumstance is unique. Each restoration will require an individual NEPA analysis. The purpose of this FPEIS is to provide an overarching NEPA analysis for these types of activities, such that any subsequent NEPA analysis can rely on and, as necessary, tier off this document. This will allow for timely and efficient analyses and help ensure restoration activities are initiated as soon as possible for the benefit of the resource.

Table ES-1 Summary of Impacts

	No Action	Debris Removal	Sediment Removal	Substrate Stabilization	Boulders & Modules	Revetment Mats	Reattachment & Transplantation
Location & Area Use	**LM-** Lm-	**LM+** Lm+	**LM+** Lm+	**SLm-**	**Sm-**	**LM+/Sm-**	**LM+**
Water Quality	Lm-	**Sm-**	**Lm+**	**Sm-** Lm+	**Sm-** Lm+	**Sm-**	**Sm-**
Geology	**LM-** LM-	**Lm+** Lm-	**Lm+** Lm-	**LM+/Sm-** Lm+	**LM+/Sm-** Lm+	**LM+/Sm-**	**LM+**
Biology	**LM-** Sm-/Lm-	**LM+** LM+	**LM+** Lm+	**LM+-/Sm-** Lm+/Sm-	**LM+/Sm-** Lm+/Sm-	**Lm+** LM+/Sm-	**LM+** LM+/Sm-
Infrastructure		**Sm-**	**Sm-**	**Sm-**	**Sm-**	**Sm-**	
Cultural Resources	Lm-	**LM+**					
Hazardous Substances		**Lm+**					
Socioeconomics	Lm-	**Sm-** LM+	**Sm-** Lm+	**Lm+/Sm-**	**LM+/Sm-**	**Lm+/Sm+**	**Lm+**
Quality of Life	Lm-			**Lm+**	**Lm+**	**Lm+**	**Lm+**

Legend:
LM = long-term major SM = short-term major + = beneficial
Lm = long-term minor Sm = short-term minor - = adverse
Bold entries are direct; non-bold are indirect

CHAPTER 1. PURPOSE AND NEED FOR ACTION

1.1 INTRODUCTION

Healthy coral communities serve critical ecological and economic functions. From an ecological perspective, coral reefs serve as habitat and a source of food for numerous species of plants and animals, including endangered and threatened species. In turn, the viability of recreational and commercial fishing industries depends on healthy reef communities. Coral reefs also function as storm barriers, and associated seagrass beds and mangroves serve as natural filters to reduce the level of sediments in the water. Restoration of coral reef injuries helps to reduce the cumulative impact of vessel groundings and other physical impacts.

The Florida Keys reef tract, located seaward of the Florida Keys, is one of the largest bank-barrier reef systems in the world. Ranging in depth from near the surface to 70 m (230 ft), the reef extends 356 km (221 miles), from near Miami to the Tortugas region. In 1990, Congress recognized the significance of this area when it designated the area as a National Marine Sanctuary, by means of the Florida Keys National Marine Sanctuary and Protection Act (FKNMSPA). In 2001, ONMS expanded the remote westernmost portion of the FKNMS to include 96 square nautical miles (nmi^2) and established the Tortugas Ecological Reserve (Ecological Reserve or Reserve) (a 151 nmi^2 no-take zone). The FKNMS is a premier recreational destination and is an area with significant commercial fisheries.

Flower Garden Banks National Marine Sanctuary (FGBNMS), located about 177 km (110 miles) off the coasts of Texas and Louisiana, harbors the northernmost coral banks in the United States and serves as a regional reservoir of shallow water Caribbean reef fishes and invertebrates. The coral banks rise to within 16 m (52.4 ft) of the surface. The Banks are surface expressions of salt domes whose formation began 160 to 170 million years ago in what was a shallow sea, subject to evaporation. In October 1996, Congress expanded the Sanctuary by adding a small third bank. Stetson Bank is also a salt dome, located about 112.7 km (70 miles) south of Galveston, Texas. Because of its location, average temperatures during the winter are several degrees cooler than at the Flower Gardens. Consequently, the corals do not thrive and build into reefs. Instead, this bank supports a coral/sponge habitat and rich assemblages of associated animals and plants where the siltstone bedrock can still be seen in many places. Today, FGBNMS has become a premier diving destination and attracts scientists from around the world.

Section 312 of the National Marine Sanctuaries Act (NMSA) authorizes NOAA to seek damages from those responsible for injuring sanctuary resources. The goal of a Natural Resource Damage Assessment (NRDA) under § 312 is to assess the extent of the injury to the Sanctuary resources, recover response and damage assessment costs, and implement primary and compensatory restoration to make the environment and public whole for the losses resulting from the injury. “Primary restoration” refers to restoration activities at the actual injury site. The goal of primary restoration activities is to return injured coral communities as much as possible to pre-injury, or “baseline” conditions. For coral reef communities, “baseline” refers to the level of ecological services (type, quality, and coverage of coral assemblages) existing prior to the incident. Baseline conditions are typically measured via field assessment techniques in the undisturbed reef communities bordering the injury area (Hudson and Goodwin, 2001). “Compensatory restoration” refers to a restoration project, typically off-site, that compensates the public for the loss of interim ecological services from the time of the injury to the time it takes for the original “primary” injury to return to baseline conditions (Shutler et al, 2006). Funds collected for small compensatory restoration projects may be pooled together for the implementation of a larger compensatory restoration project. For instance, if an orphan site requires 10 m^2 of restoration, compensatory settlements for injuries of 3, 5, and 2 m^2 could be pooled to restore the orphan injury.

1.2 NEED FOR ACTION

Human presence in and around marine environments can have detrimental effects. The cumulative impact of vessel groundings and other mechanical injury has led to a pervasive destruction of coral habitat throughout the Caribbean. The most visible injury caused by human activities results from the carelessness of ship captains, boaters, fishermen, divers, snorkelers and beachgoers. Injuries to resources result from vessel impacts, standing on coral, improper placement of anchors, inexperienced boat handling, and destructive fishing methods. Florida Fish and Wildlife Conservation Commission (FWCC) dispatch records indicate that in the FKNMS each year there are between 400 and 500 vessel groundings reported and responded to at some level; of this number, approximately 14 percent (of those with citations issued) occur in coral reef habitats (personal communication, W. Goodwin). Injury caused by human impact hinders the ability of marine life to recover from natural stressors. Some intervention is needed for reefs to recover the hundreds to thousands of years-worth of growth that is sometimes obliterated through mechanical injury. Intervention is even more crucial in areas where corals are subjected to physical stresses, like hurricanes, that can greatly increase the size of injured areas.

Coral reef injuries in the FKNMS typically include a combination of: 1) framework fracturing, 2) coral colony scarring or crushing by impact from blunt and/or sharp objects, 3) dislodging of coral colonies, and 4) destruction of benthic communities caused by disturbance of the bottom. While many injuries are to living coral, the destruction of standing coral framework (i.e., non-living stands of branching corals) is common and causes a loss of essential three-dimensional habitat. Although mechanical injury can result from a variety of sources (see Appendix A), by far the most common source of anthropogenic injury results from vessel impacts. The severity (width and depth) of injuries varies depending on many factors including the size of the vessel and the extent and manner in which the vessel is forced onto the coral reef, extent of power used to remove the vessel, and type of reef substrate. The protocols used for injury assessment are provided in Appendix B. Without stabilization of coral fragments or some physical rebuilding of the underlying structure, recruitment and growth of coral and other benthic species may be delayed or may not occur. In the Tortugas Reserve, anchoring injuries are most common as this area is too deep for vessel groundings.

Physical injuries to the coral reefs of the FGBNMS are of a different nature. Due to the depth of coral, vessel impacts are rare, but anchor, fishing and other types of injury may be more common. For example, past injury has resulted from seismic cables becoming caught on the reef, and from towing cables of barges that service the oil and gas industry.

1.3 PURPOSE

ONMS's coral reef restoration objectives are to conduct feasible and cost-effective restoration using the best available techniques to accelerate recovery of the injured areas to the pre-injury baseline levels. In addition, ONMS will seek to facilitate the prevention of future coral reef injuries through the implementation of preventative actions or projects. Given the slow growth of most corals (millimeters per year) and the long time (centuries) required to fully develop a coral reef, the best that ONMS can do in the short-term is to repair and replace the injured resources to the greatest degree possible and using the best techniques available. This provides a jumpstart for the natural recovery of a fully functional ecological community. It is this long time-lag to full functionality that increases the importance of implementing compensatory restoration, that is, to do "additional" restoration to compensate for the lost resources during the recovery time.

These restoration and injury prevention objectives are in keeping with the goals and policies of the NMSA, the FKNMSPA, the FKNMS and FGBNMS Management Plans and the sovereign submerged land policies of the State of Florida. The NMSA, 16 U.S.C.§1443(d)(2) (A), (B), and (C), define the appropriate uses of recovered damages in order of priority as "(A) to restore, replace, or acquire the equivalent of the sanctuary resources that were the subject of the action…; (B) to restore degraded sanctuary resources of the National Marine Sanctuary that was the subject of action, giving priority to sanctuary resources and habitats that are comparable to the sanctuary resources that were the subject of the action; and (C) to restore degraded sanctuary resources of other National Marine Sanctuaries." Under the NMSA, ONMS sometimes considers salvage and prevention projects to be restoration; this is most likely in a situation where prevention of additional injury through removal of a large vessel could provide greater benefit than future restoration of a significant injury. Prevention projects may include the protection of equivalent resources, which falls under (A) above, and serve to reduce the likelihood that injury will occur at a later time.

The purpose of this FPEIS is to streamline the environmental review process for restoration projects. As Federal actions, all Sanctuary restoration projects are subject to the review requirements of NEPA. In general, many restoration actions qualify for categorical exclusion (CE), but larger or more complex projects may require an EA or EIS. This FPEIS is intended to analyze the most feasible and likely actions to be undertaken for coral restoration projects. NEPA analyses will still be required for individual restoration actions, but the documentation required will be abbreviated since the majority of the analysis should be incorporated here. For most cases, a CE is all that is expected to be required, relying on the analyses described here. If a more extensive analysis is required, the documentation (EA or EIS) will tier off of this FPEIS and focus on the specific circumstances of the injury and location, or specific restoration requirements.

1.4 SCOPE

This Final Programmatic Environmental Impact Statement (FPEIS) systematically evaluates the short and long-term environmental and socioeconomic effects related to the implementation of coral reef restoration and coral reef injury prevention projects in the Gulf of Mexico and Caribbean waters of the National Marine Sanctuary System, which includes the FKNMS and the FGBNMS. As the ONMS is only trustee for reef areas within the NMSS, this document will be relevant only for reefs under jurisdiction of NMSS, not all NOAA jurisdictions. Additionally, this FPEIS is only applicable to the Gulf of Mexico region; while the restoration alternatives may be applicable to other coral areas within the NMSS, environmental and logistical realities require different analyses, and thus would need to be addressed in a separate document. The trustee for the FGBNMS is the National Oceanic and Atmospheric Administration (NOAA), and the trustees for the FKNMS are NOAA and the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida, ("State of Florida" or "state"). For the purposes of this document, "NOAA" should be construed to include the state trustee, unless specifically stated otherwise. This document is intended to comply with the National Environmental Policy Act of 1969 (NEPA) and its implementing regulations, and the NOAA guidelines for compliance with NEPA (USDOC 1999). As this document focuses on future regional coral reef restoration and injury prevention activities within both sanctuaries, the discussion of potential positive and negative impacts on biological resources, social considerations, and economic activities cannot be site- or case-specific; instead, it is general in scope. Therefore, the goal of this FPEIS is to describe a range of coral reef restoration techniques used for both primary and compensatory restoration projects that potentially may be implemented in these sanctuaries.

CHAPTER 2. CORAL RESTORATION ALTERNATIVES

ONMS staff has evaluated reef restoration alternatives from throughout the Caribbean and other reef areas, and are working to refine those alternatives and develop new techniques for the specific habitats and management requirements of the National Marine Sanctuary Program (NMSP) (NOAA 1995, 1996). Monitoring of previous restoration actions also provides valuable information on the effectiveness of restoration alternatives; protocols used in the FKNMS are provided in Appendix C. ONMS staff strives to implement restoration techniques that provide the greatest overall environmental benefit in the most cost-effective manner. This evolutionary process includes the use of both new and modified physical (structural) restoration techniques, as well as innovative biological techniques. Traditional biological methods to restore coral have involved only the transplantation of coral colonies or fragments; as the understanding of reef ecology continues to expand, the options for biological restoration are expected to expand. This document is meant to be inclusive of current proven technology. As new techniques and methods are developed and refined, they will be evaluated for further consideration and incorporated into this document. See section 2.2.4 below for further descriptions of emerging techniques.

2.1 CORAL RESTORATION SELECTION CRITERIA

Based on ONMS's experience with coral ecology and restoration, general criteria will be considered for selecting the appropriate restoration alternatives for coral reef injury sites. The criteria in Table 2-1 are used to evaluate and select the preferred restoration alternative(s) for a given injury site. For any site, injury to species protected under Federal or State statutes is given consideration for priority action, provided that technical and site-specific criteria can be met. These criteria ensure that the restoration objective is satisfied, while taking into account technical, environmental, economic and social factors.

Table 2-1 - Criteria for Evaluating Coral Reef Restoration Options

Criteria	Definition
Technical Feasibility	Likelihood that a given restoration action will work at the site and the technology and management directives exist to implement the restoration action.
Recovery Time	Measures that accelerate or sustain the long-term natural processes important to recovery of the affected resources and/or services injured or lost in the incident.
Additional Injury	Likelihood that the requirements, materials, or implementation of a restoration action minimize the potential for additional injury.
Aesthetic Acceptability	Likelihood that a restoration action will create substrates and topography that most closely resemble the surrounding habitat and minimize visual degradation.
Site-Specific Context	Environmental conditions at the site including, but not limited to: location, extent and severity of the injury, hydrological characteristics, coral reef species composition, and other social, economic and resource management concerns.

2.2 CORAL RESTORATION OPTIONS

Coral restoration options include: 1) no action; 2) physical restoration, which includes stabilization and recreation of reef structure; and 3) biological restoration, which includes reattachment of live coral as well as jump-starting community development. Several emerging technologies are also described; these may be considered further in the future when more data on their efficacy is available.

2.2.1 No Action

The regulations of the Council on Environmental Quality (CEQ) require that an agency consider the "no-action" alternative in its analysis. It serves as a benchmark against which all other alternatives are evaluated. The no-action alternative would leave the reef in its post-injury condition, allowing natural recovery processes to occur. The no-action alternative could have three general outcomes: 1) natural recovery on a longer time scale; 2) no recovery; or 3) possible further deterioration of the reef system. It is important to note that in cases where NOAA has recovered damages for coral injury under NMSA § 312, the no-action alternative may not be a legally acceptable choice. NOAA always retains the alternative, however, as a basis of comparison, and for purposes of technically with CEQ's NEPA regulations.

A no-action alternative relies on natural settlement and growth of coral species, natural sediment filling of blowholes and propeller scars, and natural redistribution and consolidation of loose rubble. A no-action alternative can increase the risk of secondary injury to nearby coral communities from the unstable conditions created by fractured framework and loose rubble from crushed corals and reef framework at a grounding site. Progressive deterioration of coral reef injuries from storm and hurricane force wave energy has been documented (NOAA, 2002). The no-action alternative is most often used for injuries when ONMS determines that an injury site is likely to recover in a short period of time with a low likelihood of injury expansion, or where other social, environmental, or logistical considerations dictate that no-action is the best course. Determination of a no-action alternative for primary restoration does not necessarily preclude the assessment of compensatory restoration actions.

2.2.2 Physical Restoration

Alteration or destruction of three dimensional habitat complexity is one of the most common types of coral injury. In general, this complexity must be restored prior to restoration of the biological community. Physical, or structural, restoration only addresses injuries to the reef substrate, not the live coral community. The following represents options for physically restoring coral habitat complexity.

2.2.2.1 Debris and Vessel Removal

Groundings of large vessels often result in vessel debris—propellers, engines, running gear, anchors and associated chain, etc.—or even entire vessels left on the reef. Large pieces of remnant debris can have severe adverse impacts to a reef through alteration of the seafloor, continued erosion of the reef, and contamination. High-energy events, such as severe winter storms or hurricanes, can generate waves of sufficient force to move debris and cause further injury at the same or nearby locations. Note that removal of debris that originates on land and is transported offshore via storm/hurricane action is not directly addressed by the FPEIS as it is the result of natural processes, not of direct anthropogenic action. However, FKNMS and NOAA may coordinate debris cleanup activities after significant storm events. In some instances where circumstances of the injury or logistics make other restoration options nonviable, the removal of the vessel or debris during emergency restoration may be all that is possible. Although the goal of the action is to remove the debris from the water, certain logistical considerations may, at times, suggest a preference for sinking the material offshore rather than bringing it to shore.

Removal of vessels and debris is typically accomplished at high tide, when additional water over the reef facilitates vessel removal. Depending on its size, a vessel may be removed using a single floating towline to another vessel, or may require multiple tugs and floating towlines. Careful selection of an exit path is required in order to minimize collateral injury to surrounding reefs as the vessel is taken out. For larger efforts with multiple or heavy towlines, it is also important to monitor the placement and use of towlines to ensure that they do not get caught on reef material and break coral heads or scrape the tops of coral heads. Removal of other debris may require additional equipment, including cranes, specialized vessels, and commercial dive equipment.

2.2.2.1 Sediment and Rubble Removal

For corals to successfully recruit and grow in a disturbed area, the substrate on which corals settle must be conducive to their establishment (Richmond, 1997; Crisp and Ryland 1960). The lack of stable substrate coupled with the loose sediments generated by the injury is not conducive to coral settlement because water movement may re-suspend sand and bury and kill recently settled coral colonies. High-energy events, such as severe winter storms or hurricanes, can generate waves of sufficient force to hurtle coral rubble projectiles into the nascent coral colonies, fracturing or dislodging them (Endean 1976). Some authors have termed this a downcurrent "domino effect" (i.e., one colony is shattered and its fragments can cause a cascade of injury to nearby colonies before coming to rest on the benthos). Anthropogenic disturbances that produce great quantities of coral rubble and fine sediment material include large vessel groundings and vessels anchoring on coral reefs.

Research has revealed that rubble created by natural mechanical injury to a reef (usually in the form of hurricane injury) is important to future reef framework development (Perry, 1999; Blanchon, et al., 1997), especially for *Acropora* and other species that reproduce through fragmentation. Following mechanical injuries and rubble generation, rubble layers are often quickly colonized by crustose coralline algae (e.g. *Neogoniolithon* sp., *Tenarea* sp., *Fosliella* sp., *Lithophylluma* sp. *Porolithon* sp., and *Hydrolithon* sp.) and other encrusters such as foraminifera, bryozoans and serpulids. However, stabilization of rubble (as well as some fraction of the sediment) does not occur until these organisms have had a chance to cement together the reef debris (Perry 1999; Blanchon, Jones and Kalbfleisch 1997), a process that can take many years. Therefore, unstable substratum will often persist for long periods, and thus coral re-establishment will likewise be delayed (Riegl and Luke 1998). Mechanical injuries often create a far larger quantity of rubble than might be created naturally, and therefore, natural stabilization would take a very long time to occur, all the while presenting a greater risk for further injury. Therefore, it is on balance better to remove large quantities of rubble to both speed recovery and reduce additional injury.

In general, managers have advocated clearing sites of rubble, and doing so as soon as possible after the injury (Gittings et al, 1988; Zobrist, 1999; Hudson and Diaz, 1988), as a first step before any other type of restoration is undertaken. This prevents collateral injury, allows preservation of large pieces of live coral, and provides a more suitable substrate for subsequent restoration actions (NOAA, 1999b). In certain circumstance, the rubble may be stockpiled for later use in constructing restoration replacement structures and/or ornamentation of other reef repairs. Small quantities of coral rubble can be removed by divers using baskets, lift bags, etc., while larger amounts require using a barge with suction, guided by underwater divers.

2.2.2.3 Substrate Stabilization

Reef injuries often leave large pieces of reef "crust" loose. These may be large pieces of the substrate that are not suitable for removal, but which leave the reef and surrounding area at risk for future injury from scouring and wave action. This substrate can be stabilized using marine epoxy (Schmahl et al, 2006) or concrete to fill in cracks and holes or to otherwise solidify the substrate. This is often referred to as a "puddle pour" since a small hole or area of unstable substrate is filled in by pouring concrete to bring it to grade. Such a pour is usually "dressed" with fragments of relict (or live, if available) coral to provide relief, a more natural appearance, and some cryptic habitat. This technique is typically used in combination with others, often the addition of limestone and/or preformed modules, and reattachment.

2.2.2.4 Limestone Boulders and Preformed Modules

In areas with significant alteration to three-dimensional structure, limestone boulders of appropriate size or preformed concrete and limestone modules can be used to fill depressions and re-create relief. Boulders of varied sizes can be placed in the injured area and then stabilized with underwater concrete that flows and has very low turbidity so it does not mix with the water column (known as a “tremie pour”). The boulders can be stacked so as to replace and recreate some of the relief and rugosity that were destroyed. Plastic composite rebar (which is lighter, easier to use, and more durable than steel) can be placed in the concrete to improve attachment between the boulders, and between boulder and concrete layers. For larger areas, modules created from a combination of materials, including concrete, limestone boulders, or reef rubble, and steel or composite reinforcing rods, are preferred. Modules are similar to tremied concrete/boulder conglomerate, but are larger and heavier, and they can be designed in a variety of shapes and sizes, depending on the nature of the restoration needs. They can be designed to create more internal void spaces (i.e., caves, tunnels, etc.), thereby more closely replicating the habitat functions of well developed yet highly bioeroded reef structures. Once in place, tremie is poured around the modules for stabilization and smaller rocks are placed in the concrete to cover the concrete and blend sharp vertical faces with the surrounding habitat. In addition to creating relief, the greater weight of modules can also be effective at stabilizing underlying framework injury. However, the use of large quantities of manmade material dictates that this option be used sparingly. Situations in which this would be reasonable include destruction of reef spurs or other large framework injury.

While the general characteristics (combination of pre-poured concrete & limestone fragments or boulders) of this restoration alternative remain consistent, engineering specifications for large injuries are customized for each injury in order to meet injury- and site-specific requirements. See Hudson and Franklin (2005), Mulcahy and Graham (2004), CP&E (1996 and 2001), and Bodge (1996) for details on recent restorations. For smaller injuries, modules are more commonly prepared in-house; these lack engineering specifications, but are much smaller and designed using staff expertise (W. Goodwin, personal communication).

This technique has a large equipment requirement, as it typically needs to be done using a barge, crane, onsite cement mixer, commercial dive equipment, etc. The appearance of the resulting substrate closely approximates that of naturally occurring, nonliving coral reef structure, which may enhance benthic recolonization, and provides holes or openings as habitat for cryptic organisms. Aesthetic factors are important in the creation of any modules, as they need to look as naturalistic as possible.

2.2.2.5 Revetment Mats

Revetment mats consist of concrete blocks, usually 1 square foot, interconnected by flexible polypropylene, Kevlar, or similar cables. They are traditionally used for stabilization of man-made structures, such as culverts, outfall pipes, etc. These mats are usually assembled on land and then installed in place from a construction platform, using a crane and spreader bar. They are relatively flexible structures that conform to the shape of the natural contour. It is uncertain whether revetment mats could crush or crack the underlying reef structure. Revetment mats were used in the restoration of the Contship *Houston* site in 1997 (Schmahl et al, 2006), but subsequent injury resulting from Hurricane Georges required some relocation and rearticulation of the mats at that site as the leading edge of one mat lifted and broke apart. In future uses, mats should be more securely fastened to the bottom. Situations in which this would be a reasonable alternative include sites with a large rubble zone in a relatively low energy environment where rubble needs to be stabilized and removal is not feasible or recommended. Due to their bulky nature and the complexities of installation, these are not appropriate for temporary placement to facilitate short-term stabilization.

2.2.3 Biological Restoration

Even though structural restoration has traditionally been the focus of coral reef restoration, the length of time required for a coral community to develop can mean that even after the physical environment has been restored the injured site will take many years to resemble (aesthetically and functionally) a mature coral ecosystem. Therefore, ONMS is very interested in the use of techniques to enhance the rate at which coral communities re-develop in an injured area.

2.2.3.1 Reattachment and Transplantation

Fractured, dislodged, and overturned coral, if salvaged (triaged) before mortality and degradation, can be stabilized via reattachment. Reattachment of live framework coral pieces and, if no live coral remains onsite, transplantation of live scleractinian and gorgonian coral, are effective techniques to facilitate the redevelopment of coral communities on injured or degraded reefs (Gleason et al, 2001; Jaap and Morelock, 1998; Franklin et al, 2006; Schittone et al, 2006). In addition to on-site coral fragments that can be reattached, there are several other potential donor sources for scleractinian corals, including at risk coral pieces collected from small or "orphan" groundings and held (cached) until restoration is implemented; corals removed from artificial structures (such as seawalls, piers, or pilings) prior to replacement; corals from within the footprint of proposed and permitted projects (e.g., construction or dredging); and nursery corals that have been grown under controlled conditions expressly for placement back on the reef[1]. This includes on-site underwater nurseries (farms) as well as using coral husbandry techniques in laboratory settings to enhance recruitment, growth, and propagation of key species. Corals reared under laboratory settings must be certified for health prior to release back into the natural environment. The colonies used for transplantation should not be harvested from donors on surrounding reefs; this ensures that restoration is not accomplished at the expense of surrounding habitats.

In most cases, scleractinian and framework fragments are attached directly to any solid substrate that will provide suitable orientation and support using either underwater epoxy (for fragments <10 cm (3.9 in)) or Portland Type II cement. In addition, branching corals may be reattached to appropriate substrate using wire and/or cable ties or by wedging fragments into small crevices and voids. In areas of unconsolidated substrate such as *Porites* rubble zones or areas composed of *Acropora* "bones" (i.e., the Dry Tortugas) where coral heads grow but are only attached deep at their base, NOAA has used cut nails, wire, and small manta ("duckbill") anchors to secure coral fragments (Bruckner & Bruckner, 2006; DARRP, nda, ndb). Large pieces of framework may require additional support from reinforcing rods in order to secure them in place. Transplantation of live coral should be primarily of small coral colonies or fragments, while framework pieces may be much larger. Every effort should be made to transplant the diversity of species found at the original site, but diversity and number of each species transplanted ultimately depends on availability. Coral species that compete with each other via interspecific aggression should be kept apart to reduce mortality and stress. If transplanted with care (i.e., no excess stress), live translocated fragments should continue to grow at a normal rate.

[1] FKNMS has funded several coral nursery efforts to propagate coral from fragments. ONMS anticipates that within a short time, small quantities of coral colonies should be available for small-to-medium restoration projects where coral species and habitat requirements permit.

In addition to scleractinian corals, gorgonian coral colonies can also be translocated and reattached. Such colonies may be either entire colonies dislodged during the injury event, or clippings from local mature colonies. The branching nature of gorgonians means that clippings can readily be harvested from local donors without causing additional habitat injury or endangering the donor colony. Gorgonian transplantation is accomplished using either cement or epoxy to reattach an entire colony to solid substrate, or by inserting the axis of a clipping into a hole and affixing it in place using epoxy (Stratton, 2001; FKNMS, 2009). Depending on the nature of the species and clippings being used, as well as the physical environment, masonry nails or plastic cable ties may also be used to assist in stabilizing colonies during the reattachment process (TRAF, 2009; FKNMS, 2009).

When appropriate, other sessile benthic fauna such as sponges may also be reattached and stabilized. This typically occurs only during emergency restoration, which takes places as soon as possible after an injury occurs. In general, techniques for reattachment of other fauna are less developed than for scleractinian and gorgonian corals (Donahue, 2007; McMurray and Pawlik, 2008).

Reattachment is included as part of many ONMS injury response actions. As long as there are live fragments available, reattachment is appropriate for any injury, either used alone or to complement physical restoration. Reattachment can be accomplished quickly by NMSP staff using small boats, or contractors operating on a larger scale, as required.

2.2.4 Emerging Technologies

Although there are several new techniques currently being developed that should expand the range of alternatives available for restoration, ONMS will only consider techniques with a proven track record (i.e., field-tested and published in peer-reviewed literature) of successful implementation. As new techniques become less experimental, ONMS may consider adopting their use after an appropriate NEPA analysis. Descriptions of several of these new techniques are provided below, but due to their experimental nature, these alternatives will not be considered in Chapter 4, Environmental Consequences.

2.2.4.1 Electroaccretion

One proposal for structural restoration of coral reefs is the *in situ* formation of semi-artificial substrate by electrolysis, known as electroaccretion, in which calcium and magnesium ions present in seawater are deposited on a template through electrochemical deposition. The accreted material consists mainly of calcium carbonate and is chemically similar to reef limestone. For restoration purposes, coral nubbins are often inserted into the mesh or metal template to increase the rate of growth and development of the coral community. This process has been patented as the Biorock® Process and used primarily in the Indo-Pacific by the Global Coral Reef Alliance (GCRA).

While there has been some limited use in the Caribbean, this technique has been implemented primarily in small applications across the Pacific and Indian Oceans and there have been few rigorous scientific investigations of its success, potential to increase coral growth or cementation of fragments, and potential to provide long-term restoration. A recent review of the technique (Borell et al, 2010) found marked differences in growth rate and coral development between two species, and found that overall the suggested benefits of the technology should be considered with caution. Therefore, while electroaccretion is promising on many fronts, the lack of peer-reviewed publications that demonstrate its effective use in the greater Caribbean region prohibit its further consideration in this FPEIS.

2.2.4.2 Recruitment Enhancement

There are several new technologies being developed to restore coral populations, many of which focus on increasing the settlement of coral larvae. ONMS is particularly interested in the potential use of larval "flypaper" and settlement tents. The larval flypaper technique (Morse, et al, 1994, Morse and Morse, 1996) requires the placement of chemical stimuli (metamorphic inducers) on the reef surface to attract coral larvae. The use of the chemical stimuli increases the likelihood that coral larvae will settle onto the selected reef location. This has been tested successfully in Pacific areas, but has not been used with Caribbean corals. The settlement tent technique (Miller and Szmant, 2005) uses larvae collected during spawning events and held in a lab until they are competent to settle (usually a few days). The larvae are then introduced into a fine-mesh net enclosure deployed over the injured area and held for another two or three days until they have settled onto the substrate. Constraining the larvae in a tent for a few days over the reef provides greater likelihood of their settling on the selected reef substrate than if they were free floating and subject to currents, tidal influences, and predation. These two techniques would take different approaches to capitalizing on the natural abundance of coral larvae throughout the Keys, with the intent of increasing the density of settlers at a specific site.

2.2.4.3 Community Modification

In some situations, actions to address community structure are more beneficial than injury-specific restoration. At least one method being developed to focus on community structure is the reintroduction of the long-spined sea urchin, *Diadema antillarum*. In the 1983-1984, *Diadema*, a keystone herbivore throughout the Caribbean, suffered a mass mortality throughout the Caribbean and western Atlantic (Bak, 1985; Lessios et al, 1984; Lessios, 1995) and has yet to recover in most locations (Chiappone et al, 2002; Nedimyer and Moe; 2003, but see Carpenter and Edmunds, 2006). *Diadema* played an essential role in regulating algal communities on coral reefs. Since the die-off, many reefs have suffered from algal overgrowth that is believed to be a direct result of loss of urchin populations. The reintroduction of *Diadema* has the potential to reduce algal overgrowth, increase settlement of juvenile corals, and increase overall percent cover of stony corals, thus increasing the overall health of coral habitats. Several efforts have been undertaken to investigate the potential for *Diadema* restoration, including translocation of wild juveniles and transplantation of cultured juveniles (The Nature Conservancy, et al 2004, Leber et al, 2008). Initial work translocating wild juveniles has shown that translocation of even small numbers (hundreds) can result in noticeable benthic changes in one year (TNC, 2004). Rearing cultured *Diadema* has shown some promise, but transplanting cultured juveniles to the field has had limited success (Miller and Szmant, 2006); efforts are ongoing to refine these techniques. At this time this technique has not been used on a large scale, but may be suitable in certain circumstances. Data is not currently available to calculate the efficacy and effects of this option.

2.2.5 Options Not Considered

The following two options are possible, but due to their reliance on synthetic materials, lack of aesthetics, difficult implementation logistics, and general use as an interim measure, they are unsuitable for serious consideration as appropriate for use in the NMSS. Additionally, although they may have applicability in reef restoration situations, they have not been employed as such to date, and thus are not appropriate for further consideration at this time. Should they be considered for use at some point, appropriate NEPA analysis would be conducted prior to implementation.

2.2.5.1 Concrete Pillows

This category includes several options that all require filling sacks with concrete and placing them around the perimeter of an injury to protect the area from further deterioration. The pillows, mattresses, or tubes are constructed out of reinforced material, such as Kevlar, to add external support and are filled with non-separable marine concrete. The filling operations are fairly complex: concrete must be prepared and tubes filled on-site due to the distance from land and the requirement for a downhill gradient. Due to the complexity of installation, pillows are not likely to be a cost-effective option for small-scale restoration projects. This technology also entails the use of synthetic materials (Kevlar, for example), which generally are not preferred in sanctuaries.

2.2.5.2 Gabions

Gabions are prefabricated steel or tenser grid cages containing loose rubble that are used to stabilize the surface of disturbed areas and can be useful for bringing a hole back up to surrounding grade. The standard design for gabions consists of a sturdy plastic webbed mattress that is filled with gravel (or sand, if an internal filter fabric is used). Due to their weight, it is uncertain whether gabions would crush or crack the underlying reef structure. Gabions are generally considered a temporary measure or for interim relief until a more permanent structure can be constructed. The technique entails the use of synthetic materials and has the potential for causing additional framework injury. Gabions are likely to be costly due to the logistics, requirement for a barge, and subsequent removal if used as an interim measure.

2.2.6 Compensatory Restoration

The initial goal of restoration is to expedite recovery of the injured area to its pre-injury state. These actions are referred to as primary restoration. Compensatory restoration refers to those actions taken to compensate the public and the environment for lost interim services from the time of the injury until the return to the conditions that would have existed, but for the injury. Compensatory restoration is usually done off-site of the original incident location and may be done either in combination with or in lieu of primary restoration. The latter occurs when primary restoration actions are not feasible or determined to be less preferable than natural recovery.

Compensatory restoration takes place within similar types of coral injury locations, and may occur on "orphan sites", (i.e., injury sites for which funds are not otherwise available for restoration). Acceptable compensatory restoration alternatives may also include measures to prevent future injuries of the same type. The amount (i.e., "scale") of compensatory restoration deemed necessary depends upon the size and severity of the initial coral reef injury, and how quickly the coral and associated ecological and recreational services are predicted to return to conditions that would have existed, but for the injury.

The appropriate compensatory restoration funds for any injury may be pooled with compensatory recoveries from other injuries. Pooled recoveries may be used to implement larger compensatory restoration projects and achieve economies of scale. All of the identified primary restoration methods, monitoring, and oversight requirements are the same for compensatory restoration activities.

ONMS has an ongoing process to develop a list of sites appropriate for compensatory restoration. These include comparable, off-site restoration at an orphan site (i.e., site with no identifiable responsible party) and prevention projects (e.g., placement of navigation aids or mooring buoys).

2.3 PROPOSED ACTIONS

In all cases, factors including location, likely logistics, and composition of injured resources (presence of protected species) are first considered to determine whether or not restoration is possible. Once a decision to undertake restoration is made, selection of an appropriate project is undertaken. In most coral restoration projects, a combination of one or more of the alternatives presented is identified as the preferred alternative(s) in an injury-specific restoration plan. ONMS staff with expertise in coral restoration ecology and first-hand experience with the injury site select the proposed preferred alternative. Rubble removal and coral reattachment may occur at the time of injury assessment, if warranted. If there has been loss of three dimensional habitat complexity, limestone boulders or modules may be used to stabilize and reestablish the habitat complexity. If live coral fragments are available at one site, or if there has been a significant loss of live coral cover, reattachment and transplantation will occur once the substrate has been stabilized and any structural restoration has been implemented. Finally, if it is determined that the injury site is likely to recover rapidly, or primary restoration is not appropriate for other reasons, the no-action alternative may be selected for part of or the entire injury site. Table 2-2 summarizes the alternatives available, the conditions under which they may be chosen, and the ultimate results of their applications.

Table 2-2. Coral Restoration Alternative Matrix/Comparison

ALTERNATIVE	SITE CONDITION FOR USE	RESULT
No Action: Leaving the injury unrestored.	The no-action alternative is most often used for cases when ONMS determines that an injury site is likely to recover in a short period of time with a low likelihood of injury expansion, or where other social, environmental, or logistical considerations dictate that no-action is the best course.	The no-action alternative would leave the reef in its current post-injury condition, allowing natural recovery processes to occur. The no-action alternative could have three general outcomes: natural recovery on a longer time scale; no recovery; or possible further deterioration of the reef system.
Debris and Vessel Removal	Appropriate where a vessel is sunk, aground or broken up. Also applicable for marine debris from a vessel or other source, such as debris dumped for artificial habitat or lost fishing gear.	Precludes further impacts from vessel or debris. Facilitates opportunities for either natural recovery or for additional restoration work as necessary. Does not restore any physical or biological properties.
Sediment, Rubble Removal: Removing loose material from the injury area.	Appropriate for disturbances that produce quantities of coral rubble and fine sediment material, including large vessel groundings and anchor injuries.	This prevents collateral injury and also allows preservation of large pieces of live coral. Does not repair any physical or biological properties.
Limestone Boulders and Modules: Placement of limestone boulders or preformed modules in injury area, stabilized with tremie concrete pour & rebar.	Appropriate for large areas of injured framework, rubble and sediment too copious for removal; requires stabilization in-place. Modules are capable of creating more natural internal void spaces (i.e., caves, tunnels, etc.) thereby more closely replicating the habitat functions of well developed yet highly bioeroded reef structures.	This provides long-term stabilization of substrate and creation of permanent relief. Provides physical restoration only. Given the use of artificial, man-made components, this option is only appropriate on a case-by-case basis.
Revetment Mats: Concrete blocks interconnected by flexible cables. Must be assembled on land and then installed in place from a construction platform, using a crane and spreader bar.	Appropriate for stabilization of large rubble zones in a relatively low energy environment. Revetment mats would likely be used in combination with other alternatives.	Because of bulky nature and the complexities of installation, these are not appropriate for temporary placement to facilitate short-term stabilization. Requires use of manmade materials and results in unnatural appearance.
Reattachment and Transplantation: Facilitate the redevelopment of coral (hard and soft) communities on injured or degraded reefs. Other benthos (such as sponges) may also be reattached and stabilized, typically during emergency restoration.	Used at any site with live coral fragments to save as much live coral as possible. Often used in combination with other structural options. Frequently used after structural restoration to re-create biological characteristics.	Stabilizes fragments to prevent further loss and injury. Reduces live coral loss; once cemented in place, corals recover a majority of their baseline function. Does not reestablish injured framework.
Emerging Biological Technologies: Diadema, recruitment enhancement, electroaccretion.	Potential for use in sites with low live coral cover to "jumpstart" coral growth. Many techniques are not appropriate for use until technology is better tested.	Increases coral cover, coral growth rates, and whole community. Establishes a more stable basis for long-term development of reef.

CHAPTER 3. AFFECTED ENVIRONMENT

3.1. HABITAT TYPES

Coral reefs are complex and diverse ecosystems found in the tropics and subtropics where environmental conditions are relatively constant and not prone to large or frequent climatic fluctuations. They are composed of concentrated complexes of corals and other similar organisms that, given the availability of suitable substratum, temperature, light, and limited sedimentation, construct a limestone structure in shallow water (Jaap, 1984).

Reef-building (hermatypic) corals require very specific environmental conditions. Their geographic range generally is between 30^{o} north and 30^{o} south of the equator. Corals have a low tolerance to severe perturbations in salinity, temperature, or water quality. Reef corals require clear, relatively low-nutrient water and circulation from turbulence or ocean currents. The water temperature generally must be between 68° and 86° F and reef-building corals do not thrive in continually turbid water, although patch reefs may develop in areas that are often turbid.

Reef communities provide habitat for a large number of species. Algae grow in and around the coral and provide an excellent food source to the numerous herbivorous grazing fish, crustacea, and mollusks. In turn, these animals rely on the small holes and crevices provided by the reef for food and protection from both predators and strong wave activity. As a result of the numerous small inhabitants, the coral reefs are also prime feeding grounds for larger predatory animals common to the area.

Reef-building corals can be characterized as shallow water (generally considered above 90 meters (300 ft) depth), wave-resistant, three-dimensional carbonate accretions constructed by limestone-secreting organisms such as corals, algae, and bryozoans, on a pre-existing hard substrate (Jaap, 1984). Several coral reef habitat types exist. For example, livebottoms are typically small communities living in extremely shallow, low current energy locations; whereas patch, transitional, and bank reefs are larger and are located in deeper and higher current energy waters.

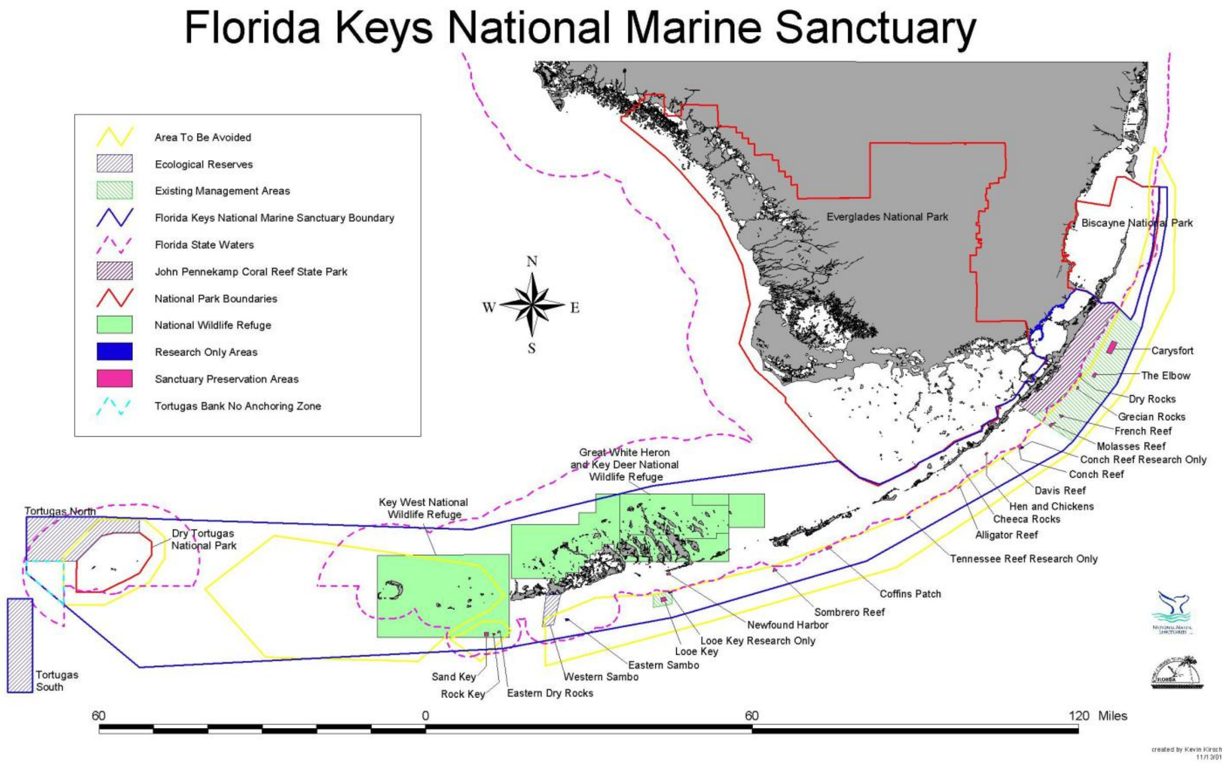
This document addresses potential impacts to two reef areas: the bank-barrier system of FKNMS and the deep coral banks of FGBNMS.

3.2 FLORIDA KEYS, FLORIDA

3.2.1. Location

The FKNMS encompasses approximately 2,900 nmi^2 of submerged lands and waters between the southern tip of Key Biscayne and the Dry Tortugas (Figure 3-1). North of Key Largo, it includes Barnes and Card Sounds, and to the east and south, the oceanic boundary approximates the 90-meter (300-foot) isobath. The Sanctuary also contains the part of Florida Bay not protected by Everglades National Park, and most of the Florida reef tract (USDOC, 1996). The Tortugas region of the Sanctuary refers to an approximately 480 nmi^2 area of open-ocean containing several carbonate banks, one of which is emergent with 7 small, sandy islands. The Tortugas is remotely located in the westernmost portion of the FKNMS–approximately 112.7 km (70 mi) west of Key West and over 225.3 km (140 mi) from mainland Florida. The Sanctuary encompasses the deeper sand channels, seagrass habitats, and coral reefs of the Tortugas region; the Dry Tortugas National Park encompasses shallow habitats under separate jurisdiction within the FKNMS.

Figure 3-1



3.2.2 Climate

The Keys have a tropical maritime climate with moderate temperatures and essentially two seasons: long, wet summers and mild, dry winters (Schomer and Drew, 1982). Summer lasts from May to October and is characterized by numerous thunderstorms. Winter lasts from November to April and is characterized by dry conditions and infrequent, fast moving cold fronts (Schomer and Drew, 1982; USDOC, 1996). The average annual temperature is 78^{o}F (26^{o}C) with an average low of 69^{o}F (21^{o}C) and an average high of 85^{o}F (30 ^{o}C) in July. The average annual rainfall is 100 cm (39.4 inches) (USDOC, 1996).

Localized convective storms and intense low-pressure systems in the form of tropical storms and hurricanes are integral climate components. Storms normally occur between June and November, peaking in late September/early October (Schomer and Drew, 1982). Both tropical storms and hurricanes can cause major injury to the Keys' natural environment. Storm waves and currents can destroy extensive areas of ecosystems, large blocks of coral can be broken from reefs and moved great distances, sediments can abrade corals or bury them completely, and entire islands can be defoliated (USDOC, 1996).

During the winter, large-scale, mid-latitude cyclonic systems may be transported over the Keys by fluctuations in the winter polar jet stream. These systems occur approximately once a week, but are quickly moderated by the surrounding warm waters (Schomer and Drew, 1982). Although they do not spread much precipitation, these cyclonic systems can have a significant effect on the Keys' marine environment. Shallow areas may experience a decrease in water temperature and an increase in turbidity, and nutrient and salinity levels also may be affected. During the passage of an especially strong cold front, fish and coral kills may occur, with recovery taking several decades (Voss, 1988; USDOC, 1996).

3.2.3 Water Quality

Circulation over the outer to middle part of the southwest Florida continental shelf is dominated by the Loop Current, which enters the Gulf of Mexico through the Yucatan Straits and moves in a northerly direction as far landward as the 100 m (328 ft) isobath. Turning in a clockwise direction to the south, it parallels the southwest continental shelf before shifting to the east, just southwest of the Dry Tortugas. It then becomes the Florida Current, meandering through the Straits of Florida confined by the 250 m and 500 m (820 ft and 1640 ft) isobaths. It pinches landward south of the Marquesas and is deflected seaward by the Pourtales Terrace. It turns to the northeast near the Upper Keys and continues on as the Gulf Stream. Periodic changes in the location of these currents result in the formation of circulation gyres (large, circular currents) of various sizes moving at speeds ranging from 2 to 20 km (1.2 to 12.4 mi) per day that affect both the transport and entrainment of Sanctuary waters. The variability of these boundary currents, in conjunction with local meteorology and runoff, affects the nature of the water and its transport into and within the Sanctuary (USDOC, 1996).

Wind dominates the circulation and transport landward of the regional boundary currents. A mean westward current occurs in Hawk Channel due to the prevailing southeasterly winds caused by the persistence of the Bermuda/Azores High. The current is most pronounced during the spring and summer, conveying waters from the Middle Keys to the Lower Keys and enhancing exchanges between the Gulf and the Atlantic through the Middle Keys tidal passes. In the Lower Keys, surface waters are forced onshore due to shoreline orientation and the rotation of the Earth, causing an offshore movement of water at depth (USDOC, 1996).

Tides in the Florida Keys generally exhibit two highs and two lows of uneven amplitude per tidal day (Schomer and Drew, 1982). The tidal range (0.5 -1 m (1.6 – 3.3 ft)) decreases from Fowey Rocks in the upper Florida Keys to Sand Key offshore of Key West. The major effect of tides on reef communities is the reduction of water depth during spring low tides when shallow reef flats may be close to or above the water’s surface (NOAA, 1999a).

Tidal currents reverse in direction with the ebb and flow of tides. These currents show a slight westward component especially in the middle and lower Florida Keys (Enos, 1997). However, recent studies indicate that there is a long-term net flow from Florida Bay/Gulf of Mexico to the Atlantic Ocean (Pitts, 1994). Tidal current velocities range from 5 to 15 centimeters per second (2-6 in per sec) but velocities as high as 130 centimeters (51 in) per second have been recorded (NOAA, 1999a).

The combination of downstream transport in the Florida Current, onshore Ekman transport along the downwelling coast, upstream flow in the coastal countercurrent and recirculation in the Tortugas gyre forms a recirculating recruitment pathway stretching from the Dry Tortugas to the middle Keys and beyond. Onshore Ekman transport and horizontal mixing from frontal instabilities enhance export from the oceanic waters into the coastal zone.

Recent declines in coral recruitment, increases in the frequency and size of fish kills, and seagrass die-offs are examples of the impacts of declining water quality within the Sanctuary. Pollutants of concern to the Sanctuary include hydrocarbons, pesticides, herbicides, heavy metals, and nutrients. Potential sources of pollutants are wastewater treatment facilities, water supply treatment plants, industrial facilities, power plants, marinas, abandoned landfills, stormwater runoff, and agriculture (USDOC, 1996).

Corals grow best in warm, clear, nutrient-deficient waters, thus maintaining water quality in the Keys is essential. Minor changes in water temperature or nutrient levels can influence coral development. Turbidity caused by the suspension of sediment in the water column can also adversely affect coral and other benthic filter-feeding organisms (USDOC, 1996). Water quality throughout the Keys varies over periods lasting several years primarily driven by alterations in water masses flowing into the Keys from the Gulf of Mexico (Boyer and Briceno, 2009).

3.2.4 Geology

The Florida Keys are located at the southern edge of the Florida Plateau, a large carbonate platform composed of 7 km (4.3 mi) of marine sediments. The plateau incorporates all of Florida and the adjacent continental shelves of the Gulf of Mexico and Atlantic Ocean. Sediments have been accumulating in the region for 150 million years and have been structurally modified by subsidence and sea level fluctuation. Crystalline and sedimentary basement rocks of the South Florida Basin underlie the plateau (USDOC, 1996).

Sea level fluctuations attributed to glaciation are largely responsible for the region's current morphology. During the Wisconsin Glaciation, sea level dropped between 15 and 30 m (49 and 97 ft), exposing the entire platform to marine and subaerial erosion. Sea level rose again starting approximately 6,000 years ago, flooding the area and forming the current physiographic regions. Lithified remnants of the ancient reef complex formed the Upper Keys, while the Lower Keys were formed from the oolitic sand bars. Florida Bay occupies the southern portion of the old lagoonal structure (USDOC, 1996).

The Florida Keys Reef Tract is an arcuate band of living coral reefs paralleling the Keys. The reefs are located on a narrow shelf that drops off into the Straits of Florida. Approximately 6,000 patch reefs lie along the Florida Keys Reef Tract. They are circular to oval in shape, 30 to 700 m (98 to 2,296.6 ft) in diameter, and occur in water between 2 and 9 m (6.7 and 29.5 ft) deep in the low-energy environment on the back side of the outer reefs. Additionally, about 130 km (80.8 mi) of bank reefs stretch from Fowey Rocks to the Marquesas. Some of their most noticeable structures are seaward-facing spur-and grove formations, constructional features formed in part by wave energy. Spurs are encrusted with reef organisms and separated by grooves containing carbonate sands and reef rubble. These features may extend 1 to 2 km (0.6 to 1.2 mi) off the main reef, from depths of 1 to 10 m (3.2 – 32.8 ft). Bank reefs exist in a high-energy environment and absorb the full impact of wave action, protecting adjacent coastline (USDOC, 1996).

The Holocene reefs that comprise the Dry Tortugas are approximately 14 m (46 ft) thick, composed of massive head corals such as *Montastraea spp.*, and situated upon an antecedent high of the Key Largo Limestone (~135 thousand years ago) reef also composed of massive head corals. The reefs surrounding the area represent windward reef margins in regards to their orientation relative to the dominant wind and wave energies. Tidal energy is also important in the study area, with exchange occurring between the southwest Florida Shelf (Gulf of Mexico waters) to the north and the Florida Straits to the south.

Two additional significant carbonate banks are situated in close proximity to the Dry Tortugas. These include Tortugas Bank and Riley's Hump. Tortugas Bank crests at approximately 20 m (65.6 ft), and is located directly west of the Dry Tortugas islands. A northeast-southwest trending channel, approximately 34 m (111.5 ft) deep and 5 km (3.1 mi) wide, separates Tortugas Bank from the Dry Tortugas reefs. Tortugas Bank has a 30-m (98 ft) escarpment on the west side and a 15-m (49 ft) face on the east side. Sediment aprons drape the flanks of the bank and small patch reefs occur on the top of the bank. Recent geological investigations by the University of South Florida Department of Marine Science show that Tortugas Bank consists of reef framework formed during multiple sea-level fluctuations. Studies indicate that Tortugas Bank was formed at the same time as the outlier reefs seaward of the Keys reef tract (USDOC, 2000)

Riley's Hump is a carbonate bank cresting at approximately 30 m (98 ft) directly south-southwest of Tortugas Bank. The southern face of the bank exhibits a 20-m (65.6 ft) escarpment situated at the shelf/slope break. Thick sedimentary deposits fill a trough separating Riley's Hump from Tortugas Bank to the north. Based on the position of Riley's Hump, it may be equivalent in age to the Florida Middle Ground.

3.2.5 Air Quality

National Ambient Air Quality Standards (NAAQS) have been set for six "criteria" pollutants: sulfur dioxide, carbon monoxide, ozone, nitrogen oxides, lead, and inhalable particulate matter. The problems associated with the pollutant carbon monoxide and inhalable particulate matter are usually related to localized conditions, such as congested traffic intersections or construction activities. The other criteria pollutants are associated with more regionalized problems that result from the interactions of pollutants from a great number of widely dispersed sources (e.g., a large city containing many stationary and mobile sources). The Florida Department of Environmental Protection (FDEP) monitors the concentrations of the criteria pollutants and is responsible, where necessary, for developing implementation plans (State Implementation Plans) to ensure that the national standards are achieved and maintained. Areas within the state that fail to meet the NAAQS are designated as "nonattainment areas" and are potentially subject to regulatory enforcement. Monroe County is classified as being in complete attainment of NAAQS as of November 2005 (USEPA, 2005).

Motorized vessels release combustion products to the atmosphere (NOAA, 1995). The principal emission source in the vicinity of the reefs is motorboat traffic, but overall those are not a significant source of pollution. Large emission sources on the Florida mainland do not appear to be positioned to affect local air quality consistently. The general wind patterns are such that air masses passing over the Keys from the Gulf of Mexico or the Atlantic Ocean do not first pass over the mainland.

Winds are from the east-southeast during the summer and the east-northeast during the winter, shifting to the northwest infrequently and for short periods during the passage of cold fronts (Schomer and Drew, 1982). The region's overall air quality is good (even with short-term air emissions) due to the cleansing effect of the winds, which are primarily easterly and average 9 to 12 mph (NOAA, 1995).

The Dry Tortugas are far enough offshore that there is little pollution, except that carried from the mainland. Overall air quality is similar to that of the rest of the Keys.

3.2.6 Noise

Noise on the reef tract predominately originates from recreational and commercial activities of boaters, including personal watercraft, particularly during the day when boaters are actively using the moorings in the Sanctuary. There are no other significant noise sources aside from natural wind and wave action or occasional aircraft. Noise from shore (e.g., traffic on U.S. Route 1) has a marginal impact, at worst, on ambient noise levels in the vicinity of the reefs. Conversely, the noise of motorboat traffic around reefs is probably insufficient to affect any shoreside residences. Boats visiting offshore reefs that depart from and return to shoreside locations may occasionally create annoying noise levels for residents (NOAA, 1999a).

Because of the isolated location of the Dry Tortugas, natural wind and wave action are the primary sources of noise in this area. Other sources of noise are associated primarily with motors from boats and aircraft that occasionally visit or fly over the area.

3.2.7 Biological Resources

3.2.7.1 Habitat Types

The Florida Keys Reef Tract is one of the largest bank-barrier reef systems in the world. It consists of four discernible types of reef morphology that occur in a generally seaward progression--nearshore hardbottom, patch reefs, transitional reefs, and bank reefs (Jaap, 1984). The relief, or height above the bottom, and the dominance of stony corals as a structural element also increase in a seaward progression (NOAA, 1999a).

The nearshore hardbottom is found in two different circulation regimes, high velocity tidal channels and poorly flushed areas with weak nearshore currents. All of these communities are characterized by close proximity to shore, shallow depth, very low relief and a substrate composed of limestone bedrock. Those communities found adjacent to tidal channels often have low sediment accumulation. In contrast, hardbottom communities in areas with poor circulation have greater sediment accumulation.

There are two types of patch reefs in the FKNMS: dome-type patch reefs (inshore patch reefs) and linear patch reefs (offshore patch reefs). Both types can be found adjacent to large seagrass meadows and/or bare sand areas. Also adjacent to patch reefs are sand halos, which are a result of grazing by herbivorous fishes and urchins. Dome-type patch reefs are roughly circular or elliptical in shape. They often occur in clusters, and usually consist of large coral heads. Linear patch reefs are restricted in distribution to the upper Florida Keys. Their structure consists of coral fingers oriented perpendicular to the direction of dominant wave energy, and thus have the same orientation as spur and groove communities.

Transitional bank reefs, also known as relict bank reefs, occur offshore of most well-developed bank reefs. They have moderate to low relief, low coral cover, and very high algal cover. This type of bank reef has limestone ridges capped by a thin layer of reef biota.

3.2.7.2 Communities

The coral communities of FKNMS are as diverse as the habitats they live in. Bank reefs are elongated structures located near the abrupt change in bottom at 5 to 10 m (16.4 to 32.8 ft) depth. Distinctive characteristics of these reefs include vertical zonation of coral by depth, the presence of seaward spur-and-groove formations, and the presence of *Acropora palmata* prior to its die-off in the 1980s (Jaap, 1984; Wheaton and Jaap, 1988). The spur and groove system at one well-studied reef area, Looe Key, extends approximately 1.2 km (0.75 mi) east to west, and individual spurs may reach lengths of 200 m (656 ft). *A. palmata* and *A. cervicornis* were the dominant shallow-water reef-builders, but they now exist throughout the Keys primarily as relict patches since their Caribbean-wide demise, mainly because of white band disease (Bruckner, 2003). Overall, the FKNMS monitoring program has shown a decline in coral health and cover from 1996 to 1999 (NOAA, 2003), with little change in cover between 1999 and 2006 (Callahan, et al, 2007).

Wheaton and Jaap (1988) divided the shallow spur and groove community into three zones to reflect changes in dominance patterns with increasing depth--*Millepora*-*Palythoa*, *Agaricia*-transition, and *Montastraea*-octocoral zones. The shallow zone of the reef is characterized by extensive sheets of *Palythoa caribbea* (previously named *P. caribaeorum*) and dense clusters of bladed firecoral, *Millepora complanata*, both species that can tolerate a wide range of environmental fluctuations. The back reef, located at a depth of 6 m (19.7 ft), is a marginally developed area consisting of isolated coral colonies but dominated by the octocorals *Plexaura flexuosa* and *Eunicea succinea*, and the fire coral *Millepora alcicornis* (Chiappone, 1996). The dominant algae are large, frondose species from the genera *Laurencia, Dictyota*, *Sargassum, Liagora,* and *Acanthophora* (Littler et al, 1986).

Octocorals and stony corals become more prevalent in the transition from a relatively flat, high-energy, shallow reef to an elevated three-dimensional system where the increased depth and spatial diversity increase the availability of hiding places. In the transitional zone, *A. palmata* occurs on top and lettuce coral, *Agaricia agaricites*, is prolific on the vertical faces of the spurs (Wheaton and Jaap, 1988). Octocorals become more abundant, with the number of species doubling compared to the preceding shallower zone. Sheets of *P. caribbea* are replaced by small, isolated mats, and *M. complanata* remains moderately abundant (NOAA, 1999a).

The *Montastraea* - octocoral zone is characterized by the proliferation of octocorals on the top of spurs as their height diminishes moving seaward and massive mounds of *M. annularis* complex (Wheaton and Jaap, 1988). Smaller stony coral species and numerous octocorals occupy the low-relief rocky platforms, which are interrupted by wide sedimentary areas. Excavations indicate that the undersides of the massive colonies of *Montastraea, Diploria, Colpophyllia,* and *Siderastrea* increase the cryptic habitat and the biotic complexity of this zone (NOAA, 1999a).

The dominant algal species in the spur-and-groove community consists of nonarticulated coralline algae (*Porolithon* sp., *Hydrolithon* sp., and *Lithophyllum* sp.) and filamentous forms (*Wrangelia* sp., *Ceramium* sp., *Centroceras* sp., and *Polysiphonia* sp.). The predominance of these species indicates high grazing pressure (Littler et al., 1986).

During a survey of Looe Key Reef, Wheaton and Jaap (1988) identified 59 species of Cnidaria. Of the 23 species of octocorals, 16 were members of the family Plexauridae and 5 were members of Gorgoniidae. Fifty-five percent of the octocorals consisted of three plexauriid species—*P. flexuosa, E. succinea,* and *P. homomalla*. Also noted were 31 scleractinian species distributed among 10 families, of which Faviidae and Mussidae contained the most species. Nearly half of the fauna sampled consisted of four species and 30 percent were composed of *A. agaricites* and *Porites astreoides*. Two hydrozoan milleporids constituted about 19 percent of the fauna. Diversity values were moderate to high among stony corals and octocorals, except in the rubble zone (NOAA, 1999a).

The coral found in the FKNMS is on the northern edge of the required temperature range, which makes it vulnerable to extreme conditions.

In the area of the Tortugas Ecological Reserve are several deepwater coral banks, Tortugas Bank, Sherwood Forest, and Riley's Hump. In contrast to the rest of the FKNMS, these deep reefs have not been well studied or mapped. Water depths surrounding the banks are 20 to 24 m (66 to 78 ft); the shallowest portions of these banks are 11 to 15 m (36 to 48 ft) deep. Diving observations reveal complex, karst-like limestone banks with abundant attached reef organisms such as sponges, corals, and octocorals. All are described in greater detail in the Supplemental Environmental Impact Statement for the Tortugas Ecological Reserve (NOAA, 2000), which is incorporated here by reference.

3.2.7.3 Other Benthic Organisms

The stratification of resources and space found in the community structure of coral reefs has similarities to that of rain forests (i.e., canopy, understory, and substory). The physical structure built by the corals provides the community's foundation and represents the canopy. Living within this structure is a complex and diverse assemblage of infaunal and epifaunal species that is another essential component of the reef environment.

The understory comprises photosynthetic organisms, such as algae, sponges, ascidians, and foraminifera that contain algal symbionts, which contribute to the organic productivity of the reef and benefit from nutrients brought to the reef by mobile organisms. Epibenthic organisms such as polychaetes and bryozoans dwell on the dead portions of the coral reefs. The substory is composed of cryptofauna, which live within the structural framework of the reef. Crustaceans, molluscs, ophiuroid echinoderms (brittle stars), fish, and polychaete and sipunculid worms inhabit smaller caves and spaces within the reef. Larger caves and excavations are inhabited by fish, crabs, and lobster, and provide surfaces on and within the reef for sessile organisms, such as bryozoans, ascidians, and serpulid worms.

Besides corals, algae and sponges are the organisms most critical to the reef community (Jaap, 1984). Four groups of benthic algae are found on coral reefs: crustose coralline algae, which encrust corals, reef rock, and other limestone skeletal material; filamentous and fleshy algae, which can be either sparse or dense depending on grazing pressure; algae on unconsolidated sediments, which are erect macroalgae and mats of cyanobacteria (blue-green algae); and excavating or boring algae (Jaap, 1984). The marine algae at Dry Tortugas include at least 377 species. One early researcher found 50 species of algae within a few yards off the northwest beach of Loggerhead Key. In addition to biomass and oxygen, algae such as *Halimeda* contribute significant amounts of carbonate sediments to the system.

Sponges are a major competitor for space on reefs and have the greatest overgrowth capability compared to other major groups of encrusting organisms. Sponges play an important role in reef ecosystems by providing shelter and food for other reef organisms, and they are a major force in the bioerosional process on reefs (Jaap, 1984). Some 135 species of sponges have been identified in the Keys.

3.2.7.4 Fish and Crustacean Populations

Numerous crustaceans are native to the FKNMS. Some of them include the commercially important spiny lobster and stone crab, the guinea or spotted lobster, and the Spanish or slipper lobster. Primary producers such as plankton and algae are also rich in the FKNMS (NOAA, 1995).

Studies indicate that more than 500 different species of fish exist in the FKNMS (USDOC, 1996). Some of these fish are of commercial and/or recreational value. Some important species include groupers, mackerels, dolphin, snappers, hogfish, tarpon, pompano, jacks, and bonefish. In addition, there is a small fishery for the collection and sale of live reef species. Data is not available for the Keys only, but this fishery has been managed by FWCC since 1991 (Donahue et al, 2008).

Coral reefs exhibit rich fish species diversity. Reef fishes represent the most evolutionarily advanced species of fish and constitute a highly diverse fauna. Reef fish assemblages are typically associated with highly diverse coralline or hard-bottom habitats and have a high number of species within a relatively small spatial dimension (Chiappone and Sluka, 1996). General characteristics of reef fish assemblages include individuals that are territorial and will strongly defend a particular site; mutualistic interspecific associations, such as cleaning stations; and Batesian mimicry, in which one inoffensive species mimics another noxious or dangerous species. Most reef fishes are highly site-faithful and even the larger predatory species, such as snappers and groupers, tend to be very reef-specific, rarely traveling far from the reef, except for spawning (Chiappone and Sluka, 1996).

A 1987 study surveyed the reef fish assemblages at Looe Key Reef (Bohnsack et al., 1987). The habitats surveyed included high-relief spur-and-groove (fore reef), low-relief hard-bottom, and soft-sediment (e.g., seagrass, bare sand) habitats. Six families were represented by eight or more species. The families that dominated the reef by numerical abundance included Pomacentridae (29 percent), Labridae (27 percent), Haemulidae (20 percent), Gobiidae (6 percent), Scaridae (5 percent), Lutjanidae (3 percent), Acanthuridae (3 percent), Carangidae (1 percent), and Chaetodontidae (1 percent). The dominant species were the bluehead wrasse *(Thalassoma bifasciatum*, 23 percent), bicolor damselfish (*Pomacentrus partitus*, 13 percent), tomtate (*Haemulon aurolineatum*, 13 percent), sergeant major (*Abudefduf saxatilis*, 12 percent), and the masked goby (*Coryphopterus personatus*, 6 percent).

In addition to the species specific to reefs (e.g. triggerfishes, trunkfishes), the Florida Keys/Tortugas Region is considered a faunal transitional zone based on the presence of one or more demersal assemblages (Schomer & Drew, 1982). Some have described assemblages of fish as either insular (reef-associated species from abiotically stable environments) or continental (species found over muddy bottoms or turbid waters). The merging of temperate and tropical species is also apparent in other taxa (e.g., invertebrates and benthic algae) as reported in Chiappone and Sluka (1996). This unique convergence of abiotic and biotic factors provides for diverse and variable fish communities relative to the more tropical (Caribbean) and more temperate (e.g., northern Gulf of Mexico) environments in the western Atlantic.

Little is known about distribution and abundance of highly migratory species in the Tortugas region or about the region's importance to these species. However, one study serendipitously discovered that the Tortugas region likely serves as a spawning ground for a variety of migratory species such as bluefin tuna. In an analysis of the regurgitated food of sooty terns (*Sterna fuscata*) and brown noddies (*Anous stolidus*), Potthoff and Richards (1970) found 40 juvenile bluefin tuna (*Thunnus thynnus*) and other juvenile scombrids such as blackfin tuna (*Thunnus atlanticus*), bullet mackerel (*Auxis* spp.), little tuna (*Euthynnus alletteratus*), and skipjack tuna (*Katsuwonus pelamis*). Whale sharks have also been spotted within FKNMS.

3.2.7.5 Endangered and Threatened Species

Several species of sea turtles and marine mammals that use the FKNMS have been listed as federally endangered or threatened species. Although not permanent residents of the FKNMS, these species are known to occur in or travel through the area during seasonal migrations. The Sanctuary provides an ample food source for these animals, as well as sandy beaches that can be used by sea turtles to lay their eggs. Federally-listed endangered species of sea turtles that are visitors to the FKNMS include the leatherback turtle (*Dermochelys coriacea*), green turtle (*Caretta mydas*), Kemp's Ridley turtle (*Lepidochelys kempii*), and hawksbill turtle (*Eretmochelys imbricata*). In addition, the loggerhead turtle (*Caretta caretta*), listed as threatened, is also a seasonal visitor. Marine turtles are provided protection through Florida's Marine Turtle Protection Act and the federal Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.).

Endangered or threatened marine mammals that occur in the area include: the West Indian manatee (*Trichechus manatus*), which is a species indigenous to the FKNMS, the humpback whale (*Megaptera novaeangliae*), right whale (*Balaena glacialis*), blue whale (*Balaenoptera musculus*), finback whale (*Balaenoptera. physalus*), Sei whale (*Balaenoptera borealis*), and sperm whale (*Physeter. macrocephalus*). Whale sightings in the FKNMS are rare, but do occur. In the Tortugas region, the most common dolphins found are: Bottlenose dolphins (*Tursiops truncatus*), spotted dolphins (*Stenella frontalis*), offshore spotted dolphins (*Stenella attenuata*), and Risso's Dolphins (*Grampus griseus*) (USDOC, 2000). Bottlenose dolphins are undoubtedly the most common cetacean in the area. Given the deep depths in the south portion of the Tortugas Ecological Reserve, it is likely that some of the deeper diving whales (sperm, right, and minke) may be found there. See Lott (1997) for a list of cetaceans found in the Florida Keys and environs. Marine mammals are protected under the Marine Mammals Protection Act of 1972 (16 U.S.C. 1361), as well as the ESA of 1973.

Two species of coral that live in the FKNMS have been federally-listed as threatened species. On May 4, 2006, *Acropora cervicornis* and *A. palmata* were determined to be threatened species under the ESA of 1973. Both of these species have historically been found throughout the Florida Keys, though current populations are less common; see Section 3.2.7.2, Communities, above, for information on their distribution.

Table 3-1 Relevant endangered and threatened species occurrence in the FKNMS

Species	Approximate Time of Occurrence
Leatherback turtle (*Dermochelys coriacea*)	April to July*
Green turtle (*Chelonia mydas*)	June to September*
Kemp's ridley turtle (*Lepidochelys kempii*)	April to June*
Hawksbill turtle (*Eretmochelys imbricata*)	July to October*
Loggerhead turtle (*Caretta caretta*)	April to June*
West Indian manatee (*Trichechus manatus*)	year-round depending on the temperature and distribution of seagrasses
Staghorn, elkhorn coral (*Acropora cervicornis & A. palmata*)	Year-round

*Juvenile turtles inhabit the Florida Keys year-round. Adults are seasonal migrants.
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Source: FFWCC, 2004; USFWS, 2004

3.2.7.6 NMFS Species of Concern

The National Marine Fisheries Service (NMFS) maintains a list of "Species of Concern", which are species or vertebrate populations for which there is concern or great uncertainty about status. These species are not listed under ESA (though they may be under consideration) nor are they protected by other statues, but they could benefit from proactive conservation measures, including consideration during any action that may affect them. Species of Concern that may occur within FKNMS are listed in Table 3-2.

Table 3-2 NMFS Species of concern that occur in FKNMS

Dusky shark (*Carcharhinus obscurus*)	Speckled hind *(Epinephelus drummondhayi)*
Nassau grouper (*Epinephelus striatus*)	Mangrove rivulus *(Rivulus marmoratus)*
Warsaw grouper (*Epinephelus nigritus)*	Ivory bush coral (*Oculina diffusa*)
Key silverside *(Menidia conchorum)*	

Source: www.nmfs.noaa.gov/pr/species/concern/

3.2.7.7 Florida Listed Species

In addition to the species listed for Federal protection, each state is responsible for identifying local or regional species in need of protection. The Florida FWCC maintains the Florida state list of animals designated as endangered, threatened, or species of special concern. The Florida listed species which occur within the FKNMS are identified in Table 3-3 below. Of all the listed species, pillar coral (*Drendrogyra cylindrus*) is the only one likely to be directly impacted by, or indeed be the focus of, restoration. The other marine species, while they may occur near the impacted area, are transient and thus rarely inhabitants of the reef habitats most often injured.

Table 3-3 Relevant Florida Listed Species occurring within FKNMS

Common Name	Scientific Name	Common Name	Scientific Name
Atlantic sturgeon	*Acipenser oxyrinchus*	least tern	*Sterna antillarum*
shortnose sturgeon	*Acipenser brevirostrum*	roseate tern	*Sterna dougalli*
Rivulus	*Rivulus marmoratus*	reddish egret	*Egretta rufescens*
key silverside	*Menidia conchorum*	snowy egret	*Egretta thula*
American alligator	*Alligator mississippiensis*	little blue heron	*Egretta caerulea*
American crocodile	*Crocodylus acutus*	tricolored heron	*Egretta tricolor*
key ringneck snake	*Diadophis punctatus acricus*	white ibis	*Eudocimus albus*
Eastern indigo snake	*Drymarchon corais couperi*	wood stork	*Mycteria americana*
red rat snake	*Elaphe guttata*	roseate spoonbill	*Platalea ajaja*
Florida brown snake	*Storeria dekayi victa*	burrowing owl	*Athene cunicularia*
Florida ribbon snake	*Thamnophis sauritus sackeni*	Osprey	*Pandion haliaetus*
Florida Key mole skink	*Eumeces egregius egregius*	peregrine falcon	*Falco peregrinus*
loggerhead sea turtle	*Caretta caretta*	key deer	*Odocoileus virginianus clavium*
green sea turtle	*Chelonia mydas*	sei whale	*Balaenoptera borealis*
leatherback sea turtle	*Dermochelys coriacea*	fin whale	*Balaenoptera physalus*
hawksbill sea turtle	*Eretmochelys imbricata*	North Atlantic right whale	*Eubalaena glacialis*
Kemp's ridley sea turtle	*Lepidochelys kempii*	humpback whale	*Megaptera novaeangliae*
piping plover	*Charadrius melodus*	Florida manatee	*Trichechus manatus*
American oystercatcher	*Haematopus palliatus*	pillar coral	*Drendrogyra cylindrus*
brown pelican	*Pelecanus occidentalis*		

3.2.8 Cultural Resources

Due to the navigational hazards presented by the reefs and weather in the FKNMS, and because the Florida Keys are located on historically important trade routes, shipwrecks have occurred in the area for centuries. Hundreds of Spanish, British, and American ships have sunk in the waters off the Florida Keys (USDOC, 1996). Historically, Spanish ships dominated the waters in the Keys. Hurricanes, reefs, and military conflicts claimed hundreds of Spanish ships; in some cases, entire fleets were lost in the area (Terrell, 2007).

Salvage operations for shipwrecks began as early as the mid-1500s. Various groups (e.g., Spanish, French, Dutch, English, Calusa Indians) are documented as having attempted recovery of vessels lost in the Keys. Commercial salvage in the Keys began in the 1800s and continues today (Terrell, 2007). Many divers come to this region to view the archaeological remnants of these shipwrecks.

Because of the potential for shipwrecks, many light stations were constructed in the Keys region. Approximately 16 lighthouses are located within or near the FKNMS. Three of the lighthouses are listed on the National Register of Historic Places. Of the existing lighthouses in the Sanctuary, some are built directly on the reef. Construction of Carysfort Reef Lighthouse, the first of six original lighthouses erected on the reef was begun in 1848 and completed in 1852. Other significant historical reef lighthouses include Sand Key Light (1853), Sombrero Key Light (1858), Alligator Reef Light (1873), Fowey Rocks Light (1878), and American Shoal Light (1880) (NOAA, 1996).

The Secretary of Commerce, through the National Oceanic and Atmospheric Administration (NOAA), and the State of Florida, developed a Programmatic Agreement (“Agreement”) to manage submerged cultural resources. The purpose of this Agreement is to define the relative relationship of the State of Florida, as owner of all submerged cultural resources (hereafter "SCRs") (Chapter 267, Florida Statutes) located in State waters, with NOAA, and to jointly develop a policy, as represented by the Agreement, for protection and management of historic resources in the Florida Keys National Marine Sanctuary by the Co-Trustees, the State of Florida and NOAA. The Advisory Council on Historic Preservation (Council) agrees that the Programmatic Agreement meets the requirements under sections 106 and 110 of the National Historic Preservation Act (NHPA) and implementing regulations.

Management and protection of the historic resources in the Sanctuary shall be administered in accordance with the Florida Keys National Marine Sanctuary & Protection Act (FKNMSPA), the National Marine Sanctuaries Act (NMSA), the Abandoned Shipwreck Act and the State regulations guiding archaeological removal of SCRs, provided they do not conflict with the federal archaeological program. Any ONMS management actions taken which are consistent with the procedures in this Agreement satisfy NOAA's Section 106 and 110 responsibilities for all individual federal undertakings affecting the historic resources within the Sanctuary.

3.2.9 Social and Economic Environment

The socioeconomic indicators described in this section include regional economic activity, employment statistics, and demographics. These indicators characterize the region of influence (ROI). An ROI is a geographic area selected as a basis on which the social and economic impacts of projects are analyzed. The ROI is the area most affected by changes resulting from project implementation and is usually based on where project employees reside, local commuting and purchasing patterns, and the size and scope of the proposed project. Typically, a county is the smallest unit of analysis for an ROI. Because coral restoration is relatively limited in scope and will involve few workers over a short period, the ROI for the social and economic environment of this FPEIS is defined as Monroe County, Florida. Although residents of nearby counties, such as Broward and Dade, may be indirectly affected by project implementation (i.e., they may vacation in the Keys and dive on the coral reefs or have insurance companies that also cover residents in the Florida Keys), they will not be directly affected. Additionally, the economic base of these nearby counties is much more highly diversified into areas other than fishing and tourism than that of Monroe County.

Because a high percentage of Monroe County residents often use the reefs for recreational and commercial fishing and to conduct commercial tourism activities (approximately 46%) (English et al, 1996), they will directly benefit from the restoration of coral reefs to their baseline conditions. Additionally, the protection from storm events that healthy reefs provide has an impact on the vulnerability and value of their homes. However, because the dollar cost of the restoration actions themselves is low, they will not create a significant number of jobs for Monroe county residents.

3.2.9.1 Regional Economic Activity

The primary sources of employment in the ROI are services, retail trade, and government services. As shown in Table 3-4, these sectors accounted for more than 75 percent of the county’s total employment in 1999. The economy of Monroe County is heavily dependent on tourism. In 1996, lodging proprietors’ employment accounted for more than 21 percent of the county’s total employment, compared to 14.5 percent for Florida and 16.4 percent for the United States (USDOC, 1998). This statistic indicates the central importance of small businesses in the tourist economy. A recent study estimated that tourist/recreational activities provided more than 46 percent of the county’s employment and about 60 percent of the county’s total economic output (English et al, 1996). Consistent with these statistics, four of the six largest employers in the county are tourism related.

Table 3-4. ROI Employment by Major Sectors (2000 Monroe County)

Employment Sector	Percent of Total Employment
Services	39.4
Retail Trade	29.7
Government Enterprises	8.8
Construction	6.2
Transportation, Com. Utilities	6.8
Finance, Insurance, Real Estate	4.8
Wholesale Trade	2.3
Manufacturing	1.6
Agricultural, Forest, Fisheries	0.9

Source: Key West Chamber of Commerce, 2002

Table 3-5. Demographics of Monroe County
Race / Ethnicity Percent of Total Population (2005-2007 Estimate)

Race Ethnicity	Percent of Total Population
White not Hispanic	74.2
Black not Hispanic	5.6
Hispanic	18.0
Other	2.2

Source: Key West Chamber of Commerce, 2010

In 1997 to 1998, recreating visitors to the Florida Keys spent an estimated $1.38 billion in Monroe County (Leeworthy and Vanasse, 1999). In addition, a significant number of retired persons live in Monroe County, generating a large amount of income in transfer payments flowing into the local economy in the form of pensions, retirement pay, dividends and interest on investments, and social security. In 2007, an estimated 14 percent of the total population was 65 years of age or older. This creates a base of income in Monroe County that is independent of employment. In 2007, the per capita income was $61,216, which is higher than the overall Florida per capita income average of $38,417 (Key West Chamber of Commerce, 2010). The military and commercial fishing industries are also important sectors of the region's economy. The unemployment rate for Monroe County was 5.8 percent in 2009, compared to 8.6 percent for the United States (Key West Chamber of Commerce, 2010). It should be noted that much of the employment is seasonal and rates vary during the year.

3.2.9.2 Demographics

In 2008, the population of Monroe County was estimated to be 72,243. In comparison to the previous decade where the population increased by 2 percent (1990-2000), the population of Monroe Country decreased by 9 percent from 2000-2008 (Key West Chamber of Commerce, 2010). The population is projected to grow, though at a slow rate. Table 3-5 shows the racial/ethnic breakdown of the population estimates for 2005-2007.

Peak tourist populations occur from January to March of each year. The tourist season is longer in the Upper Keys than in the Lower Keys, extending from January to August, and is based on weekend tourists from Miami and south Florida. The functional population (the sum of the peak seasonal and resident population) was 159,113 in 2000 (Monroe County Growth Management, 2001). The seasonal population accounts for nearly 56 percent of the functional population during the peak tourist season.

3.2.9.3 Fishing

Spiny lobster, stone crabs, grouper, snapper, shrimp, and king mackerel are the Florida Keys' biggest fisheries. In 1990, the ex-vessel value of commercial fishing in the sanctuary totaled $46 million (Maryland Sea Grant Program, 2003). The Dry Tortugas region of the sanctuary accounts for a large portion of the FKNMS' productive and profitable fisheries. In 1997, for example, the Tortugas fisheries accounted for 17 percent of the spiny lobster caught in Monroe County, as well as 60 percent of the pink shrimp and 26 percent of the reef fish (USDOC, 2000).

3.2.9.4 Commercial Shipping/ATBA

The Straits of Florida have historically been the access route for all vessels entering the Gulf of Mexico from the north and east. Consequently, the area is one of the most heavily trafficked in the world. It is estimated that 40 percent of the world's commerce passes within 1.5 days' sailing time of Key West.

According to the Navy, over the past several years approximately 1,000 - 1,200 commercial ships from over sixty different countries have transited the area of the FKNMS annually. Cargo ships (over 300), tankers (over 300), and bulk carriers (over 300) comprise most of this traffic. However, there are also some 30-40 passenger ships, 8-16 tugboats, 7-12 research vessels, and several service, fishing, training, and miscellaneous vessels transiting this area annually.

In 1990, the FKNMSPA declared an "Area to be Avoided" (ATBA) that is off-limits to tankers and other vessels 50 m (164 ft) or greater in length. This ATBA was developed jointly by the Coast Guard and NOAA, and later adopted by the International Maritime Organization (IMO), in response to the region's many historical and then recent groundings. Large vessels are prohibited from operating in the ATBA located along the Florida Reef Tract. There are four separate ATBA areas, which together account for 600 nmi^2 of waters within and adjacent to the Sanctuary. In addition, the waters surrounding the Florida Keys were designated as a Particularly Sensitive Sea Area (PSSA) by the IMO in May 2002 (effective December 2002). PSSA designation provides marking on international charts and greater awareness by the international shipping community of the sensitive nature of the FKNMS resources.

3.2.9.5 Academic Research

Research and monitoring are critical to achieving the Sanctuary's primary goal of resource protection. The Keys' ecosystem is diverse and complex, and many of its processes and their interrelationships are not well known. Research and monitoring activities must focus on fundamental processes and specific management-driven topics. Both the Environmental Protection Agency (EPA) and ONMS have direct mandates to conduct monitoring efforts in the Sanctuary. Through memoranda of understandings, the Sanctuary has designated the NMFS Southeast Fisheries Science Center as the reef fish monitors and the National Undersea Research Center as the research arm of the Sanctuary. The Florida Fish and Wildlife Research Institute has developed a data management system that includes raw data, metadata, and mapping tools accessible on the Internet. Research is conducted by many groups, including local, State, and Federal agencies; public and private universities; private research foundations; environmental organizations; and independent researchers.

3.2.10 Existing Jurisdictional Responsibilities and Institutional Arrangements

Most of the management techniques applied in the FKNMS are non-regulatory and are administered through various action plans. Over 120 protected areas covering nearly 3,800 square miles of land and water managed by federal, state and local governments, as well as private organizations, comprise the FKNMS. Most of these areas are managed by the federal government and include four national wildlife refuges (the Key Deer, Great White Heron, Key West, and Crocodile Lake National Wildlife Refuges) and three national parks (Everglades, Biscayne, and Dry Tortugas National Parks) (FKNMS, 1999).

The jurisdictions of several resource management agencies converge in the Dry Tortugas region. The FKNMS is managed cooperatively by NOAA and the State of Florida. ONMS/NMSP and FDEP share co-trusteeship for management and protection of natural and cultural resources. The United States Department of Interior/National Park Service is responsible for protection and interpretation of Dry Tortugas National Park. NOAA's NMFS, Gulf of Mexico and South Atlantic Fishery Management Councils, United States Fish and Wildlife Service, and Florida FWCC share responsibility for aspects of natural resource management in the area. The U.S. Coast Guard (USCG), ONMS and FWCC are responsible for enforcement.

3.3 EAST AND WEST FLOWER GARDEN AND STETSON BANKS, GULF OF MEXICO

Perched atop salt domes and rising above the surrounding sea floor, FGBNMS contains the northernmost coral reefs in the continental United States. The area was designated a national marine sanctuary in 1992 and includes the East and West Flower Garden Banks, located approximately 100 nautical miles south of the Texas/Louisiana border (Figure 3-2). Stetson Bank, located 112 km (70 miles) south of Galveston, Texas, was added to the FGBNMS in 1996[2]. Sanctuary status was designated primarily to protect the coral reefs from ship anchoring injury and because the area is a regional reservoir of shallow water Caribbean reef fishes and invertebrates in the Gulf of Mexico. FGBNMS encompasses 126 km^2 (48.5 square miles) (Ditton et al, 2002), including 345 acres of coral reef. The coral reefs rise to within 18 m (59 feet) of the surface. The Banks themselves are surface expressions of salt domes whose formation began 160 to 170 million years ago in what was a shallow sea, subject to evaporation.

3.3.1 Location and Area Use

The Flower Garden Banks are located due south of the Texas-Louisiana border at the edge of the continental shelf. The East Flower Garden Bank is approximately 220 km (136.7 mi) south southwest of Cameron, LA, and the West Bank is 203 km (126 mi) southeast of Galveston, TX. Stetson Bank is located 112 km (70 miles) south of Galveston. The total area of the banks is less than 3.4 km^2 (1 nmi^2) with a reef crest totaling approximately 35 acres.

3.3.2 Climate

The Flower Garden and Stetson Banks are geographically situated in a warm temperate zone. Rainfall is substantial on the mainland northeast of the Banks, averaging 125 – 150 cm (50 to 60 inches) per year. Precipitation diminishes southward along the coast, approaching semi-arid conditions between Baffin Bay, TX and the Rio Grande River (64 cm (25.2 in)/yr). Runoff from rivers in Louisiana and north Texas

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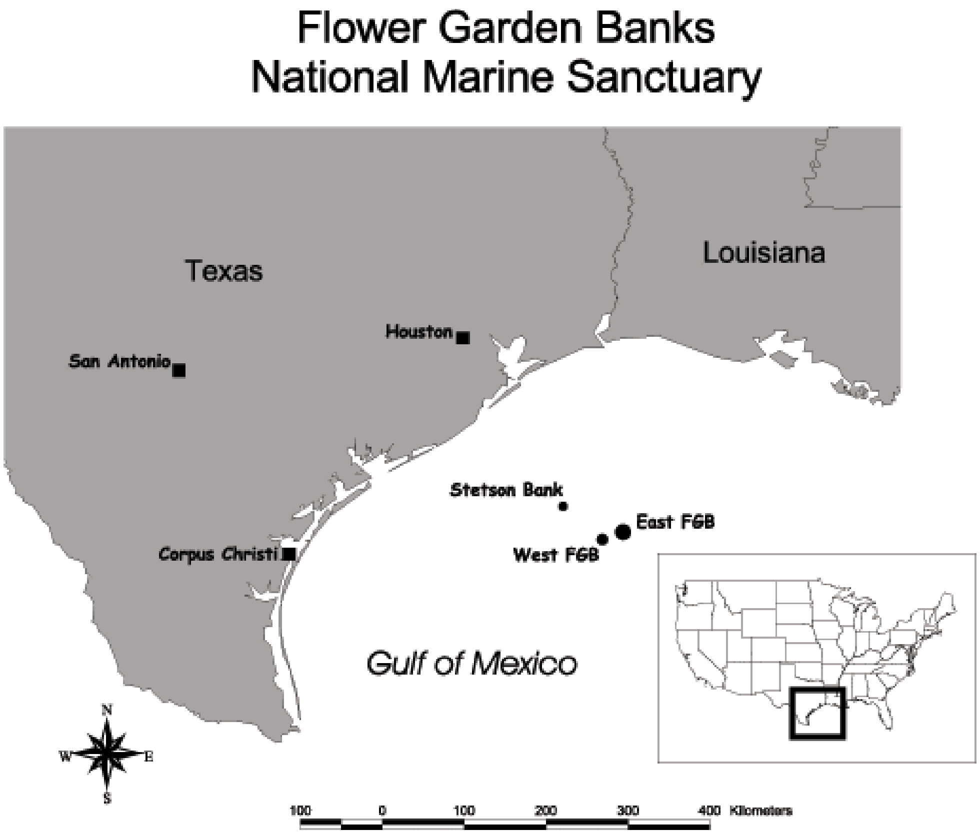
[2] The FGBNMS Management Plan Review underway in 2010 is proposing to incorporate an additional seven banks into the Sanctuary. If that proposal is approved, any additional area would be covered under this PEIS.

Figure 3-2



greatly impacts coastal hydrography in the northwestern Gulf. At peak discharge, the Mississippi River alone can transport more than 100,000 m^3 of fresh water per second into the Gulf.

Winds vary seasonally. In January, regional winds affecting the offshore waters in the northwestern Gulf are generally from the northeast. By March, they have shifted and blow primarily from the east. In summer, prevailing winds are out of the southeast. These average conditions are perturbed in winter by intrusions of polar air masses into the Gulf in the form of frontal passages (northers) that may result in severe storms at the Flower Garden Banks, with waves well over 5 m (16.4 ft) in height. Furthermore, the northwestern Gulf is in the path of hurricanes that may pass through the region during the summer and fall. Evidence of these tropical disturbances is seen resulting in up to 1.5 m (4.9 ft) sand waves in sand patches. Coastal runoff resulting from Hurricane Rita (September 2005) resulted in an enormous plume that reached the Flower Garden Banks region. Hurricanes Rita (2005) and Ike (2008) mechanically impacted the FGBNMS, resulting in 3-4 m (9.8–13.1 ft) boulders being strewn over the reef, the destruction of a significant thicket of pencil coral (*Madracis auretenra)*, removal of large barrel sponges, and severe scouring of sand flats.

3.3.3 Water Quality

On the outermost shelf where the Flower Garden Banks are located and on the inner shelf of Stetson, the general shelf circulation pattern and prevailing winds allow the tropical oceanic water masses of the open Gulf to predominate. Such conditions promote a strong tendency for the coastal water masses to be held on shore and shunted west (particularly during February to May). Typically, currents on the inner shelf between the Mississippi and central Texas are directed downcoast (westward and southwestward). Currents on the outer shelf usually flow toward the northeast and east. In the summer, this pattern may be disrupted, resulting in current reversals and considerable cross-shelf exchange west of the Mississippi.

The net result of this tenuous balance between neritic and oceanic water movement is a shelf-edge zone wherein the near-surface water comes primarily from the south, is perpetually clear and well lit, comparatively oligotrophic, varies little in salinity beyond 34-36 ppt, and ranges in temperature from 18°C (68°F) to 30°C (86°F). However, in 2005, salinity was recorded as low as 31.1 ppt (June), and summer temperatures were recorded at above 30°C (86°F) for at least 10 days in Aug/Sept. (Precht et. al, in press).

3.3.4 Geology

The introduction of uplifted substratum into these waters by salt diapirism has provided suitable habitat for the development of tropical Atlantic reef communities on at least 17 shelf-edge banks off Texas and Louisiana. The East and West Flower Garden and Stetson Banks are seafloor expressions of domes (diapirs) formed by the intrusion of salt from Jurassic evaporite deposits approximately 10 km (6.2 mi) below the sea floor. Diapirism and faulting are currently active at both Flower Garden Banks. The faulting of Bank crusts resulting from a combination of tensional forces due to domal uplift and the removal of salt by dissolution is more advanced at the West Flower Garden Bank. Consequently, it possesses a larger and more conspicuous central subsidence features (down-faulted depression) than does the East Bank.

The salt plugs beneath the Banks are quite near the sea floor. High salinity brine seepage has been detected on the East Flower Garden at 45 m (147.6 ft) depth, indicating that the top of the salt may lie directly beneath the central reef. A larger brine seep on the southeastern edge of the Bank at a depth of 71 m (232.9 ft) flows at a rate of 400-700 m^3 per day. This discharge of 200 parts per thousand (ppt) brine is thought to represent the removal of 10,000 to 22,000 m^3 of solid salt per year from beneath the East Flower Garden. Stratigraphic traps formed on the flanks of the salt plugs are known to contain natural gas deposits, and scattered seeps of natural gas of biogenic and petrogenic origin occur on both Banks from their crests to their bases.

Surficial hard substratum at the Flower Garden Banks is exclusively carbonate rock, constructed primarily by contemporary populations of coralline algae and corals. Exposed sedimentary facies on the Banks and their environs are strongly correlated with depth, and parallel closely the distribution of biotic communities, which are dominated by reef-building organisms above approximately 52 m (170.6 ft) depths.

Living coral reefs, made up primarily of massive heads produced by 18 species of tropical Atlantic corals are the primary features between 15 m (49.2 ft) and 46 m (150.9 ft) depths. The coral debris facies at depths of 25 to 50 m (82 to 164 ft) consist of coarse carbonate sand and gravel in basins and valleys between coral heads and in narrow aprons surrounding the reefs. An Algal Nodule Zone (Gypsina - Lithothamnium Facies), consisting predominantly of algal nodule gravel formed *in situ* with occasional algal reefs and pavements, extends downward and outward from the coral debris facies to depths of 60-70 m (197 to 230 ft).

Below the Algal Nodule Zone are carbonate sands consisting mainly of the skeletal remains of the foraminifer, *Amphistegina*, derived from living populations on higher bank surfaces. The *Amphistegina* Sand Facies extends to depths of 90-100 m (295 – 328 ft), where it is replaced by a Quartz-Planktonic Foraminifera Facies consisting of planktonic foraminifers, pteropods, mollusc, and echinoderm fragments, and reefal detritus in various mixtures with silt and fine, sand-sized quartz grains and clay. This facies represents a transition between the carbonate bank sediments and the terrigenous sediments normally found on this part of the continental shelf (Hickerson et al, 2008; Schmahl et al, 2008).

3.3.5 Air Quality

Due to the great distance from shore, air quality at FGBNMS is generally very good. The nearest source of any pollution would be nearby oil platforms.

3.3.6 Noise

On the surface, natural wave and wind noise are the primary sources of noise. Low levels of occasional noise may result from passing vessels, those that visit the sanctuary, or from nearby oil platforms. However, any noise is short-term and very localized.

Underwater, noise may be a very important issue that is unexplored, particularly in the Gulf of Mexico. Frequent high-intensity acoustic noise related to seismic sub-bottom profiling occurs in the area. Constant low- to high-level noise from platform and drilling related operations occurs in the vicinity. It is unknown what impact this has on benthic organisms.

3.3.7 Biological Resources

The Flower Garden Banks harbor at least 21species of coral, 80 species of algae, over 200 known macro-invertebrate species, and almost 280 fish species (Hickerson et al, 2008; Schmahl et al, 2008). The reef-building corals and coralline algae construct and maintain the substratum and, through a multitude of intraspecific and interspecific relationships, largely control the structure of benthic communities occupying the Bank. Thus they are by far the most important organisms in the Flower Garden ecosystem (ONMS, 2008).

Stetson Bank has at least 9 species of coral, 80 species of algae, over 250 macroinvertebrate species, and more than 150 fish species associated with the reef. Three species of sea turtle have been documented at the Sanctuary (ONMS, 2008). The primary resident species is the loggerhead (*Caretta caretta*), and secondary, the hawksbill sea turtle (*Eretmochelys imbricata*). None of the corals on the reef are large and branching. Much of the Stetson environment is dominated by low lying coral species and invertebrates (primarily sponges) (Hickerson, et al, 2008).

3.3.7.1 Habitat Types

The Flower Garden Banks bear the most well developed Atlantic coral reef in the Gulf of Mexico. The FGBNMS also harbors a localized assemblage of organisms associated with a hypersaline, anoxic brine seep, having a chemosynthetic energy base analogous to that found at deep-sea vents. These communities are otherwise known only on the world's continental shelves.

East Flower Garden Bank is a single platform rising to a crest of about 15 m (49.2 ft) below the water surface. Within the 100 m depth contour, the bank is 5.4 nautical miles long and 3.5 nautical miles wide. West Flower Garden Bank consists of three platforms cresting at 20, 60, and 70 m (65, 197, 230 ft)). Within the 100 m (328 ft) contour, West Flower Garden Bank is 5.4 nautical miles long and

3 nautical miles wide. The Flower Garden Banks harbor approximately 500 acres of submerged tropical coral reefs with up to 30 species of hermatypic corals. Cresting at approximately 15 m (49.2 ft) below the water surface, the reefs extend downward to 46 m (151 ft) depths, where the hermatypic coral community is replaced by a reef community dominated by coralline algae. This deeper "algal terrace" covers most surfaces down to a depth of 88 m (288.7 ft).

Stetson Bank occupies about 64 acres of sea bottom, rising from a base depth of around 52 m (170.6 ft) to a crest of 19 m (62.3 ft). The substratum of the bank is primarily a soft claystone the surface of which is extensively perforated with boring pelecypod holes. The morphology of the bank consists of a relatively level claystone top penetrated in places by thin, nearly vertical beds of more highly indurated rock and often broken by abrupt upward outcropping claystone structures of approximately 0.3 to 3 meter horizontal and vertical dimensions.

The FGBNMS research team has recently updated the biological characterization scheme (Hickerson et al, 2008; Schmahl et al, 2008).

3.3.7.2 Communities

Up to 36 species of corals are found on the Flower Garden and Stetson Banks. All three banks in the Sanctuary lack gorgonian soft corals in the "shallow" areas and branching corals like elkhorn and staghorn, although two elkhorn recruits have been documented (WFGB in 2002, EFGB in 2005: Zimmer et al, 2006). The lower-lying benthic communities at the Flower Garden Banks, however, are representative of reef assemblages occurring on other outer continental shelf banks in the northwestern Gulf of Mexico. All of the biotic zones so far recognized on the other shelf-edge carbonate banks (except the *Millepora*-sponge zone, which occurs only on claystone-siltstone outcrops) are represented at the Flower Garden Banks.

The hard substratum and high relief of Stetson Bank provides habitat for, and attracts, a moderately diverse assemblage of epifauna, mobile invertebrates and groundfishes. The surrounding level soft-bottom at the base of the bank supports a sparse community of infauna, mobile benthos and, where isolated rocks or sponges occur, epifauna and ground fishes can be found. There are five primary biological habitats within FGBNMS (ONMS, 2008), which are described below.

3.3.7.2.Coral Reef Zone

This is the shallowest zone, at depths between 17 to 44 meters (55.8 to 144.3 ft), and the one most familiar to visitors. This zone is dominated by large, closely spaced star and brain coral heads, many quite large in size. Reef topography is relatively rough. There are numerous sand patches and channels between the corals.

This zone is characterized by a high diversity coral assemblage dominated by *Montastraea* spp, *Diploria strigosa*, *Colpophyllia natans* and *Porites astreoides*. Coralline algae, and filamentous and leafy algae also occur on reef substrates but are not dominant members of the benthic assemblage. *Madracis mirabilis* forms large monotypic stands in deeper portions of the coral reef community. Sponge and *Agaricia* spp. are common in crevices and cavities of the reef (ONMS, 2008)

3.3.7.2.2 Coral Community Zone

The coral community zone is comprised of areas that, while not "true" coral reefs, do contain hermatypic coral species at low densities, or are characterized by other coral reef associated organisms, such as *Millepora* spp, sponges, and macroalgae. Coral communities are found in depth ranges similar to those that contain coral reefs but where other environmental factors have not allowed full development of coral reefs. The coral community at the Flower Garden Banks is characterized by *Stephanocoenia intersepta*, *Montastraea cavernosa*, and *Colpophyllia natans*, and occurs between depths of 40 to 55 meters (131.2 to 180.4 ft). At Stetson Bank, the coral communities are dominated by the *Millepora*-sponge assemblage, along with areas of *Madracis decactis* and individual colonies of *Diploria strigosa* and several other coral species (ONMS, 2008)

3.3.7.2.3 Coralline Algae Zone

The coralline algae zone is found at depths of 45 to 90 meters (147.6 to 295.3 ft), and is made up of algal nodule fields, pavements and coralline algal reefs. Coralline algae occurs within the photic zone above approximately 85 meters (278.9 ft), as coralline algae is a photosynthetic organism. This zone is biologically rich in sponges, algae, gorgonians, and black coral and harbors healthy populations of deep reef fish including rough tongue bass (*Pronotogrammus martininicensis*), scamp (*Mycteroperca phenax*) and marbled grouper (*Dermatolepis inermis*). At Flower Garden Banks, this zone is dominated by crustose coralline algae that form large beds of algale nodules or massive reef structures composed of large plates and ridges. A variety of sponge species are abundant in this zone, along with numerous antipatharians and octocorals (ONMS, 2008).

3.3.7.2.4 Deep Coral Zone

Found in depths typically below 90 meters (295.3 ft), the deep coral zone is dominated by eroded reef outcroppings, azooxanthellate solitary hard corals, antipatharian and gorgonian corals, deep reef fish, sponges, bryzoans, and crinoids. Rock surfaces are often highly eroded and lack coralline algae growth. The deep coral zone is sometimes characterized by turbid water conditions, and reef outcrops may often be covered with a thin layer of silt, (ONMS, 2008).

3.3.7.2.5 Soft Bottom Community Zone

Large expanses of mud, sand, and silt substrates, which typify the soft bottom community zone, are found in the deepest parts of the banks, and surrounding the banks. Features of the soft bottom community include pits, burrows, *Cirrihipathes* (*Stichopathes*) fields, stalked anemones, and echinoderms. Squat lobster (*Munida* sp.) are often observed in this zone.

Deeper areas of the sanctuary are characterized by a soft, level bottom composed of both terrigenous sediments originating from coastal rivers and carbonate sediments resulting from calcareous planktonic remains and erosion of rocky outcrops and coral reef communities. Soft bottom communities are often characterized by sand waves, burrows and mounds. Transitional zones between soft bottom communities and hard bottom features area characterized by exposed rubble, isolated patch reefs or exposed hard bottom. Areas with buried or exposed carbonate rubble are often colonized by antipatharians, octocorals, or solitary hard corals. Soft bottom communities serve as important feeding areas for reef and reef-associated fishes (ONMS, 2008).

3.3.7.3 Other Benthic Organisms

Reef surfaces shallower than 30 m (98.4 ft) provide a habitat for various types of mollusks. Table 3-6 lists mollusks and other invertebrates found on the banks.

Table 3-6 Mollusks and other Invertebrates at FGBNMS

Scientific name	Common name	Scientific name	Common name
Spondylus americanus	Atlantic thorny oyster	Order Ophiurida	brittle star
Family *Malleidae*	Scallops	Class Echinoidea	sea urchins
Conus testudinarius	turtle cone	*Hypsicomus elegans*	feather duster worm
C. mindanus	Mindanao cone	*Panulirus argus*	spiny lobster
Genus *Cypraea*	Cowries	*P. guttatus*	spiny lobster
Strombus raninus	Hawk-wing conch	*Scyllarides aequinoctialis*	Spanish lobster
Latirus infundibulum	brown-lined latirus		
Cymatium pileare	Atlantic Hairy Triton		

Source: Lipka, 1975

3.3.7.4 Fish Populations

At least 280 species of fish have been documented at the Flower Garden Banks and Stetson Bank (ONMS, 2008). Reef-associated fish at the Flower Garden Banks include a number of small, brightly colored reef fishes such as the blue tang (*Acanthurus coruleus*), the gobies (Family Gobiidae), the bluehead wrasse (*Thalassoma bifasciatum*), the damsel fishes (Family Pomacentridae), the butterfly fishes (Family Chaetodontidae), some of the parrotfishes (Family Scaridae), and some of the triggerfishes (Family Balistidae) (Bright and Cashman, 1974). The most important of the larger, harvestable fish are groupers of various kinds, wahoo (*Acanthocybium solandri)* and red (*Lutjanus campechanus)*, vermillion (*Rhomboplites aurorubens*), and other types of snapper.

Larger pelagic species can also be found in Flower Garden Banks. Scalloped hammerhead sharks, as well as spotted eagle rays, school near the banks every winter. Whale sharks occur during the summer. Horse-eye and crevalle jacks and manta rays can be found there year-round.

Benthic and demersal fish, such as snapper and groupers, play a major role in the coral-reef ecosystem. Some larger carangids and some species of triggerfish occasionally move or uproot coral during their feeding and nest-building activities. Parrotfish and other species feed on corals directly (Randall, 1974). Although such activities are destructive to coral, they reflect normal ecological relationships among biota in the reef system.

The fish most often found at Stetson Bank include the Rock hind, (*Epinephelus adscensionis),* Reef butterflyfish (*Chaetodon sedentarius),* French angelfish (*Pomacanthus paru)* and squirrelfish (*Holocentrus* sp. *rufus* or *ascensionis*). Large schools of king mackerel (*Scomberomorus cavalla*), and little tunny (*Euthynnus alletteratus*) occur seasonally at Stetson Bank. Large groupers are particularly characteristic of the Hard-Bank Zone. An endemic wrasse to the FGBNMS, the Mardi Gras wrasse (*Halichoenes bureki*), is found at Stetson Bank as well as the East and West Flower Garden Banks.

3.3.7.5 Endangered and Threatened Species

Sea turtles are often seen at Flower Garden Banks. The loggerhead (*C. caretta*), is most commonly seen. Loggerheads and hawksbills are resident at all three banks throughout the year (ONMS, 2008). While marine mammals are rarely reported at the FGBNMS, the spotted (*S. plagiodon*) and bottlenose (*T. trancatus*) dolphins are most common.

Two species of coral that may live in the FGBNMS are federally-listed as threatened species. On May 4, 2006, *Acropora cervicornis* & *A. palmata* were determined to be threatened species under the ESA of 1973. Neither of these species has historically been resident in the Flower Gardens, but two colonies of *A. palmata* were recently found there. See Section 3.2.7.2, Communities, above, for information on their distribution. Fossil *A. cervicornis* and *A. palmata* have both been discovered as the underlying base of the Flower Garden Banks at the East and West Bank (Schmahl et al, 2008).

3.3.7.6 Other Species of Concern

There are three NMFS Species of Concern at FGBNMS: the Dusky shark (*Carcharhinus obscurus*), Nassau grouper (*Epinephelus striatus*), and the Warsaw grouper (*Epinephelus nigritus*).

3.3.8 Cultural Resources

FGBNMS lies well seaward of any area identified as having a high probability of containing either historical or prehistoric cultural resources (Terrell, 2007). It is considered unlikely that historical/cultural resources of any significance exist inside the boundaries of the FGBNMS. However, several anchors greater than 200 years old have been documented within the sanctuary boundaries.

3.3.9 Social and Economic Environment

3.3.9.1 Regional Economic Activity

Although the FGBNMS is located far offshore, it is utilized for a number of economic purposes, including shipping, oil and gas operations, commercial and recreational fishing, recreational diving, and research.

3.3.9.2 Oil and Gas Activities

Oil and gas production occurs in parts of the FGBNMS. The Minerals Management Service (MMS) divides the Gulf of Mexico into lease blocks. Portions of 15 lease blocks fall within sanctuary boundaries. All but two are actively leased and ten have active platforms or other infrastructure (i.e., pipelines) (Schmahl, 2003, personal communication). However, although inside sanctuary boundaries, these areas are outside the “no activity zones” established by the MMS before the sanctuary was designated. The direct economic impact of this oil and gas activity is proprietary information of the oil companies and is thus unknown.

Hydrocarbon reserves in the sanctuary are generally expected to be natural gas, but the presence of oil at the FGBNMS cannot be discounted; at least small quantities of oil are normally recovered from gas wells. The closest crude oil production facility is located approximately 12 km (7.5 mi) northwest of the West Bank. Oil company activity involving the leasing of tracts, exploratory drilling, and production operations seem to indicate a favorable outlook for the development of hydrocarbon deposits in the vicinity of the Banks. A production platform known as High Island A389A (HIA389A) was constructed in 1981 one nautical mile southeast of the East Bank. Increased activity of the platform has been noted in recent years (Schmahl, 2003, personal communication).

Monitoring efforts by the FGBNMS have thus far shown no long-term environmental impacts to the coral reef community as a result of oil and gas activity (Schmahl, 2003, personal communication). Contaminants and degradation of soft bottom communities in the vicinity of the platform HIA389A have, however, been documented. (Deslarzes, 1998).

3.3.9.3 Commercial Fishing

Several types of fish occurring at the Flower Garden Banks and other regional banks are of proven or potential value to fisheries. Red and vermillion snappers and yellow-edged groupers have been harvested in the vicinity of the Flower Garden Banks by commercial hook-and-line fishermen since the 1880's. Currently, the commercial-fish harvest consists predominantly of snapper and grouper. These and other banks rimming the Gulf are frequented by snapper and grouper boats with homeports scattered throughout the Gulf. The fishing effort in the FGBNMS is directed toward the fringe of the coral reef cap in 30-50 m water depths where snappers seem most abundant. Fishing vessels have also targeted non-reef sections of the sanctuary (Schmahl 2003, personal communication).

3.3.9.4 Recreational Diving and Fishing

The primary base-ports for recreational users are Freeport, Houston-Galveston, and Port Arthur, Texas, and Cameron, Louisiana. Peak recreational use occurs in July, August and September when weather conditions are generally most favorable and leisure time is greatest.

Only the most experienced private recreational boat operators are willing to attempt the trip to FGBNMS. Because of the often rigorous offshore conditions, private recreational boats visiting the reef are seldom smaller than 9 m (29.5 ft) in length. Trips out to the Flower Garden Banks and back require an average of 16 hours. Therefore, many boats remain overnight, weather permitting.

The attractiveness of the area for recreational fishing is enhanced by the HIA389A platform. Platforms provide new habitats for fish, and platform crews can furnish emergency assistance to boats in distress. Nonetheless, the sanctuary's distance from shore will continue to limit recreational usage. Sport fishersvisit the Flower Garden Banks in small parties on private boats or in larger groups on charter vessels. Fishers on both classes of vessels spend one to several days in the area using hook and line to fish for snapper and grouper (Schmahl 2003, personal communication). These vessels tend to fish along the reef margins in water 30 to 36 m (98.4 to 118.1 ft) deep where snapper and grouper are most likely to be found, but also have been reported to fish the upper limits of the banks for grouper, wahoo, amberjack, king mackerel, and little tunny. It is common to encounter discarded fishing line/longlines on the reefs in the deeper portion of the banks during Remotely Operated Vehicle surveys, as well as up on the reef cap.

Recreational boats visiting the Flower Garden Banks for diving purposes visit the shallowest portions of the reefs. Although more experienced divers may explore the deeper water at the edges of the reefs, charter boat divers, and probably most divers visiting in private craft, tend to limit their dives to the bank tops, where there is a 40 m (131.2 ft) dive limit (Schmahl, 2003; Hickerson, 2003, personal communication).

A 1997 study of the economic output of sport diving using a dive charter boat in the FGBNMS and surrounding artificial reefs found that the combined direct, indirect and induced economic impacts totaled between $725,907 and $998,003 per year at the state level (this includes only out of tourist money) (Ditton et al, 2002). The economic impacts of private boats have not been studied in such detail. The study also cites the fact that 26 percent of FGBNMS divers are visitors to Texas.

3.3.9.5 Commercial Shipping

The area surrounding the Banks is transited by commercial cargo-carrying vessels en route to and from Texas coastal ports. A major east-west shipping fairway, the "Gulf Safety Fairway," passes 6 nautical miles (11 km) south of West Flower Garden Bank. This fairway leads to Corpus Christi, Texas, and connects with other fairways serving major Texas and Louisiana ports. One of these connecting fairways is located some 35 nautical miles (65 km) west of the West Bank and another is located about 45 nautical miles (83 km) east of the East Bank.

3.3.9.6 Anchoring by Large Vessels

At the time of designation, the banks were subject to injury from anchors and anchor chains. Both the coral reefs above 46 m (151 ft) depths and the algal terraces below have been subjected to injury by ground tackle (anchors, chains, and cables) from vessels for many years. Anchor injury probably began in the 1800's with the onset of the commercial snapper-grouper fishery, and it has become more serious in recent times. Lost anchors, chains, and cables are not uncommon on the Banks and have been encountered repeatedly.

In 2001, regulations were updated to prohibit anchoring in the sanctuary (15 C.F.R. § 922.122(a)(2)(i)). ONMS made this change to conform the regulations to anchoring prohibitions adopted by the International Maritime Organization, which designated the Flower Garden Banks as the world's first international no-anchoring zone. The new regulations prohibit all anchoring and mooring in the Sanctuary with the exception of vessels 100 feet (30.48 m) and under in length, which are permitted to moor at existing Sanctuary mooring buoys. Since the no-anchoring regulations were implemented, the incidence of anchor injuries has declined (Schmahl, 2003).

3.3.9.7 Academic Research

The FGBNMS provides a good forum for long-term monitoring and research programs. The annual mass coral spawning in late summer provides many scientists with the opportunity to not only study coral in their environment, but also learn ways to aid reef restoration in other parts of the world. Studies have also been conducted using satellite-tracked drifter buoys to study dispersal of coral larvae. Current research and monitoring projects include: coral reproduction, long-term monitoring of coral cap, deep reef characterizations, biomolecular and acoustic tracking of manta rays and whale sharks (Hickerson, 2008, personal communication).

3.3.10 Existing Jurisdictional Responsibilities and Institutional Arrangements

In response to limited financial resources, the FGBNMS works to create innovative partnerships with other federal agencies, the academic community, sport diving organizations, and the petroleum industry. USCG occasionally conducts overflights and on water observations. Dive boat operators keep a close watch over sanctuary activities. Partnerships with businesses and federal agencies such as the MMS have been successful in promoting sanctuary safeguards. Recreational divers and charter boat staff have also accepted responsibility for protecting sanctuary resources (Schmahl, 2003). NOAA and USCG are responsible for enforcement.

CHAPTER 4. ENVIRONMENTAL CONSEQUENCES

4.1 INTRODUCTION

The alternatives analysis describes the environmental and socioeconomic consequences of implementing each alternative at each sanctuary. The restoration methods to be discussed include: 1) no action, 2) debris and vessel removal, 3) sediment and rubble removal, 4) substrate stabilization, 5) limestone boulders and preformed modules, 6) revetment mats, and 7) reattachment. The direct and indirect effects of each alternative are discussed with respect to 13 resource categories. For four of these categories (land use, climate, air quality, noise), both the direct and indirect effects are identical for all seven restoration actions. These categories are discussed in this introduction, and are not repeated in the individual restoration alternative sections. The effects (adverse or beneficial), or lack thereof, are described according to duration (short-term or long-term) and intensity (minor or major). Minor effects are considered those that could be avoided with proper mitigation; major effects are those that are unavoidable and would threaten the viability of a resource. As this document is non-site specific, the potential impacts are discussed in general terms for a hypothetical restoration site that may include the combination of injuries. A summary of the impacts for each restoration method is presented in Table 4-1. For restoration cases that present the possibility for unique and extensive environmental or socioeconomic impacts, additional project-specific analyses may be necessary.

Although this document covers two sanctuaries, ONMS believes that the environmental impacts to both are similar and can be addressed in one analysis. In general, any restoration activity in the FGBNMS or the Tortugas region of FKNMS will be more expensive, more complicated, and take longer than an equivalent effort elsewhere in FKNMS due to the greater distance from shore and the greater depths at which coral is found. Most activities in those locations will also require the placement of a mooring system, with associated potential impacts and permitting requirements.

4.1.1. Surrounding Land Use (All Restoration Alternatives)

Direct Effects. No direct effects would be expected.

Indirect Effects. No indirect effects would be expected.

4.1.2 Climate (All Restoration Alternatives)

Direct Effects. No direct effects would be expected.

Indirect Effects. No indirect effects would be expected.

4.1.3 Air Quality (All Restoration Alternatives)

Direct Effects. Short-term minor adverse effects would be expected related to the use of motorized vessels and equipment. Given the relatively short period of the restoration, the total emission amounts would be negligible and too small to impact regional air quality.

Indirect Effects. No indirect effects would be expected.

4.1.4 Noise (All Restoration Alternatives)

Direct Effects. Short-term minor adverse effects would be expected related to the use of motorized vessels and equipment,. The greatest noise source would likely be any heavy lift equipment required

Table 4-1 Summary of Impacts

	No Action	Debris Removal	Sediment Removal	Substrate Stabilization	Boulders & Modules	Revetment Mats	Reattachment & Transplantation
Location & Area Use	**LM-** Lm-	**LM+** Lm+	**LM+** Lm+	**SLm-**	**Sm-**	**LM+/Sm-**	**LM+**
Water Quality	Lm-	**Sm-**	**Lm+**	**Sm-** Lm+	**Sm-** Lm+	**Sm-**	**Sm-**
Geology	**LM-** LM-	**Lm+** Lm-	**Lm+** Lm-	**LM+/Sm-** Lm+	**LM+/Sm-** Lm+	**LM+/Sm-**	**LM+**
Biology	**LM-** Sm-/Lm-	**LM+** LM+	**LM+** Lm+	**LM+-/Sm-** Lm+/Sm-	**LM+/Sm-** Lm+/Sm-	**Lm+** LM+/Sm-	**LM+** LM+/Sm-
Infrastructure		**Sm-**	**Sm-**	**Sm-**	**Sm-**	**Sm-**	
Cultural Resources	Lm-	**LM+**					
Hazardous Substances		**Lm+**					
Socioeconomics	Lm-	**Sm-** LM+	**Sm-** Lm+	**Lm+/Sm-**	**LM+/Sm-**	**Lm+/Sm+**	**Lm+**
Quality of Life	Lm-			**Lm+**	**Lm+**	**Lm+**	**Lm+**

Legend:
LM = long-term major SM = short-term major + = beneficial
Lm = long-term minor Sm = short-term minor **-** = adverse
Bold entries are direct; non-bold are indirect

to maneuver multi-ton limestone modules; other sources would include multiple motor boats, a barge-mounted 50-ton crane, small batch cement mixers, and/or air compressors. Restoration would increase the ambient noise levels within several miles of the restoration site and generate underwater noise that could diminish the quality of recreation. During restoration, the increased noise levels would impact nearby recreational divers and could disrupt some fish behavior patterns. However, given the near constant use of FKNMS waters by recreational and commercial vessels, and the oil and gas industry surrounding FGBNMS, ONMS does not expect that the additional noise generated from restoration activities (vessel traffic, barge lifts, cement mixer, underwater drill) would have any significant impact on resources, particularly as it would all be of short-duration. Previous reef restoration efforts have demonstrated the adaptation of local fish to these construction activities (NOAA, 1995, 2002). Noise levels would return to ambient levels immediately upon completion of the structural restoration phase.

Indirect Effects. No indirect effects would be expected.

4.2 NO ACTION

The no action alternative leaves the injured area unrestored, allowing natural processes to control restoration of the injury. This alternative does not require any direct restoration. This will allow either the site to recover at a natural rate or cause the site to continue to degrade from natural erosion and storm action.

Pros: The no action alternative is non-invasive and would not require any additional interference at the site that might result from the implementation of construction activity.

Cons: The no action alternative would usually lead to further degradation of the habitat. Under this alternative, no effort would be made to repair any injuries. In the short term, coral that could have been repaired would die. Over time, this would lead to a loss of coral cover and a loss of natural habitat. The continued presence of unstablized substrate would provide additional opportunity for additional storm-induced injury.

4.2.1 Location and Area Use (No Action)

Direct Effects. Long-term minor adverse effects may be expected. Without reef restoration, fewer people would use the immediate area for recreational diving and snorkeling due to descreased presence of marine life. In addition, the injury area would continue to be exposed to further degradation from severe storms.

Indirect Effects**.** Long-term major adverse effects would be expected. Without restoration, the injured area would be a source of further injury as storms expanded the injury area and re-distributed unconsolidated rubble, thereby degrading the surrounding area as well.

4.2.2 Geology (No Action)

Direct Effects. Long-term major adverse effects on injured and adjacent uninjured habitats would be expected because any excavated areas would be likely to expand as a result of modified current flows and annual storms. Without restoration, future storms would likely result in collateral damage from chunks and fragments torn loose, and further erosion. Also, hard corals, gorgonians, etc., that recruit onto compromised substrate within the unrestored site would likely be lost during such storm events.

Indirect Effects. Long-term major adverse effects would be expected. Reef structure adjacent to the impact areas would be at risk for collateral injury due to ongoing redistribution of loose sediment and rubble resulting from annual storms.

4.2.3 Water Resources (No Action)

Direct Effects. No direct effects would be expected.

Indirect Effects. Long-term minor adverse effects would be expected. Higher than normal turbidity levels could result from modified current flows, the absence of a secure reef structure, and annual storm events.

4.2.4 Biological Resources (No Action)

Direct Effects. Long-term major adverse effects would be expected. Depending on the scale of injury, natural recovery of the coral communities would not be expected to occur in the foreseeable future without unprecedented, major Caribbean-wide changes in climate, sea level, and species composition and abundance. Therefore, implementing the no action alternative would virtually ensure the continued loss of coral communities for the foreseeable future.

Other benthic communities would be expected to experience long-term adverse effects as well. The physical structure of the coral reef provides habitat for a complex and diverse community of benthic organisms, many of which are critical for maintaining the ecological integrity of the reef ecosystem. Fragmented and unstable reef substratum has a limited benthic community compared to the surrounding reefs, and this low diversity reef community would not experience any enhancement under the no action alternative. Failure to restore injured three-dimensional structure would result in a net loss of rugosity, a reduction in the abundance and diversity of benthic organisms in the area and a long-term loss of these communities in the injured area.

Coral reef fish communities are directly or indirectly dependent on the existence of the reef for food, shelter, and reproduction. Failure to restore the three-dimensional structure of the reef would result in lower abundance and diversity of fish communities in the area.

Threatened *Acropora* species could experience major long-term adverse impacts due to the lack of stable substrate for settlement and growth as well as loss of critical habitat. No direct effects on other endangered and threatened species would be expected because populations are transient.

Indirect Effects. Short-term major adverse impacts would be expected due to increased turbidity that may result from the presence of any unconsolidated sediment in the injury area. Over long periods, the low light levels that result from increased turbidity could affect photosynthetic biota such as corals, anemones, benthic algae, and phytoplankton by reducing their ability to carry out photosynthesis, and thus affecting metabolic processes of the coral and reef growth itself.

Long-term minor adverse indirect effects on the coral community would be expected. The loss of habitat and reef-dwelling species results in a reduction in the abundance and diversity of other species that either directly or indirectly depend on the reef. The loss of mature corals results in a loss of seeding populations of reef organisms and a decrease in recruitment due to the absence of suitable substrate or chemical stimulants for settling of larvae. In addition, if left exposed, blowholes and other excavations could be expected to expand during annual storms, thereby encroaching on and possibly damaging nearby communities. Without restoration, expansion of the injury area would be expected from future storms.

Long-term minor adverse effects to threatened *Acropora* species could be expected from decline in habitat quality. No indirect effects on other endangered and threatened species would be expected.

4.2.5 Infrastructure (Construction and Vessel Moorings) (No Action)

Direct Effects. No direct effects would be expected.

Indirect Effects**.** No indirect effects would be expected.

4.2.6 Cultural Resources (No Action)

Direct Effects**.** No direct effects would be expected.

Indirect Effects. Additional erosion and scouring of the area could lead to exposure and degradation of any artifacts that remain buried in or near the injury area.

4.2.7 Hazardous and Toxic Substances (No Action)

Direct Effects. No indirect effects would be expected.

Indirect Effects. No indirect effects would be expected.

4.2.8 Socioeconomics (No Action)

Direct Effects. No direct effects would be expected.

Indirect Effects. Long-term minor adverse effects would be expected from the continued presence of an injured reef. Potential expansion of injury areas would, over time, decrease the availability of aesthetically pleasing reefs for recreational divers and snorkelers, as well as the loss of productive areas for recreational fishing. In addition, the loss of structural integrity may also exacerbate storm impacts to shoreline areas. There are also long-term adverse impacts due to the decreased fisheries that may result from loss of nursery forgaging grounds.

4.2.9 Quality of Life (No Action)

Direct Effects**.** No direct effects would be expected.

Indirect Effects. Long-term minor adverse effects would be expected for significant groundings or anchorings or for cumulative injuries. Without reef restoration, aesthetic value could continue to degrade along with recreational opportunities associated with the reef ecosystem in the area.

4.3 DEBRIS AND VESSEL REMOVAL

This alternative requires the removal of the vessel, vessel debris, and other foreign debris from the injury area. Small amounts of debris can be removed by divers using baskets, lift bags, etc., but this action typically involves large pieces of vessel debris, including engines, keel pieces, anchors, and rigging, and thus may require using a barge with winch, guided by underwater divers. Although some debris may be loose, some lines, rigging, and pieces of vessel may be entangled or wedged into reef material, and thus removal may require direct contact with and/or additional injury to reef substrate.

Pros: This alternative removes non-reef material from the site but does not require the addition of new material, so there are no construction activities, and thus opportunity for collateral injury is minimized. If implemented quickly, this can prevent significant adverse structural and shading impacts.

Cons: This alternative does not restore the reef's original characteristics, either structural or biological. Although there is no construction activity required, removal of vessel and other debris from large grounding sites still requires the use of a salvage vessel, and thus presents potential for additional injury.

4.3.1 Location and Area Use (Debris Removal)

Direct Effects. Long-term major beneficial effects would be expected from removal of vessel debris that could cause additional injury if redistributed during storms.

Indirect Effects. Long-term minor beneficial effects would be expected, due to prevention of additional injury.

4.3.2 Geology (Debris Removal)

Direct Effects. Long-term minor beneficial impacts would be expected to occur due to the removal of loose material that might otherwise pose the potential for collateral injury.

Indirect Effects. Long-term minor adverse impacts would be expected to result from the continued potential for erosion from the unrestored injury area. Should significant erosion occur, these effects could become major.

4.3.3 Water Resources (Debris Removal)

Direct Effects. Short-term adverse impacts may result from seabed disturbance/increased turbidity during removal activities, but these will cease as soon as the work is completed.

Indirect Effects. No indirect effects are expected.

4.3.4 Biological Resources (Debris Removal)

Direct Effects. Long-term major beneficial impacts would be expected. Loose debris and non-reef material can abrade, crush or destroy habitat and injure corals and invertebrates. The removal of such debris will expose buried substrate for settlement of corals and colonization by other invertebrates and would limit additional mortality due to shading.

Acroporid species may experience long-term beneficial effects through the provision of a more stable and cryptic habitat. Other endangered and threatened species would likely experience no direct effects because their populations are transient.

Indirect Effects. Long-term major beneficial impacts would be expected. Removal of debris would enhance the potential for natural settlement and growth of reef communities. However, failure to recreate three-dimensional relief would have long-term adverse impacts on community structure and the ability of the reef organisms to recreate original habitat.

4.3.5 Infrastructure (Construction and Vessel Moorings) (Debris Removal)

Direct Effects. Short-term minor adverse impacts may result if additional mooring buoys are required to accommodate large vessels/barges. Installation would follow standard sanctuary guidelines (FKNMS, nd).

Indirect Effects. No indirect effects are expected.

4.3.6 Cultural Resources (Debris Removal)

Direct Effects. Long-term major beneficial effects are expected if the injury occurs and debris remains on or near cultural resources. Removal of debris would limit the chance of injury or destroying the cultural resources. Should any cultural resources be discovered during restoration activities, the Sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered by a marine archaeologist and then turned over to the sanctuary, if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the State Historic Preservation Office (SHPO) in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd).

Indirect Effects. No indirect effects are expected.

4.3.7 Hazardous and Toxic Substances (Debris Removal) [3]

Direct Effects. Long-term minor beneficial effects would be expected from the removal of non-reef material. If left in place, long-term corrosion and degradation of vessel components could release hazardous or toxic substances that may adversely impact the reef community.

Indirect Effects. No indirect effects are expected.

4.3.8 Socioeconomics (Debris Removal)

Direct Effects. Short-term minor adverse impacts may result if the area is under a temporary closure during debris removal, but would only expected for very large injuries.

Indirect Effects. Long-term minor beneficial impacts are expected to result due to the decreased potential for continued injury of the site, which will protect and maintain the attractiveness of the area as a dive and recreation location.

4.3.9 Quality of Life (Debris Removal)

Direct Effects. No direct effects are expected.

Indirect Effects. No indirect effects are expected.

[3] For purposes of this analysis, hazardous and toxic substances include oil, although it is regulated under different authorities (the Oil Pollution Act instead of Superfund).

4.4 SEDIMENT AND RUBBLE REMOVAL

This alternative requires the removal of large quantities of loose, non-living coral material from the injury area. Small quantities of coral rubble can be removed by divers using baskets, lift bags, etc., while larger amounts require use of a barge with suction, guided by underwater divers.

Pros: This alternative removes loose material from the injury area, but does not require the addition of new material. There would be limited construction activities, therefore, the opportunity for collateral injury would be limited.

Cons: This alternative does not address any structural injury or restore any live coral injured in the incident. It does not restore the reef's original characteristics. Although there is no construction activity required, rubble removal from large injury sites would still require the use of a large vessel, and thus involves the potential for additional injury.

4.4.1 Location and Area Use (Rubble Removal)

Direct Effects. Long-term major beneficial effects would be expected from the removal of loose material that could cause additional injury if redistributed during storms.

Indirect Effects. Long-term minor beneficial effects would be expected due to the prevention of additional injury.

4.4.2 Geology (Rubble Removal)

Direct Effects. Long-term minor beneficial impacts would be expected to occur due to the removal of loose rubble. This action will decrease the potential for collateral injury from redistribution.

Indirect Effects. Long-term minor adverse impacts would be expected to result from eliminating the continued potential for erosion in the injury area that would exist without further stabilization. Should significant erosion occur, these effects could become major.

4.4.3 Water Resources (Rubble Removal)

Direct Effects. Long-term minor beneficial effects would be expected to occur due to a decrease in the presence of unconsolidated material, which could otherwise cause an increase in turbidity. Short-term adverse impacts may result from increased diver use and an associated increase of grey water discharge.

Indirect Effects. No indirect effects are expected.

4.4.4 Biological Resources (Rubble Removal)

Direct Effects. Long-term major beneficial impacts would be expected. Unstable sediments can abrade, crush or destroy habitat and injure corals and invertebrates. The removal of large quantities of unconsolidated sediments and rubble will provide more stable substrate for settlement of corals and colonization by other invertebrates. Removal of rubble may cause a temporary decrease in the three-dimensional relief and availability of cryptic habitat, but ultimately will improve the community and facilitate reestablishment of a stable reef environment.

Acroporid species may experience long-term beneficial effects through the provision of a more stable and cryptic habitat. Other endangered and threatened species would likely experience no direct effects because their populations are transient.

Indirect Effects. Long-term minor beneficial impacts would be expected. Failure to recreate three-dimensional relief would have long-term adverse impacts on community structure and the ability of the reef to recreate original habitat.

4.4.5 Infrastructure (Construction and Vessel Moorings) (Rubble Removal)

Direct Effects. Short-term minor adverse impacts may result if additional mooring buoys are required to accommodate salvage or construction vessels. Installation would follow standard sanctuary guidelines.

Indirect Effects. No indirect effects are expected.

4.4.6 Cultural Resources (Rubble Removal)

Direct Effects. No direct effects are expected. Should any cultural resources be discovered during restoration activities, the Sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered, if necessary, by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the SHPO in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd).

Indirect Effects. No indirect effects are expected.

4.4.7 Hazardous and Toxic Substances (Rubble Removal)

Direct Effects. No direct effects are expected.

Indirect Effects. No indirect effects are expected.

4.4.8 Socioeconomics (Rubble Removal)

Direct Effects. Short-term minor adverse impacts may result if the area is under a temporary closure during rubble removal, but that would only be expected for very large injuries.

Indirect Effects. Long-term minor beneficial impacts are expected to result from the decreased potential for continued erosion of the site, which will protect and maintain the attractiveness as a dive and recreation location.

4.4.9 Quality of Life (Rubble Removal)

Direct Effects. No direct effects are expected.

Indirect Effects. No indirect effects are expected.

4.5 SUBSTRATE STABILIZATION

This alternative involves the stabilization of injured bottom habitat by securing fractured pieces or cracked areas of framework with epoxy or cement to fill holes and cracks.

Pros: This alternative maximizes the use of existing substrate with minimal additional disturbance of existing communities. The stabilization of the natural materials at the site is aesthetically pleasing, minimizes additional deterioration of the injury, and allows flexibility to design the structure to mimic the appearance of the surrounding area. Substrate stabilization also facilitates natural recovery or additional restoration by providing a stable substrate for attachment.

Cons: This alternative does not recreate anything lost, just stabilizes that which remains. This alternative introduces manmade substances in the form of concrete and rebar.

4.5.1 Location and Area Use (Substrate Stabilization)

Direct Effects. Short-term minor adverse effects would be expected due to the loss of the immediate area for recreational purposes during the restoration.

No long-term minor adverse effects would be expected from the action, but there would be no significant beneficial aesthetic effects, as the lack of any reef structure similar to that which existed prior to the injury would continue. The stabilization of the loose framework would do little to increase the recreational value of the reef since the stabilized reef would not as closely resemble the site prior to the injury or the surrounding reef area and use would be expected to remain low.

Indirect Effects. No indirect effects would be expected.

4.5.2 Geology (Substrate Stabilization)

Direct Effects. Long-term major beneficial effects on geology would be expected to occur. Stabilizing the injured reef framework would, over time, enable the development of a stable community. Long-term benefits would result in the form of decreased erosion and decreased collateral injury.

Short-term minor adverse effects on geology could result from the disturbance of the substrate during construction activities. However, ONMS resource protection staff would oversee the activities of contractors to minimize impacts.

Indirect Effects. Long-term minor beneficial effects would result from the decreased expansion of unstable areas.

4.5.3 Water Resources (Substrate Stabilization)

Direct Effects. Short-term minor adverse effects would result from increased turbidity generated during restoration activities. Turbidity plumes may be expected to occur in and around the work area as small rubble and debris were moved in preparation for stabilization. Short-term turbidity would also be expected to result if the installation of construction mooring buoys is required, and during the placement of concrete during the restoration, but would subside upon completion of the restoration activities. Short-term adverse impacts may result from increased diver use and the associated increase of grey water discharge.

Indirect Effects. Long-term minor beneficial effects would result from a decrease in turbidity resulting from the stabilization and capping of loose sediments.

4.5.4 Biological Resources (Substrate Stabilization)

Direct Effects. Long-term major beneficial effects would result from the creation of a stable substratum suitable for larval settlement and conducive to the survivorship of recruits and juvenile colonies. The proximity to established colonies should enhance colonization of the restored reef.

Acroporid species may experience long-term beneficial effects through the provision of a more stable and cryptic habitat. Other endangered and threatened species would likely experience no direct effects because their populations are transient.

Short-term minor adverse effects would result to organisms in or around the edges of areas in need of stabilization. Direct contact with concrete can be extremely toxic to gorgonians and other invertebrates, so major adverse impacts could occur if proper technique is not employed. These sensitive resources would be removed or covered during restoration activity, and mobile invertebrates might be forced to move elsewhere.

Long-term major adverse impacts to fish would be expected. Coral reef fish communities are directly dependent on the existence of the reef for food, shelter, and reproduction. Failure to restore stable reef framework would result in reduced availability of those habitat characteristics, and thus to reduced abundances and populations of fish communities in the area for the foreseeable future. At the same time, short-term beneficial impacts to fish would be expected due to a decrease in turbidity and re-distribution of loose rubble after stabilization.

Long-term major beneficial effects would result for threatened *Acropora* species because this action would provide stable substrate for its growth and reproduction. No direct effects would be expected to other endangered and threatened species because their populations are transient.

Indirect Effects. Long-term minor beneficial effects on coral communities would be expected. Improved integrity of the substrate would be expected to benefit all communities inhabiting the area. The restoration would lessen the chances of the surrounding communities' being adversely affected by the forces exerted by annual storms and dispersion of unconsolidated limestone out of the injury area.

Fish communities would be expected to experience minor beneficial effects. Additional food sources for fish living on or near the reef would be provided by the eventual growth of benthic organisms, including algae, on the stabilized substrate, as well as from an increase in numbers of territorial fish.

Short-term minor adverse effects on biological resources due to increased turbidity would be expected. Most corals can cope with the moderate levels of turbidity that naturally occur in coral reef ecosystems. It is anticipated that during restoration, higher-than-normal levels of turbidity would be created. However, there is a great deal of natural variation in the turbidity conditions both on the outer reef line as well as some backreef areas. Turbidity induced by the short-term stabilization efforts would not greatly exceed the natural range. After the restoration, turbidity would decrease as currently unstable sediments would be capped.

Short-term minor adverse effects would be expected from shading while the barge is located on-site. If the barge remained in place for an extended time, it is possible that underlying corals could bleach and perhaps suffer long-term consequences. However, while shading may cause short-term limits for photosynthesis, the barge would not be left on-site for more than two weeks and would not be anchored over one spot for more than a week. Thus, any stress-induced conditions would be expected to return to normal as soon as the barge is removed (Goodwin, 2004).

In areas with original three-dimensional complexity, addressing injury with restoration by substrate stabilization alone would result in long-term major adverse impacts due to a failure to replace the topographical relief of the pre-injury area, and thus would result in loss of the associated coral community. Due to a resulting lower level of habitat complexity (lower three dimensional relief, lower diversity), the habitat value of the injured site would remain at a lower level than existed before the grounding.

Continued erosion of substrate could result in major long-term adverse impacts to the Acroporids in the area. No indirect effects on other endangered and threatened species would be expected because populations are transient.

4.5.5 Infrastructure (Construction and Vessel Moorings) (Substrate Stabilization)

Direct Effects. Short-term minor adverse effects would result from the likely installation of a four-point mooring system plus a deeper storm anchor point for construction vessels; temporary site exclusion buoys may also need to be installed. Installation would follow standard sanctuary guidelines. Restoration activities would generate minor short-term increases in solid waste generated from the use of cement, rebar, and associated packaging, none of which would be disposed of onsite.

Indirect Effects. No indirect effects would be expected.

4.5.6 Cultural Resources (Substrate Stabilization)

Direct Effects**.** No direct effects would be expected. Should any cultural resources be discovered during restoration activities, the Sanctuary manager would be notified immediately; artifacts would be mapped in place by a marine archaeologist and then they would be turned over to the Sanctuary to be conserved following accepted conservation standards. An ONMS biologist and cultural resource staff person would be involved in site selection for the placement of any mooring points to ensure that the mooring anchors are placed where they do not impact cultural resources. If installation of mooring points would necessarily threaten cultural resources, the Sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the SHPO in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd).

Indirect Effects. No indirect effects would be expected.

4.5.7 Hazardous and Toxic Substances (Substrate Stabilization)

Direct Effects. No direct effects would be expected. Restoration would not intentionally introduce significant new hazardous materials into the environment. Most construction materials would come from natural sources (e.g., limestone mined from inland quarries), and would be inert. The largest amounts of introduced material anticipated would be the specialty concrete/mortar mixes and/or epoxies. The mortar is a low-separation mix that has been successfully used to restore other nearby reef areas and would not pose a significant new toxic/hazardous substance threat. The contractor would be required to have adequate spill prevention, response and clean-up plans.

Indirect Effects. No indirect effects would be expected.

4.5.8 Socioeconomics (Substrate Stabilization)

Direct Effects. Long-term minor beneficial effects would be expected to occur. By stabilizing the substrate, the project would accelerate the natural restoration of the reef. This action would minimize any further reductions in recreational and human use services associated with the no action alternative.

Short-term minor adverse effects would also be expected. ONMS would request that the public avoid the site during restoration. Depending on the size and location of the injury site (i.e., whether it is in a high recreational use area), the restoration project could potentially reduce the number of visits to the reef. This situation, however, would be temporary, and economic losses, if any, resulting from loss of access would be outweighed by the long-term economic benefits of a healthy reef habitat. The project itself would also generate some income to the local economy. Restoration may generate a small number of secondary jobs due to the procurement of goods and services in the local economy.

Indirect Effects. No indirect effects would be expected.

4.5.9 Quality of Life (Substrate Stabilization)

Direct Effects. Long-term minor beneficial effects would be expected. Stabilization of the reef would facilitate greater settlement of corals. However, that would require a long time for identifiable results, and thus recreational opportunities would not increase in the foreseeable future.

Indirect Effects. No indirect effects would be expected.

4.6 LIMESTONE BOULDERS AND PREFORMED MODULES

This alternative involves the stabilization of injured bottom habitat by placing limestone boulders and/or preformed modules (constructed from limestone or coral rubble, composite rebar and concrete) in and around injured areas, and securing them in place using concrete to recreate structural three-dimensional relief and habitat destroyed by the injury. Limestone boulders and/or modules of appropriate size are placed in the injured area and then stabilized with underwater concrete that flows with very low turbidity so it does not mix with the water column (known as a "tremie pour"); smaller rocks are placed in the concrete to decrease the amount of exposed concrete and to blend sharp vertical faces with the surrounding habitat. The boulders can be stacked so as to replace and recreate some of the relief and habitat complexity that were destroyed; modules can be designed to mimic natural relief. Plastic composite rebar (which is lighter, easier to use, and more durable than steel) can be placed in the concrete to improve attachment between boulder and concrete layers.

Pros: Limestone, a good settlement substrate, should encourage coral growth. This is a long-term solution to framework injury and should facilitate the re-growth of the reef community by providing structural relief and stabilization. The use of natural substrate is also aesthetically pleasing, and allows flexibility to design the structure to mimic the appearance of the surrounding area. Modules can be designed in a variety of sizes and patterns to meet site-specific needs.

Cons: This alternative requires construction from a barge and introduction of manmade substances in the form of concrete and rebar. Also, this is expensive and can only be done efficiently for injuries of significant magnitude. Modules can be costly to construct and both boulders and modules are heavy to move and require large amounts of cement to secure. Implementation requires an onsite barge and construction activities, thus there is potential for additional injury. In addition, there remains some debate in the scientific community about the efficacy of modules as settlement platforms for coral and other invertebrates and thus long-term biological monitoring is required. Initial monitoring results from the FKNMS indicate that successful recruitment is occurring at both the M/V *Alec Owen Maitland* and M/V *Wellwood* restoration sites (Hudson et al, 2007 and 2008).

4.6.1 Location and Area Use (Boulders and Modules)

Direct Effects. Short-term minor adverse effects are expected due to the loss of the immediate area for recreational and commercial purposes during the restoration. Long-term major beneficial effects would be expected to result from the restoration of three-dimensional relief that would provide many aspects of habitat value and habitat for settling corals and other benthic organisms.

Indirect Effects. No indirect effects would be expected.

4.6.2 Geology (Boulders and Modules)

Direct Effects**.** Long-term major beneficial effects on geology would occur as a result of restoring injured reef framework. The repair of injured reef framework would re-establish the pre-existing characteristics of the system and, over time, enable the return to approximate pre-impact physical characteristics.

Short-term minor adverse effects on geology could result from the disturbance of the substrate during construction activities if proper mooring and anchoring of work vessel procedures are not followed and equipment is not maintained. Long-term major beneficial effects on geology would occur as a result of stabilization and rebuilding the three-dimensional relief; this would help reestablish topographic complexity and provide habitat more similar to that which was present prior to the impact.

Indirect Effects. Long-term minor beneficial effects would result from the decreased expansion of unstable areas.

4.6.3 Water Resources (Boulders and Modules)

Direct Effects. Short-term minor adverse effects would result from increased turbidity generated during restoration activities. Turbidity plumes would be expected to occur in and around the excavated holes as rubble and debris were moved in preparation for stabilization. Short-term turbidity would also be expected to result from the installation of construction mooring buoys and the placement of concrete during the restoration, but would subside upon completion of the restoration activities. Short-term adverse impacts may result from increased diver use and associated increase of grey water discharge.

Indirect Effects. Long-term minor beneficial effects would result from a decrease in turbidity resulting from the stabilization and capping of loose sediments.

4.6.4 Biological Resources (Boulders and Modules)

Direct Effects. Long-term major beneficial effects would result from the re-creation of a stable substratum suitable for larval settlement and conducive to the survivorship of recruits and juvenile colonies. The proximity to established colonies should enhance colonization of the restored reef. Long-term major beneficial effects for the coral community would be expected from the restoration of the three-dimensional relief. The structural relief would increase habitat complexity, thereby providing the appropriate structure and habitat for the recolonization of diverse and more abundant benthic organisms. The new physical structure could enhance larval settlement and increase the survivorship of recruits and juvenile colonies of other benthic organisms and the overall ecosystem by providing additional settlement locations and shelter. However, the addition of physical structure would not directly increase the populations of those benthic communities without additional biological restoration.

Short-term minor adverse effects would result to organisms in or around the edges of areas in need of stabilization. Direct contact with concrete can be extremely toxic to gorgonians and other invertebrates, so major adverse impacts could occur if proper technique is not employed. These sensitive resources would be removed or covered during restoration activity; mobile invertebrates would be forced to move elsewhere.

Coral reef fish communities would experience long-term major direct beneficial effects. The physical restoration of the three-dimensional relief would increase habitat complexity and space available for fish to establish territories. Restoration would also provide food resources for reef-dwelling species as well as larger, predatory species. Available space on the reef is extremely limited and once the restoration was completed, individuals would be quick to colonize and repopulate the area.

Acroporids would likely experience long-term major beneficial effects from the re-creation of a stable substratum for larval settlement. Other endangered and threatened species would likely experience no direct effects because populations are transient.

Long-term minor adverse impacts may also be expected if restoration increases the number of recreational divers and snorkelers using the site who may injure biological resources.

Indirect Effects. Long-term minor beneficial effects on all communities inhabiting the area would be expected due to the improved integrity of the substrate. The restoration would lessen the chances of the surrounding communities being adversely affected by the forces exerted by annual storms and dispersion of unconsolidated limestone out of the injured area; and would provide greater habitat and stable substrate suitable for coral and other invertebrate settlement.

Fish communities would experience long-term major beneficial effects. The eventual growth of benthic organisms, including algae, plus an increase in numbers of territorial fish would provide additional food sources for fish living on or near the reef, including the larger predatory species that roam reef margins in search of prey.

Short-term minor adverse effects on biological resources due to increased turbidity during construction would be expected. Most corals can cope with the moderate levels of turbidity that naturally occur in coral reef ecosystems. It is anticipated that during restoration, higher-than-normal levels of turbidity would be created. However, there is a great deal of natural variation in the turbidity conditions both on the outer reef line as well as some backreef areas. Turbidity induced by the construction involved in this alternative will not greatly exceed the natural range. After the restoration, turbidity would decrease as currently unstable sediments would be capped.

Additional short-term minor adverse effects would be expected from shading while the barge or workboat is located on-site. If the vessel remained in place for an extended time, it is possible that underlying corals could bleach and perhaps suffer long-term consequences. However, while shading may cause short-term limits for photosynthesis, the barge would not be left on-site for more than two

weeks and would not be anchored over one spot for more than a week, and thus any adverse impacts are expected to return to normal as soon as the barge is removed.
No indirect effects on non-Acroporid endangered and threatened species would be expected because populations are transient.

4.6.5 Infrastructure (Construction and Vessel Moorings) (Boulders and Modules)

Direct Effects. Short-term minor adverse effects would result from an increase in vessel traffic during restoration activities. Short-term minor adverse effects would also result from the installation of a four-point mooring system plus a deeper storm anchor point for construction vessels. Installation would follow standard Sanctuary guidelines. Restoration activities would generate minor short-term increases in solid waste generated from the use of cement, rebar, and associated packaging, which would be properly disposed of off-site.

Indirect Effects**.** No indirect effects would be expected.

4.6.6 Cultural Resources (Boulders and Modules)

Direct Effects**.** No direct impacts would be expected. Should any cultural resources be discovered during restoration activities, the sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered, if necessary, by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the SHPO in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd). A ONMS biologist and cultural resource staff person will be involved in site selection for the placement of the barge mooring points to ensure that the mooring anchors are placed where they do not impact cultural resources. If installation of mooring points would necessarily threaten cultural resources, the resources would be documented, recovered if necessary, and properly conserved and curated.

Indirect Effects. No indirect effects would be expected.

4.6.7 Hazardous and Toxic Substances (Boulders and Modules)

Direct Effects. No significant effects would be expected. Restoration would not be expected to introduce significant new hazardous materials into the environment. Most construction materials would come from natural sources (e.g., limestone mined from inland quarries) and would be inert. In addition to limestone, the largest introduced material anticipated would be the specialty concrete/mortar and/or epoxy used to join replacement reef boulders. The mortar is a low-separation type substance that has been successfully used to restore other nearby reef areas and would not pose a significant new toxic/hazardous substance threat. The contractor would be required to have adequate spill prevention, response, and clean-up plans.

Indirect Effects. No indirect effects would be expected.

4.6.8 Socioeconomics (Boulders and Modules)

Direct Effects. Long-term major beneficial effects would be expected to occur. By stabilizing the substrate and re-creating three-dimensional relief, the project would accelerate the natural restoration of the reef. This action would minimize any potential reductions in recreational and human use services associated with the no action alternative.

Short-term minor adverse effects would also be expected. ONMS would request that the public avoid the site during restoration. During the peak season, the restoration project could potentially reduce the number of visits to the reef. This situation, however, would be temporary, and economic losses, if any, would be outweighed by the long-term economic benefits of a healthy reef habitat. The project itself would also generate some income to the local economy. Restoration is expected to generate a small number of secondary jobs due to the procurement of goods and services in the local economy.

Indirect Effects. No indirect effects would be expected.

4.6.9 Quality of Life (Boulders and Modules)

Direct Effects**.** Long-term minor beneficial effects would be expected. Stabilization of the reef would facilitate greater settlement of corals. However, that would require a long time for identifiable results, and thus recreational opportunities would not increase in the foreseeable future.

Indirect Effects. No indirect effects would be expected.

4.7 REVETMENT MATS

This alternative involves the placement of articulated mats onto areas of injured substrate in order to stabilize loose rubble and fractured substrate. Revetment mats consist of concrete blocks, usually 1 square foot, interconnected by flexible polypropylene, Kevlar, or similar cables. These mats are usually assembled on land and then installed in place from a construction platform, using a crane and spreader bar.

Pros: Good for coverage of large areas of surficial framework injury, the mats' articulated nature allows conformity to bottom features.

Cons: Placement can be difficult because mats need to be laid flat and attachment must be done well to prevent shifting. If not properly secured, they can move and break during storms. The unnatural appearance detracts from its success, and the lack of three-dimensional nature often requires the use of additional alternatives in combination with revetment mats.

4.7.1 Location and Area Use (Revetment Mats)

Direct Effects. Long-term major beneficial effects would be expected due to the stabilization of unconsolidated rubble, which would enhance the ecosystem and increase its habitat value.

Short-term minor adverse effects would be expected from the temporary loss of the area for recreational and commercial purposes.

Indirect Effects. No indirect effects are expected.

4.7.2 Geology (Revetment Mats)

Direct Effects. Long-term major beneficial effects on geology would occur as a result of stabilizing the unconsolidated framework. Restoration would reestablish the pre-existing characteristics of the system (assuming it was used in a hard-bottom, low-relief area) and, over time, would enable the reestablishment of approximate pre-impact three-dimensional characteristics.

Short-term minor adverse effects on geology could result from the disturbance of the substrate during construction activities if proper mooring and anchoring of work vessels and equipment were not maintained, but this is not expected.

Indirect Effects. No indirect effects are expected. If not properly anchored, the mats may shift and could cause additional injury.

4.7.3 Water Resources (Revetment Mats)

Direct Effects. Short-term minor adverse effects would result from increased turbidity generated during restoration activities. Turbidity plumes would be expected to occur as rubble and debris were moved in preparation for mat placement. Short-term turbidity would also be expected to result from the installation of construction mooring buoys, but would subside upon completion of the restoration activities.

Indirect Effects. No indirect effects are expected.

4.7.4 Biological Resources (Revetment Mats)

Direct Effects. Long-term minor beneficial effects for the coral community would be expected from the installation of revetment mats. The mats should provide stable substrate and some limited cryptic habitat; this, in turn, would increase habitat complexity, thereby enhancing the recolonization of diverse and abundant benthic organisms. However, in the event of failure or poor anchoring, long-term major adverse impacts could result from shifts in mat placement and destruction of immediately adjacent biological resources.

Coral reef fish communities would experience similar long-term minor beneficial effects from the provision of stable substrate and additional cryptic habitat.

Acroporid species may experience long-term beneficial effects through the provision of a more stable and cryptic habitat. Other endangered and threatened species would likely experience no direct effects because their populations are transient.

Indirect Effects. Long-term major beneficial effects on coral communities would be expected. The addition of mats would provide stable substrate suitable for coral and other invertebrate settlement, which would benefit all reef communities. The restoration would also be likely to lessen the chances of the surrounding communities being adversely affected by the forces exerted by annual storms.

Short-term minor adverse effects on biological resources due to increased turbidity during construction would be expected. Most corals can cope with the moderate levels of turbidity that naturally occur in coral reef ecosystems. It is anticipated that during restoration, higher-than-normal levels of turbidity would be created. However, there is a great deal of natural variation in the turbidity conditions throughout the reef area. Turbidity induced by the construction involved in this alternative will not greatly exceed the natural range. After the restoration, turbidity would decrease when construction activities ended. Short-term minor adverse impacts on settled corals would also be expected; any corals that would be adversely impacted by the mats would be moved prior to placement of the mats and reattached after placement was complete.

Short-term minor adverse effects would be expected from shading while the barge or work boat is located on-site. If the vessel remained in place for an extended time, it is possible that underlying corals could bleach and perhaps suffer long-term consequences. However, while shading may cause short-term limits for photosynthesis, the barge would not be left on-site for more than two weeks and would not be anchored over one spot for more than a week, and thus any adverse impacts are expected to return to normal as soon as the barge is removed.

No indirect effects on other endangered and threatened species would be expected.

4.7.5 Infrastructure (Construction and Vessel Moorings) (Revetment Mats)

Direct Effects. Short-term minor adverse effects would result from an increase in vessel traffic. Short-term minor adverse effects would also result from the installation of a four-point mooring system plus a deeper storm anchor point for construction vessels. Installation would follow standard Sanctuary guidelines. Restoration activities would generate minor short-term increases in solid waste.

Indirect Effects. No indirect effects are expected.

4.7.6 Cultural Resources (Revetment Mats)

Direct Effects. No direct impacts would be expected. Should any cultural resources be discovered during restoration activities, the sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered, if necessary, by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the SHPO in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd). A ONMS biologist and cultural resource staff person will be involved in site selection for the placement of the barge mooring points to ensure that the mooring anchors are placed where they do not impact cultural resources. If installation of mooring points would threaten cultural resources, the resources would be documented, recovered if necessary, and conserved and curated appropriately.

Indirect Effects. No indirect effects are expected.

4.7.7 Hazardous and Toxic Substances (Revetment Mats)

Direct Effects. No significant effects would be expected. Restoration is not expected to introduce significant new hazardous materials into the environment. The contractor would be required to have adequate spill prevention, response and clean-up plans.

Indirect Effects. No indirect effects are expected.

4.7.8 Socioeconomics (Revetment Mats)

Direct Effects. Long-term minor beneficial effects would be expected to occur. Placement of mats to stabilize the reef would accelerate restoration of the reef and thus would have a positive impact on associated recreational and commercial values.

Short-term minor adverse effects would also be expected. ONMS would request that the public avoid the site during restoration. This situation, however, would be temporary, and economic losses, if any, would be outweighed by any long-term economic benefits of a healthy reef habitat. The project itself would also generate some income to the local economy. Restoration is expected to generate a small number of secondary jobs due to the procurement of goods and services in the local economy.

Indirect Effects. No indirect effects are expected.

4.7.9 Quality of Life (Revetment Mats)

Direct Effects. Long-term minor beneficial effects would be expected. Restoration of a stable substrate should enhance the ecosystem and recreational opportunities within the area. However, the unnatural appearance of the revetment mats may have the opposite effect, and could drive recreational users away from the area.

Indirect Effects. No indirect effects are expected.

4.8 REATTACHMENT/TRANSPLANTATION

This alternative requires reattachment of injured or transplanted live corals or non-living framework pieces into the injury area in order to replace injured communities. Depending on the size and nature of the fragments, reattachment may be accomplished using just epoxy or cement, or may require reinforcing rods and heavy machinery to install. In most cases, scleractinian and coral framework fragments are attached directly to any solid substrate that will provide suitable orientation ("jelly side up") and support using either 2-part underwater epoxy (for fragments <10 cm(3.9 in)) or Portland Type II cement. In addition, branching corals may be reattached to appropriate substrate using wire and/or cable ties or by wedging fragments into small crevices and voids. In areas of unconsolidated substrate such as *Porites* rubble zones or areas composed of *Acropora* "bones" (i.e., the Dry Tortugas) where coral heads grow but are only attached deep at their base, ONMS has used cut nails, wire, and small manta ("duckbill") anchors to secure the coral fragments. Large pieces of framework may require additional support from reinforcing rods in order to secure them in place. Gorgonian transplantation is accomplished using epoxy to reattach an entire colony to solid substrate, or by inserting the axis of a clipping into a hole and affixing it in place using epoxy.

Pros: This alternative, which rescues original fragments thereby preserving the original coral pieces injured in the incident, is easy to implement in shallow/midwater. It uses natural materials, typically from the injury area and areas immediately adjacent. It is highly effective in jump-starting future growth and settlement of the biological community for live transplants.

Cons: Depending on the health of original fragments and whether large numbers of fragments are brought in from other reefs, reattachment can result in a habitat composition different from the original community. For large injury areas, it can be difficult to get the same level of coral cover as existed before the injury occurred.

4.8.1 Location and Area Use (Reattachment)

Direct Effects. Long-term major beneficial effects would be expected due to restoration of the reef ecosystem. This would increase its habitat value.

Indirect Effects. No indirect effects are expected.

4.8.2 Geology (Reattachment)

Direct Effects. Long term major beneficial impacts are expected. The growth of reattached corals would, over time, provide consolidation of reef framework.

Indirect Effects. No indirect effects are expected.

4.8.3 Water Resources (Reattachment)

Direct Effects. Very minor short term adverse impacts may be expected due to increased turbidity during implementation. Turbidity plumes would be expected to occur in and around the injury area if rubble and debris need to be moved in preparation for reattachment. Some adverse effects may result during the use of the cement and/or epoxy for transplants; although both adhesives are designed to have minimal dispersion, there is a minor amount of sloughing during use. This is likely to have only very minor and temporary impacts.

Indirect Effects. No indirect effects are expected.

4.8.4 Biological Resources (Reattachment)

Direct Effects. Long-term beneficial impacts are expected to the ecosystem due to the restoration of the original biological community, the rescue of injured fragments, and the preservation of the reef communities with reduced disruption of ecological continuity. The re-attachment of adult colonies of corals and proximity to established and thriving colonies should enhance colonization of the restored reef. In addition, the reattached corals would increase coral cover and diversity at the site while also providing additional relief. Also, reattachment of framework fragments would provide habitat and food source for those fish that feed on or around corals; corals provide habitat as well for small fish/invertebrates at overhangs and between corals.

Long-term major beneficial effects are expected for *Acropora* species. Reattachment of this threatened species is vital to maintenance of existing populations. No direct effects on endangered and threatened species would be expected because their populations are transient.

Indirect Effects. Long-term major beneficial effects on coral communities would be expected. Improved ecological integrity would benefit all communities inhabiting the sanctuary. Fish communities would experience long-term major beneficial effects. Reattached fragments would provide additional habitat as well for small fish/invertebrates at overhangs and between corals, and the eventual growth of benthic organisms, including algae, plus an increase in numbers of territorial fish would provide additional food sources for fish living on or near the reef, including the larger predatory species that roam reef margins in search of prey.

Minor adverse impacts may also be expected if restoration increases the number of recreation divers and snorkelers using the site who may injure biological resources.

Long-term major beneficial impacts are expected for Acroporids. Maintenance of current populations is vital to the maintenance of community structure and rebuilding populations. No indirect effects on other endangered and threatened species would be expected because their populations are transient.

4.8.5 Infrastructure (Construction and Vessel Moorings) (Reattachment)

Direct Effects. No direct effects are expected.

Indirect Effects. No indirect effects are expected.

4.8.6 Cultural Resources (Reattachment)

Direct Effects. No direct impacts are expected. Should any cultural resources be discovered during restoration activities, the sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered, if necessary, by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the SHPO in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd). A ONMS biologist and cultural resource staff person will be involved in site selection for the placement of the barge mooring points to ensure that the mooring anchors are placed where they do not impact cultural resources. If installation of mooring points would threaten cultural resources, the resources would be documented, recovered if necessary, and conserved and curated appropriately.

Indirect Effects. No indirect effects are expected.

4.8.7 Hazardous and Toxic Substances (Reattachment)

Direct Effects. No direct effects would be expected. The largest introduced material anticipated would be the cement/epoxy for reattachment and rebar for larger pieces. These materials have been successfully used to restore other nearby reef areas and would not pose a significant new toxic/hazardous substance threat.

Indirect Effects. No significant effects would be expected.

4.8.8 Socioeconomics (Reattachment)

Direct Effects. Long term beneficial effects would be expected. By using corals and original framework to recreate a more natural appearance of the reef, the project would accelerate the restoration of the reef. These actions would minimize the reductions in recreational and human use services associated with the no action alternative.

Indirect Effects. No indirect impacts are expected.

4.8.9 Quality of Life (Reattachment)

Direct Effects. Long term minor beneficial impacts would result through the preservation of the ecological integrity of habitat. The aesthetic and recreational value of the reef would be increased as a result of the restoration.

Indirect Effects. No indirect impacts are expected.

4.9 CUMULATIVE EFFECTS

Cumulative effects are the direct and indirect impacts that result from the incremental effects of an action when considering past, present, and reasonably foreseeable near-term future actions and conditions, regardless of the agencies or parties involved. Cumulative effects can result from individually minor, but collectively significant, factors taking place over time as they may relate to the entire region. While corals are resilient and typically able to recover from injury and illness, multiple and recurring impacts severely weaken corals and compromise their ability to recover.

For NEPA purposes, the context of cumulative effects for this FPEIS is restoration actions in the context of the environmental conditions in the Florida Keys and the Flower Garden Banks. Within that framework, there are many threats to the coral communities in the FKNMS and the FGBNMS, including both natural (severe storms, climate change, and disease) and anthropogenic (water degradation, over-fishing, and vessel groundings) stressors. Natural threats are frequent and appear to be increasing. This includes the frequency of severe hurricanes, whose large powerful waves can break apart coral heads and scatter fragments. Severe storms can cause significant physical injury to coral reefs, and although the injuries may occur in a very short time (hours), the physical devastation often has longer-term impacts. The weakened corals take a long time to re-develop the previously existing physical attributes. In contrast, changes in typical weather patterns, such as those that occur during an El Nino, may have significant adverse impacts due the duration of change, which often takes place over several months. El Nino and other climatic changes often lead to extended periods of bleaching, which may cause greater susceptibility to disease as well as increased mortality. Anthropogenic threats also appear to be increasing. Pollution and declining water quality result from coastal development, agriculture, dredging, and multiple commercial and industrial activities. The resulting changes in water quality compromise the narrow environmental conditions required for coral growth and thus compromise coral health. Extractive uses of coral communities, including fishing and collecting for the aquarium trade, can have severe detrimental impacts resulting from habitat destruction, loss of biodiversity, and modification of community structure. And physical impacts from vessel groundings and anchor damage also often result in habitat destruction and loss of habitat complexity.

The actions considered in this FPEIS would address just a small percentage of the impacts described above: direct physical injuries resulting primarily from vessel groundings, but also other anthropogenic sources including anchor damage, entanglement of lines and nets, or dredging. Relative to the range of cumulative stressors that are currently affecting coral communities, the actions considered in this FPEIS would have long-term, major beneficial impacts due to the restoration of primary habitat and re-establishment of community structure, both biological and physical. This FPEIS will benefit the environment by allowing ONMS to act more quickly to restore coral reef injury. Timely restoration of injured coral resources should have a beneficial cumulative effect by providing the coral communities a better chance of withstanding impacts from the other stressors described.

4.10 MITIGATION MEASURES

Prior to the implementation of any restoration activities, a detailed restoration plan, including any necessary mitigation measures, must be prepared and approved by ONMS. This will ensure that the most appropriate methodologies are used, given the nature of the restoration and the environmental circumstances at the injury site. During the restoration activities, mitigation measures would be undertaken to minimize the potential long-term and short-term adverse effects that could result from restoration activities. ONMS developed many of the mitigation measures outlined below during previous restoration efforts (NOAA, 2002). These measures would be employed at restoration sites as appropriate. ONMS resource protection field staff would be onsite at all times during construction to oversee contractor activities in order to minimize and mitigate any potential adverse impacts.

4.10.1 Geology

The potential for adverse effects will be reduced if precautions are taken to ensure that vessels and equipment do not contact or injure the seabed or reef framework. Navigation by the construction team within the site area during darkness or periods of reduced visibility is not permitted, and a foul weather and hurricane evacuation contingency plan must be developed to remove work vessels from the reef area if changes in weather or sea-state conditions warrant. In addition, ONMS resource protection staff would oversee the activities of contractors to minimize impacts.

4.10.2 Water Resources

Several mitigation measures that ONMS developed for the construction phase of earlier restorations should be implemented as appropriate (NOAA, 2002). These include use of the tremie placement technique to minimize turbidity resulting from concrete placement, inclusion of an anti-washout ingredient in cement mixtures, and avoiding contact with fresh pours to minimize mixture of the cement and water. Additionally, the construction contractor would be required to comply with all applicable federal, state, and local regulations governing environmental pollution control and abatement and would be required to have adequate prevention, response and clean-up plans. Turbidity monitoring would take place during implementation as appropriate and required. In instances of high turbidity, care would be taken to clean sensitive areas to reduce the impacts of sedimentation. Slumping or excess from tremie work would be removed as necessary.

4.10.3 Biological Resources

Collateral injury to existing and recruiting organisms can be mitigated through the temporary relocation of corals away from the injury site, with transplantation back onto the site once construction is complete. In addition, ONMS resource protection field staff would oversee the activities of contractors to minimize potential direct impacts. For the protection of fish and wildlife, ONMS and the contractor would carefully monitor and oversee construction related activities to minimize injuries to fish, wildlife, and habitat, including *Acropora* species. This includes instructing personnel on the proper procedures for conducting work in this type of habitat. Specifically, personnel would be required to: prevent any blockage to the movement of manatees, sea turtles, dolphins, porpoises, or whales in the environment; operate vessels at “no wake/idle” speeds when in shallow waters; and stop work when manatees, sea turtles, or whales move to within 15.2 meters (50 ft) of the construction operation. To prevent any collateral bleaching or other injury resulting from the barge’s extended mooring over the reef, the contractor would be required to periodically relocate the barge. Additionally, the contractor would be required to comply with all applicable federal, state, and local regulations governing the protection of natural resources.

4.10.4 Infrastructure (Construction and Vessel Moorings)

Close coordination with ONMS personnel would be required with respect to the mooring of construction vessels to avoid collateral injury to the reef. Consideration would be given to the use of buoyant mooring lines to keep the lines from striking the bottom during loading from wave attack. Substantial anchors, placed off the reef in sand or bedrock areas, might be necessary to resist wave-induced mooring loads. Adequate, approved disposal options would be required to be available for solid waste.

There is also the potential that injuries to the reef and the benthic environment could result from movement of any required barge caused by waves and tides. Based on previous restoration experience, four barge anchor points should be sufficient (NOAA, 1999a). Anchoring and installation of additional mooring buoys is prohibited by FGBNMS regulations and in portions of FKNMS, so no work could be implemented without appropriate permitting review by the site. It is assumed that weather during the construction might force the barge to move and take shelter at some point during the construction rather than stay in place; the contractor must also establish a storm anchor point in deep water. For any sites located significant distances offshore, it is also reasonable to assume that supply vessels ferrying personnel and supplies to and from the restoration site would create an increased potential for reef strikes. If required, the installation of temporary exclusion buoys could create additional injury, though adherence to standard installation considerations would limit collateral injury.

4.10.5 Cultural Resources

In accordance with the NMSA and NHPA, if any artifacts were discovered post injury or during restoration, the Sanctuary manager would be notified immediately; artifacts would be mapped in-place and recovered, if necessary, by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, to be conserved following accepted conservation standards in accordance with 36 C.F.R Part 79 (McAllister, 2007); or to the SHPO in the Florida Department of State, to be conserved in accordance with Florida state standards (FLDHR, nd). Restoration activities would cease until the artifacts had been properly addressed.

4.10.6 Hazardous and Toxic Substances

Small petroleum, oil, or lubricant (POL) leaks might occur during heavy construction operations. Under normal conditions, these leaks or spills would be of insufficient volume to affect the sensitive coral habitats and would likely evaporate or be washed away from the area. Only if a catastrophic POL spill were to occur could there be a measurable impact on local communities. The likelihood of this type of spill is small overall, and the short duration of the construction phase would help to minimize the potential for a catastrophic release. Spill prevention, response and clean-up plans would be developed for approval by ONMS prior to the restoration activity. The plan would include spill response actions and delineate the remediation activities of responsible parties. Additionally, the contractor would be required to comply with all applicable federal, state, and local regulations governing environmental pollution control and abatement.

4.10.7 Socioeconomics

ONMS would request that the public avoid the area during restoration activities to ensure public safety. ONMS would ensure that appropriate notice was given to the public to use alternative locations. Only construction-related persons/activities would be allowed on site. These activities would all likely to result in short-term decreased use of the site during that period, including potential loss of revenue from dive, fishing, and other charters, with subsequent losses in state taxes, etc, but these would be compensated for when the project was complete and the reef resources were restored to their original level of ecological, socioeconomic and aesthetic values.

4.11 SELECTION OF PREFERRED ALTERNATIVES

After consideration of the criteria for evaluating coral restoration options presented in Table 2-1, the description of the restoration options provided in Chapter 2 (summarized in Table 2-2), and the environmental and socioeconomic consequences detailed in this chapter, the restoration options below have been selected as the most preferred, depending on site-specific conditions: However, any of the alternatives described in this document may be appropriate for use on a case-by-case basis, depending on the specific injury parameters.

1. *Debris, Vessel, Sediment or Rubble Removal*: Removal of any loose items—vessel or fishing debris, and any reef material—provides two benefits. First, removal of loose items decreases the potential for future injury from movement and redistribution that can injure existing habitat. Second, it enhances the ability of the habitat to recover by providing more stable and suitable substrate for coral and other benthic colonization. Without adding anything to the reef, completion of this action as soon as possible after injury can provide great benefits for the majority of injuries, particularly the smaller ones. Based on field experience, it is estimated that 50% of restorations will include debris, sediment or rubble removal.

2. *Substrate Stabilization*: The stabilization of loose and fractured reef substrate creates a major benefit by providing stable substrate upon which juvenile corals and other benthic organisms can settle. This is a non-invasive technique that provides maximum benefit through use of stabilizing natural reef material and recreating, to the extent possible, any three-dimensional relief that was lost as a result of the injury. Based on field experience, it is estimated that 80% of restorations will include substrate stabilization.

3. *Reattachment and Transplantation*: Reattachment of corals that were dislodged or fragmented due to an injury has several benefits. First, it preserves natural material and mimics the relief and dimensions of the reef to the extent practicable. Second, it uses the original reef materials, which preserves the biological community, especially if fragments are reattached immediately after assessment. Based on field experience, it is estimated that 95% of injuries with live coral will require reattachment. Reattachment of coral framework fragments is an important technique that allows reestablishment of three-dimensional relief most closely resembling the original community. Based on field experience, it is estimated that 20% of restorations will include framework reattachment.

These three preferred restoration options are not mutually exclusive. In fact, the majority of injured sites will most effectively be restored by employing at least two options, if not all three. In addition, it must be recognized that the selection of these preferred options is based upon a “typical” injury. As such, the selection of these preferred options does not preclude the use of the other restoration techniques at individual injury sites. Depending on site-specific conditions, other techniques may be most appropriate, especially for larger, more significant injuries, or those in unique habitats. Based on field experience, it is expected that modules and revetment mats will be included in less than 10% of restorations.

4.12 CONCLUSIONS

The proposed actions to restore coral injuries in the FKNMS and FGBNMS have been analyzed by comparing the environmental and socioeconomic effects associated with the range of potential restoration alternatives. Baseline environmental and socioeconomic conditions for areas subject to potential coral injuries in these sanctuaries and the region of influence have been described, and the environmental and socioeconomic consequences of implementing the proposed actions have been evaluated. The analysis shows that, unless noted in a separate document, the environmental and socioeconomic conditions at the grounding sites and their immediate surroundings will not be significantly affected in a negative way by proceeding with any of the restoration alternatives discussed.

CHAPTER 5. RELATIONSHIP TO OTHER LAWS AND PROGRAMS

The implementation of the restoration alternatives requires ONMS to obtain proper permits, comply with the provisions of federal and state regulations, and notify appropriate organizations before conducting any restoration activity. This FPEIS serves as the primary document to communicate to the public the proposed criteria for restoration consideration, restoration alternatives, and anticipated restoration impacts.

5.1 NATIONAL ENVIRONMENTAL POLICY ACT OF 1969 (Public Law 91-190)

This document has been prepared in accordance with NEPA requirements. The purpose of this document is to assist in determining whether the proposed federal actions will have significant impacts on the quality of the human environment.

5.2 NOAA ADMINISTRATIVE ORDER ON ENVIRONMENTAL REVIEW PROCEDURES (NAO 216-6)

NOAA Administrative Order (NAO) 216-6 requires that all proposed Federal projects be reviewed for their environmental consequences on the human environment. This review must result in the issuance of an EIS, an EA with a Finding of No Significant Impact, or a CE. Restoration actions are generally eligible for a CE because the actions meet the following criteria set forth in NAO 216-6 §6.03.b.2:

1) are intended to restore an ecosystem, habitat, biotic community, or population of living resources to a determinable pre-impact condition;
2) use for transplant only organisms currently or formerly present at the site or in its immediate vicinity;
3) do not require substantial dredging, excavation, or placement of fill; and
4) do not involve a significant added risk of human or environmental exposure to toxic or hazardous substances.

Consistent with these criteria, the purpose of coral restoration is to return coral habitat to pre-injury conditions. With regard to the preferred restoration options selected in this FPEIS, coral fragments for reattachment will be taken from injured corals proximate to the injury areas, the placement of fill will be minimal and is necessary for coral stabilization, and there is no added risk of human or environmental exposure to toxic or hazardous substances as a result of the restoration. Furthermore, the on-site, in-kind restoration of coral restoration is specifically mentioned in the NOAA NEPA guidance as an example action eligible for categorical exclusion (NAO 216-6).

The actions described in this FPEIS to address coral injuries do not individually or cumulatively pose significant impacts on the human environment. Although this FPEIS provides analysis of the impacts for typically expected restoration results, each injury site and circumstance is unique. Each restoration will require an individual NEPA analysis. The purpose of this FPEIS is to provide an overarching NEPA analysis for these types of activities, such that any subsequent NEPA analysis can rely on and, as necessary, tier off of this document. Prior to implementing restoration at each injury site, ONMS will prepare the information necessary to support a categorical exclusion determination, including site specific restoration plans. This documentation will be provided to NOAA's NEPA Coordinator for review. If the NEPA Coordinator determines that the action does not qualify for a CE, an EA will be prepared in accordance with NAO 216-6 and NEPA. Because of the frequency of vessel groundings and other injuries to coral in the FKNMS and FGBNMS, and the similarity of site-specific preferred restoration options, several individual restoration projects may be included in the same categorical exclusion review. Regardless of whether restorations are subjected to categorical exclusion review individually or as part of a group of projects, each site will have an individual restoration plan drafted.

5.3 NATIONAL MARINE SANCTUARIES ACT (16 U.S.C. Sec. 1431 et seq.)

As required by the NMSA (formerly known as Title III of the Marine Protection, Research, and Sanctuaries Act of 1972), ONMS will expend settlement monies toward restoration of the injured sites and on resource injury prevention actions. The restoration alternatives proposed in this FPEIS represent the preferred alternatives identified by ONMS. Under Section 312, the NMSA mandates that recovered amounts in excess of those required to be expended for response costs and damage assessments, must be used, in order of priority, to restore, replace, or acquire the equivalent of the injured sanctuary resources where the subject resources are located, to prevent injury of other resources at the site, or to prevent injury to sanctuary resources elsewhere in the sanctuary system. Amounts recovered for injuries to sanctuary resources lying within the jurisdiction of the State of Florida must be used in accordance with the Agreement for the Coordination of Civil Claims between NOAA and the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida.

5.4 FLORIDA KEYS NATIONAL MARINE SANCTUARY AND PROTECTION ACT (Public Law 101-605)

The FKNMSPA requires that NOAA coordinate with the appropriate federal, state, and local governmental agencies and entities to support implementation of the Sanctuary management plan. The proposed actions analyzed in this document will at times occur within the boundaries of the FKNMS, and therefore ONMS will ensure that all activities in the FKNMS are consistent with the Sanctuary management plan.

5.5 CLEAN WATER ACT (33 U.S.C. Sec. 1251 et seq.)

When FKNMS restoration is in state waters, ONMS may be required to submit a Joint Application for Works in the Waters of Florida to federal and state authorities to obtain permission under the Army Corps of Engineers Nationwide Permit 32.

5.6 COASTAL ZONE MANAGEMENT ACT (16 U.S.C. Sec. 1451 et seq.)

When restoration actions may affect the coastal zones of the States of Florida, Texas or Louisiana, ONMS will file a consistency determination under the Coastal Zone Management Act with the appropriate state(s).

5.7 ENDANGERED SPECIES ACT (16 U.S.C. §§ 1531-1543)

If ONMS determines that site-specific restoration actions may adversely affect federally-listed endangered or threatened species, consultation with the NMFS will be conducted pursuant to Section 7 of the ESA.

5.8 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT (16 U.S.C. Sec. 1801 et seq.)

The Magnuson-Stevens Act requires that the regional Fishery Management Councils identify essential fish habitat (EFH). Once designated, the Act requires all federal agencies to consult with NMFS when any activity proposed to be permitted, funded, or undertaken may have adverse effects on EFH. Consultation is not required if the federal agency determines that adverse impacts to EFH will not occur. Restoration activities that result in the conversion of habitat from one type to another type, when both types are designated as EFH, generally result in a permanent adverse impact on the original EFH type. Consultation would be necessary for such restoration actions.

The coral restoration actions described in this document are designed to restore coral EFH in those areas that supported coral EFH prior to injuries. Therefore, there will be no conversion from one EFH habitat type to another type; but simply a replacement of what once was present. In addition, as described in chapters 3 and 4, it is anticipated that the restoration techniques to be employed will not result in any adverse impacts to other EFH types. NMFS has indicated that for most restoration activities, EFH assessments and EFH consultation will not be required. If, however, ONMS determines that site-specific restoration recommendations may endanger other EFH types, consultation will occur in accordance with the Act. If consultation is required, individuals from NMSP will initiate discussions with NMFS.

5.9 MARINE MAMMAL PROTECTION ACT (MMPA) (16 U.S.C. §§ 1361 et seq.)

The MMPA is designed to protect all species of marine mammals. The MMPA is implemented by NMFS and FWS. The Act provides for a moratorium the "taking" of marine mammals and for the protection of depleted populations of marine mammals. If ONMS determines that site-specific restoration actions may adversely affect marine mammals, consultation will be conducted pursuant to the MMPA, and if necessary, the contractor will be required to obtain any required MMPA authorization prior to initiating restoration activities.

5.10 NATIONAL HISTORIC PRESERVATION ACT (NHPA) (16 U.S.C. § 470 et seq.)

The NHPA authorizes the Secretary of Interior to maintain a National Register of "districts, sites, buildings structures, and objects significant in American history, architecture, archaeology, and culture." On occasion, sites have been listed on the National Register that include or are composed entirely of ocean waters and submerged lands within state waters or in federally-managed areas outside of state waters. ONMS will consult the individual site's database of information about historical resources, NMSP's database of Resources and Underseas Threats, and ONMS's ARCH II databases to identify potential resources at risk. Any identified resources will be handled in accordance with the Programmatic Agreement among The NOAA and The State of Florida for Historical Resource Management in the FKNMS.

5.11 FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION, BUREAU OF SUBMERGED LANDS AND ENVIRONMENTAL RESOURCES

Under state law, Florida has jurisdiction over dredge and fill operations in or connected to waters of the state. In addition to water quality certification, an environmental resource permit will provide approval for activities conducted on state sovereign submerged lands.

5.12 FLORIDA DEPARTMENT OF STATE, DIVISION OF HISTORICAL RESOURCES

ONMS will consult the FKNMS database of information about historical resources, NMSP's database of Resources and Underseas Threats, and ONMS's ARCH II databases to identify potential resources at risk. Any identified resources will be handled in accordance with the Programmatic Agreement among The NOAA and The State of Florida for Historical Resource Management in the FKNMS.

5.13 MONROE AND DADE COUNTY DEPARTMENTS OF ENVIRONMENTAL RESOURCE MANAGEMENT

Permits for restoration actions within the jurisdiction of Monroe County, Florida will be secured. If limestone boulders for the restoration are taken from Dade County, ONMS will consult with the Dade County Department of Environmental Resource Management regarding environmental requirements.

5.14 UNITED STATES COAST GUARD

ONMS will notify the Coast Guard concerning the nature and timing of restoration activities so that the Coast Guard can issue a notice to mariners.

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APPENDIX A: SOURCES AND TYPES OF ANTHROPOGENIC INJURIES TO CORAL REEFS AND CORAL COMMUNITIES

Although National Marine Sanctuaries are set aside for protection of natural and cultural resources, Sanctuary regulations encourage multiple uses of Sanctuary waters, and in general do not prohibit traditional (including recreational) uses of sanctuary areas. In addition, many uses of the sanctuary – boating, fishing, public enjoyment– carry inherent risks to the environment. Thus even though the most typically destructive activities, such as mineral drilling, are prohibited within most Sanctuaries, many potential sources of coral reef injury remain. The majority of these impacts arise from vessel use, but injuries from resource collection and general public use are also of concern. This section will describe the types of injuries that may occur in coral habitats and their sources.

A.1 Framework Fracturing

One of the most common injury types is fractured framework. Most reefs are made up of a hard crust (solidified reef rubble) over unconsolidated reef rubble. When the surface is cracked or fractured, large pieces of "crust" can peel away and unconsolidated rubble can be distributed. This type of injury is most often caused by impact from vessel hulls, propellers or dredging equipment, but can also result from any hard object colliding with the substrate. When a vessel cracks the surface of a coral reef, the framework generally becomes destabilized and prone to subsequent mobilization and destruction. Reef rock can be destroyed, and topography altered. Mobile reef rock can cause incidental injury to nearby animals and plants. Repair involves the use of adhesives and other materials to secure broken portions of reef rock together before it is mobilized by subsequent disturbances. While stabilization may fail in cases with extensive fracturing, current technologies enable high success rates for this restoration activity.

A.2. Framework Crushing

Another common injury is framework crushing. Surface framework can be obliterated as a vessel pulverizes the relatively soft reef rock, particularly from large vessels and by anchors from freighter and tankers. This can happen during ingress or as the vessel bounces or twists once aground. Large coral skeletons and high points on the reef can be reduced to fine calcium carbonate sediments that may be washed away or clog reef crevices and other habitat otherwise suitable for colonization, and thus limit opportunities and material for reef repair. Small pieces of rubble are also typically generated. Restoration of such areas may involve removal of sediments and rubble, and the construction of artificial structures to replace lost three-dimensional surfaces. Current restoration materials and methods do not allow for thorough or exact replacement of the lost structure, but modification of the area through physical and biological processes over many years may be necessary to fully regain all the habitat qualities and characteristics affected by the incident.

A.3 Framework Displacement

When a vessel grounds on a reef, reef rock is broken free and plowed by the keel or hull moving across the bottom. It is also generated through propeller wash excavation when operators attempt to back off a reef, dredging activities, or dragging effects from fishing or other activities. Displacement can alter hydraulics and rubble often continues to move in water currents, posing a high risk for collateral injury. It is important to remove the rubble either by replacing it into the excavated area or removing it to another location. When it is replaced into the excavated area, it can be stabilized using either a concrete and reef rock cap or pouring concrete into the spaces between the rubble.

A.4 Coral Toppling

One of the common forms of mechanical injury to reefs involves dislodgement of coral colonies without immediate tissue destruction. This is most commonly caused by vessels, but can also result from fishing, anchor movement, or other dragged gear, as well as by individual snorkelers and divers. Detached corals often land upside down or sideways and end up resting on live tissue; they can then roll, causing additional tissue abrasion or relocation into unfavorable habitats. Most remain unstable in subsequent energetic events and are vulnerable to continued stress or delayed mortality (Knowlton et al, 1981). Repair often involves reattachment to the substrate using epoxy or cement as soon as possible after the injury. It has long been known that stress in the interim can lead to deterioration of tissues that manifests over several days, weeks or months (e.g., tissues can bleach in a matter of days or even die over a substantially longer period) (Gittings et al, 1988; Goreau, 1964). Recovery of coral tissue requires stabilization of the injured area followed by resumption of normal metabolic function.

A.5 Coral Abrasion

Contact by a vessel, anchor, divers, or other moving objects can cause superficial injury to coral, destroying tissue but leaving skeletons intact. For this type of injury, no effective primary restoration exists, and ONMS relies on natural recovery, whereby margins of the tissue grow back over the denuded area. Work by several researchers studying common Caribbean corals suggest corals can regenerate tissue after small abrasions within six months of injury (Cróquer et al., 2002; Van Veghel and Bak, 1994; Meesters et al, 1997; Mascarelli and Bunkley-Williams, 1999, Nagelkerken and Bak, 1998; Nagelkerken et al, 1999; Lirman, 2000; Nagelkerken et al, 2000). The long-term effects of such injuries depends on a variety of injury characteristics: not only on the size of the abrasion, but also the species, shape, depth and location of the lesion, colony size, colony reproductive status, bleached (or not) status, depth of colony, colony morphology, sedimentation and/or algal colonization rates at site, water quality, and colony growth status.

A.6 Coral Gouging

Groundings, anchor and tackle, and fishing nets/gear typically cause gouges of varying depths on injured soft tissues and skeleton. Recovery entails tissue regeneration via lateral growth, as well as accretionary (skeletal) growth, which eventually may fill the gouge. Small gouges are slower to heal than small abrasions, partly because of the need for accretionary growth, but also because the depressions tend to accumulate sediments and other debris inimical to lateral growth. Gouges on corals tend to remain visible for many years. It is possible, however, that small injuries could heal within a fairly short time without primary restoration. For example, the tissue surrounding a gouge less than 2 cm wide and 2 cm deep could stabilize during the first year following injury, heal over the open space within the next two years via lateral growth, then fill the void space over the next two years (Hudson, 1981; Gittings et al, 1993).

A.7 Fragmentation

Most incidents of mechanical damage result in either fragmentation of branching corals or fracturing of massive (i.e. non-branching) corals. When impacted by significant force, coral branches will break and coral heads will fragment into many pieces. Soft tissue injury on affected colonies is comparable to that on abraded or gouged colonies. However, skeletal injury is sufficient to dislodge the fragment, making it vulnerable to displacement and later movement, particularly for smaller fragments (Bowden-Kirby, 2001). Repair of fractured colonies generally involves reattachment to the substrate or to other colony fragments using epoxy, cement, plastic covered wire, cable ties, monofilament line, or uncoated wire. For properly secured colonies, lateral and accretionary growth over exposed areas and adhesives could result in recovery in as few as five years (essentially the same mechanisms as those described for gouging). Though large fragments of broken colonies can remain sexually mature, small ones may lose their ability to reproduce until they grow to a minimal size (Bak, 1976; Szmant-Froelich, 1985), thus further delaying the return to a functional reef habitat.

A.8 Crushing

The most severe form of injury to coral reefs is crushing, when whole heads, skeletal and live tissue alike, are pulverized into calcium carbonate sediments or very small rubble. This type of injury is impossible to repair using original material, because there is none left. The whole area must be recreated using live coral "donated" from other reefs and adding structure from boulders or modules and some cementing material. In extreme cases, like the 1984 *M/V Wellwood* Florida Keys grounding, a vessel may obliterate corals and flatten the coral reef, resulting in large swaths that resemble parking lots (Gittings & Bright, 1988; Precht et al, 2001). The primary difference between this type of injury and others is that recolonization (via recruitment or corals and other species) is required for recovery to occur. For these injuries, the natural recovery horizon is extraordinarily long, arguably perpetuity.

A.9 Sedimentation/Smothering

The creation and settling of fine sediments on top of live tissue can cause severe distress or mortality for corals. This can be caused by dredging or other construction activities, and may also be a collateral impact from crushing or other destruction of hard corals. A fine layer of sedimentation may be removed during natural water movement and storms, while heavier amounts may require hand fanning or other mechanical removal via "vacuum". If removal from healthy corals occurs promptly, there is little long-term impact to coral health. Long-term persistence or settlement on stressed corals often results in mortality.

A10 Entanglement of Lines (anchor or fishing)

Fishing lines & traps, vessel rigging, and anchor lines often become entangled in coral reef habitats when used in the area or when lost overboard. Such entanglement may cause tissue death where lines rest on or around a coral colony, or may cause toppling if the line is large enough and surrounds an entire colony head. Loose coral fragments that are still entangled in line may cause additional injury as long as they remain in the water column or are dragged through additional reef areas. Removal of line can only effectively be done by hand.

A.11 Marine Debris

Discharge, intentional or not, of any non-marine items, including the types of lines described above, into reef areas is considered marine debris, and may lead to potential crushing/toppling/abrasion of live tissue, smothering of seafloor habitat, or collateral injury as the debris moves around. Marine debris often begins as fishing gear (nets, traps, associated lines), or boating accessories washed or thrown overboard (bottles, bags, garbage, packing material, batteries). Once loose in the ocean, such items become debris that is harmful to the habitat.

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APPENDIX B: INJURY ASSESSMENT PROTOCOLS

This appendix describes the protocols used for assessing coral injuries in the Sanctuaries. It assumes a medium to large-sized vessel grounding, and differences in procedure or technique for smaller vessel groundings and large vessel anchoring injuries are noted appropriately.

B.1 INJURY LOCATATION: VESSEL STILL AGROUND

The location of the injury should be precisely documented for evidentiary purposes and to facilitate injury assessment and restoration planning. When the vessel is still aground, the following steps should be taken.

B.1.1 Georeferencing and site marking

Acquire differential-GPS (DGPS) coordinates of the grounding site, including the location of the endpoints of the path the vessel traveled, the positions of the ship's bow and stern, and enough data points to sufficiently locate/describe the major features of the injury for comparison to like coordinates taken after the removal of the vessel. This will help determine if any additional injury occurs during the salvage operation. Search at the location of the last set of coordinates (the grounding site) to insure that all damage has been located. Use all sets of coordinates and a navigational chart to plot out the path traveled before the vessel ran aground to identify possible areas of additional resource injury. Examination of the areas adjacent to the vessel while it is still on the reef can yield critical information for the removal of the vessel, as well as subsequent damage assessment.

In addition to getting DGPS fixes of the various reference points, marking of the site with visual reference aids should also be performed. For small vessel situations, simply marking key features with weighted buoys may be sufficient, whereas a freighter grounding site requires a much more robust marking system due to the fact that the marking devices will need to be in place over the duration of what will undoubtedly be a lengthy assessment process. In this situation, large, sturdy buoys affixed to the periphery of the grounding site with heavy lines running to permanently installed eyebolts or some other heavy-duty anchoring system are in order. These markers may also be useful when interpreting aerial photographs of the site. This kind of sturdy, highly visible marking system is a must in ship anchoring investigations, as they occur in deeper water, thereby making relocation of the site difficult. It also aids the returning assessment personnel in minimizing the amount of time looking for features, and thus maximizing precious bottom time.

B.1.2 Vessel's Direction Of Travel And Compass Bearings

Use the information and a navigational chart to identify possible areas of resource injury. This is not applicable to anchor injury incidents.

B.1.3 Description Of Grounding Incident

Response officials or trained law enforcement personnel should prepare an in-depth description of the grounding incident. Use the information and a navigational chart to identify possible areas of resource injury. This may or may not be of value in anchoring incidents.

B.1.4 Plotting On A Navigational Chart

Use a combination of DGPS coordinates, direction of travel, compass bearings and a description of the incident to plot onto a navigational chart, and extrapolate for the entrance and exit paths. A portable (laptop) computer with navigational and/or GIS software installed can greatly expedite this step. From the chart identify possible areas of resource injury.

B.1.5 Overflights

Helicopters/fixed wing aircraft can be used to fly over a grounding location if good weather (good visibility, relatively calm sea state) conditions exist; they can assist in locating an injury, and entrance and exit scars.

Photo document the site. If true vertical photography is not possible with available aircraft, high quality oblique photos and even video can be useful for evidentiary documentation (particularly if the vessel is still hard aground) and provide useful information for subsequent assessment activities.

Injuries from small to medium size class vessels are often too small-scale to appear very prominently in aerial photography, although an overflight may assist in the location of additional injuries, especially in cases where damage inflicted was heavy.

In ship anchoring situations, overflights may or may not provide any useful information, as the depth of water will usually preclude sufficient light penetration for adequate visibility.

B.1.6 Samples/Photographs and Video

Samples and photographs or video should be taken of relevant debris (pieces of propellers and other running gear, spilled or jettisoned vessel contents, bottom paint smear samples, etc.) and injuries to reef substrate. Acquisition of this documentation at this time is particularly important as vessel debris can be lost over time due to storm events and reef injuries will become obscured by epibiotic overgrowth. All appropriate chain of custody protocols should be followed.

B.1.6.1 Paint Chips/Scrapings/Pieces of Vessel from Injury Sites

- Assign exhibit number of sample before collection.
- Take photos of sample before collection.
- Use underwater writing tablet to display the exhibit number for that sample in photos.
- Take close up photo from distance to give a reference of the location of the sample being collected.
- If possible use the same tool (i.e., dive knife) to collect paint samples from features too large to collect.
- Document what tool was used to collect each sample. Store samples in sea water and refrigerate.

B.1.6.2 Document Compass Bearings of Paint Striations or Grounding Scars

Take photos of each compass bearing obtained. This information can be used to help determine exit/entrance direction

B.1.6.3 Evidence Should be Numbered in the Field

Carry a copy of evidence log in the field (allows for consistent numbering)

B.2 REMOVAL OF VESSEL

Coral reef resource managers and/or response personnel must be prepared to address considerations for removing vessels specific to coral reef groundings, such as removing vessels at high tide; using incoming tract for outbound removal (unless there is a shorter, less injurious exit path to suitably deep water); not allowing grounded vessel to "power-off"(using forward and/or reverse throttle to attempt extrication); obtaining as much towing and salvage assistance as necessary; conducting operations so that damage is minimized (including retrieval of large vessel anchors that will cause the least amount of additional injury); etc.

Other possible concerns/considerations are:

- Determine direction and whether likely to refloat at high tide
- Whether sea state or impending foul weather will result in more serious resource injury if vessel is left aground until the optimal tide is reached
- Whether refloating/removal likely to cause spills or breakup of vessel
- Consider whether necessary to lighter/remove fuel/cargo
- Ensure salvage lines do not cause collateral damage

B.3 INJURY LOCATION: VESSEL NO LONGER AGROUND

When the formerly grounded vessel has been removed or has extricated itself, the following information and techniques may be used to establish the footprint of the grounding. If the assessment personnel were not present while the vessel was aground, it is important that a member or members of the initial response team accompany them to the site to aid in locating it as well as to point out primary injury features. They may also be able to provide valuable information about the direction of travel of the vessel prior to grounding, the final resting area and orientation of the grounded vessel, the direction of removal of the vessel, etc.

B.3.1 DGPS coordinates including the location of the grounding site or the path the vessel traveled.

Conduct a thorough search at the location of the last set of coordinates (the grounding site) to determine if all injury has been accounted for within the presumed terminus of the grounding track. This is also a good opportunity to make a preliminary swim-through of the grounding track to determine the boundaries of the injury, and helps plan for the establishment of an assessment baseline (or baselines) through the most reasonable (usually the longest or most linear) axis of the grounding path. If DGPS coordinates are not available use the information listed below.

B.3.2 Vessel's Direction of Travel and Compass Bearings

Use the information and a navigational chart to identify possible areas of resource injury. In the case of large vessel anchoring situations, it must be kept in mind that although the vessel was presumably not underway while at anchor, she may have dragged anchor during its deployment, or the ship may have swung while at anchor, causing a "windshield wiper" effect, that is, a broad arc of damage as opposed to a simple linear one. Topic 3.3 below may help assessors make these kinds of determinations, but diver inspection is the surest method to locate the totality of the injury.

B.3.3 Description of Grounding Incident

A sketch of the grounding track and the footprint of the vessel's hull should be made while the injury is "fresh" to assist assessment personnel with the determination of the boundaries of the area of impact if a complete assessment is to be conducted at a future date. Also, a general description of the type(s) of injuries within the sketched area should be included to further aid any future determinations of extent of injury.

B.3.4 Plotting on a Navigational Chart

Use a combination of DGPS coordinates, direction of travel, compass bearings and a description of the incident to plot onto a navigational chart, extrapolate for entrance and exit paths. From the chart identify possible areas of resource injury. Electronic charting software or GIS installed on a laptop computer can greatly expedite this procedure.

This may or may not be of particular assistance in the assessment of large vessel anchor damage, although it is possible that plotting the position of the anchor site on a detailed bottom-chart may suggest nearby topographic highs that could have been impacted if the anchor dragged or the ship swung while at anchor.

B.3.5 Search Patterns by Boat

Using towlines attached to stern of assessment vessel, pull snorkelers behind boat at a slow, steady rate of speed. This is most efficient if pulling two people. While pulling snorkelers, boat driver should run parallel transects through search area. Have floats and weights ready to drop onto injury sites when located by snorkelers. Lobster/crab trap floats or similar buoys tethered to large-sized lead dive weights with sturdy line, such as parachute cord, are suitable for temporary markers. To avoid duplication of effort, buoys of a different color may be placed to delineate previously inspected transect lines.

This technique may or may not be of value in the case of deeper water anchoring injuries. If the assessment team has access to them, electrically powered underwater scooters or remotely operated vehicles (ROVs) can be of great assistance in covering large areas at depth in delineating the total extent of damage.

B.3.6 Overflight

Helicopters/fixed wing aircraft can be used to fly over the grounding location. If the weather is good and sea conditions right, they can assist in locating large-scale injury features, as well as entrance and exit scars. True vertical, low-altitude, high resolution aerial photographs of the site can be utilized to analyze, quantify and interpret the injuries, especially if they are of the extensive type most often caused by freighters and other large commercial vessels. These photos can be digitized and imported into computer aided drafting (CAD) software packages that allow the injuries to be outlined and measured, or better still, fed into a GIS system which will not only allow for making area measurements, but will also georectify the image and plot it onto a nautical chart, a benthic map of the area, or pre-existing photographic basemap, or layer it with any combination of these. Aerials need to be georeferenced to be useful in calculating injury size. DGPS-referenced aerial photo targets (at least a meter across for most digital interpretation applications, painted white or some other highly reflective color) affixed to the bottom in shallow water at key points within the injury site. Alternatively, large, brightly colored surface buoys can be tight-line rigged to the bottom with anchoring devices within the grounding site and their locations fixed by DGPS. The types of targets that are fixed to the bottom provide more precise referencing, as tidal movement, wind and waves, or currents do not influence them. Whichever aerial photo target methodology is used, it is generally agreed upon by those who work in the field of geospatial analysis that the more targets the better, but a minimum of four reasonably spaced targets is necessary to properly georectify a true vertical remote image.

Aerial photography is generally of little aid to the assessment of ship anchoring injuries, due to the depth of water in which they typically occur. Likewise, aerial photography may or may not be appropriate to document smaller vessel groundings, as the injuries are usually not of a scale that can be resolved even in low-altitude photographs. Aerial photography is relatively expensive, and therefore should only be utilized in situations appropriate for its use. However, there is no question that in the case of large vessel groundings producing extensive footprints and scars, high quality aerial photos may be a cost effective alternative to hours and hours of field measurements by assessment personnel, as well as serving as dramatic qualitative documentation of a catastrophic event.

B.4. INJURY ASSESSMENT

B.4.1 Types of Injury Possible (See Table 1)

- Barge tow cable markings: Characteristic injury from cable strikes will show as striations in coral and on hard surfaces. Cables can impart extensive damage to stands of branching corals. The cable will also injure or remove other invertebrates such as soft corals or sponges.
- Scraping from bottom of vessel: Depending upon the configuration of the hull, this injury can be characterized by dislodged and/or overturned coral colonies and reef rock; "flat topped" areas where all living invertebrates and framework have been removed to a certain depth leaving a flat surface; broken and shattered ("exploded") coral colonies. Larger vessels will create extensive scarified areas of reef substrate, or "footprints".
- Scars from propellers or keel of vessel: Fractured, crushed, or trenched substrate where vessel's props, running gear and keel contacts substrate, generating very characteristic injuries. The fractures that penetrate the nonliving coral framework can sometimes be less obvious than the broken and crushed reef substrate.
- "Blowhole" (excavation crater): Created by vessel propeller wash as vessel operator attempted to "power-off" the reef. In some cases this may represent the most serious component of reef framework injury from a vessel-grounding incident.
- Sediment pile or berm: Created from displaced material (ejecta) generated by a vessel that excavates a "blowhole". These features can also be generated by vessel's hull as it plows up and throws to side loose reef substrate material.
- Displaced features: Whole coral colonies or sections of coral heads which have been dislodged and displaced, or large pieces of reef framework which have been fragmented and removed from their original location.
- Anchor injuries: Can include scrapes, strikes, fracturing, or toppling of individual heads. May also be characterized by broad, arcing areas of injury caused by chain as vessel swings on anchor ("windshield wiper effect").

B.4.2 Establish Baseline

A master transect line should be established centrally through the length of the injury site (usually the longest axis, starting at the beginning of the inbound path and terminating at the distal end of the final resting place). This baseline can serve as a referencing tool for mapping the site, making measurements of area of injury, location and documentation of important injury features outside of the main body of injury, and relocation of key features during subsequent assessment field visits, as well as aiding future restoration and monitoring efforts. In some cases, such as injuries involving very long inbound paths, a number of very large injury features, or a "confused" site characterized by segmented grounding tracks that change direction and/or scattered areas of intermittent damage, multiple baseline transects may be required to adequately describe the site.

Table B-1. Injury Categories vs. Restoration Options

Injury category		Characteristics	Examples and alternative Terms	Primary Restoration Options: Rubble Removal and/or Stabilization	Framework Cementation	Framework Infill	Relief Reconstruction	Coral Reattachment	Biological Enhancement*	No Action
Reef Framework	Fracturing	Cracks through surface framework, loose reef rock blocks	Cracking Splitting	X	X		X			X
Reef Framework	Displacement	Displacement of reef rock by hull, anchor, or propwash, includes back reef rubble	Gouging Grooving Hull Scars Blowout Craters	X		X	X			X
Coral Tissue and Reef Framework	Toppling	Detached, but otherwise intact colonies	Tumbling	X				X		X
Coral Tissue and Reef Framework	Destruction	Colony obliterated	Scraping Lesions	X	X		X		X	X
Coral Tissue and Cover	Abrasion	Soft tissue damage only, no or minimal skeletal damage, Bottom paint residue	Gashes						X	X
Coral Tissue and Cover	Gouging	Soft tissue and colony skeleton damaged	Fracturing Cracking Splitting				X		X	X
Coral Tissue and Cover	Fragmentation	Colony split, or breakage and dismemberment of branches	Crushing					X		X
Coral Tissue and Cover	Destruction	Colony obliterated		X	X		X		X	X

*Including, but not limited to coral transplantation, larval seeding, and chemical attractants, removal of bottom paint, or other toxic substances.

Even if aerial photography and digital analysis will be used to measure large injury features, a master transect line is indispensable for detailed field mapping and ground-truthing for remote analysis. Of course, a baseline is an absolute must if aerial photography is not an option and manual field mapping and measuring is the only alternative.

For small to medium vessel groundings, where it is known that the assessment will only require a day or two of fieldwork, a temporary baseline may be adequate. This can be as simple as a fiberglass meter tape stretched tight and made fast to stakes (sharpened stainless steel rods work well) driven into the reef substrate at the beginning and ending points of the transect.

Assessments of large vessel and ship's anchor injuries often require multiple site visits to complete, and the baseline may need to stay in place for days, weeks, or even months. Additionally, there is a high likelihood that restoration and monitoring efforts will be instituted in the future, and the original master transect is an invaluable tool for re-orienting to the site. Therefore, the transect endpoints and incremental points between them need to be permanently established by installing stainless steel or fiberglass stakes in the reef substrate, using a predrilled hole and quick setting cement or specially formulated underwater epoxy. Once the master stakes have been established, fiberglass meter tapes can be deployed between them as baselines, or sturdy cordage marked off in highly visible increments can be used and left in place over longer periods of time. A surface buoy tethered to the stakes will help in relocation on future visits.

In all cases, the baseline endpoints should be georeferenced by taking DGPS coordinates from the surface as vertically as possible above them and a compass heading for each baseline noted.

B.4.3 Site Characterization

Site characterization includes mapping and describing the injuries. Once the master transect line(s) have been established, these tasks can be accomplished.

B.4.3.1 Mapping/referencing of injuries

If the injury or injuries are broad and extensive, as is typical of larger vessel grounding and anchor damage, and aerial photography is not available, then the method known as "fishbone" mapping can be utilized. In this technique, one member of the assessment team follows the baseline carrying another meter tape and at an appropriate increment (usually one meter, unless the injury is very large and a broader increment is acceptable), the end of the meter tape is made fast to the baseline and a second member of the team uses the tape to make a perpendicular measurement out to the edge of the injury. Repeat this procedure for the other side of the baseline, recording the measurements and corresponding incremental positions along the baseline on waterproof data sheets. From this data, a base map of the injury site can be generated.

This technique can be used for mapping larger injury features of small and medium-sized vessel groundings, such as inbound tracks, final resting area footprints, and propwash excavation craters (blowholes). In many instances, smaller vessel damage is somewhat scattered, disjointed and intermittent. In this case, individual injuries can be referenced back to the baseline with a distance and compass-bearing notation. This is a useful technique for mapping features associated with large-scale incidents that lie outside the main body of damage.

B.4.3.2 Numbering injury features

Many people, including the investigating officer, biologist and, possibly, restoration contractors, will need to reference the injured sites and significant injury features. By enumerating these immediately as they are located, all references to the sites will correspond.

Use metal stakes or spikes hammered into the bottom with numbered heavy plastic or stainless steel tags attached or glue numbered tags directly to prepared surfaces of reef substrate.

B.4.3.3 Nature of injuries

Using the terminology and definitions outlined in Section 4.1, describe the injuries found within the site(s). Any given site may display a variety of damage types.

B.4.3.4 Determine species impacted

Identify injured corals and other organisms to species, if possible.

B.4.3.5 Determine percent cover of species and species diversity

Use accepted methods of determining percent cover, species diversity and relative abundance of live corals and other benthic reef species. These include visual inspection estimates of randomly placed meter square quadrats (Braun-Blanquet or similar methodology), digital analysis of photo quadrats, or use of video transects point-counting computer software.

In many cases, especially when larger vessels are involved, the coral reef substrate within the injury site may be in such disarray (or in some instances, completely obliterated) that any determination of pre-existing species cover, diversity and relative abundance is impossible. In these instances, this information can be gathered from unimpacted reef substrate immediately adjacent to the injury site, as it is reasonable to assume that this closely approximates the pre-grounding condition of the area within the injury site.

B.4.3.6 Obtain an estimate of rugosity/three dimensional relief

Use standard, accepted method to determine rugosity (index of substrate complexity) within the injury site and in the adjacent unimpacted reef as a measure of loss of three-dimensional relief. A commonly used, widely accepted technique for rugosity determination is the chain and tape method. This is accomplished by deploying a length of surveyor's tape (usually ten meters) across the reef substrate of interest, then laying a light chain (brass works well) along the length of the tape, paying out as much chain as required to conform to the substrate profile over the same distance of the meter tape. The measurement of the length of chain used is divided by the straight-line distance. The resulting number is an index of "wrinkledness" (rugosity) of the substrate. The closer this number approaches 1, the flatter the surface. Average indices within injury sites can be compared to those acquired from immediately adjacent uninjured areas to describe the change in substrate complexity caused by the grounding or anchoring incident.

B.4.4 Quantification of Injuries

Measurement and quantification of injuries can be accomplished by a variety of methods, and the particular techniques used are determined by the scale of the injuries, as well as the tools and technology available to the assessment personnel. Some of the most commonly employed techniques are as follows:

- Small quadrats and meter tapes: Measuring and quantifying minor injuries can be made quickly and efficiently with the use of a surveyor's (meter) tape, a meter stick and a quadrat (a square constructed of PVC pipe, $0.25m^2$ in area, makes a convenient field model). The tape and rule can be employed to make length and width measurements, and the small quadrat can be utilized to visually estimate areas of minor injury.

- Meter-square quadrat: A square PVC pipe frame, 1 meter on each side, is used as a visual aid for quantifying area of larger injuries, as well as arriving at cover/diversity estimates, as described in section 4.3. The percent cover figure from the adjacent uninjured reef can be multiplied by the square meter area of injury measurements to calculate the amount of living coral (and other benthic species) lost to the incident.

- Scaled, vertical photographs of injury bounded by a quadrat can also be used to measure injuries, although it can be somewhat difficult to get a truly vertical, undistorted photograph under typical field conditions.

- Fishbone: The fishbone method of injury mapping, as described in Section 4.3, can also be used to arrive at area measurement. The polygon generated from the measurements collected can be plotted onto a sheet of scaled graph paper and the area within the polygon calculated. Similarly, this data can be plotted with CAD software (such as Canvas™ by Deneba) and the area within the polygon calculated by the program's Object Specifications function. The polygon created can then be used to produce a diagram of the injury site, with significant features, scale information, north arrow and other relevant information included.

- Aerial photos: If injury features are of sufficient scale, ground-truthed, true vertical aerial photos of known and verifiable scale can be digitized and imported into Computer Aided Design (CAD) programs that allow the user to orient the photo to a compass direction (usually due north) and trace the outlines of the features of interest. The square meter areas described by the polygons thus created can be calculated almost instantaneously by the program's Object Specs function.

Digitized, georeferenced aerial photos can also be imported into GIS programs where the injury area can be oriented, measured and layered with other geospatial information for that locality.

B.4.5 Qualitative Documentation

This primarily involves photo and/or video documentation of significant features of the injury. Photo/video documentation of the injury with an underwater still camera or video camcorder in a waterproof housing provides a permanent record of the "look" of the site which can be referred back to at any future phase of the assessment, legal case development or restoration and monitoring planning. High quality 35mm or digital images can be used to review the injury if questions regarding species identification arise, or if details about the nature of the injuries need are lacking from field notes. Perhaps most importantly, photographs and video acquired while the site is "fresh" provide a dramatic, graphic representation of the injury for anyone involved in the review of the case that could not observe the damage firsthand ("a picture is worth a thousand words"). Injuries that occur in deeper water, such as in the Tortugas or FGBNMS, may require additional mapping technology, such as multibeam acoustic sonar, to locate and identify injury areas. Such data would most often be collected in addition to standard documentation methods.

B.4.5.1 Video transects

Following the baseline from the beginning (the zero mark), make slow, steady, continuous video (digital format if at all possible) of the injury, stopping to shoot extra footage of particularly important features. If videography of key features takes the camera away from the baseline, return to the same position along the transect when the digression was made, noting the meter mark upon return (get close-up of meter increment) and proceed with videography along the baseline. The field of view of the housed camcorder may not encompass the breadth of injury, and it may be necessary to slowly, steadily pan or "sweep" from one side of the injury to the other as the transect line is followed, thereby documenting the entire scene. When procedure is followed carefully and methodically, an invaluable visual archive of the entire injury site is created.

Qualitative footage of the unimpacted reef adjacent to the injury should also be acquired as a visual reference of what the site would have presumably looked like before the incident.

Newer generations of digital video camcorders have the ability to make high-resolution digital still images in addition to the regular video mode. This can be a very useful feature when high quality still images of key features are needed, or, when used in conjunction with an attached framing rod and visual scale, images for quantitative interpretation can be acquired. Alternatively, reasonably good quality still images for illustrative purposes can be "lifted" from video with the frame-grabbing feature included in most video editing software for personal computers.

Software packages, such as Ravenview™, enable vertical video transects to be digitally rectified for moderate variances in distance from subject and angle of view, and then "stitched" or collaged together to form a digital image map of the site. Other available software allows vertical video transects to be used in statistical pointcount interpretation.

B.4.5.2 Still images

High quality digital or 35mm images of the site are desirable in that they can be utilized as an adjunct to species identification or for use as illustrations included in the production of injury assessment documents. With the proper leveling and framing apparatus and inclusion of a visual scale device, still images can be used to make measurements of injury or sizes of coral colonies, as well as use in making photo quadrats that can be used to estimate percent cover and relative abundance calculations within the injury and the adjacent unimpacted reef.

When making video, use a color-correcting filter in water deeper than 3-5 meters, and when taking close-ups with a 35mm still camera, a strobe should be used to provide necessary color and detail. When taking close-ups of either injured or unimpacted organisms, a second photo should be taken at distance to show location of injured organisms in reference to other areas. An item of known length should be used in photos to show scale. Photos should be developed and labeled as soon as possible; the same goes for downloading/filing digital images and archiving ("duping") video. Negatives and slides, as well as digital images and video, should be treated as "crime-scene" evidence.

B.4.6 Field Note Management

Field notes can be made on underwater slates or on waterproof paper. Prepared data sheets can be photocopied onto waterproof photocopy paper, like NeverTear® sheets by Xerox™, which can be filled underwater with an ordinary pencil.

In addition to data specific to the injuries, information to be included with every day's site visit include:

- Name of site and latitude/longitude reference
- Date
- Time of day
- Tide state
- Average depth of water over site
- Sea state
- Names of assessment personnel (or others assisting)

As is the case of physical samples and photo/video documentation, data sheets become legal documents and must be treated the same as other pieces of evidence

B.4.9 Create Photo Mosaic of Injured Area

In good weather, when time is limited and other technology is not available the mosaic can be completed by one diver/snorkeler swimming on surface holding another diver at a consistent arms length below the surface. The diver below surface takes continuous overlapping photos. Diver on surface guides photographer through injured area. This allows for consistent depth for photos.

B.4.10 Daily Field Notes

Upon completion of each day's field work the biologist should create sketches of each new injured area. On each sketch the biologist should include:

- The location and direction each photo was taken
- The photo numbers should correspond to the numbers on each labeled photo
- The direction of each video transects
- The location that evidence was collected and corresponding evidence number (obtained from the investigating officer)
- A drawing of the injured site with the location identification of injured organisms

The storage of original copies of sketches, drawings and field notes should be done in a manner compatible with evidence handling practice.

APPENDIX C: MONITORING PROTOCOLS

Monitoring of both primary and compensatory restoration projects is necessary to determine whether the projects are providing services in a manner consistent with restoration goals, and to assess the potential need for mid-course corrections to ensure that the projects meet designated restoration performance standards. The design of the monitoring program must permit the detection of, and response to, significant changes in coral recovery rates or damage to restoration components (structural enhancements, coral transplants, etc.) as a result of external events, such as major storms or vandalism, and in comparison to the surrounding habitat. In addition, the monitoring should be designed to assess the effectiveness of the restoration based upon technical evaluation of appropriate parameters.

C.1 Site Identification

In order to adequately determine the need for mid-course corrections, and the appropriate nature of these corrective actions, the sites will need to be monitored regularly. Consequently, the initial method of marking and locating the site must be standardized, easily repeatable, and not subject to error or individual variation by sequential monitors. Restoration and reference sites will be identified via DGPS coordinates; actual monitoring stations will be marked using other permanent (but small) identifiers, including stainless steel pins, tags, and/or other markers, that while necessary for monitoring, do not overly detract from the aesthetics of the reef.

C.2 Monitoring Schedule

Sampling frequency for each monitoring plan may vary with varying physical oceanographic conditions, coral species etc., occurring at the site. The standard plan will include a pre-restoration survey event if significant time has lapsed between injury assessment and restoration action, a baseline survey immediately post-restoration, a stability only check for stabilized framework and transplants at 1 month, and monitoring events at 1, 5, and 10 years, with an additional fish monitoring event at 2 years in the case of a “major” grounding (Jaap, 2000). The monitoring schedule should provide for one additional monitoring event to be scheduled if required. These are necessary to address any change in conditions at the site that may occur following large climatic (e.g., a hurricane) or ecological (e.g., bleaching) events.

C.3 Size of Area to be Monitored

For very small sites each stabilized, reattached, or transplanted colony should be monitored. For larger sites, some tradeoff must be made between enough sampling to be representative and statistically valid, versus cost and effort. Thus it is recommended that for larger sites approximately 20% of the planar area of the restoration site be surveyed at each monitoring event. This is subject to variation due to factors such as topographic complexity, taxonomic heterogeneity, overall extent of injury area, or whether the site requires unusual sampling effort in order to ensure statistical rigor.

C.4 Reference (Control) Sites

For each monitoring station established, a reference site of the same size, in a nearby but undisturbed location, with similar depth, species composition, etc., will also be established. These reference sites will be monitored in the same way, and at the same time (included in the field trip monitoring schedule), as the sites undergoing restoration (Rogers et al., 1994).

C.5 Types of Information Gathered

During monitoring, the following parameters may be observed and/or measured at restoration and reference sites (the number of reference stations will be based on the number, size and characteristics of restoration stations within the site):

- Structural integrity of attachments
- Percent coral cover
- Percentage of algal cover
- Growth of individual colonies
- Evidence of new recruits
- Evidence of disease/bleaching (color)
- Biodiversity indexes

C.6 Parameters to be Monitored

This section provides a short description of the parameters generally considered for monitoring. , Depending on the specific case, not all parameters may be required for each restoration site, or additional ones may be considered.

C.6.1 Physical Aspects

C.6.1.1 Restoration stability

Restoration stability should be specifically assessed one month post-restoration. In addition it should be generally assessed at every post-restoration survey. It is an indication of the strength and durability of the mechanism used to achieve reattachment, transplantation, etc. There appears to be no ideal way to measure this quantitatively, and the parameter might best be indicated by some gentle mechanical manipulation (i.e., "jiggling") of the restoration fragment to ascertain if it is stable, followed by the recording of a "yes/no" response in the monitoring report.

C.6.1.2 Surface integrity

Documenting obvious cracks in the reef surface should also be done for intermediate and major injuries, even if the substrate appears stable at the time of observation. Additionally, surrounding sediment and rubble areas should be measured for settling, i.e., consolidation and/or compaction, at those classes of injury

C.6.2 Biological Aspects

C.6.2.1 Survival

The first metric of a biological restoration that must be determined is whether the reattached or transplanted coral has survived the manipulation necessary to reestablish the colony. This can be determined visually, but, for reasons discussed in more detail below (see 6.7), will be accomplished by means of photographic documentation (either video transects or photo-quadrats) (Jokiel et al., 2001). Similarly, an assessment of survival of seeded corals (or other organisms) will be necessary at sites treated in this way.

C.6.2.2 Color, Disease, or Bleaching

Fragments that undergo the stress of mechanical damage, toppling, and subsequent reattachment often become more susceptible to coral diseases and bleaching. Again, the proportion of manipulated versus unstressed corals that are so affected could prove to be valuable monitoring information. It should be noted, however, that categorization is difficult when trying to distinguish between bare coral skeleton that has apparently been recently killed by a disease (i.e., without filamentous algae overgrowth), and that exposed due to physical damage. One must also be careful in differentiating bare skeleton from bleached coral (Rogers and Miller, 2001).

C.6.2.3 Colony Growth

Linear extension in the case of branching corals, lateral extension in the case of head or plate corals, tissue extension over skeletal areas, etc., are all restoration success parameters that would be desirable to measure quantitatively. While this could be accomplished by direct measurement (calipers, measuring tape, etc.), a more time-efficient technique is to use of digitized photographic determination (Phillips, 2002).

C.6.2.4 Recruitment

Perhaps the "gold standard" of the measure of the success of a major restoration site is whether, and if so to what extent, natural recruitment takes place in a previously impacted or degraded site that has since undergone restoration efforts. As such it is important to attempt to capture some metric of recruitment events, juvenile coral establishment and growth, etc. It is exceedingly difficult to do this, both visually in the field, as well as by photographic methods. Therefore, as a policy matter, this project will utilize photography, for reasons of better enabling comparability, both temporally and across sites, reducing variability due to observer inexperience or training, providing an archivable (and thus reviewable) permanent record, as well as in all probability reduced cost over the complete monitoring term (Jokiel et al, 2001).

C.6.2.5 Percent Cover, Size Frequency Distribution, and Density (major sites only)

Percent cover by coral colonies is perhaps the single most oft-cited measure of coral health. Frequency is calculated by dividing the number of samples in which the species is observed, by the total number of samples. Size frequency distribution is simply a measure of size categories per unit area and their abundance relative to other size categories. Density is the number of different species or colonies per unit area, usually per square meter. It is important to remember that the number of coral colonies can be independent of species diversity and coral cover. For example, a grounding that causes significant mortality (loss of cover) may bring about an increase in the number of coral colonies because of fragmentation, but the colonies would be of smaller size. Or, two reefs may have the same number of colonies, but entirely different percent cover (Rogers et al,1994).

C.6.2.6 Species Diversity and Evenness (major sites only)

Biodiversity is commonly expressed by Species Richness, the Simpson Index, or the Shannon-Wiener Index. Species Richness is the simplest measure; it is the total number of different species present. It does not take into account the apportionment of individuals among species. For example, if there were 4 different species observed at two areas, the richness would be equal, while at one location 80 percent of the total colonies could be from one species, while the other could have 25 percent of each species. The Simpson and the Shannon-Wiener Indexes account for the richness and proportion of each species. At present the latter index (also called the Shannon-Weaver) is the more common, and will be used in this program. Evenness is a measure of the similarity of the abundances of different species. When there are similar proportions of all species, evenness is unity (one), but when the abundances are dissimilar (some rare and some common species) then the value decreases (Begon et al, 1990).

C.7 Monitoring methods

C.7.1 Field Techniques

At least two divers are necessary for all monitoring events that require in-water surveys, for safety purposes as well as for reducing the potential for measurement errors. Preferred methodology depends on safety, efficacy, and costs. Given the suite of parameters to be measured, there are few techniques that might serve to accomplish all purposes required.

For the NMSP coral restoration program, a combination of visual inspection and photographic methods (permanent video transects and photoquadrats) will be used for monitoring. Details regarding the methodology will be supplied to responsible parties.

C.7.2 Data Analysis

Following each monitoring event, up to three days will be required to digitize or otherwise process the photos, obtain metrics, enter information in a database, analyze the data, and prepare a report. Also included in this period is the time necessary to transcribe field notes and to identify and archive all photographic files.

C.8 Costs and overall monitoring considerations

Visual survey coral monitoring projects are typically constrained by the most costly factor involved in any such project, namely, actual dive time, which encompasses such costly elements as boat time and labor costs for at least 4 people (2 divers, 1 safety tender, and a boat captain) (Jokiel et al., 2001). Furthermore, the labor involved in traditional visual assessments is relatively expensive, in that at least one (and usually both) of the divers must be a biologist with expertise in the field identification of reef organisms, and the divers and boat must be on the site for long periods to make the necessary observations (Rodgers and Miller, 2001).

By contrast, photographic methods capture the quantitative data much more quickly, and can be done by any competent diver. (However, significant outlays are required for the initial equipment; e.g., cameras, projectors, etc., but those are startup costs and actual implementation is less costly and more efficient using photography.) This is offset somewhat by the greater time spent in image analysis in the lab, but that involves no boat costs and can be done by one person. Photos also provide archives, and the opportunity for later evaluation.

However, in this project, visual inspection of each colony will also be done to determine prevalence rates of certain syndromes (e.g., bleaching). It takes a lot longer and is less reliable when this information is taken off a photo; even excellent photography isn't as good as field observation in distinguishing bleaching from dead coral that is just white skeleton without any tissue. Thus, a biologist will be along on each trip to record qualitative observations, even while a diver with no biological training may shoot the photos.

APPENDIX C: REFERENCES

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APPENDIX D: **RESPONSE TO COMMENTS**

This appendix summarizes the substantive comments received on the Draft Coral Programmatic Environmental Impact Statement for Coral Restoration in Florida Keys and Flower Garden Banks National Marine Sanctuaries during the Public Comment period. The name of the commenter, the substantive comments and ONMS response is provided below.

Commenter 1
DeeVon Quirolo, Executive Director, Reef Relief

1. The document notes that it is NOAA's policy not to restore reefs affected by storm damage. This is a relatively new policy and we would ask you to reconsider it. Inasmuch as coral coverage in the Florida Keys is down to a fraction of what a healthy coral reef should have, it is essential that we do all we can to insure its survival, especially when it involves allowing volunteers at little cost to take action after a destructive storm.

Response: This is longstanding policy of ONMS and NOAA. Storm damage, while unfortunate, is a natural reef process. While the goal of the ONMS is to protect and preserve the natural resources, it is not our policy to correct natural processes.

Commenter 2
Thomas Goreau, President, Global Coral Reef Alliance

2. I wish to correct serious inaccuracies in the draft statement on page 11, namely the section below:

> "One proposal for structural restoration of coral reefs is the *in situ* formation of semi-artificial substrate by electrolysis (van Treeck and Schuhmacher 1998), known as electroaccretion. Calcium and magnesium ions present in seawater can be deposited on a template by electrochemical deposition. For example, van Treeck and Schuhmacher (1998; 1999) used a template made from non-galvanized steel mesh (e.g. chicken wire). A current is passed through the template, which acts as a cathode where brucite [$Mg(OH)_2$] and aragonite ($CaCO_3$) are "electroplated." The accreted material consists mainly of calcium carbonate and is chemically similar to reef limestone.
>
> In the studies referenced above, the investigators also combined elements of biological restoration with deposition by inserting coral "nubbins" into the mesh. Although spontaneous settlement by benthic organisms can take place on the precipitated substrate without the nubbin transplantation, use of nubbins appears to hasten recovery. Van Treeck and Schuhmacher (1998) used coral fragments of species that have a high ability to form new colonies from fragments. After placement of nubbins into the mesh, current was supplied to the template using a DC power supply and experimentally determined current densities. After 8 weeks all the nubbins were well cemented to the mesh with the precipitation around them reaching a thickness of 6 to 8 mm. The authors' experience indicates that this technique is applicable for use on a large scale. However, this technique has not been used in the field, and has been tested primarily in the Pacific and Indian Oceans, with only anecdotal work in the Caribbean (Hilbertz and Goreau, 1997)."

The method described was invented by the late Prof. Wolf Hilbertz, and developed and patented by him and myself over the last 20 years. The citations given are mostly to unauthorized work that copied ours, but which made serious errors of design, materials, and operating conditions. They did not get the results that we, and those who we train to use the method properly, routinely get in the field in early 30 countries in the Caribbean as well as the Pacific, the Indian Ocean, and South East Asia. We typically get growth increases of electrified corals 2-6 times faster than uncharged controls, based on 7 independent studies, but these depend on the species and the operating conditions. Most of this work is in Indonesian, and we have not had time to prepare a summary in English. In contrast, our imitators have had much inferior results, and in fact some of those you cite published a "peer" "reviewed" paper in which it was claimed that they could only get corals to grow when the power was off!

But there is an even more important aspect of our work to restoration following physical damage than enhanced growth rates, namely the almost immediate healing of physical damage to tissue that our electrical method promotes. One of our students in Indonesia, transplanted 32 freshly broken Acropora formosa tips from a single large clone onto Electrified structures and 32 onto control uncharged structures. The electric corals grew 4.01 times faster than the controls. But more important, while the controls released mucus for two weeks after transplantation, which is typical for physical damage, THE ELECTRIC CORALS RELEASED NO VISIBLE MUCUS AND COULD BE SEEN BY EYE TO BE OVERGROWING THE SUBSTRATE WITHIN HALF A DAY. The exceptionally rapid wound healing caused by the direct current electrical field is similar to that long known in vertebrates.

We routinely use this method in rescuing naturally broken coral fragments for transplantation. Most of the natural fragments we use were long ago damaged by anchors, divers,, waves, or fishing gear, and when we get them many have been severely injured by rolling around on rock or sand, often with much of the tissue dead or necrotic. But when we put them onto electric nurseries the damaged areas heal very rapidly, and the polyps quickly extend and start feeding. The photos below taken by Leong Sze Wong at one of our projects in Indonesia show broken corals that have had only one day of electrical recuperation and were simply placed on a temporary charged substrate without being attached, as this was simply a temporary measure to restore them until they could be transplanted onto a permanent electrified structure. Their vivid colors and healthy polyp expansion of both hard and soft coral fragments are a dramatic difference from how they were when we collected them a day or two before.

In conclusion, the Biorock reef rehabilitation method is the best practice for rescuing corals from physical damage, but it requires prompt intervention for the best results. Whenever NOAA is serious about using the best methods to rescue damaged corals, we will be happy to show them how use our method properly. There are so few corals left in the Keys that it is remiss not to use the best methods for rescuing those that have been smashed by careless divers, pleasure boaters, commercial shipping, or University of Miami research vessels.

Response: At present, ONMS does not believe that it is appropriate to use this technology in the FKNMS or FGBNMS as ONMS does not employ experimental techniques in restoration. The proper vetting and peer review of this technology has not been completed and most of what has been published by the popular media is circumspect as most of it comes from unpublished materials and biased anecdotes. The FPEIS has been updated with a discussion of a recent review of this technology[4] which suggests that the technology should be "considered with caution." Based on this review, ONMS is strongly dissuaded from its use and application in the NMSP. There are many drawbacks including but not limited to aesthetics and reef functionality. However, as with any new and emerging technology, ONMS would consider research permit applications for small test plots and experiments using this methodology. At such a time as the technique has been adequately field tested and peer-reviewed, ONMS would consider it for use as a restoration alternative. In the interest of continuing to expand the range of restoration options available, ONMS strongly encourages researchers to publish data and case histories in a peer-reviewed scientific journal.

[4] Borell, Romantzki, and Ferse, 2010. Differential physiological responses of two congeneric scleractinian coral to mineral accretion and an electric field. Coral Reefs (2010) 29: 191-200.

Commenter 3

Heinz J. Mueller, Chief, NEPA Program Office, Office of Policy and Management, U.S EPA Region 4

4. The discussion of coral growth and restoration indicate that long time periods are required. We suggest adding discussion of what the time periods are for some representative species of coral. Since the result of the proposed actions would hopefully endure various perturbations well into the future, the effects of sea level rise and temperature trends on the restorations should be addressed.

Response: Coral species have widely varying recovery rates but unfortunately, there is little long-term monitoring to identify definitive species-specific growth and recovery rates. In addition, the answer depends on which aspect of recovery is of interest: coral cover, density of coral colonies, or population structure. ONMS data from one monitoring site[5] indicates that after 10 years, the restoration site was approaching convergence with the reference sites. This is in agreement with Lirman & Miller (2003) which suggests 10-20 years for recovery. Given the long time period until recovery and the many uncertainties regarding rates of sea level rise and the long-term impacts of climate change, ONMS makes restoration decisions based upon the best science and the reference habitats that currently exist without accounting for potential long-term climate alterations.

5. Hundreds of invertebrate species inhabit reefs and some such as bryozoans, sponges, and soft corals are referred to as encrusting to describe their nature of growth. Perhaps the community succession and potential species dominance at a damage site are factors in the decisions about what species to transplant. We suggest some discussion of whether these other reef inhabitants potentially could be involved in transplanting along with the hard coral species mentioned in the document.

Response: ONMS agrees that in addition to scleractinian corals, other coral reef organisms should be considered for the potential of reattachment. However, there is much less information and experience in doing this, and thus those techniques are not considered in this FPEIS. ONMS does reattach soft corals (gorgonians) and description of those techniques is included on page 9. ONMS is interested in exploring options for restoration of other benthos, and has some small pilots underway. At such a time when those methods have been adequately field tested and peer-reviewed, ONMS will include them for consideration as restoration alternatives.

6. EPA expected the Draft EIS to present data comparing the suitability of various artificial substrate materials for larval settlement and growth. It is not clear why this was not included.

Response: There are ongoing investigations into the comparative suitability of artificial substrates as well as naturally occurring limestone, but the data are not clear on whether there is an advantage to one type of substrate over another. Because larval settlement and growth are not preferred alternatives in this FPEIS, ONMS did not consider the suitability of artificial substrate for those purposes to be relevant in this document. However, whenever possible, ONMS uses natural limestone in framework restoration for aesthetic reasons as well as because NOAA's experience suggests that natural substrates are more effective options[6].

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[5] Hudson, et al, 2007. M/V Alec Owen Maitland Coral Reef Restoration Monitoring Report, Monitoring events 2004-2007. Marine Sanctuaries Conservation Series NMSP-07-06. U.S. Department of Commerce, 35 pp.

[6] Miller, M. et al, 2009. Alternate benthic assemblages on reef restoration structures and cascading effects on coral settlement. *Marine Ecology Progress Series*. 387: 147-156.

7. The ease of implementation is mentioned on page 58 of the document as being a positive factor of coral reattachment/transplantation. Reattachment of branching coral species such as *Acropora* sp. and other hard corals would seem to be tedious and labor intensive. EPA suggests providing the level of effort needed for using this alternative on sizable damage sites.

Response: As techniques are constantly changing and improving, and because the requirements of every site are different, it is generally difficult to accurately compare levels of effort for different techniques or species. Rather, the agency may do some comparisons based on size classes of fragments for particularly large cases. In most instances, restoration comparisons are based on the amount of area to be restored to a representative percent cover, not a specific number of colonies or fragments to be reattached. Our experience with restoration over a range of species has proven that coral type is not the primary factor. Rather, the key is how many coral colonies are compromised in an injury and the size of the fragments that require reattachment. Even in large groundings, coral cover is not high enough to warrant species specific activities as they generally occur simultaneously.

RECORD OF DECISION
for the
FINAL PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT
on
CORAL RESTORATION IN THE FLORIDA KEYS AND FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARIES

Introduction

This document comprises the National Oceanic and Atmospheric Administration (NOAA) Office of National Marine Sanctuaries' (ONMS) Record of Decision (ROD) for the Final Programmatic Environmental Impact Statement (FPEIS) on Coral Restoration in the Florida Keys and Flower Garden Banks national marine sanctuaries (FKNMS and FGBNMS, respectively) as required by the National Environmental Policy Act (NEPA).

The FPEIS programmatically evaluates the short and long-term environmental and socioeconomic effects related to the implementation of coral reef restoration and coral reef injury prevention projects in the Gulf of Mexico and Caribbean waters of the National Marine Sanctuary System, which includes the FKNMS and the FGBNMS. As this document focuses on the most likely and feasible future regional coral reef restoration and injury prevention activities within both sanctuaries, the discussion of potential impacts on biological resources, social considerations, and economic activities cannot be site- or case-specific. Therefore, the purpose of the FPEIS is to present and analyze the current technologies available for coral injury prevention and restoration in these regions in order to support the selection and implementation of specific actions when needed. In general, many restoration actions are expected to be adequately addressed by this FPEIS and would qualify for categorical exclusion when the decision is made. Larger more complex actions may require additional analysis and as such, the appropriate environmental analysis would tier off of this FPEIS and focus on the specific circumstances of the injury and location, or specific restoration requirements.

ONMS's coral reef restoration objectives are to conduct feasible and cost-effective restoration using the best available techniques to accelerate recovery of the injured areas to the pre-injury baseline levels. In addition, ONMS seeks to facilitate the prevention of future coral reef injuries through the implementation of preventative actions or projects. These restoration and injury prevention objectives are in keeping with the goals and policies of the National Marine Sanctuaries Act (NMSA), the Florida Keys National Marine Sanctuaries Protection Act, the FKNMS and FGBNMS Management Plans and the sovereign submerged land policies of the State of Florida. The NMSA, 16 U.S.C.§1443(d)(2), define the appropriate uses of recovered damages in order of priority as "(A) to restore, replace, or acquire the equivalent of the sanctuary resources that were the subject of the action…; (B) to restore degraded sanctuary resources of the National Marine Sanctuary that was the subject of action, giving priority to sanctuary resources and habitats that are comparable to the sanctuary resources that were the subject of the action; and (C) to restore degraded sanctuary resources of other National Marine Sanctuaries." Under the NMSA, ONMS sometimes considers salvage and prevention projects to be restoration; this is most likely in a situation where prevention of additional injury through removal of a large vessel could provide greater benefit than future restoration of a significant injury. Prevention projects may include the protection of equivalent resources, which falls under (A) above, and serve to reduce the likelihood that injury will occur at a later time.

Decision to Be Made

Although this FPEIS provides analysis of the impacts for typically expected restoration results, each injury site and circumstance will be unique. Each restoration will require an individual NEPA analysis. The purpose of this FPEIS is to provide an overarching NEPA analysis for these types of activities, such that any subsequent NEPA analysis can rely on and, as necessary, tier off this document. This will allow for timely and efficient analyses and help ensure restoration activities are initiated as soon as possible for the benefit of the resource.

Environmentally Preferable Alternative(s)

Due to the nature of this programmatic assessment, there is no one environmentally preferable alternative. Each of the alternatives evaluated has benefits and costs that will vary depending on the nature and specific circumstances of a particular injury.

Alternatives Considered

A summary of the alternatives considered is presented in Table 1.

No Action

The no-action alternative would leave the reef in its post-injury condition, allowing natural recovery processes to occur. The no-action alternative could have three general outcomes: 1) natural recovery on a longer time scale; 2) no recovery; or 3) further deterioration of the reef system. It is important to note that in cases where NOAA has recovered damages for coral injury under NMSA § 312, the no-action alternative may not be a legally acceptable choice. NOAA always retains the alternative, however, as a basis of comparison, and for purposes of technically complying with CEQ's NEPA regulations.

Physical Restoration

Alteration or destruction of three dimensional habitat complexity is one of the most common types of coral injury. In general, this complexity must be restored prior to restoration of the biological community. Physical, or structural, restoration only addresses injuries to the reef substrate, not the live coral community. The options for physically restoring coral habitat complexity were:

Debris and Vessel Removal

Groundings of large vessels often result in vessel debris—propellers, engines, running gear, anchors and associated chain, etc.—or even entire vessels left on the reef. Removal of vessels and debris is typically accomplished at high tide, when additional water over the reef facilitates vessel removal. Depending on its size, a vessel may be removed using a single floating towline to another vessel, or may require multiple tugs and floating towlines. Careful selection of an exit path is required in order to minimize collateral injury to surrounding reefs as the vessel is taken out. For larger efforts with multiple or heavy towlines, it is also important to monitor the placement and use of towlines to ensure that they do not get caught on reef material and break coral heads or scrape the tops of coral heads. Removal of other debris may require additional equipment, including cranes, specialized vessels, and commercial dive equipment.

Sediment and Rubble Removal

Removing large quantities of rubble can speed recovery and reduce additional injury. In general, clearing sites of rubble as soon as possible after the injury is done before other restoration actions are undertaken. This prevents collateral injury, allows preservation of large pieces of live coral, and provides a more suitable substrate for subsequent restoration actions. The rubble may be stockpiled for later use in constructing restoration replacement structures and/or ornamentation of other reef repairs. Small quantities of coral rubble can be removed by divers using baskets or lift bags, while larger amounts may require a barge with suction, guided by underwater divers.

Substrate Stabilization

Loose pieces of reef substrate can be stabilized using marine epoxy or concrete to fill in cracks and holes or to otherwise solidify the substrate. This is often referred to as a "puddle pour" since a small

Table 1: Coral Restoration Alternative Matrix/Comparison

ALTERNATIVE	SITE CONDITION FOR USE	RESULT
No Action: Leaving the injury unrestored.	The no-action alternative is most often used for cases when ONMS determines that an injury site is likely to recover in a short period of time with a low likelihood of injury expansion, or where other social, environmental, or logistical considerations dictate that no-action is the best course.	The no-action alternative would leave the reef in its current post-injury condition, allowing natural recovery processes to occur. The no-action alternative could have three general outcomes: natural recovery on a longer time scale; no recovery; or possible further deterioration of the reef system.
Debris and Vessel Removal	Appropriate where a vessel is sunk, aground or broken up. Also applicable for marine debris from a vessel or other source, such as debris dumped for artificial habitat or lost fishing gear.	Precludes further impacts from vessel or debris. Facilitates opportunities for either natural recovery or for additional restoration work as necessary. Does not restore any physical or biological properties.
Sediment, Rubble Removal: Removing loose material from the injury area.	Appropriate for disturbances that produce quantities of coral rubble and fine sediment material, including large vessel groundings and anchor injuries.	This prevents collateral injury and also allows preservation of large pieces of live coral. Does not repair any physical or biological properties.
Limestone Boulders and Modules: Placement of limestone boulders or preformed modules in injury area, stabilized with tremie concrete pour & rebar.	Appropriate for large areas of injured framework, rubble and sediment too copious for removal; requires stabilization in-place. Modules are capable of creating more natural internal void spaces (i.e., caves, tunnels, etc.) thereby more closely replicating the habitat functions of well developed yet highly bioeroded reef structures.	This provides long-term stabilization of substrate and creation of permanent relief. Provides physical restoration only. Given the use of artificial, man-made components, this option is only appropriate on a case-by-case basis.
Revetment Mats: Concrete blocks interconnected by flexible cables. Must be assembled on land and then installed in place from a construction platform, using a crane and spreader bar.	Appropriate for stabilization of large rubble zones in a relatively low energy environment. Revetment mats would likely be used in combination with other alternatives.	Because of bulky nature and the complexities of installation, these are not appropriate for temporary placement to facilitate short-term stabilization. Requires use of manmade materials and results in unnatural appearance.
Reattachment and Transplantation: Facilitate the redevelopment of coral (hard and soft) communities on injured or degraded reefs. Other benthos (such as sponges) may also be reattached and stabilized, typically during emergency restoration.	Used at any site with live coral fragments to save as much live coral as possible. Often used in combination with other structural options. Frequently used after structural restoration to re-create biological characteristics.	Stabilizes fragments to prevent further loss and injury. Reduces live coral loss; once cemented in place, corals recover a majority of their baseline function. Does not reestablish injured framework.
Emerging Biological Technologies: Diadema, recruitment enhancement, electroaccretion.	Potential for use in sites with low live coral cover to "jumpstart" coral growth. Many techniques are not appropriate for use until technology is better tested.	Increases coral cover, coral growth rates, and whole community. Establishes a more stable basis for long-term development of reef.

hole or area of unstable substrate is filled in by pouring concrete to bring it to grade. Such a pour is usually "dressed" with fragments of relict (or live, if available) coral to provide relief, a more natural appearance, and some cryptic habitat. This technique is typically used in combination with others, often the addition of limestone and/or preformed modules, and reattachment.

Limestone Boulders and Preformed Modules

In areas with significant alteration to three-dimensional structure, limestone boulders of appropriate size or preformed concrete and limestone modules can be used to fill depressions and re-create relief. Boulders of varied sizes can be placed in the injured area and then stabilized with underwater concrete that flows and has very low turbidity so it does not mix with the water column (known as a "tremie pour"). The boulders can be stacked so as to replace and recreate some of the relief and rugosity that were destroyed. Plastic composite rebar can be placed in the concrete to improve attachment between the boulders, and between boulder and concrete layers. For larger areas, modules created from a combination of materials, including concrete, limestone boulders, or reef rubble, and steel or composite reinforcing rods, are preferred. Modules are similar to tremied concrete/boulder conglomerate, but are larger and heavier, and they can be designed in a variety of shapes and sizes, depending on the nature of the restoration needs. Once in place, tremie is poured around the modules for stabilization and smaller rocks are placed in the concrete to cover the concrete and blend sharp vertical faces with the surrounding habitat. In addition to creating relief, the greater weight of modules can also be effective at stabilizing underlying framework injury. However, the use of large quantities of manmade material dictates that this option be used sparingly. Situations in which this would be reasonable include destruction of reef spurs or other large framework injury.

Revetment Mats

Revetment mats consist of concrete blocks, usually 1 square foot, interconnected by flexible polypropylene, Kevlar, or similar cables. These mats are usually assembled on land and then installed in place from a construction platform, using a crane and spreader bar. They are relatively flexible structures that conform to the shape of the natural contour. It is uncertain whether revetment mats could crush or crack the underlying reef structure. Situations in which this would be a reasonable alternative include sites with a large rubble zone in a relatively low energy environment where rubble needs to be stabilized and removal is not feasible or recommended. Due to their bulky nature and the complexities of installation, these are not appropriate for temporary placement to facilitate short-term stabilization.

Biological Restoration

Even though structural restoration has traditionally been the focus of coral reef restoration, the length of time required for a coral community to develop can mean that even after the physical environment has been restored the injured site will take many years to resemble (aesthetically and functionally) a mature coral ecosystem. Therefore, ONMS may use biological restoration techniques to enhance the rate at which coral communities re-develop in an injured area.

Reattachment and Transplantation

Fractured, dislodged, and overturned coral, if salvaged before mortality and degradation, can be stabilized via reattachment. Reattachment of live framework coral pieces and transplantation of live scleractinian and gorgonian coral, are effective techniques to facilitate the redevelopment of coral communities on injured or degraded reefs. In addition to on-site coral fragments that can be reattached, there are several other potential donor sources for scleractinian corals, including: at risk coral pieces collected from small or "orphan" groundings and held (cached) until restoration is implemented; corals removed from artificial structures (such as seawalls, piers, or pilings) prior to replacement; corals from within the footprint of proposed and permitted projects (e.g., construction or dredging); and nursery corals that have been grown under controlled conditions expressly for placement back on the reef. This includes on-site underwater nurseries (farms) as well as using coral husbandry techniques in laboratory settings to enhance recruitment, growth, and propagation of key species. Corals reared under laboratory settings must be certified for health prior to release back into the natural environment. The colonies used for transplantation should not be harvested from donors on surrounding reefs; this ensures that restoration is not accomplished at the expense of surrounding habitats.

Gorgonian coral colonies can also be translocated and reattached. Such colonies may be either entire colonies dislodged during the injury event, or clippings from local mature colonies. The branching nature of gorgonians means that clippings can readily be harvested from local donors without causing additional habitat injury or endangering the donor colony. When appropriate, other sessile benthic fauna such as sponges may also be reattached and stabilized. This typically occurs only during emergency restoration. In general, techniques for reattachment of other fauna are less developed than for scleractinian and gorgonian corals.

Reattachment is included as part of many ONMS injury response actions. As long as there are live fragments available, reattachment is appropriate for any injury, either used alone or to complement physical restoration. Reattachment can be accomplished quickly by ONMS staff using small boats, or contractors operating on a larger scale, as required.

Emerging Technologies
Although there are several new techniques currently being developed that should expand the range of alternatives available for restoration, ONMS will only consider techniques with a proven track record (i.e., field-tested and published in peer-reviewed literature) of successful implementation. As new techniques become less experimental, ONMS may consider adopting their use after an appropriate NEPA analysis. Examples of some of these new techniques include electroaccretion (the *in situ* formation of semi-artificial substrate by electrolysis), recruitment enhancement, and community modification.

Rationale for Selection of the Preferred Alternative

After consideration of the criteria for evaluating coral restoration options, the description of the restoration options, and the environmental and socioeconomic consequences, the restoration options below have been selected as the most preferred, depending on site-specific conditions. However, any of the alternatives described in the FPEIS may be appropriate for use on a case-by-case basis, depending on the specific injury parameters.

1. *Debris, Vessel, Sediment or Rubble Removal*: Removal of any loose items—vessel or fishing debris, and any reef material—provides two benefits. First, removal of loose items decreases the potential for future injury from movement and redistribution that can injure existing habitat. Second, it enhances the ability of the habitat to recover by providing more stable and suitable substrate for coral and other benthic colonization. Without adding anything to the reef, completion of this action as soon as possible after injury can provide great benefits for the majority of injuries, particularly the smaller ones. Based on field experience, it is estimated that 50% of restorations will include debris, sediment or rubble removal.

2. *Substrate Stabilization*: The stabilization of loose and fractured reef substrate creates a major benefit by providing stable substrate upon which juvenile corals and other benthic organisms can settle. This is a non-invasive technique that provides maximum benefit through use of stabilizing natural reef material and recreating, to the extent possible, any three-dimensional relief that was lost as a result of the injury. Based on field experience, it is estimated that 80% of restorations will include substrate stabilization.

3. *Reattachment and Transplantation*: Reattachment of corals that were dislodged or fragmented due to an injury has several benefits. First, it preserves natural material and mimics the relief and dimensions of the reef to the extent practicable. Second, it uses the original reef materials, which preserves the biological community, especially if fragments of living coral are reattached immediately after assessment. Based on field experience, it is estimated that 95% of injuries with live coral will require reattachment. Based on field experience, it is estimated that 20% of restorations will include framework reattachment.

These three preferred restoration options are not mutually exclusive. In fact, the majority of injured sites will most effectively be restored by employing at least two options, if not all three. In addition, it must be recognized that the selection of these preferred options is based upon a "typical" injury. As such, the selection of these preferred options does not preclude the use of the other restoration techniques at individual injury sites. Depending on site-specific conditions, other techniques may be most appropriate, especially for larger, more significant injuries, or those in unique habitats. Based on field experience, it is expected that modules and revetment mats will be included in less than 10% of restorations.

Mitigation Measures and Monitoring

Prior to the implementation of any restoration activities, a detailed restoration plan, including any necessary mitigation measures, must be prepared and approved by ONMS. This ensures that the most appropriate methodologies are used, given the nature of the restoration and the environmental circumstances at the injury site. During the restoration activities, mitigation measures would be undertaken to minimize the potential long-term and short-term adverse effects that could result from restoration activities. These measures would be employed at restoration sites as appropriate. If a contractor were used, ONMS resource protection field staff would be onsite at all times during construction to oversee contractor activities in order to minimize and mitigate any potential adverse impacts.

Geology: Precautions will be taken to ensure that vessels and equipment do not contact or injure the seabed or reef framework. Navigation by the construction team within the site area during darkness or periods of reduced visibility is not permitted, and a foul weather and hurricane evacuation contingency plan must be developed to remove work vessels from the reef area if conditions warrant.

Water Resources: Mitigation measures include use of the tremie placement technique to minimize turbidity resulting from concrete placement, inclusion of an anti-washout ingredient in cement mixtures, and avoiding contact with fresh pours to minimize mixture of the cement and water. Any construction contractor hired would be required to comply with all applicable environmental regulations and would be required to have adequate prevention, response and clean-up plans. Turbidity monitoring would take place during implementation as appropriate and required.

Biological Resources: Numerous mitigation measures would be required, including:

- Corals would be temporarily relocated away from the injury site, with transplantation back onto the site once construction is complete.
- ONMS resource protection field staff would oversee the activities of any contractors to minimize potential direct impacts.
- ONMS, and any contractor used, would carefully monitor and oversee construction related activities to minimize injuries to fish, wildlife, and habitat, including *Acropora* species. This includes instructing personnel on the proper procedures for conducting work in this type of habitat.
- Personnel would be required to: prevent any blockage to the movement of manatees, sea turtles, dolphins, porpoises, or whales in the environment; operate vessels at "no wake/idle" speeds when

in shallow waters; and stop work when manatees, sea turtles, or whales move to within 15.2 meters (50 ft) of the construction operation.

- Any contractor used would be required to periodically relocate the barge to prevent coral bleaching.

Infrastructure (Construction and Vessel Moorings)
Consideration would be given to the use of buoyant mooring lines to keep the lines from striking the bottom during loading from wave attack. Substantial anchors, placed off the reef in sand or bedrock areas, might be necessary to resist wave-induced mooring loads. Anchoring and installation of additional mooring buoys may require an ONMS permit. In addition, the contractor would also be required to establish a storm anchor point in deep water. If required, the installation of temporary exclusion buoys could create additional injury, though adherence to standard installation considerations would be required and would limit collateral injury. Adequate, approved disposal options would be required to be available for solid waste.

Cultural Resources
Consideration of known artifacts would be required in any construction plan. Mitigation measures would require that the sanctuary superintendent would be notified immediately if any previously-unknown artifacts were discovered post injury or during restoration. Any such artifacts would be mapped in-place and recovered, if necessary, by a marine archaeologist and then turned over to the sanctuary if they came from federal waters, or to the state if they came from state waters, to be conserved following accepted conservation standards in accordance with federal and state standards.

Hazardous and Toxic Substances
Spill prevention, response and clean-up plans would be developed for approval by ONMS prior to the restoration activity. The plan would include spill response actions and delineate the remediation activities of responsible parties. Additionally, the contractor would be required to comply with all applicable federal, state, and local regulations governing environmental pollution control and abatement.

Socioeconomics
ONMS would request that the public avoid the area during restoration activities to ensure public safety, and would ensure that appropriate notice was given to the public to use alternative locations. Only construction-related persons/activities would be allowed on site.

Daniel J. Basta, Director
Office of National Marine Sanctuaries

January 21, 2011
Date