STATE OF DEEP CORAL ECOSYSTEMS IN THE GULF OF MEXICO REGION: TEXAS TO THE FLORIDA STRAITS

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I. INTRODUCTION

This report provides a summary of the current state of knowledge of deep (defined as >50 m) coral communities that occur on hard-bottom habitats in the Gulf of Mexico region, For the purposes of this report, the Gulf of Mexico region includes the waters within the U.S. exclusive economic zone (EEZ) of Texas, Louisiana, Mississippi, Alabama, and Florida as far north as Biscayne Bay on the East Coast (Figure 7.1), which includes the Pourtales Terrace and part of the Miami Terrace. The spatial distribution of deep coral species and their associated fauna are placed in the context of the geology and hydrography of three sub-regions, all of which have extensive deep coral communities, but with very different biological structure. The sub-regions are: (1) the northern Gulf of Mexico (2) the west Florida shelf and slope, and (3) the Florida Straits. The structure of the report follows the primary hydrographic flow from west to east through the Gulf of Mexico and into the Florida Straits. Threats affecting these communities, management and conservation concerns, and research needs are also discussed.

The most extensively documented coral habitats in the Gulf of Mexico are within the Flower Garden Banks National Marine Sanctuary (FGBNMS), which is located approximately 160 km south of the Texas/Louisiana border. Since the inception of the sanctuary, most of the research has been focused on communities within SCUBA depths at the East and West Flower Garden Banks and Stetson Bank. Over the past few years however, investigation into the deeper habitats on the shelf, both within and outside the sanctuary boundaries, has expanded knowledge of the biological communities that are found below SCUBA depth limits. Extensive high-resolution multibeam mapping surveys have been conducted by NOAA, MMS and USGS, on select reefs and banks in the region (http://walrus.wr.usgs.gov/pacmaps/wg-index.html), and this information has facilitated focused ROV and manned submersible operations.

The deep shelf and slope regions of the northern Gulf of Mexico have been extensively mapped and surveyed during exploration for oil and gas deposits, which led to the discovery and subsequent research on chemosynthetic communities associated with hydrocarbon seepage. The substrate in the deep Gulf of Mexico is principally comprised of fine particulates; however, large amounts of authigenic carbonate deposits are precipitated from biogeochemical activity associated with hydrocarbon fluid seepage (Schroeder 1992). Authigenic carbonates provide hard substrate for a wide variety of benthic fauna, including the structure-forming scleractinian, *Lophelia pertusa.* In 1955, Moore and Bullis collected large quantities of *L. pertusa (=prolifera)* in 420 to 512 m of water from the northeastern continental slope approximately 74 km east of the Mississippi River delta (Moore and Bullis,1960). More recently, reports of living *L. pertusa* in the Gulf of Mexico are available from publications (Cairns 1979, 2000, Cairns and Viada 1987, McDonald et al. 1989, Schroeder 2002, Schroeder et al. 2005), and records from the National Museum of Natural History Taxonomic Database. Recent research expeditions conducted between 2000-2004 (funded by NOAA's office of Ocean Exploration and the Minerals Management Service) represent some of the first scientific submersible and remotely operated vehicle (ROV) dives in these areas, and they provide considerable new information on the distribution, habitat and biodiversity of deep coral communities in the Gulf of Mexico (Continental Shelf Associates, in review)

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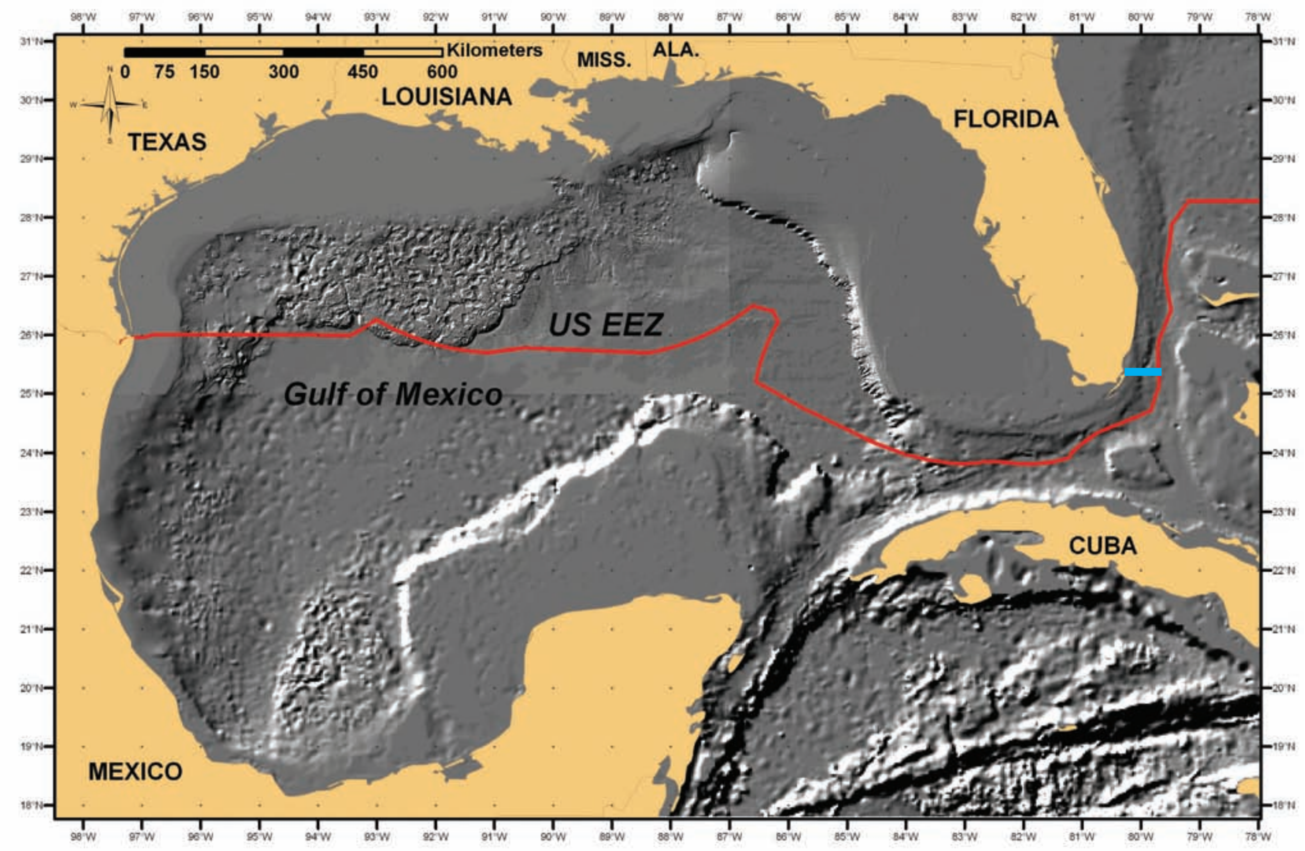

Figure 7.1 Map of the Gulf of Mexico and Florida, showing the Exclusive Economic Zone (EEZ) boundary. The Gulf of Mexico regional chapter covers deep water coral habitat enclosed by the red EEZ boundary and does not extend beyond the blue line. Map credit: Flower Garden Banks National Marine Sanctuary (FGBNMS)

Little is known about the ecology of the west Florida slope, although Collard and D'Asaro (1973) documented many benthic invertebrates of the eastern Gulf of Mexico from extensive dredging surveys, and Cairns (1978) compiled a comprehensive list of ahermatypic scleractinia for the entire Gulf of Mexico. Almost a decade later, Newton et al. (1987) described the coral mounds of the west Florida slope at depths of 500m. They found *L. pertusa, Madrepora oculata* and *Bathypsammia sp,* but none of their coral samples were living. More recent exploration of this area by Reed et al. (2004, 2005b, 2006b) has expanded our descriptive knowledge of the fauna, but ecological questions remain unanswered.

Near the western end of the Straits of Florida, the Tortugas and Agassiz Valleys exhibit hard-bottom habitats and high-relief escarpments at depths of 512-1,189 m (Minter et al. 1975). Deep, hard substrates may also exist in 500-1000 m depths on the Tortugas Terrace, 80 km west of the Dry Tortugas (Uchupi, 1968), but the fauna of these areas have not been explored. In the southern Straits of Florida and at the southern end of the Florida carbonate platform, the Pourtales Terrace provides extensive, high-relief, hard bottom habitat, at depths of 200-450 m. Louis de Pourtales discovered the feature in 1867 during a survey aboard the U.S. Coast Survey ship *Bibb* to lay a telegraph cable from Key West to Havana (Jordan et al., 1964). Alexander Agassiz (1888) named this feature the Pourtales Platform, and Jordan and Stewart (1961) later renamed it the Pourtales Terrace. Jordan (1964) discovered large sinkholes on the Pourtales Terrace. Land and Paull (2000) mapped and described nine of these sinkholes using side-scan sonar, seismic profiler, and echo-sounder profilers aboard the U.S. Navy's submersible NR-1. Reed et al. (2005) also described the fish and invertebrate communities associated with high-relief deep-water structures and deep-water sinkholes on the Pourtales Terrace using the *Johnson Sea-Link* submersible.

II. GEOLOGICAL SETTING

The Gulf of Mexico basin consists of many different topographic features. The continental shelf slopes gradually to depths between 100 and 200 m. The widest point is off southern Florida (about 300 km wide) and narrowest is at the Mississippi Delta (10 km). The continental shelf off west Florida and the Yucatan are carbonate with some complex topographic features; the eastern Gulf of Mexico and Texas-Louisiana shelves are primarily composed of terrigenous sediments. In the northern Gulf of Mexico, the Mississippi and Bryant submarine fans and the flat Sigsbee Abyssal Plain give way to the complex slump structure of the East Mexican Slope and the extremely complex topography of the Texas/Louisiana continental slope (Rowe and Kennicutt 2001). This section briefly describes the geology of each region to provide context for the more detailed description of their biological communities.

Northern Gulf of Mexico

The middle and outer portions of the Texas/Louisiana shelf are scattered with intermittent banks of various depths and shape. These are usually comprised of carbonates, with silt and clay, overlying raised salt diaper structures (Rezak et al. 1985). These banks all support hard bottom communities, with different levels of complexity, but the most well known and ecologically well developed are the Flower Gardens Banks, which are situated on top of salt domes rising from approximately 130 m to 20 m depth (Figure 7.2). Salt domes began to form 160-170 million years ago when salt layers were deposited in what was then a shallow sea, and subject to evaporation. In subsequent years, deep layers of sediments were deposited over the salt layers. Eventually, internal pressures became great enough to push isolated pockets of salt up through the sediments, forcing the seafloor to bulge upward in distinct domes. The Flower Gardens coral reef communities began developing on top of the domes 10,000 to 15,000 years ago and have now overgrown the bedrock on which they developed.

The continental slope off Texas, Louisiana, and portions of Mississippi is geologically and physiographically one of the most complex in the world. Over ninety basins and seven submarine canyons dissect the continental margin of the northwestern Gulf of Mexico. Major portions of the middle and lower slope appear to be devoid of gas seeps, while the upper slope contains salt diapiric structures (such as mud and gas mounds), fluid expulsion features, hard-grounds, erosional gullies, numerous gas seeps and gas hydrate deposits. Deposits of authigenic carbonate, produced as a byproduct of chemosynthetic activity, provide hard substrate for development of sessile benthic communities, many of which are coral-dominated (Figures 7.3a, b). Eroded into the complex topography of the Texas/Louisiana slope, are four major canyon systems: the Mississippi, Keathley, Bryant, and Alaminos Canyon (Rowe and Kennicutt 2001). In the eastern portion of the region, sediments

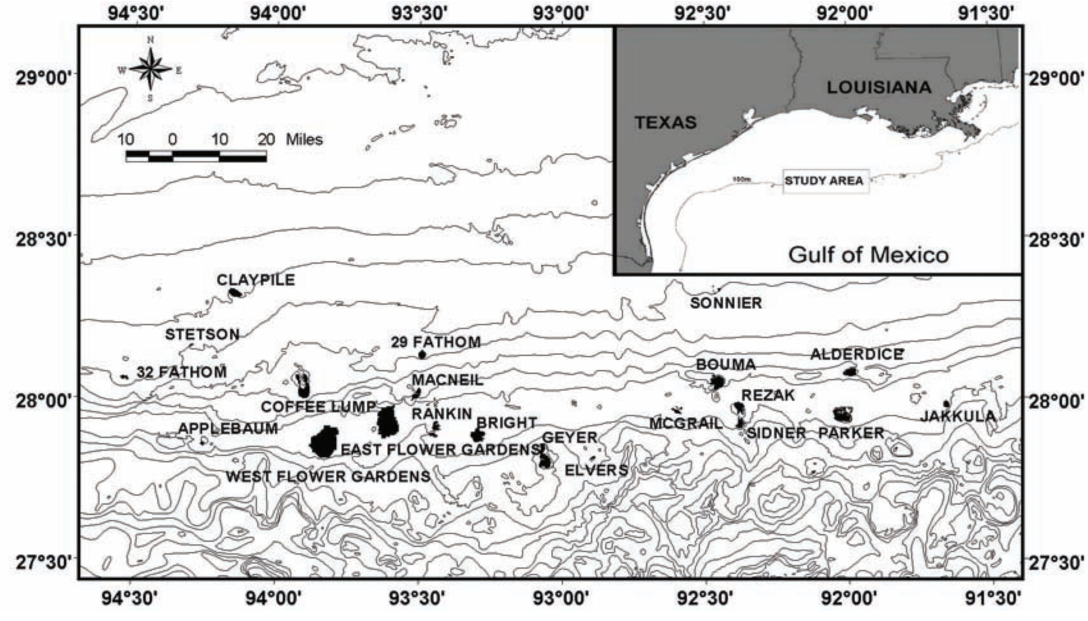

Figure 7.2. Map of the Flower Gardens area showing the location of the many reefs and banks in this area. Map credit: Resek et al. 1985.

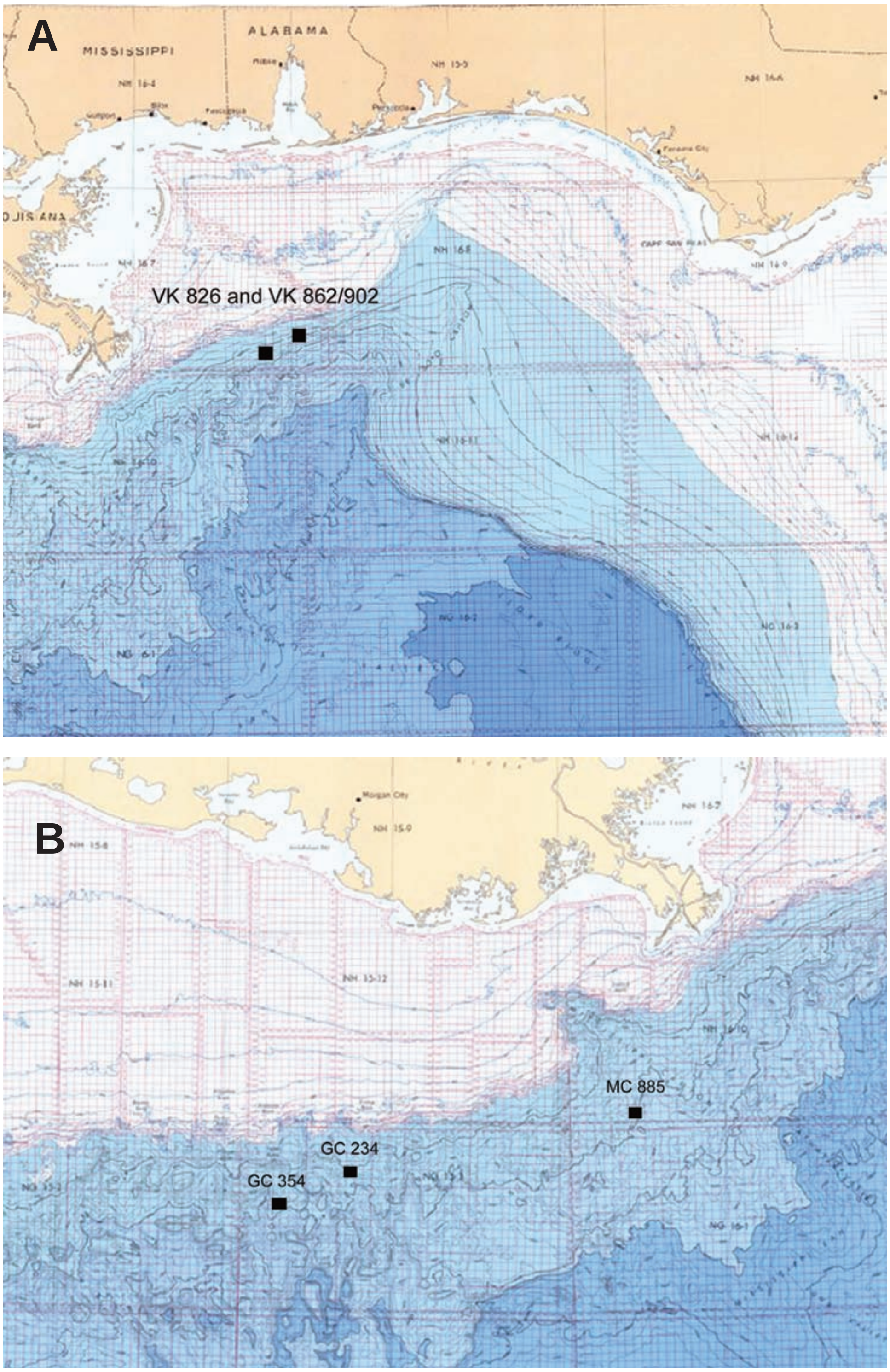

Figure 7.3. Bathymetric map of the Gulf of Mexico showing known areas of abundant coral habitat. Chart from NOAA, NOS Bathymetric maps 1986. Scale 1:100,000. A) Viosca Knoll sites: dense *L. pertusa* and other coral colonies at both VK826 and VK862/906. Map credit: OIMB for the U.S. Minerals Management Service (MMS).
B) Mississippi Canyon and Green Canyon sites: MC885 is comprised of large fields of *C. americana delta* and the Green Canyon sites support well developed *L. pertusa*. Map credit: OIMB for MMS.

from the Mississippi cover the western edge of the Florida shelf and a transition towards carbonate sediments begins. The Florida escarpment separates the Florida shelf from the Gulf Basin and also forms the southeastern side of the Desoto Canyon. In a region of high sediment deposition, the presence of the Desoto Canyon is poorly understood (Gore 1992). Some theories suggest that the canyon is the result of erosion caused by oceanic currents, possibly the Loop Current (Nowlin 1971).

West Florida shelf and slope

The west Florida shelf is a gently sloping (1-2^o) broad carbonate platform that extends 750 km from Desoto Canyon in the north to the western Straits of Florida (Holmes, 1981). Along the edge of the west Florida shelf there is a series of "drowned reefs" or fossil reefs" at water depths ranging from approximately 50 m to over 120 m. In the northern region, small areas of the shelf have been designated as protected areas (Madison Swanson, Steamboat Lumps) by

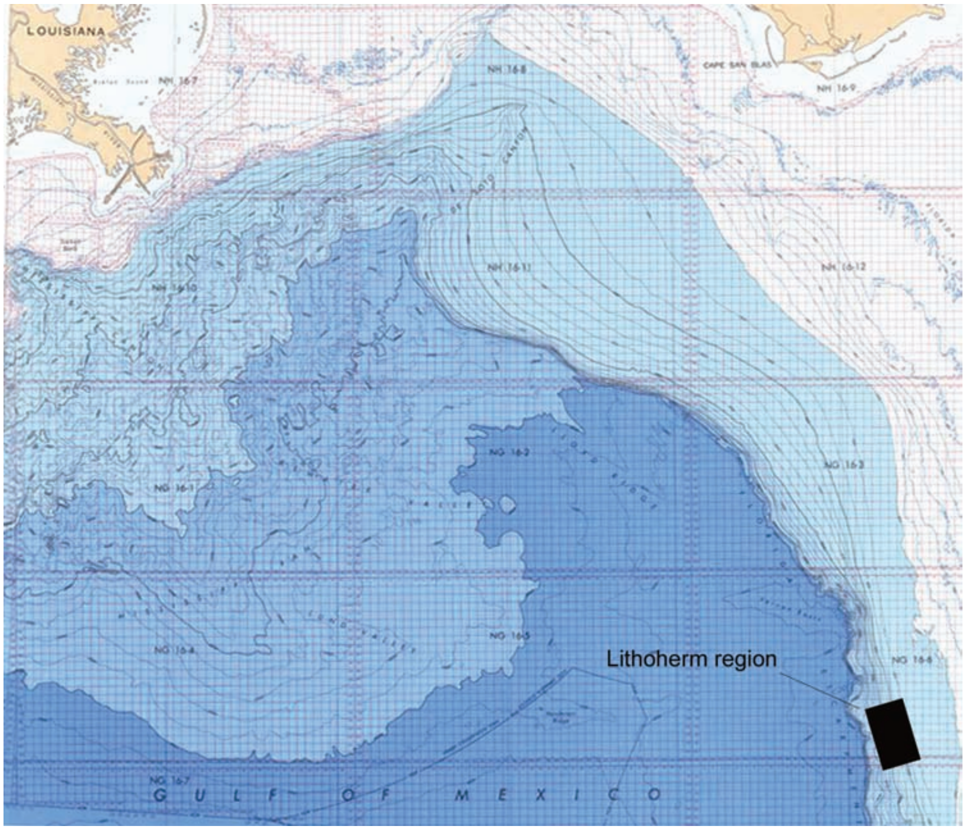

Figure 7.4a. Map of the eastern Gulf of Mexico showing the location of *Lophelia* lithoherms on the southwest Florida Slope (Reed et al. 2006). Scale 1:100,000. Map credit: NOAA, NOS Bathymetric maps 1986.

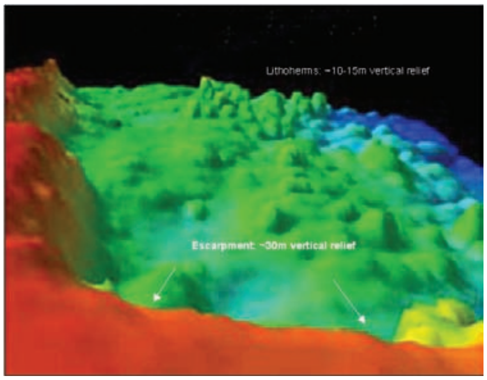

Figure 7.4b. Seabeam image of a southward view of the SW Florida Slope lithoherms (x2 vertical exaggeration). Image credit: Reed et al. and NOAA-OE.

the National Marine Fisheries Service (NMFS) on the recommendation of the Gulf of Mexico Fisheries Management Council (GMFMC) to preserve declining reef fish populations. on the southwest shelf edge, the shallowest of these ancient reefs, is Pulley Ridge, which is approximately 200 km long and supports well-developed communities of zooxanthellate scleractinian plate corals and other hard-bottom fauna at depths of 60-70 m. This area has been protected from bottom fishing to protect the fragile benthos, which is currently the deepest known hermatypic reef complex in U.S. Atlantic waters. Seaward of the shelf, at the 500m isobath on the southwest Florida slope is a 20 km long zone of high-relief (10–15 m) Pleistocene coral mounds (Figure 7.4a). This region was first recognized from high resolution seismic reflection profiles during a cruise on the *R/V Cape Hatteras* in 1984 and consists of dozens and possibly hundreds of lithoherms (Figure 7.4b) composed of rugged black phosphorite-coated limestone boulders and outcrops (10- 15 m in height), some of which are capped with thickets of *Lophelia* coral (Newton et al. 1987, Reed et al. 2004, Reed et al. 2006b). A deepwater sinkhole (200m) has also been described in detail from submersible dives off the west Florida shelf (Reed et al. 2005b). The Florida slope then grades into the Florida Escarpment, which extends from depths of 2500–3280 m into the eastern Gulf of Mexico. The face of the escarpment has steep vertical limestone cliffs of Cretaceous age, with intervening sediment-covered planes that provide habitat for dense chemosynthetic communities (Paull and Neumann 1987, Paull et al. 1990, 1991).

Florida Straits

Two Miocene-age terraces, the Miami Terrace and Pourtales Terrace, occur off southeastern Florida and the Florida Keys reef tract. The Pourtales Terrace is a large triangular area over 213 km in length that runs parallel to the Florida Keys (Figure

7.5). The terrace is the drowned southern end of the Florida carbonate platform covering 3,429 km^2 at depths of 200-450 m. The terrace provides extensive, high-relief, hard-bottom habitat with as much as 120 m vertical relief. The eastern section is comprised of a band of irregular topography and has the greatest relief on the terrace. The central section is flat with no topographic features. The southwest margin of the terrace contains a series of sinkholes that extend for approximately 100 km off the lower Florida Keys (Jordan and Stewart 1961, Jordan et al. 1964, Land and Paull 2000). One of these, the Jordan Sinkhole, has a vertical relief of 206 m and may be one of the deepest and largest sinkholes known. The Jordan and Marathon sinkholes were described in detail from submersible dives by Reed et al. (2005b). The middle and eastern portion of the Pourtales Terrace consists of a northeasterly band of karst-like topography, with depressions, flanked by knolls and ridges that extend up to 91 m above the terrace (Jordan et al. 1964, Land and Paull 2000). Further to the northeast is another zone of 40m high topographic relief that lacks any regular pattern (Gomberg 1976, Reed 2004). There are many high-relief bioherms (up to 120 m vertical relief) in this area, including a region called "The Humps" by local fishers, which is approximately 26 km south of Alligator and Tennessee Reefs in the Florida Keys (Reed 2004, Reed et al. 2005b).

III. OCEANOGRAPHIC SETTING

The Gulf of Mexico is a semi-closed basin of approximately 1.5 million km^2 with the continental shelves surrounding a deep abyss with maximum depths of approximately 3400 m in the eastern portion and 3700 m in the western portion. The surface waters of the Gulf of Mexico have been studied in great detail, but there is comparatively little information on circulation below 1000 m. Direct current measurements were rare (e. g., Pequegnat 1972, Hamilton 1990) until recently (Inoue et al. 2002, Hamilton and Lugo-Fernandez 2001). The dominant hydrographic feature in the Gulf of Mexico is the Loop Current, which is formed when the Yucatan Current intrudes northward into the Gulf of Mexico from the Caribbean, flows clockwise around the basin, and empties into the Straits of Florida.

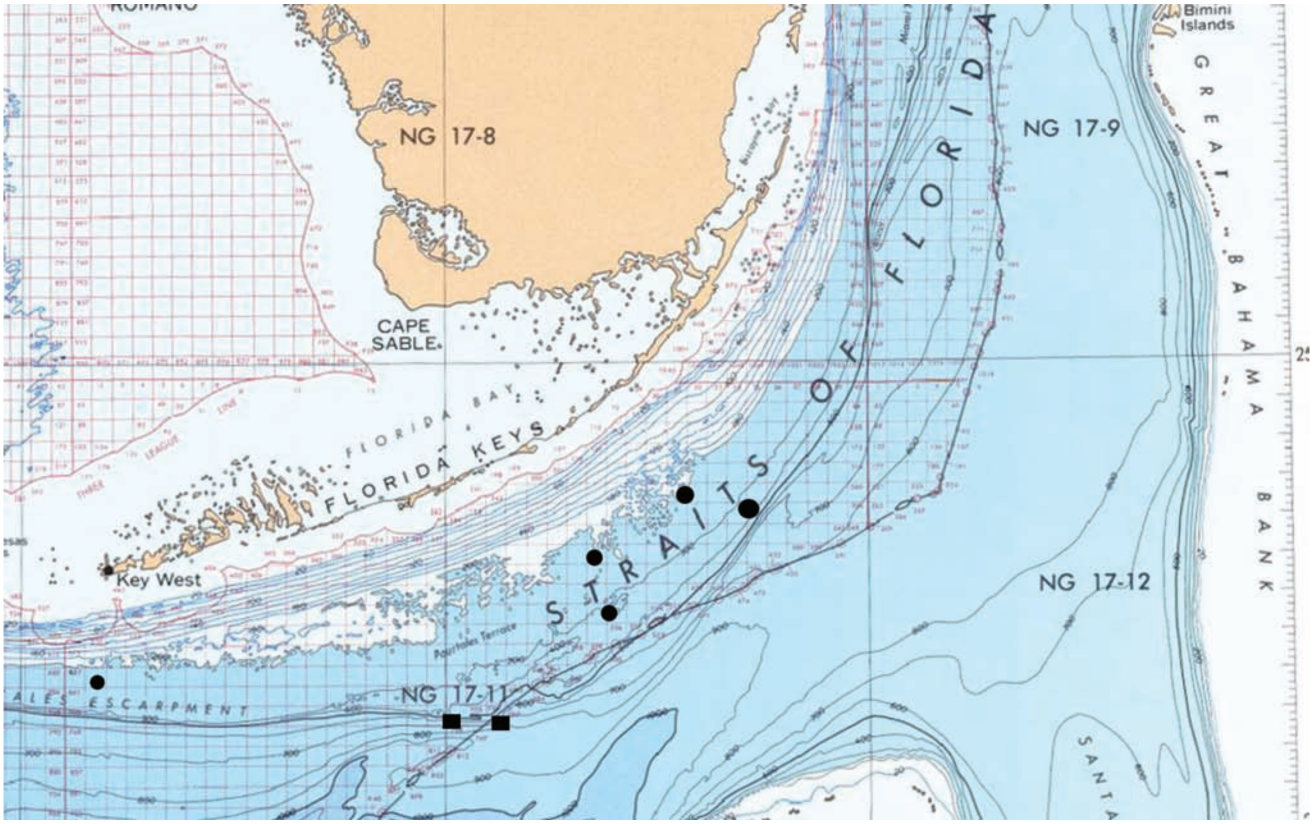

Figure 7.5. Chart of the Straits of Florida showing the Pourtales Terrace. The lithoherms are marked with black circles and the Jordan and Marathon sinkholes with black squares.(from Land and Paull 2000, Reed 2005b). Scale 1: 100,000. Map credit: NOAA, NOS Bathymetric maps 1986.

Northern Gulf of Mexico
While the Loop Current and associated rings are the major energetic currents in the Gulf of Mexico, creating extremely complex shelf and slope circulatory patterns, several other classes of energetic currents have also been observed in the deep waters of the Gulf (Bryant et al. 2000). Data collected in 1999 using the Texas A&M University (TAMU) deep-tow seismic system showed evidence of a large field of sedimentary furrows running along the base of the Sigsbee Escarpment in the Bryant Canyon area of the northwestern Gulf of Mexico (Bryant et al. 2000). Submarine furrows have been previously observed along the Blake Bahama Outer Ridge, the Bermuda Rise, the Brazilian Margin, and several other localities (see review by Flood, 1983), but the huge extent of the furrows observed in the northwestern Gulf of Mexico is unprecedented. Near-bottom current meters deployed near the base of the Sigsbee Escarpment (1978 m) have recorded flow events with velocities of more than 85 cm s^{-1} at 2000m (Hamilton and Lugo-Fernandez, 2001), during loop current eddy shedding. The effect of these strong deepwater flows on slope and shelf currents and their benthic communities is unknown and warrants further research.

West Florida Shelf and Slope
The Loop Current dominates the circulation in the eastern Gulf of Mexico and anticyclonic rings spawned by the Loop Current move west and south (Rowe and Kennicutt 2001). The Loop Current creates a vigorous north-south flow in the eastern Gulf of Mexico and as it migrates laterally over the west Florida shelf, it produces temperature variations at shallow to intermediate depths (50-500m), both seasonally and over longer time scales (Leipper et al. 1972).

Florida Straits
The Loop Current is joined in the Florida Straits by waters passing through the Old Bahama Channel to form the Florida Current, which in turn joins the Antilles Current in the Atlantic to form the Gulf Stream. Currents associated with the Loop Current can extend to great depths in the Florida Straits. High current speeds (>100 cm s^{-1}) were observed at 200 m on the Pourtales Terrace (Reed at al. 2005b). Prior to this observation, lower speeds of 10 cm s^{-1} had been recorded at 500 m depth (Cooper et al. 1990), but these persisted at one location for weeks to months. Strong current events have also been observed below 1000 m, suggesting that the Loop Current and eddies influence the hydrodynamics of the deepest portions of the Gulf of Mexico (Hamilton 1990).

IV. STRUCTURE AND HABITAT-FORMING DEEP CORALS

The Gulf of Mexico has distinct regional differences among faunal communities (Table 7.1). These include hermatypic corals in the shallower (<50 m) salt dome and carbonate shelf habitats, *Lophelia*-dominated communities on the hard substrate of the northern and eastern slope (>200m). Gorgonians and antipatharians are present to various degrees in all habitats but are primary structure-forming coral taxa in parts of the deep slope habitats in the northern Gulf of Mexico, on the shelf between 50-150 m, associated with hardbottom features in and around the reefs and banks, and in parts of the deep slope habitats. Stylasterid hydrocorals are locally abundant on the Florida carbonate shelf and provide some structure but do not form large thickets. Three species of Pennatulacea (sea pens) have been recorded from the northern Gulf of Mexico (National Museum of Natural History (NMNH) database) but do not form significant structural habitat as in some other regions. There are also over 40 species of cup corals present throughout the Gulf of Mexico (Appendix 1), but again, these do not contribute greatly to habitat structure.

a. *Stony corals* (Class Anthozoa, Order Scleractinia)

The dominant azooxanthellate colonial scleractinian coral in the deep (>100m) Gulf of Mexico is *Lophelia pertusa.* Extensive thicket development occurs in the northern Gulf of Mexico, the southwest Florida lithoherms and on parts of the Pourtales and Miami Terraces (Schroeder 2002, Reed et al. 2005b, Reed et al. 2006). The most extensive *L. pertusa* habitat in the northern Gulf of Mexico is situated within the Minerals Management Service lease block Viosca Knoll 826. Further details are given below in the section on spatial distribution of coral species and habitats. The *L. pertusa* colonies found in the Gulf of Mexico exhibit two different morphologies; a heavily calcified thick branching structure which is seen at the Viosca Knoll area and a more fragile form with shorter internodes that is found elsewhere (Figure 7.6). An extensive study of *L. pertusa* habitats in the northern Gulf of Mexico, funded by the Minerals Management Service, was completed in 2005 (Continental Shelf Associates in review). This study addressed various aspects of *L. pertusa* biology and ecology, including *in situ* growth of stained colonies, timing of gametogenesis, tolerance a range of sediment loads and temperatures, and community characterization. The staining experiment showed that *L. pertusa* growth was highly variable (some polyps grew and produced multiple new polyps, but others on the same branch did not grow at all) but on average the linear extension was between 2.4-3.36 mm yr^{-1}. This is slightly lower than published growth data (e.g. average linear extension of 5.5 mm yr^{-1} by Mortensen and Rapp 1998), but was measured for the heavily calcified morphotype, which may be different from the more fragile growth forms. The gametogenic cycle of *L. pertusa* in the Gulf of Mexico is of similar duration to those in the Eastern Atlantic but is offset by several months. In the fjords of Norway, *L. pertusa* spawns in late February/early March and the subsequent gametogenic cycle has already begun before the prior cycle ends (Brooke and Jarnegren unpublished). In the Gulf of Mexico, mature oocytes were found in early September and primary oocytes in November, which indicates that spawning occurs sometime in October (Continental Shelf Associates in review). The causes of the difference in timing of reproduction are unknown and warrant further investigation. Temperature tolerance experiments showed that *L. pertusa* can survive for short periods of time at temperatures as high as 20° C for 24 hours, but long term survival requires a temperature between 10° C and 15° C. This corresponds to published observations that the upper thermal limit of *L. pertusa* distribution is approximately 12° C (Rogers 1999). Sediment experiments conducted in the laboratory (Continental Shelf Associates in review) show that *L. pertusa*

Table 7.1. Structure-forming attributes of deep corals in the Gulf of Mexico region

Taxa	Reef-building	Abundance	Maximum colony size	Morphology	Associations with other structure forming invertebrates	Colony spatial dispersion	Overall rating of structural importance
Lophelia pertusa	Yes	Medium	Large	Branching	Many	Solitary/ Clumped	High
Madrepora oculata	No	Low	Large	Branching	Few	Solitary	Medium
Callogorgia americana delta	No	Medium	Large	Branching	Few/Many	Solitary/ Clumped	Medium
Isididae	No	Medium	Medium/ Large	Branching	Few/Many	Clumped	Medium
Other Alcyonacea	No	Medium	Medium/ Large	Branching	Few/Many	Solitary/ Clumped	Medium
Antipathidae	No	Medium	Large	Branching	Few/Many	Solitary/ Clumped	Medium
Stylasteridae	No	High (Florida Straits)	Small	Branching	Many	Solitary/ Clumped	High (Florida Straits)

Table Key	
Attribute	**Measure**
Reef-Building	Yes/No
Relative Abundance	Low/ Medium/ High
Size (width or height)	Small (<30cm)/ Medium (30cm-1m)/ Large (>1m)
Morphology	Branching/ Non-branching
Associations	None/ Few (1-2)/ Many (>2)
Spatial Dispersion	Solitary/ Clumped
Overall Rating	Low/ Medium/ High

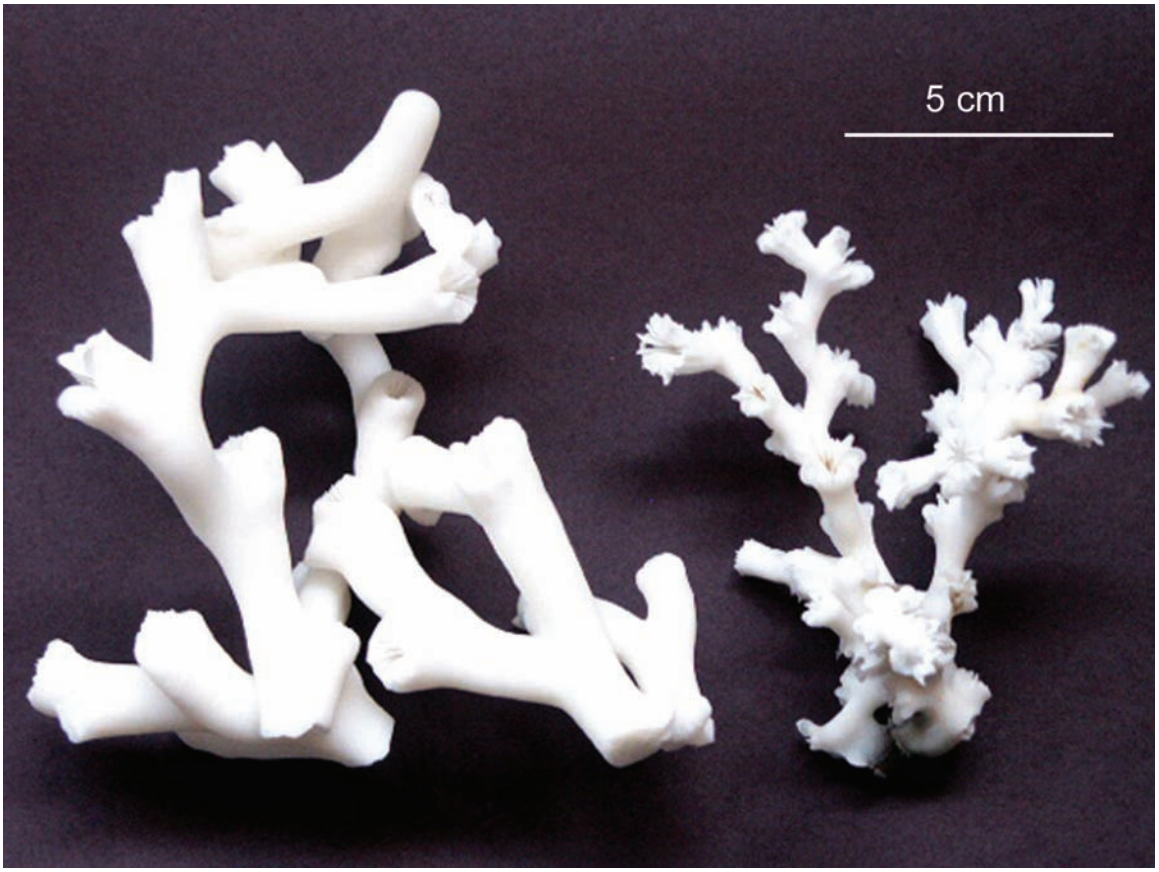

Figure 7.6. Samples of *Lophelia pertusa* colonies collected from the Gulf of Mexico showing (left morph) heavily calcified morphology (brachycephala) with large polyps from VK826, and (right morph) fragile morphology (gracilis) from GC354. Photo credit: S. Brooke OIMB.

could tolerate sediment loads of 54 mg L^{-1} for up to 2 weeks with approximately 90% survival, but increasing the sediment load to 103 mg L^{-1} caused almost 50% mortality over the same time period.

Other colonial species found in this region include *Madrepora oculata* (Linnaeus 1758), which forms large individual colonies on authigenic carbonate boulders in the northern Gulf of Mexico (Figure 7.7), but unlike *L. pertusa,* does not form monospecific coral stands and does not co-occur with *L. pertusa* thickets as habitat forming structure. M*adrepora carolina* has also been recorded from the northern Gulf of Mexico and the Florida Straits (Cairns 1979). In addition, *Solenosmilia variabilis* and *Enallopsammia profunda* are found on the carbonate slope habitats in the eastern Gulf of Mexico, but the extent of either species is unclear.

In addition to these azooxanthellate scleractinian corals, there are areas in the Gulf of Mexico where zooxanthellate coral reefs have been found at depths greater than 50m. These areas include the reefs of the East and West Flower Gardens Banks and the unique communities at McGrail Bank, which are dominated by *Stephanocoenia* sp. (Schmahl and Hickerson 2006). Zooxanthellate structure-forming scleractinians are also found on Pulley Ridge on the southwest Florida shelf, where zooxanthellate corals such as *Agaricia* sp., thrive at depths of 60-70m. Since these are not true deepwater corals, but rather shallow water species that have extended into deeper water, they will not be addressed in detail in this report.

b. *Black corals* (Class Anthozoa, Order Antipatharia)

At least 20 species of antipatharians have been documented for the Gulf of Mexico region (Appendix 1) with at least half of these identified from the Flower Gardens Banks area. Other samples have been collected and are awaiting identification or description (S. Brooke pers. obs.). Black corals are locally very common in some areas of the northern Gulf of Mexico and the Florida Straits. Some species grow into large bushy colonies (eg *Leiopathes*

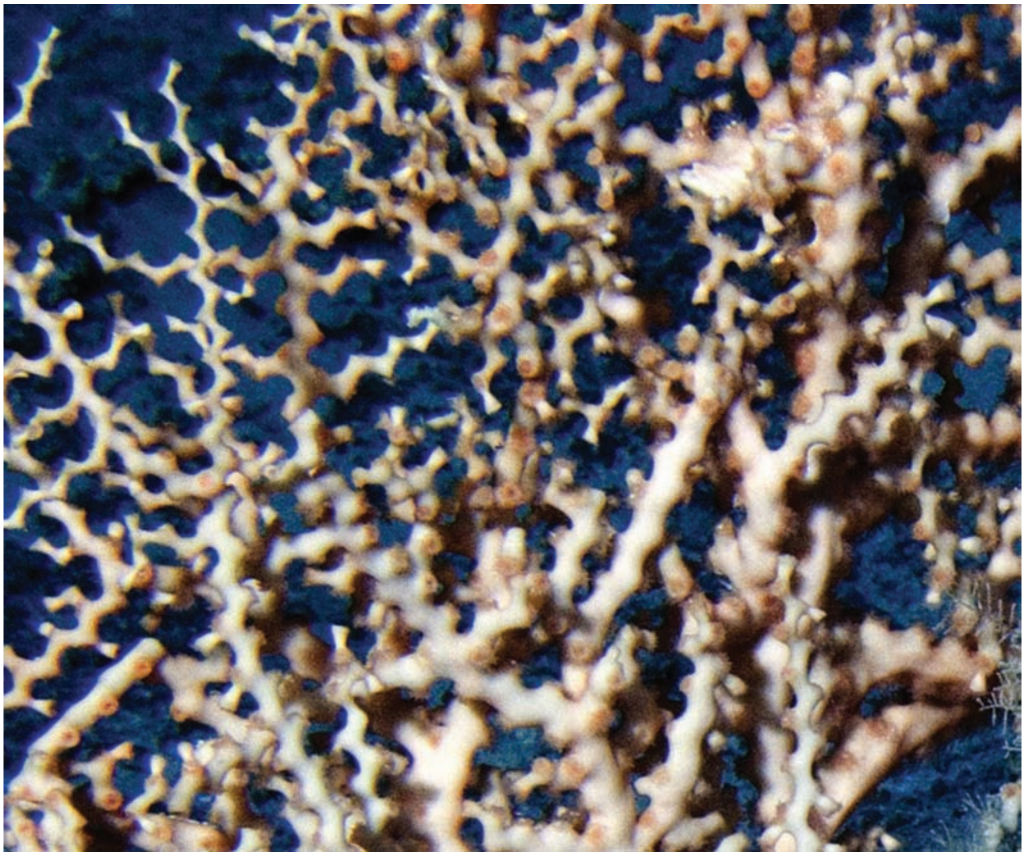

Figure 7.7. Large colony of *Madrepora oculata* showing distinctive zig-zag branch morphology. Photo credit: Brooke et al. and NOAA-OE

sp.*)* which may provide substrate and refuge for other organisms. Unlike some of the other taxa, there seems to limited geographical separation in the distribution of most of the species. Exceptions to this observation are the *Leiopathes* species, which were only documented for the northern Gulf of Mexico. Three colony colors (red, orange and white) have been collected and deposited at the National Museum of Natural History, but it is still unclear whether they are conspecific color morphs or distinct species (D. Opresko pers.comm.). The most thorough investigation on reproduction of black corals was conducted on *Antipathes fiordensis* from the southwestern New Zealand Fjords (Parker et al. 1997). Colonies were gonochoristic, and gametogenesis was rapid and synchronous, beginning in November and terminating in March. Colonies reached sexual maturity between the heights of 70 and 105 cm which corresponded to a minimum age for sexual maturity of about 31 yr. Such information is not available for the deep Gulf of Mexico species therefore it is unknown whether late reproductive maturity is a characteristic of this taxa.

c. *Gold corals* (Class Anthozoa, Order Zoanthidea)

Gold corals are not known in this region.

d. *Gorgonians* (Class Anthozoa, Order Alcyonacea)

There are numerous species of octocorals in the deep waters of the Gulf of Mexico (many of which are still unidentified), the majority of which belong to the family Plexauridae; however Cairns and Bayer (2002) have identified several species of the habitat-forming primnoid *Callogorgia* spp. occurring throughout the Gulf of Mexico. At least one subspecies, *Callogorgia americana delta* is endemic. Most of these species contribute to multi-species coral habitats, but some occur as dense monotypic assemblages in localized areas in the northern Gulf of Mexico. These include the bamboo coral *Acanella arbuscula* (family Isididae) and *C. americana delta*, which is known to provide nursery habitat for oviparous cat sharks that deposit their egg cases on the branches (Etnoyer and Warrenchuck in press, S. Brooke pers. obs.), and is often seen with large fleshy ophiuroids (*Asteroschema* sp.) entangled in the colonies (Figure 7.8). A list of octocorals found in the Gulf of Mexico region can be found in Appendix 1. A comprehensive octocoral species inventory is currently being updated by Dr. S. Cairns of the National Museum of Natural History for publication in 2007. Gorgonians are an important component of the shelf edge reefs and banks of the northwestern Gulf of Mexico between 50 and 120m depth, and the FGBNMS research team is developing catalogs of octocorals, antipatharians and sponges found on these features (E. Hickerson pers.comm.). Despite being an important component of many deepwater hard-bottom communities, octocoral biology is not well understood. A study of reproduction in multiple species of common deepwater octocorals is currently underway (Simpson, pers.comm.). Information to date shows that there is variation in reproductive strategy within this order (Fitzsimmons–Sosa et al. 2004, Brooke unpublished data).

e. *True soft corals* (Class Anthozoa, Order Alcyonacea)

Several species of soft corals have been documented for this region (Appendix 1). *Anthomastus* (*Bathyalcyon) robustus delta* was often found in hardbottom habitats of the northern Gulf of Mexico at ~274m and at shallower depths (50-135m) *Chironepthya (=Siphonogorgia) caribaea* was encountered regularly in surveys of hardbottom areas in the NW GOM (E. Hickerson pers. comm.). None of the soft coral species contribute significantly to habitat structure since they neither form large colonies nor have solid skeletons. Very little is known about the biology of these taxa.

f. *Pennatulaceans* (Class Anthozoa, Order Pennatulacea)

There are at least two species of pennatulaceans recorded for the Gulf of Mexico, and these were collected at greater depths (2683m) than the majority of the other cnidaria in the region (NMNH database). These taxa are often found on soft substrate and are the dominant benthic fauna in some areas (e.g. *Halipteris willemoisi* in Alaska); however there is insufficient information on distribution and abundance to determine whether this is the case for the pennatulaceans in the Gulf of Mexico.

g. *Stylasterids* (Class Hydrozoa, Order Anthoathecatae, family Stylasteridae)

Stylasterid hydrocorals are common components of the benthic communities of the bioherms and sinkholes of the Florida Straits, and the SW Florida shelf lithoherms, but have not been recorded in

Figure 7.8. *Callogorgia americana delta*, a gorgonian from the northern Gulf of Mexico, showing *Euryalid ophiuroids* entwined in the branches. Photo credit: OIMB for MMS.

the northern Gulf of Mexico basin. Stylasterids are usually absent from areas with high suspended-sediment, which may be detrimental to both juvenile and adult colonies (Ostarello 1973, Cairns 1992). They generally have slow growth rates, long life, and brooded larvae, and may be out-competed by more aggressive species in high nutrient waters, finding refuge in low nutrient and/or less competitive environments such as cryptic and deep-water habitats (Sanders 1979, Thayer 1989, Cairns 1992). A list of stylasterid species currently documented for the Gulf of Mexico, is presented in Appendix 7.1. Taxonomic descriptors follow revisions of the taxa by Cairns (1986). Dense communities of stylasterids have been observed on the bioherms of the central and eastern Pourtales Terrace, primarily along the tops and flanks of the structures (Reed et al. 2005b) and thick piles of dead and live stylasterid colonies were observed in some locations, but without coring the interior, it was not possible to ascertain how much contribution these stylasterid colonies made to the accumulation of the bioherms. Stylasterids are also one of the dominant sessile taxa of the southwest Florida Shelf *Lophelia* lithoherms (Reed 2004, Reed et al. 2006b)

V. SPATIAL DISTRIBUTION OF CORAL SPECIES AND HABITATS

The distribution of coral communities in the Gulf of Mexico region can be divided by geologic setting and depth. Dozens of reefs and banks are scattered across the shelf edge of the Gulf of Mexico, particularly in the northwestern region. Many of these features are formed by salt diaparism, which have pushed the sediments up into the photic zone. On the shallowest of these domes, zooxanthellate coral reefs and coral communities have developed, and are flanked by diverse communities of octocorals, antipatharians, and sponges. Authigenic carbonate deposits

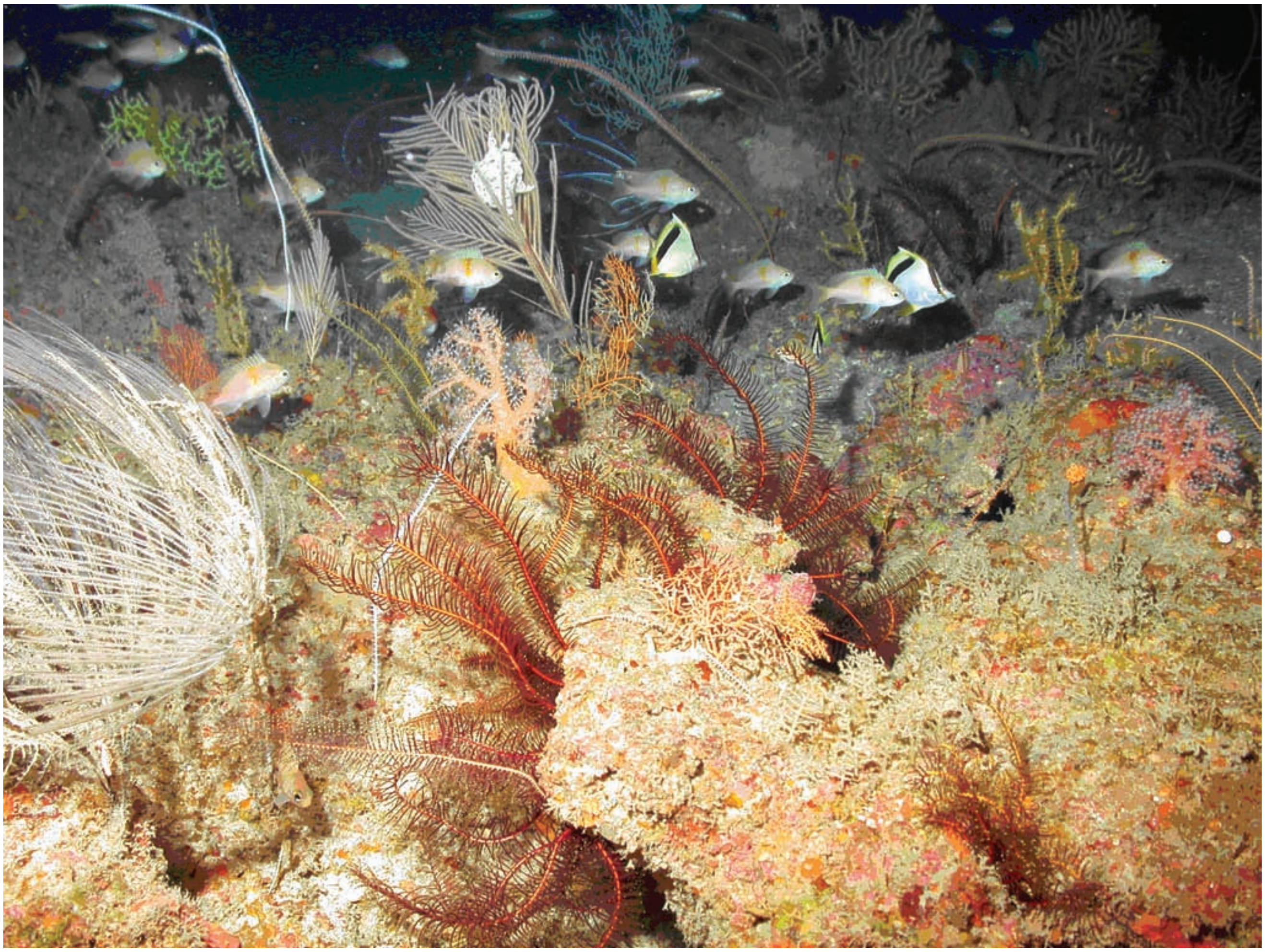

Figure 7.9. An example of deep coral habitat at the Flower Garden Banks National Marine Sanctuary, typical of the NW Gulf of Mexico habitats. Image includes octocorals, antipatharians, echinoderms, sponges, octocorals and deep water fishes. Photo credit FGNMS/NURC-UNCW.

along the deeper parts of the northern shelf and slope provide hard substrate for *L. pertusa* communities as well as other scleractinians octocorals and antipatharians (see Cairns et al. 1994). Zooxanthellate coral reefs are also found along the top of the west Florida shelf (<100m), and, at deeper depths, the west Florida slope and the terraces of the Florida Straits support extensive *L. pertusa* formations as well as stylasterine and sponge-dominated communities (Reed et al. 2005b).

Northern Gulf of Mexico

The benthos of the northwestern Gulf of Mexico is composed of terrigenous sediments, interspersed with dozens of reefs and banks, many of which are connected by corridors of hardbottom features. The East and West Flower Garden Banks, within the FGBNMS, support the northernmost zooxanthellate coral reefs in the U.S.A., with scleractinian coral cover of up to 70%, which is much higher than comparable coral reefs in the Caribbean basin (Precht et al. 2005; Rezak et al. 1985). These banks are just two of many reefs and banks that support rich communities of antipatharians, octocorals and sponges at depths between 50 and 150m (Figure 7.9). The FGBNMS has developed a database of information derived from more than 8300 digital images, taken during >160 ROV surveys in the northwestern GOM. In addition, approximately 200 antipatharian, octocoral and sponge samples were collected in order to produce regional catalogs for each taxon.

The deeper regions on the northern Gulf of Mexico slope cannot support zooxanthellate corals but are known to have fairly extensive areas of *L. pertusa* communities. These are located in an area known as Green Canyon off Louisiana and on the upper flanks and on Viosca Knoll, a deep-water salt dome off Alabama and Mississippi. More detailed distribution patterns are described below.

Viosca Knoll

The most well developed and well-documented *L. pertusa* communities in the Gulf of Mexico occur on the southwest flank of a mound in the southwest corner of Viosca Knoll lease block 826 (29^{o} 09.5′ N 88^{o} 01.0′ W, 430-520 m) on the upper DeSoto slope. Bottom sediments consist of authigenic carbonate and unconsolidated clay, silty clay, disarticulated shells, and shell hash. Authigenic carbonate formations are abundant at this site, especially on the crest and flanks of the mound, and occur in the form of large plates, slabs, and irregular shaped blocks, boulders, and rubble (Schroeder 2002). Representative ranges of near-bottom temperature, salinity, and dissolved oxygen values for the coral habitat obtained ~13 km east of the site), are 7.0-9.3° C, 34.9-35.1 psu, and 2.6-3.2 ml L^{-1}, respectively (Schroeder 2002).

Hard substrate on the crest and flanks of the mound support large and abundant colonies of *L. pertusa* (Schroeder 2002). These colonies have a bushy morphology composed of irregular, dendritic branches that are highly anastomosed and heavily calcified with large polyps. Individual colonies range in size from a few centimeters to over 1.5 m in diameter, while aggregations of closely associated colonies attain 1.5 to 2 m in height and width and 3 to 4m in length. Many of the aggregated colonies appear to be in the first phase of the "thicket" building stage described by Squires (1964). Colonies less than 25 to 50 cm in diameter were predominantly 100% live. Larger colonies and aggregated colonies often had dead branches (light to dark brown in color) at their base and center with live terminal branches, and some were 100% dead coral. This site is associated with a mature chemosynthethic community, consisting primarily of living tubeworm aggregations, but no known mussel beds or hydrates.

In 1955, the *M/V Oregon* collected approximately 136 kg of *L. pertusa* from a deep-water reef system, comprised of several sections up to 300 m long and 55 m deep (Moore and Bullis, 1960). The coordinates of the sampling site (29^{o} 05.0’N, 88^{o} 19.0’W, 421-512m) were revisited by the U.S. Navy submarine NR-1 in 2002 (Schroeder pers. obs.), but there were no *L. pertusa* reefs found at this location. The depth recorder tracing presented by Moore and Bullis (1960) is similar to the cross-sectional profile of a submarine canyon in lease block VK 862/906 (29^{o} 06.4’N, 88^{o} 22.9’W). This area is comprised of a topographic high located on the northern edge of an exposed carbonate rock complex that extends southward for over 2 km to the eastern rim of the canyon. Water depths range between 300 - 500 m. This lease block region has been explored using ROV (Sonsub Innovator), submersible (JSL) and submarine (NR-1) but the *L. pertusa* habitat

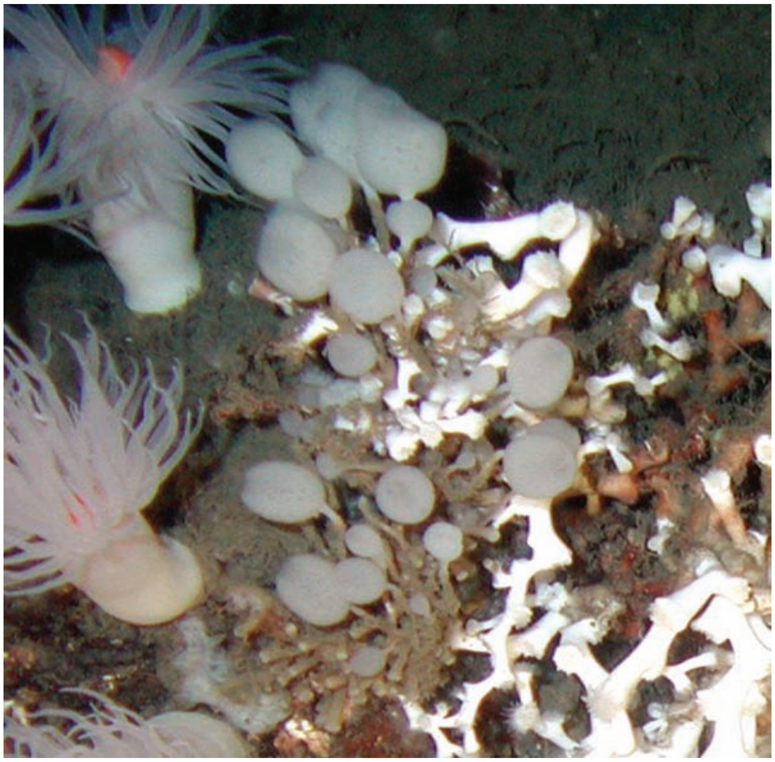

Figure 7.10. Image of unidentified white anemones and hexactinellid sponges found in high numbers at VK862 (Figure 7.3) Photo credit: OIMB for MMS.

described by Moore and Bullis has not been located. This reef may have been buried by a slumping event, or simply has not yet been found.

An unidentified species (or several species) of white anemone dominates the fauna in this region (Figure 7.10). They can be extremely abundant (up to 94 m^{-2}) and occur on flat substrate as well as carbonate outcroppings (Figure 7.11), and often co-occur with an unidentified species of hexactinellid sponge. The large carbonate boulders support diverse assemblages of corals including *L. pertusa* colonies, dense aggregations of bamboo corals (Isididae), *C. americana delta* (Primnoidae) and large black corals (Antipathidiae) (Continental Shelf Associates in review)

Mississippi Canyon

A low relief mound-like sea floor feature with abundant authigenic carbonate rock lies within Mississippi Canyon lease block 885 at a depth of 625 m (28˚03.78’N, 89^{o}42.62’W). It is an area of active seepage and includes bacterial mats, mussel beds, shells of dead clams, tubeworm aggregations and brine seepage. Interspersed among these areas of active seepage are carbonate outcrops with small *Lophelia pertusa* colonies and larger carbonate mounds with larger colonies of both *L. pertusa* and *Madrepora oculata.* There are also areas of high *C. americana delta* abundance, but overall coral species diversity at this site is low (Continental Shelf Associates in review)

Green Canyon

Thickets of aggregated *L. pertusa* colonies exist along a single ridge in an area of Green Canyon lease block 234 (27^{o} 44. 81 ’N, 91^{o} 13.13 ’W). The ridge is approximately 130 m in length and is comprised predominantly of dead *Lophelia pertusa* with live outer branches. Some of the thickets are large (several m^{3}) with occasional colonies of 100% live coral. On one side of this ridge is a large area with extremely abundant *Callogorgia americana delta* colonies. This is an area of active seepage, as evidenced by tubeworm aggregations observed close to the coral ridge.

Green Canyon lease block 184/185, commonly known as Bush Hill, is a low-relief knoll located in approximately 580 m of water. In addition to numerous aggregations of old tubeworms, both gas hydrates and mussel beds are present at this site. The central chemosynthetic communities are bordered on the northwest corner of the knoll by a series of large authigenic carbonate outcrops. Abundant large gorgonians (*C. americana delta* and other species) and colonies of *L. pertusa* are present on these outcrops and on an escarpment on the western side of the knoll.

The explored part of Green Canyon lease block 354 (between 27^{o} 35.9’N 91^{o} 49.6’W and 27^{o} 35.8’N, 91^{o} 49.4’W) is part of a slope that descends from 520 to 560 m. Abundant authigenic carbonate boulders on the upper portion of the slope support large *Lophelia pertusa* thickets of 5 to 10 m in diameter. Scattered vestimentiferans and some large tubeworm aggregations are interspersed with these boulders. Down-slope of this area, there are occasional large pockmarks with slumping sediments and authigenic carbonate outcrops supporting smaller *L. pertusa* and *Madrepora* *oculata* colonies (Continental Shelf Associates in review)

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West Florida Shelf and Slope

There are numerous hardbottom habitats along the west Florida shelf from Panama City to the Dry Tortugas (Schroeder et al. 1989). One of the most well-known is the Florida Middle Grounds in the eastern Gulf of Mexico. The bank formations consist of two parallel ridges separated by a valley and 23 species of stony coral and 170 species of fish have been recorded from this area (Nipper et al. 2006). Other high relief reefs off the western Florida panhandle are associated with the rim of the De Soto Canyon. These reefs are popular fishing grounds for snapper and grouper and include Madison Swanson, Mud Banks and Twin Ridges to the northeast and lower relief structure such as The Edges and Steamboat Lumps. Southern shelf edge reef areas include Howel Hook, Hambone Ridge, Northwest Peaks, Christmas Ridge and Pulley Ridge (Koenig et al. 2000b). Pulley Ridge is a series of drowned, barrier islands on the southwest Florida Shelf which form a ridge about 5 km across with less than 10 m relief. The shallowest parts of the ridge are about 60 m deep and the southern portion supports zooxanthellate scleractinian corals, making it the deepest hermatypic reef in the U.S.A. Atlantic. The corals *Agaricia* sp. and *Leptoceris cucullata* are most abundant, forming plates up to 50 cm in diameter. Less common species include *Montastraea cavernosa, Madracis formosa, Madracis decactis, Porites divaricata,* and *Oculina tellena* (Halley et al. 2005). Deepwater ahermatypic coral mounds occur along the 500 m isobath of the west Florida Slope for approximately 20 km between 26º 20’N, 84º 45’W to 26º 30N, 84º 50’W, with individual coral mounds between 5 and 15 m tall. The lithoherms consist of rugged black phosphorite-coated limestone boulders and outcrops capped with 0.5-1.0 m tall thickets of *L. pertusa* (Reed et al. 2006). The *R/V Aleutian Bounty* collected the first recorded samples of *Lophelia pertusa* and *Madrepora oculata* from this area (26º30.0′ N, 84º50.0′ W, 640 m) in a trawl net in 1983. In 1984 the *R/V Cape Hatteras* also collected samples of corals from the mounds using rock dredges (Newton et al. 1987). Colonies of *M. oculata* were also reported at much lower abundance, together with a solitary coral *Bathypsammia*

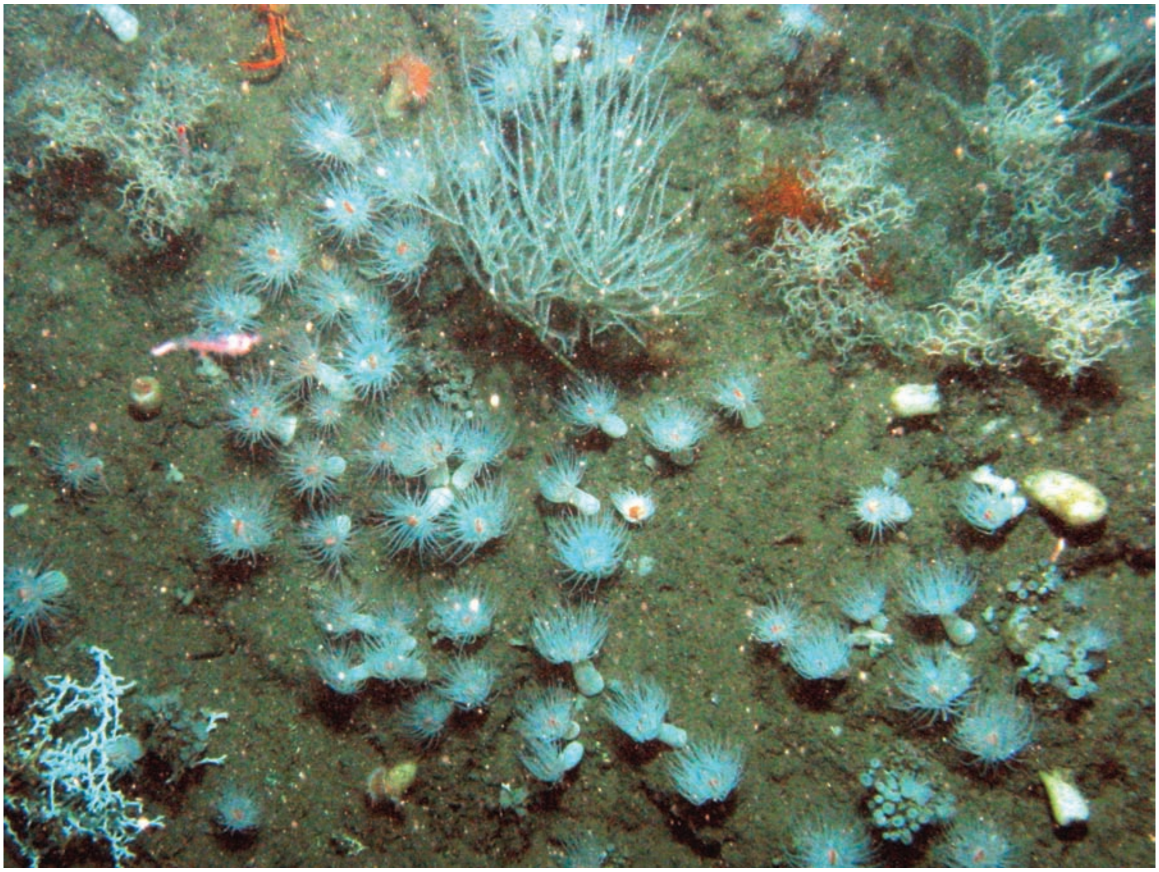

Figure 7.11. This image shows the different kinds of anemones that represent the dominant benthic fauna at VK862 (See figure 7.3). Photos credit: OIMB for MMS.

sp. All corals recovered in the 1984 collections were dead; however in 2003, the SONSUB ROV was used to ground-truth three of the slope features: a 36-m tall escarpment and two of the many lithoherms (Reed et al. 2004, Reed and Wright 2004, Reed et al. 2005b). The dominant fauna on the 36 m escarpment consisted of an antipatharian species (approx 30 cm high), an isidid bamboo coral (30-40 cm high) and numerous other octocorals, plus several species of sponge (*Heterotella* sp., *Phakellia* sp., Corallistidae). The benthic communities of the lithoherms differed from those of the escarpment in that thickets of live and dead *L. pertusa* were found on some of the slope terraces and the top ridges. Coral cover was estimated at <5% to >50% in some areas, but was only 1-20% alive (Reed et al. 2006). Dominant sessile macrofauna included stony corals, octocorals, stylasterid hydrocorals, black corals (*Antipathes* sp. and *Cirrhipathes* sp.) and sponges from the families Hexactinellidae and Demospongiae (Reed et al. 2004).

Florida Straits

Between 1999 and 2005, the *Clelia* and *Johnson-Sea-Link* (JSL) submersibles were used to survey several high relief sites on the Pourtales Terrace, including the Jordan and Marathon sinkholes and five of the high relief lithoherms on the central portion of the terrace (Reed et al. 2004, 2005b). The peaks of some of the mounds were covered with thick layers of stylasterid corals along with dense and diverse communities of sponges and octocorals (Reed et al., 2005b). Cnidarians included 3 species of antipatharian black coral, 5 stylasterid hydrocorals, 11 octocorals, and 1 scleractinian. Stylasterid and antipatharian corals were also common on the flat pavement adjacent to the base of the mounds. High densities of sponges, stylasterid corals and octocorals were observed, particularly on the bioherm plateaus and terraces. Sponges and stylasterids also dominated slopes of the bioherms but at much lower densities than the plateaus, whereas the octocorals were generally found at higher densities on the slopes (Reed et al. 2005b). Certain species occurred only on the Pourtales sinkholes and were not found on the bioherms; these included two identified species of antipatharians (*Antipathes rigida* and *A. tanacetum*), three species of octocorals (*Paramuricea placomus, Plumarella pourtalesii* and *Trachimuricea hirta)* and the scleractinian *Solenosmilia variabilis.*

Along the eastern edge of the Miami Terrace at a depth of 365 m is a 90 m tall steep rock ridge capped with *L. pertusa,* stylasterid corals, bamboo coral, black coral, and various sponges and octocorals (Reed et al. 2004, 2006b). The benthic communities of the Pourtales Terrace bioherms however, differ from those of the lithoherms along the northeastern Straits of Florida (Messing et al. 1990) primarily due to an absence of *L. pertusa* and a dominance of stylasterid corals and stalked crinoids (Reed et al. 2004, 2006b).

Shipwrecks

There are 7,000 reported shipwrecks in the Gulf of Mexico. While most pose no threat to the environment many were carrying cargoes of fuel and other materials and these may lose their structural integrity over time. The contribution of these wrecks to habitat development is currently unknown; they may serve as temporary substrate for coral colonization and structure for fish and invertebrate populations, until their deterioration releases fuel and other pollutants. They also may serve as an initial focus for development of an established habitat.

The 'Deep Wrecks Project' funded by the Minerals Management Service and NOAA, with researchers from C&C Technologies, Inc., used an industrial ROV (Sonsub Inc) to archaeologically and ecologically assess seven World War II era vessels sunk by U-boats in the Gulf of Mexico. Since these sites ranged in depths from 87 m to almost 2,000 m, they offered biologists a unique opportunity to study the artificial reef effect in differing ecological niches. Three of the vessels, the *Virginia, Halo* and *Gulfpenn,* are located south of the Mississippi delta in water depths of 87 m, 143 m and 554 m, respectively and supported several deep sea coral families. Scleractinians were found on all three wrecks, with four of the five species occurring on the *Virginia* (*Madracis myriaster, Oculina varicosa, Paracyathus pulchellus* and *Pourtalosmilia conferta),* two species on the *Halo* (*M. myriaster* and *P. conferta)* and two species on the *Gulfpenn* (*P. conferta* and *L. pertusa).* Gorgonians were collected from and/or observed on the two shallowest wrecks. The *Halo* had a well-developed gorgonian fauna, including four species that were collected from the wreck (*Placogorgia rudis, Thesea* sp. cf. *T. grandiflora, Thesea* sp. cf. *T. rubra* and *Thesea* sp.*)* and one unidentified species recorded on video. A single, large colony of *Muricea pendula* was found on the *Virginia,* together with two species of antipatharians (*Antipathes furcata* and *Stichopathes* sp. cf. *S. pourtalesi),* which occurred only on the *Virginia. A*ll species, except *Oculina varicosa,* have previously been reported from the Gulf of Mexico.

VI. SPECIES ASSOCIATIONS WITH DEEP CORAL COMMUNITIES

Information on deepwater coral-associated fauna in the Gulf of Mexico region comes from historic trawl and dredge samples (e.g., Agassiz 1869, Moore and Bullis 1960, Newton et al. 1987), and also from recent ROV and submersible operations.

Northern Gulf of Mexico

Antipatharian, octocoral, and sponge communities associated with hardbottom areas in the Northwestern Gulf of Mexico contain abundant populations of both commercial and non-commercial fish species, including *Lutjanus campechanus* (red snapper), *Rhomboplites aurorubens* (vermillion snapper)*, Pronotogrammus martinicensis* (roughtongue bass)*, Anthias tenuis* (threadnose bass), and several species of grouper. Initial observations from the FGBNMS research suggest correlations between the benthic community structure and composition and the mobile fauna (E. Hickerson pers. comm.). Rezak et al. (1985) provide a list of fish associated with reefs and banks in the northwestern Gulf of Mexico.

Unlike many other *Lophelia* reefs, the northern Gulf of Mexico *L. pertusa* communities have not been shown to support commercially important fisheries species. Large schools of *Hyperoglyphe perciformis* (barrelfish) have been observed at Viosca Knoll lease block 862 (S. Brooke pers. obs.). These are caught along with *Polyprion americanus* (wreckfish) along the U.S. eastern coast, and they are marketed along with *Beryx splendens* and *B. decadactylus* (alfonsinos)*. A*lthough there is currently no commercial fishery for barrelfish in the northern Gulf of Mexico, there is potential for development of a future fishery for this species. Information on *Lophelia*-associated fish species has been documented (Sulak et al, in press) during a series of cruises in the northern Gulf of Mexico.

Commercially important deepwater invertebrates that exist in the northern Gulf include *Pleoticus robustus* (royal red shrimp) and *Chaceon fenneri* (golden crab) (Snyder 2000), although there is currently no fishery for golden crab species in the northern Gulf of Mexico. Royal red shrimp occur over specific substrata in different areas: terrigenous silt and silty clay off the Mississippi Delta and calcareous mud off the Dry Tortugas, with peak abundance at 250-500 m depth. Golden crabs occur over a similar depth range, but prefer hard bottom and outcroppings such as the Florida escarpment (Lindberg and Lockhart 1993). The Moore and Bullis site (located in 1955) discussed previously, was reported to be 'over half a mile long and up to 180 ft thick'. Records indicate a single trawl drag recovered "several hundred pounds of fish, shrimp, starfish, urchins and other animals". This site has not been found since that time, but recent research in the nearby Viosca Knoll area (Continental Shelf Associates in review) has shown that *L. pertusa* habitat supports a similar coral-associated community as that reported by Moore and Bullis. In addition, *L. pertusa* colonies provide habitat for the surrounding slope community, but probably do not directly provide food to other organisms, with the exception of the gastropod *Coralliophila* sp. Some species are found at higher densities close to *L. pertusa* or have been found only in tight association with coral habitat. These species include the squat lobster *Eumunida picta*, comatulid crinoids, unidentified sponge species and, in dead coral skeleton only, sabellid polychates (Continental Shelf Associates in review).

West Florida Shelf and Slope

NMFS landing statistics show higher landings of deepwater reef species than the rest of the Gulf. For the grouper family (Serranidae), the highest catches were for *Epinephelus flavolimbatus* (yellowedge grouper), which are associated with low-relief hard bottom habitats up to 250 m deep. Other serranid species such as *E. niveatus* (snowy grouper), *E. drummondhayi* (speckled hind) and *E. nigritus* (warsaw grouper) were also found on deepwater hard bottom structure, but landings of these species were consistently much lower than for *E. flavolimbatus*.. Hard-bottom species such as *Etelis oculatus* (queen snapper) and *Hyperoglyphe perciformis* (barrelfish) were minor contributors to the commercial fishery. These data encompass the entire west coast of Florida, including the popular shallower fishing grounds on the Florida shelf and shelf edge. These habitats serve as spawning aggregation sites for commercially valuable species such as *Mycteroperca microlepis* and *M. phenax* (gag and scamp) as well as habitat for other commercial grouper and snapper species. In June 2000 the Madison Swanson/Steamboat Lumps marine reserves were implemented (with a 4 year sunset clause that was extended in 2004), and all fishing was banned except trolling for highly migratory and coastal pelagic species between May 1st and October 31st. This was done in an effort to protect grouper spawning stocks and has proved a successful policy, despite illegal fishing, which is still a problem on these offshore areas (Koenig pers. comm.). There are no landings data currently available specifically for the deepwater coral lithoherms, and since many are deeper than 250 m, the shallower nearshore regions are probably contributing the majority of the catch. There is also a small fishery for *Chaceon fenneri* (golden crab), which reached a peak of 640 metric tons in 1995, but by 2004 had declined to 25 metric tons. During a study of golden crab distribution and behavior (Lindberg and Lockhart 1993), the greatest density was found among gorgonians and in crevices on hard bottom at depths of 350-550 m. The coordinates of the survey correspond to the lithoherm region on the west Florida slope, but fishing data do not indicate precisely where landed crabs were caught.

Dominant sessile macrofauna on the west Florida slope lithoherms included stony corals, gorgonians, stylasterids, antipatharians and sponges (Reed and Wright, 2004). These coral habitats provide complex structure for abundant and diverse communities of associated fish, crustaceans (including the golden crab, *C. fenneri),* mollusks, echinoderms, polychaete and sipunculan worms, anemones, terebratulid brachiopods, bryozoans and other sessile and motile macrofauna, some of which are probably undescribed species (Newton et al. 1987, Reed 2004). Preliminary studies discovered new species of octocorals and sponges from some of these sites (Reed et al. 2004). Messing (unpublished) found an unstalked crinoid assemblage (159 m) not known to occur elsewhere in Florida but characteristic of deeper Cuban and Bahamian waters (>300 m).

Florida Straits

A total of 31 fish taxa (of which 24 were identified to species level) have been identified from the sinkhole and bioherm sites of the Pourtales Terrace (Reed et al. 2004). Common species on the high-relief bioherms included *Antigonia capros* (deepbody boarfish), *Lopholatilus microps* (blueline tilefish), *Epinephelus niveatus* (snowy grouper), and *Holanthias martinensis* (roughtongue bass). Some species, such as the snowy grouper, blackbelly rosefish (*Helicolenus dactylopterus)* and mora (*Laemonema melanurum),* were common at both the sinkhole and bioherm sites. This region is shallower in places than the SW Florida lithoherms or the Northern Gulf of Mexico regions, and supports commercially valuable species such as *E. drummondhayi* (speckled hind), *E. flavolimbatus* (yellowedge grouper), *E. nigritus* (warsaw grouper), *Pagrus pagrus* (red porgy), *Seriola* sp. (amberjack) and *Pareques iwamotoi* (blackbar drum), as well as deeper species such as *E. niveatus* (snowy grouper), *H. dactylopterus* (blackbelly rosefish), *Lopholatilus* sp. (tilefish) and *Urophycis* sp. (phycid hakes). The fish densities appeared insufficient to support a viable commercial or recreational fishery, since only a few individuals of the larger grouper species were present at any one site (Reed 2004). A swordfish was also observed on top of Pourtales Terrace from the NR-1 submersible (C. Paull, pers. obs.), and the JSL submersible was attacked twice during dives on the Terrace and sinkholes (Reed pers.comm.)

There is extremely limited information on coral associated fauna from the Pourtales Terrace. Trawl collections from the Terrace (Agassiz 1869) contained an abundant and unique benthic assemblage of invertebrates rarely found elsewhere in the Straits of Florida, e.g., the hydroid *Cladocarpus sigma,* and the unstalked crinoids *Comatonia cristata* and *Coccometra hageni* (Bogle 1975, Meyer et al. 1978). The most recent published information on the communities of the Florida straits deepwater habitats are by Reed (2004) and Reed et al. (2005b). These manuscripts document the coral communities and their associated fauna collected during submersible and ROV cruises, but represent a

Table 7.2 Potential and Current Fishing Gear Impacts on Deep Sea Corals

Gear Type	Potential Severity of Impact	Potential Extent of Impact from Fishing Gear	Current Geographic Extent of Use in Region	Overlap of use with coral habitat	Overall Rating of Gear Impact
Bottom Trawl	High	High	Low	Uncertain	Low-Medium
Mid-water Trawl	Low	Low	Medium	Uncertain	Uncertain
Dredge	High	Low	N/A	N/A	N/A
Bottom-set Longline	Medium	Low	Low	Uncertain	Low
Bottom-set Gillnet	Medium	Medium	N/A	N/A	N/A
Longline traps or pots	High	Medium	Low	Uncertain	Uncertain
Single pots	Low	Medium	Low	Uncertain	Uncertain
Hook and line	Low	Low	Low to medium*	Yes	Low
	*may increase as recreational trophy fishing increases				

small percentage of the highly biodiverse habitat assemblages.

VII. STRESSORS ON DEEP CORAL COMMUNITIES

The most significant global threats to deep corals are destructive fishing practices, particularly trawling, that compromises the habitat infrastructure, and often occurs repeatedly in the same area, thus preventing and habitat recovery; however, trawling is not a significant problem in the deep Gulf of Mexico (Table 7.2). Another potential stressor is the expanding exploration and exploitation of fossil fuel reserves in the deep Gulf of Mexico.

Fishery Effects

Bottom trawling

Trawling for the various varieties of shrimp (*Farfantepenaeus duorarum, Penaeus setiferus, P. aztecus)* represents the most lucrative fishery in the Gulf of Mexico; however these shrimp are fished over soft sediments at less than 50 m depth therefore it is unlikely that these shrimp fisheries have damaged deep coral habitats. Trawling for *Pleoticus robustus* (royal red shrimp) occurs in water depths of 400-500 m off Florida Texas and Alabama. Gear used for royal red shrimp is similar to trawling gear for shallow species, but to work in deepwater the trawl doors and lines must be much heavier. Since royal red shrimp inhabits soft substrate (silt and calcareous mud) this fishery probably does not target deepwater coral habitat, but damage could occur if the shrimp habitat is adjacent to coral communities or if equipment is erroneously deployed in coral habitat. There are currently no other deepwater trawl fisheries operating in this region.

Scallop dredges

There is a dredge fishery in the Gulf of Mexico for *Argopecten gibbus* (calico scallops); it is infrequent but when scallops are present in high numbers, vessels come from as far as the mid-Atlantic coast to participate in the fishery (Arnold 2006; NMFS 1982), and there is some potential for impacts to deep coral since these scallops can be found in water depths of 10-400 m. The present condition of stock in the South Atlantic region is unknown because of large fluctuations in abundance and the last commercial landings of calico scallops from the Gulf coast of Florida was in 2000 (http://research.myfwc.com)

Deep Gill Nets

Gillnets are allowed for the spanish and king mackerel fishery, and for non-FMP commercial and recreational fisheries. There is no deep water managed species that is fished using gillnets.

Bottom Long-lines

Fishing for ‘highly migratory species’ such as tuna and swordfish (*Xiphias gladius*) is one of the most lucrative in the Gulf of Mexico, primarily using surface long-lines. These are not deep enough to interfere with coral habitat, but damage could occur however if the lines break and drag across the coral habitat. Many sharks are fished with bottom longlines, particularly on the shelf-slope break and these have potential to damage fragile benthos.

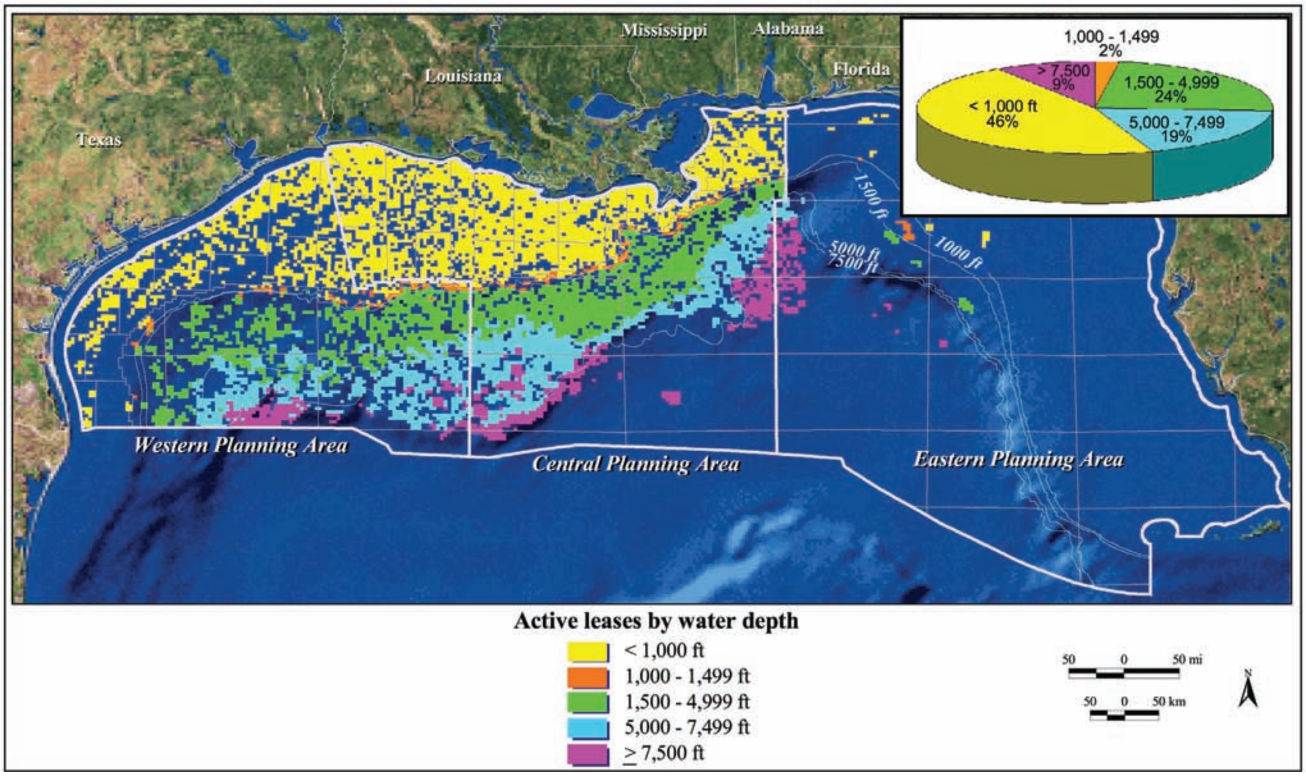

Figure 7.12. Active oil and gas leases in the Gulf of Mexico. Map credit: MMS

Demersal or reef fishes caught in deepwater include *Epinephelus flavolimbatus* (yellowedge grouper), *E. niveatus* (snowy grouper), *E. nigritus* (warsaw grouper), *Etelis oculatus* (queen snapper) and *Lutjanus vivanus* (silk snapper), plus *Caulolatilus microps* (blueline tilefish) and *Caulolatilus chrysops* (goldface tilefish), which are generally found on soft sediment benthos rather than reefs or hardbottom. These species are primarily harvested using bottom long-lines, with some traps or hook and lines used. Bottom long-lines are much shorter than pelagic lines, but can be up to 30 km long (Snyder 2000). These lines can damage fragile coral habitat, especially in areas of high current where lines may be dragged or heavily weighted. Numerous lost long-lines have been observed on the seafloor during submersible dives in the deepwater Naples sinkhole (200m) on the west Florida shelf, and deepwater sinkholes and bioherms of the Pourtales Terrrace (Reed pers. comm.)

Traps and Pots

Golden crab gear consists of rectangular wire mesh traps that are attached in series along a weighted mainline and are recovered by hauling the mainline aboard the boat. Golden crabs have been observed on hard bottom habitat in the region of the Florida lithoherms (Lindberg and Lockhart 1993) and are fished on the Pourtales Terrace (Reed pers.comm.). If the traps were placed close to the coral, recovery of the trap could result in dragging it over the coral and potentially damaging the coral.

Harvest of precious corals

There is currently no commercial harvesting of precious corals in this region; however there are areas that support abundant populations of antipatharians, which are harvested in other areas (e.g. Hawaii) for making ornaments and jewelry.

Effects of Other Human Activities

Oil and Gas Exploration and Extraction

The Gulf of Mexico supports the largest offshore oil and gas extraction fields in the nation. Currently, there are approximately 4,000 producing platforms, of which about 1,962 are major platforms and approximately 152 companies are active in the Gulf of Mexico (http://www.gomr.mms.gov) (Figure 7.12). The deep waters of the Gulf of Mexico (>300 m) where deep coral resources may occur have been an area of increasing exploration and development over the past decade. Deep-water oil production has risen 386% since 1996 and accounts for 62% of the total oil production in the Gulf of Mexico. By the end of 1999, approximately 1,200 wells had been drilled in water depths greater than 1000 ft (305 m). In 2003, an estimated 350 million barrels were produced from deepwater rigs. Deep water gas production has increased by 407% since 1996, reaching an estimated 1.42 trillion cubic feet (Tcf) in 2003, and has surpassed shallow water production (U.S. Department of the Interior 2000, 2004).

Direct physical impact to the substrate has been observed at Viosca Knoll 826 (Schroeder 2002). At 496 m on the western flank, a furrow was observed in the soft sediment that extended both up- and down-slope. The furrow alternated between a completely disrupted surface over a 1-1.5 m swath, and a clean, narrow cut into the soft sediment. There was no extensive destruction of carbonate structures; however, numerous colonies and aggregations of *L. pertusa*, attached to buried carbonate material, were severely damaged. It was surmised that this disruption occurred when a wire anchor cable, deployed in conjunction with oil and gas drilling operations in this region, struck the bottom one or more times. Apart from the physical impact, the other primary environmental threat from oil and gas exploration/extraction is accidental leakage of drilling fluids or oil into the water column. Drilling in deep water requires special drilling fluids that can operate at low temperatures. Synthetic-based drill fluids (SBF) have been used in the Gulf of Mexico since 1992 and are well suited to deepwater use (Boland et al. 2004). These fluids do not contain the toxic polycyclic aromatic hydrocarbons that are found in non-synthetic drill fluids that are refined from crude oil. Use of SBF in the Gulf of Mexico is limited to rapidly-biodegradable esters and internal olefins; however, the accidental release of drilling fluid still presents potential environmental hazards through release of large quantities of sediment and anaerobic decomposition of the organic SBF material at the sediment surface. Drilling fluid may also be mixed at the time of release with oil containing toxic components.

The number of chemical spills in the Gulf of Mexico has steadily increased. In 1998 27% of all incidents in U.S. waters took place in the Gulf of Mexico (Boehm et al. 2001). In 2003, an SBF spill occurred when a drilling pipe fractured in two places at an oil lease block site in Mississippi Canyon (MC778), located at 28.19°N, 88.49°W at a depth of 1840 m. An environmental impact assessment conducted by MMS (Boland et al. 2004) concluded that the SBF dispersed into the water, settled to the seafloor and biodegraded. The SBF would cause a temporary decrease in dissolved oxygen at the sediment water interface therefore the less motile animals within the nearby benthic community (mud bottom with low biodiversity) could have smothered under a layer of SBF or from anoxic conditions resulting from biodegradation, but that the community would recover once the SBF biodegrades. In this case, there were no strong currents, the sediment settled close to the accident and fortuitously did not impact a sensitive habitat, but this may not always be the case. If oil rather than SBF was released, the fluid would be more toxic, although it may be carried vertically away from the benthos since it is less dense than water. Interestingly, the report mentions that the closest chemosynthetic communities were at VK826, and were not close enough to be impacted by the spill, but made no mention of potential impact to the extensive *Lophelia* communities in the same lease block. Deposition of organic and potentially toxic sediment could cause extensive coral mortality from direct toxicity, smothering by sediments, and reduction in oxygen content. These reefs are slow growing and their recruitment rates are unknown. As oil and gas exploration increases, it is vital that corals are included in the MMS environmental impact assessments and are given the same status as chemosynthetic communities.

Deployment of Gas Pipelines and Communication Cables

The deployment of gas pipelines and cables can impact deep coral communities through sediment re-suspension during the burial process (especially in shallower areas), and can cause habitat destruction during pipeline deployment as a direct result of the pipes and also from anchor-cable sweep and anchor drag. While there has been a decline in the production of natural gas from the shallower existing lease areas in the Gulf of Mexico, the Minerals Management Service (MMS) began offering incentives in 2001 to encourage drilling in deeper waters. Koenig et al. (2000a) reported on the potential impact of gas pipelines proposed for deployment in two marine protected areas in the Gulf of Mexico and evaluated the potential destructive effects of the process. MMS regulations do not require burial and anchoring of pipelines laid at depths greater than 61 m. Other habitat impacts may be associated with deployment of pipelines. Each anchor measures approximately 5 x 6 m and weighs at least 13 tons and together with the cables cover a swath approximately one nautical mile wide As they are positioning the anchors, the cables act like trawls or dredges as they sweep across the bottom. The combined effects of the anchor-cable sweep, anchor drag and sea state determines the extent of the habitat damage.

The extent of the damage caused by pipeline construction is evaluated by MMS using clearly defined habitat descriptions. The MMS considers live-bottom to be "seagrass communities or those areas which contain biological assemblages consisting of sessile invertebrates, such as sea fans, sea whips, hydroids, anemones, ascidians, sponges, bryozoans, or corals living upon and attached to naturally-occurring hard or rocky formations with rough, broken, or smooth topography; or areas whose lithotope favors the accumulation of turtles, fishes, and other fauna" (Koenig et al. 2000a). Since the MMS does not require oil and gas exploration companies to survey areas at a depth greater than 100 m important habitats including coral areas may be exposed to potential damage or destruction. These habitats include: essential fish habitat (EFH) for *Lopholatilus chamaeleonticeps* (tilefish), *Caulolatilus microps* (blueline tilefish), *Epinephelus nigritus* (warsaw grouper), *E. niveatus* (snowy grouper), *E. drummondhayi* (speckled hind), and *E. flavolimbatus* (yellowedge grouper) (Parker and Mays 1998). The southwest Florida shelf has been found to have extensive live-bottom coverage (65%) at depths of 120 to 160 m (Phillips et al. 1990), however the number, extent and location of deep coral habitats in the Gulf of Mexico are unknown.

Gulf Fiber Corporation installed a deep water fiber optic cable system called Fiber Web in 1999. This has been updated over the past 3 years and stretches from Texas to Florida in a loop that runs from onshore to the 200 m isobath, along the shelf edge and back onshore again. These cables are not thick and heavy like pipelines, but there is potential for environmental impact when they are laid or replaced. In 2003, Florida Department of Environmental Protection initiated a policy that directs underwater communications cables to be sited through gaps in reef tracts. This protects reefs under Florida state jurisdiction, but there is no such legislation for deep water corals in federal waters.

Mineral mining

The Gulf of Mexico has extremely large stores of methane hydrate, which is a solid crystal lattice comprised of water and methane. Research over the past two decades has shown that methane hydrate exists as void-filling in shallow sediments, and as massive mounds, often associated with chemosynthetic biota. At the moment, the extraction of these hydrates is in the experimental phase, but there is an interagency road map in place for the research and development of methane hydrate as a potential future energy source (U.S. Department of Energy, 2006). In the deep Gulf of Mexico, corals are often found close to chemosynthetic activity, since the hard substrate is of authigenic origin. Methane hydrate extraction is not an immediate threat but could have future consequences for deep water chemosynthetic and coral communities.

Sedimentation

There are natural events that could temporarily increase sedimentation, such as benthic storms or deepwater gyre activity, but unless they are unusually severe or protracted, the sessile benthic fauna will have evolved to deal with such events. Anthropogenic sediment input could be caused by fossil fuel exploration or extraction, not only by resuspension of local sediments but also from drilling muds. Release of petroleum products or other extraction related contaminants is also a potential threat to benthic organisms. Currently the MMS Notice to Lessees issued in 2000 states that "*If you propose activities that could disturb seafloor areas in water depths 400 meters (1,312 feet) or greater, maintain the following separation distances from features or areas that could support high-density chemosynthetic communities: 1) At least 1,500 feet from each proposed muds and cuttings discharge location and 2) At least 250 feet from the location of all other proposed seafloor disturbances (including those caused by anchors, anchor chains, wire ropes, seafloor template installation, and pipeline construction).*" This notice does not mention avoidance of coral communities.

VIII. MANAGEMENT OF FISHERY RESOURCES AND HABITATS

Fisheries in the area covered by this report are managed undr fishery management plans (FMPs) by two regional councils, the Gulf of Mexico Fishery Management Council (GMFMC) and the South Atlantic Fishery Management Council (SAFMC). The Gulf of Mexico Fishery Management Council is responsible for fisheries in federal waters off the coasts from Texas to the west coast of Florida (www.gulfcouncil.org) and the South Atlantic Fishery Management Council is responsible for fisheries in federal waters off the coasts of North Carolina, South Carolina, Georgia and east Florida to Key West (http://www.safmc.net).

The GMFMC produced a Coral and Coral Reefs FMP with the SAFMC in 1982. The species currently covered under this FMP include "species belonging to the Orders Stolonifera, Telestacea, Alcyonacea (soft corals), Gorgonacea (horny corals, sea fans, sea whips), and Pennatulacea (sea pens) in the Subclass Octocorallia; Orders Scleractinia (stony corals) and Antipatharia (black corals) in the Subclass Zoantharia; and the Orders Milleporina (fire corals, stinging corals) and Stylasterina in the Class Hydrozoa". These classes include many deep coral species and therefore apply to deep corals as well as their shallow water counterparts. In March 2005, the GMFMC proposed amending their description of coral EFH to "the total distribution of coral species and life stages throughout the Gulf of Mexico including: coral reefs in the North and South Tortugas Ecological Reserves, East and West Flower Garden Banks, McGrail Bank, and the southern portion of Pulley Ridge; hard bottom areas scattered along the pinnacles, reefs, and banks from Texas to Mississippi along the shelf edge and at the Florida Middle Grounds; the southwest tip of the Florida reef tract, and the predominant patchy hard bottom offshore of Florida from approximately Crystal River south to the Keys".

On January 23, 2006, the National Marine Fisheries Service established Habitat Areas of Particular Concern proposed by the Gulf of Mexico Fisheries Management Council. Fishing restrictions prohibit bottom longlining, bottom trawling, buoy gear, dredge, pot, or trap and bottom anchoring by fishing vessels at West and East Flower Garden Banks, Stetson Bank, McGrail Bank, and an area of Pulley's Ridge. Additional restrictions on fishing were already in place at the Tortugas Ecological Reserves and Madison-Swanson and Steamboat Lumps Marine Reserves. Other Gulf of Mexico HAPC's that do not carry any regulations are the remainder of Pulley Ridge, the Florida Middle Grounds, and the following banks: 29 Fathom, MacNeil, Rezak, Sidner, Rankin, Bright, Geyer, Bouma, Sonnier, Alderdice, and Jakkula Banks. No regulations are currently in place for these HAPC areas, but they will be considered during individual fishery plan review and development.

These EFH HAPC were targeted toward the zooxanthellate coral communities, some of which occur at deeper depths than usual, but include areas that are biologically significant due to their antipatharian, octocoral, and sponge communities. The HAPCs do not include habitats where the structure-forming azooxanthellate scleractinians such as *L. pertusa* are found. Currently there are no proposed protected areas for these communities which are only found at depths >300 m in the Gulf of Mexico. The SAFMC however, has proposed the designation of HAPC status to several areas within their jurisdiction, including the deep-water coral habitats on the Pourtales Terrace. For further information and updates, refer to the SAFMC website.

Flower Gardens Banks National Marine Sanctuary

In the 1970's researchers and recreational divers initiated a 20 year effort to protect the reefs of the Flower Gardens Banks, culminating in the designation of the FGBNMS in 1992, which comprised the Eastern and Western Flower Gardens Banks. In October, 1996, Congress expanded the Sanctuary by adding Stetson Bank, which is a small salt dome located about 110 km south of Galveston, Texas. The total area of the sanctuary encompasses 144 km^2, which includes 1.6 km^2 of reef crest at approximately 18-25m, with zooxanthellate corals occuring to at least 52 m. Fishing within the Sanctuary is regulated through fishery management plans developed in cooperation with the Gulf of Mexico Fishery Management Council. In addition to the original protected areas, HAPC designations were granted in 2006 for selected deeper banks noted above. These sites were proposed to the GMFMC by the FGBNMS based on the deepwater communities of octocorals, gorgonians, and antipatharians.

IX. REGIONAL PRIORITIES TO UNDERSTAND AND CONSERVE DEEP CORAL COMMUNITIES

Deepwater corals exist throughout the Gulf of Mexico however their distribution has not been comprehensively surveyed or mapped and there are a very limited number of publications on coral habitat or associated fauna (Agassiz 1869, Moore and Bullis 1960, Bogle 1975, Meyer et al. 1978, Newton et al. 1987, Lindberg and Lockhart 1993, Schroeder 2002, Reed 2004, Reed et al. 2004, Reed and Wright 2004, Reed et al. 2006). Most of the information regarding deep coral habitat is either anecdotal, proprietary or in preparation from current projects. NOAA's Office of Ocean Exploration has supported, and continues to support, exploration of deepwater coral habitat throughout the U.S. EEZ. The Flower Garden Banks NMS approaches deepwater investigations on a regional basis, and will continue to look for opportunities to further the science in the northwestern Gulf of Mexico. The Minerals Management Service has recently funded a 3-year research project to characterize coral habitat, associated fauna and coral biology in the northern Gulf of Mexico (Continental Shelf Associates in review), but there is still a need for additional research in many areas, some of which are listed below.

Map coral habitat

- Deep coral habitat may be far more extensive than current knowledge indicates. In shallower areas on the shelf (<200m), there are extensive areas of hardbottom, produced primarily through salt tectonics, which provide substrate for coral community development. The deeper slope and basins are dominated by soft sediment habitats, but sessile organisms (such as corals and sponges) colonize exposed rocky outcrops of authigenic carbonate. The geology of the Gulf of Mexico has been well studied, primarily because of fossil fuel interests, so there is some indication of the distribution of different substrate types. This information has been used (and should continue to be used) as a starting point for 'ground-truthing' explorations. Areas of special ecological importance should be defined so that protection can be proactive rather than reactionary.

Priority mapping areas

- The high numbers of hard bottom lithoherms on the Southwest Florida slope, together with the diverse habitats discovered in the few explorations undertaken in this region indicate tremendous potential for unexplored coral and fish habitat.
- The Pourtales Terrace region has a different community composition from the other two regions and the limited exploration to date has shown community difference between sinkholes and lithoherms, which raise interesting ecological questions. Also, this region supports several potential fisheries species, but little is known of their abundance or ecological association with the corals.
- In the Northwestern Gulf of Mexico, the Flower Gardens NMS has identified a priority for mapping geological features between banks that may connect them, biologically and ecologically. Limited groundtruthing has revealed deepwater assemblages including octocorals, antipatharians and sponges associated with these features.

Identify and describe areas of EFH

- Since the GMFMC manages deep coral species under its Coral and Coral Reefs FMP the protection measures available under EFH regulations should provide a framework for the application of the Magnuson-Stevens Fishery Conservation and Management Act (National Marine Fisheries Service, 1996). Most areas currently identified by the Council primarily reflect the distribution of shallow-water hermatypic corals. There is a need to identify the locations of deep coral communities, particularly in those areas that may be subject to future trawling (e.g., for royal red shrimp) or other anthropogenic impacts (e.g., pipeline construction or other oil and gas-related activities).

Increase research of important but understudied taxonomic groups

- Most deepwater coral research to date has focused on the structure-forming scleractinia; however, members of the antipatharia, gorgonacea and stylasterids also provide habitat structure and may be an important part of an ecosystem. Taxonomic and some distributional data are available from museum inventories and institutional databases; however, with the increase in deepwater exploration in recent years, the databases may not be current. There are also many images available from underwater still and video cameras, but in many cases these cannot provide definitive identification. Additionally almost nothing is known about the ecology of these important groups.

- The porifera are also in urgent need of study, but the identification of the many taxa that contribute to habitat complexity is an extensive undertaking.

With the increasing level of oil and gas exploration in the northern Gulf of Mexico, surveying for fossil fuel exploration and environmental impact assessments by the energy industry could potentially provide video footage and anecdotal information on coral distribution. These data are not always available; however with increased cooperation between industry and science, such information could become a valuable resource. The SERPENT (Scientific and Environmental ROV Partnership using Existing Industrial Technology) program is an example of successful cooperation between multiple industry and scientific partners around the globe, including the Gulf of Mexico (http://www.serpentproject.com).

Cooperation with the MMS could potentially change environmental impact and protection policies to include areas of diverse hard bottom communities in the deep Gulf of Mexico and elsewhere. Policies could be implemented to protect coral communities and EFH from the direct effects of exploration and extraction of oil and gas, including deployment of cables and pipelines. Additionally, buffer zones could be created so that fossil fuel operations would be excluded within a ‘reasonable’ distance (to be defined) from coral habitat, to minimize the effect of construction and accidents.

X. CONCLUSION

The extent of deepwater coral habitat in the Gulf of Mexico is unknown at present, but in general, where there is hard substrate there is some degree of benthic community cover, and this is frequently dominated by cnidarians. Coral communities are found under various environmental conditions, from the hard substrate scattered throughout the shelf and slope of the northern Gulf of Mexico, to the carbonate shelf and slope of the west Florida shelf and the Florida Straits. Corals require hard substrate for settlement and sufficient water flow to deliver food and oxygen, and remove waste products, but not so much that feeding mechanisms or skeletal growth is impacted. They require particulate food since the true deepwater corals are azooxanthellate and must obtain their nutrition from zooplankton (possibly augmented by marine detritus and dissolved organic material), therefore factors that drive zooplankton dynamics may also influence coral distribution. Sediment load may affect coral communities, particularly those groups with very small polyps such as the stylasterids. The removal of fine particles from coral polyps is facilitated by mucous shedding and requires energetic expenditure. Finally (but not exhaustively) currents must deliver larvae to the appropriate habitats. There are large areas of bare, apparently suitable substrate in the northern Gulf of Mexico that have not been colonized (S. Brooke pers. obs.). Recruitment limitation is one possible explanation, but our understanding of the ecology of these deepwater coral habitats is still rudimentary.

The role of *L. pertusa* in structuring the surrounding slope community appears to be through the provision of habitat rather than direct provision of nutrition by *L. pertusa,* with the possible exception of the gastropod *Coralliophila* sp. *L. pertusa* creates habitat for a number of associated species, many of which show significantly higher densities in proximity to coral or have been found only in tight association with *L. pertusa* in the Gulf of Mexico. These include *Eumunida picta* (a species of squat lobster commonly seen on deepwater coral habitats in the southern U.S.A.), comatulid crinoids, sabellid polychaetes, and sponges (Continental Shelf Associates, in review). The coral associated species found in the Gulf of Mexico appear similar to those encountered on the *L. pertusa* reefs off the east coast of Florida, although there has not yet been a rigorous comparison. The coral communities in the Florida Straits are different from those of the northern Gulf of Mexico and the west Florida shelf and are dominated by stylasterine and sponge communities. Several species of Pleurotomarid gastropods are found on the shallower carbonate slopes and sinkholes on the Pourtales Terrace, but are not found in the Gulf of Mexico basin.

Of all the deepwater coral communities addressed in this report, the only ones that show evidence of human impact are the shallower fishing grounds on the west Florida shelf. The grouper spawning aggregations on these mounds have been severely overfished (Koenig et al. 2000b), which prompted the GMFMC to grant protected status to Madison Swanson and Steamboat Lumps. The reefs and banks on the continental shelf edge of the northern Gulf of Mexico are protected through various regulatory agencies (NOAA's National Marine Fisheries Service and Minerals Management Service). Regulations do not overlap, which may allow environmental impacts to occur, such as dynamiting coral reefs for salvage purposes, and methods of closing these gaps should be investigated and proposed. Whatever these alternatives are, should also be considered for off-shelf deepwater communities. The golden crab fishery could potentially damage coral on the west Florida slope, especially if the fishery expands in the future, but there are currently no major commercial trawl fisheries in the Gulf of Mexico to seriously impact deepwater coral habitat. The oil and gas industry is expanding rapidly in deepwater and will probably continue to do so far into the future. The laying of pipelines and cables, boat anchors and spills could all potentially cause extensive damage to coral habitat unless activity is restricted by regulations and enforced appropriately. The most well studied and most extensive *L. pertusa* habitat in the Gulf of Mexico is within the the Viosca Knoll lease block 826, and the adjacent lease block 862 also supports a highly biodiverse area with abundant fish populations (Continental Shelf Associates in review). Although there is no apparent immediate threat, these areas are unique as far as current investigation can determine and as such are worthy of protection from potential anthropogenic impact. Another region of interest is the lithoherm habitat on the west Florida shelf edge. The extent and health of this system is unknown and is a high priority for further research. There are many areas of the deep Gulf of Mexico that have not been explored and further investigation may discover more coral habitats. At present there are fewer immediate threats to Gulf of Mexico ecosystems than in certain other areas, but a proactive approach to habitat protection may be more effective than one which reacts to user groups that are already invested in the exploitation of a resource.

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Appendix 7.1 Species list of deep coral species found in the Gulf of Mexico. Outlined/highlighted text indicates major structure forming species. Depth ranges are global depth ranges extracted from the literature. National Musuem of Natural History (NMNH), Texas A&M University (TAMU)

Taxon	Species	Distribution	Depth (m)*	Reference
Phylum Cnidaria				
Class Anthozoa				
Subclass Hexacorallia				
Order Scleractinia				
Family Caryophyllidae	*Anomocora fecunda* Pourtales 1871	SW Florida, N, NE GOM	73-779	Cairns 1978, 1987
	Asterosmilia prolifera Pourtales 1871	N. GOM	32-311	Cairns 1978
	Caryophyllia ambrosia Alcock 1898	SW Florida, N, NE GOM	183-2360	Cairns 1978
	Caryophyllia berteriana Duchassaing 1850	SW Florida, N.GOM	100-850	Cairns 1978, 1987
	Caryophyllia cornuformis Pourtales 1870	SW Florida	137-931	Cairns 1978
	Caryophyllia parvula Cairns 1979	N GOM	68-136	Cairns 1979
	Coenosmilia arbuscula Pourtales 1871	SW Florida	109-807	Cairns 1978
	Dasmosmilia variegata Pourtales 1871	SW Florida	185-600	Cairns 1978
	Dasmosmilia lymani Pourtales 1871	N. GOM	33-366	Cairns 1978
	Deltocyathus italicus Michelotti 1838	SW Florida, N.GOM	403-2634	Cairns 1978, 1987
	Deltocyathus calcar Pourtales 1874	SW Florida, N.GOM	101-675	Cairns 1978
	Deltocyathus eccentricus Cairns 1979	SW Florida, N.GOM	183-910	Cairns 1978
	Desmophyllum dianthus Esper 1794	NE SE GOM	900-1210	NMNH
	***Lophelia pertusa* (Linnaeus, 1758)**	**SW Florida, N. GOM, Wrecks**	**60-2170**	**Cairns 1978**
	Oxysmillia rotundifolia Milne Edwards and Haime 1849	N. GOM	46-640	Cairns 1978
	Paracyathus pulchellus Philippi 1842	SW Florida, N.GOM, Wrecks	25-838	Cairns 1978, TAMU
	Pepnocyathus stimpsonii Pourtales 1871	SW Florida	110-293	Cairns 1978
	***Pourtalosmilia conferta* Cairns, 1978**	**Wrecks**	**87-554**	**Schroeder pers. comm.**
	***Solenosmilia variabilis* Duncan, 1873**	**Florida Straits**	**220-3383**	**Cairns 1978, Reed et al. 2005b**
	Stephanocyathus diadema Moseley 1876	N. GOM	795-2133	Cairns 1978
	Stephanocyathus paliferus Cairns 1977	SW Florida	229-1158	Cairns 1978

Taxon	Species	Distribution	Depth (m)	Reference
	Stephanocyathus coronatus Pourtales 1867	N. GOM	543-1280	Cairns 1978
	Thalamophyllia riisei Duchassaing and Michelotti 1860	N. GOM	18-1317	Cairns 1979, 1987
	Theocyathus laevigatus Pourtales 1871	SW Florida	183-576	Cairns 1978
	Trochocyathus flos Pourtales 1878	N. GOM	22-560	Cairns 1978
	Trochocyathus rawsonii Pourtales 1874	SW Florida	131-622	Cairns 1978
Family Dendrophylliidae	*Balanophyllia palifera* Pourtales 1878	N. GOM	53-708	Cairns 1978, 1987
	Balanophyllia floridana	NE GOM	92m	Wicksten pers. com.
	Bathypsammia tintinnabulum Pourtales 1868	SW Florida	210-1079	Cairns 1978
	Bathypsammia? sp. Marenzeller, 1907	SW Florida	418-640	Reed et al. 2005b
	Dendrophyllia cornucopia Pourtales 1871	SW Florida	132-960	Cairns 1978
	Dendrophyllia alternata Pourtales 1880	N. GOM	276-1200	Cairns 1978
	***Enallopsammia profunda* Pourtales 1867**	**SW Florida**	**146-1748**	**Cairns 1978**
	Rhizopsammia manuelensis Chevalier 1966	N. GOM	55-366	Cairns 1978
Family Fungiacyathidae	*Fungiacyathus crispus* Pourtales 1871	SW Florida, N.GOM	183-1010	Cairns 1978
Family Flabellidae	*Flabellum moseleyi Pourtales 1880*	*SW Florida, N. GOM*	*216-1097*	*Cairns 1978*
	Flabellum fragile Cairns 1977	SW Florida	80-366	Cairns 1978
	Javania cailleti Duchassaing and Michelotti 1864	SW Florida, N. GOM	86-2165	Cairns 1978
	Rhizotrochus fragilis Pourtales 1868	SW Florida	90-796	Cairns 1978
Family Guyniidae	*Guynia annulata* Duncan 1872	SW Florida, N. GOM	3-653	Cairns 1978
	Schizocyathus fissilis Pourtales 1874	SW Florida, N. GOM	88-640	Cairns 1978
	Stenocyathus vermformis Pourtales 1868	SW Florida	128-1229	Cairns 1978
Family Oculinidae	***Madrepora oculata* Pourtales 1758**	**N. GOM**	**80-1500**	**Cairns 1978**
	***Madrepora carolina* Pourtales 1871**	**SW Florida, N.GOM**	**53-1003**	**Cairns 1978**
	***Oculina varicosa* Lesueur, 1821**	**Wrecks**	**87**	**Schroeder pers. com.**
Family Pocilloporidae	*Madracis brueggemanni* Ridley	N GOM	55-127	NMNH
	Madracis myriaster Milne Edwards and Haime 1849	SW Florida, N.GOM, Wrecks	37-875	Cairns 1978
	Madracis formosa Wells 1973	SW Florida	46-104	NMNH

Taxon	Species	Distribution	Depth (m)	Reference
	Madracis pharensis	SW Florida	90	Wicksten pers. com.
Order Antipatharia				
	Acanthopathes thyoides	N. GOM	124	FGBNMS/Opresko
	Antipathes atlantica	N. GOM	77	FGBNMS/Opresko
	Antipathes sp. cf. *gracilis*	N. GOM	70	FGBNMS/Opresko
	Antipatharia, unid.	Florida Straits, N. GOM	283-767	Reed et al. 2005b
	Antipatharia, unid.	Florida Straits, SW Florida	328-515	Reed et al. 2005b
	Antipathes columnaris Duchassaing 1870	SW Florida	73-567	Cairns 1993
	Antipathes furcata Gray, 1857	Wrecks, N.GOM	87-106	FGBNMS/Opresko
	Antipathes rigida Pourtales, 1880	Florida Straits, S, N GOM	64-640	Cairns 1993, Reed et al. 2005b
	Antipathes pedata Gray 1857	SW Florida, N. GOM	60-308	Cairns 1993
	Antipathes tanacetum Pourtales 1880	Florida Straits, N. GOM	46-915	Cairns 1993
	Antipathes salix Pourtales 1880	SW Florida, N. GOM	107-263	Cairns 1993
	Aphanipathes abietina Pourtales 1874	SW Florida, N. GOM	31-310	Cairns 1993
	Aphanipathes pedata	N. GOM	131	FGBNMS/Opresko
	Bathypathes patula Brook 1889	SW Florida	100-5000	Cairns 1993
	Bathypathes alternata Brook, 1889	SW Florida	466-716	Reed et al. 2005b
	Elatopathes abietina	N. GOM	106	FGBNMS/Opresko
	***Leiopathes glaberrima* Esper., 1786**	**N. GOM**	**176-549**	**Cairns 1993**
	Phanopathes expansa	N. GOM	121	FGBNMS/Opresko
	Plumapathes pennacea	N. GOM	61	FGBNMS/Opresko
	Stichopathes sp. cf. *S. pourtalesi* Brook, 1889	Wrecks	87	Schroeder pers. com.
	Stichopathes lutkeni	N. GOM	64	FGBNMS/Opresko
	Tanacetipathes barbadensis	N. GOM	89	FGBNMS/Opresko
	Tanacetipathes tanacetum	N. GOM	107	FGBNMS/Opresko
Subclass Octocorallia				
Order Alcyonacea				
Family Alcyoniidae	*Anthomastus (Bathyalcyon) robustus delta* Bayer 1993	N GOM	274	NMNH
	Anthomastus sp.	Florida Straits		NMNH

Taxon	Species	Distribution	Depth (m)	Reference
Family Clavulariidae	*Telesto flavula* Deichmann 1936	N GOM		
	Telesto fruticulosa Dana	N GOM		
Family Nidaliidae	*Nidalia occidentalis* Gray 1835	N GOM	76-214	NMNH
	Siphonogorgia agassizii Deichmann 1936	N GOM	58-190	NMNH
	Chironepthya (Siphonogorgia) caribaea Deichmann 1936	NW GOM	75-135	NMNH/FGBNMS
Family Plexauridae	*Bebryce cinerea*	N GOM	107	FGBNMS/Williams
	Bebryce sp. cf. *cimeria*	N GOM	91	FGBNMS/Etnoyer
	Bebryce parastellata Deichmann 1936	N GOM	46-586	NMNH
	Caliacis nutans Duchassaing & Michelotti, 1864	SW Florida, N GOM	101-238	NMNH
	Echinomuricea atlantica Johnson, 1862	SW Florida	101-183	NMNH
	Hypnogorgia pendula Duchassaing & Michelotti, 1864	N GOM	60-183	NMNH
	Muricea pendula Verrill, 1864	Wrecks, N GOM	53-87	Schroeder pers. com., FGBNMS/ Cairns
	Muriceides sp. cf. *furta*	N. GOM	91	FGBNMS? Etnoyer
	Muriceides sp.	Florida Straits	191	Reed et al. 2005b
	Paramuricea multispina Deichmann, 1936	Florida Straits	176	NMNH
	Paramuricea placomus Linnaeus, 1924	Florida Straits	462-470	Reed et al. 2005b
	Paramuricea multispina Deichmann, 1936	Florida Straits	189-715	Reed et al. 2005b
	Placogorgia tenuis Verrill, 1883	Florida Straits, N. GOM	86-557	NMNH, Reed et al. 2005b, Etnoyer
	Placogorgia mirabilis Deichmann, 1936	Florida Straits, N. GOM	172-212	Reed et al. 2005b
	Placogorgia sp. *(red unidentified)*			
	Placogorgia rudis	Florida Straits, Wrecks	143-238	NMNH, Schroeder pers. com.
	Plumarella pourtalesi Verrill, 1883	Florida Straits	171-753	Reed et al. 2005b
	Scleractis guadaloupensis Duchassaing & Michelotti, 1860	N. GOM	58-190	
	Swiftia casta Verrill, 1883	Florida Straits	53-942	NMNH, Reed et al. 2005b

Taxon	Species	Distribution	Depth (m)	Reference
	Swiftia new sp.?	Florida Straits	497	Reed et al. 2005b
	Thesea sp. cf. *T. grandiflora* Deichmann, 1936	SW Florida, N GOM, Wrecks	143	NMNH, Schroeder pers. com.
	Thesea sp. cf. *T. rubra* Deichmann, 1936	N GOM, Wrecks	61-143	NMNH, Schroeder pers. com.
	Thesea sp.	Wrecks	143	Schroeder pers. com.
	Trachymuricea hirta Pourtales, 1867	Florida Straits	462	Reed et al. 2005b
	Thesea parviflora Deichmann, 1936	Florida Straits	183	Reed et al. 2005b
	Villogorgia nr. nigrescens Duchassaing & Michelotti, 1860	Florida Straits	215	Reed et al. 2005b
Order Gorgonacea				
Family Anthothelidae	*Diodogorgia nodulifera* Hargit in Rogers and Hargitt 1901	N. GOM	86	FGBNMS/Etnoyer
Family Chrysogorgiidae	*Chrysogorgia elegans*	SW Florida, N. GOM	162-732	NMNH
	Chrysogorgia spiculosa	Florida Straits, N. GOM	1256-2360	NMNH
Family Ellisellidae	*Ellisella atlantica* (Toeplitz)	N GOM	56-100	NMNH
	Ellisella barbadensis Duchassaing & Michelotti	Florida straits, NW, N GOM	64-390	NMNH
	Ellisella funiculina Duchassaing & Michelotti	NE GOM	55-92	NMNH
	Ellisella elongata Pallas	NE GOM	55-91	NMNH
	Nicella deichmani	N. GOM	107	FGBNMS/Cairns
	Nicella guadalupensis Duchassaing & Michelotti 1846	N GOM	68-159	NMNH
	Nicella goreaiu	N. GOM	86	FGBNMS/Etnoyer
	Riisea paniculata Duchassaing & Michelotti 1860	N GOM	188	NMNH
Family Gorgoniidae	*Leptogorgia stheno* Bayer	N GOM	69	NMNH
Family Isididae	***Acanella arbuscula***	**SW Florida, NW GOM**	**940m**	**NMNH**
	Acanella sp.	GOM	183-1216 m	Wicksten pers. com.
	***Keratoisis flexibilis* Pourtales 1868**	**N GOM, SW Florida, Florida Straits**	**378-816**	**NMNH**

Taxon	Species	Distribution	Depth (m)	Reference
Family Keroeididae	*Thelogorgia stellata* Bayer 1992	N. GOM	89	FGBNMS/Cairns
Family Primnoidae	***Callogorgia americana delta* Cairns and Bayer, 2002**	**N GOM**	**366-570**	**Cairns and Bayer 2002**
	Callogorgia americana americana Cairns and Bayer, 2002	Florida Straits	183-732	Cairns and Bayer 2002
	Callogorgia gracilis Milne Edwards and Haime, 1857	N. GOM	110	FGBNMS/Cairns
Order Pennatulacea				
	Umbellula guntheri Kolliker, 1880	N GOM	2683	NMNH
	Umbellula lindahlii Kolliker, 1874	N GOM	2683	NMNH
	Funiculina quadrangularis Pallas	N GOM	768	NMNH
Class Hydrozoa				
Order Anthoathecatae				
Family Stylasteridae	Stylasteridae, unid. sp.	Florida Straits	173-742	Reed et al. 2005b
	Stylaster erubescens Pourtales, 1868	Florida Straits	175-186	Reed et al. 2005b
	Stylaster miniatus Pourtales, 1868	Florida Straits	175-220	Reed et al. 2005b, NMNH
	Stylaster filogranus Pourtales, 1871	Florida Straits	175-366	Reed et al. 2005b, NMNH
	Stylaster unid. sp.1	Florida Straits	557	Reed et al. 2005b
	Stylaster laevigatus Cairns, 1986	Florida Straits	366	NMNH
	Stylaster aurantiacus Cairns, 1986	SW Florida	159-166	NMNH
	Stylaster gemmascens	Florida Straits	183	NMNH
	Distichopora foliacea Pourtales, 1868	Florida Straits	175	Reed et al. 2005b
	Crypthelia glossopoma Cairns, 1986	Florida Straits	205-210	NMNH
	Pliobothrus echinatus Cairns, 1986	Florida Straits	175	NMNH, Reed et al. 2005b
	** Note: Depth ranges are not just GOM samples, but are global depth ranges extracted from the literature*			