SNMREC-TR-12-110

FINAL REPORT

Siting Study for a Hydrokinetic Energy Project Located Offshore Southeastern Florida: Protocols for Survey Methodology for Offshore Marine Hydrokinetic Energy Projects

23 February 2012

Submitted to:
United States Department of Energy
Golden Field Office
1617 Cole Boulevard
Golden, Colorado 80401

DOE Grant Award Number: DE-EE0002655.000

Submitted by:
Dehlsen Associates, LLC
in Cooperation with:
Ecology & Environment, Inc.,
Nova Southeastern University Oceanographic Center,
and
Florida Atlantic University (Southeast National Marine Renewable Energy Center/
Harbor Branch Oceanographic Institute)

This page left blank intentionally.

Project Summary/Abstract

Dehlsen Associates, LLC was awarded a grant by the United States Department of Energy (DOE) Golden Field Office for a project titled "Siting Study Framework and Survey Methodology for Marine and Hydrokinetic Energy Project in Offshore Southeast Florida," corresponding to DOE Grant Award Number DE-EE0002655 resulting from DOE funding Opportunity Announcement Number DE-FOA-0000069 for Topic Area 2, and it is referred to herein as "the project."

The purpose of the project was to enhance the certainty of the survey requirements and regulatory review processes for the purpose of reducing the time, efforts, and costs associated with initial siting efforts of marine and hydrokinetic energy conversion facilities that may be proposed in the Atlantic Ocean offshore Southeast Florida. To secure early input from agencies, protocols were developed for collecting baseline geophysical information and benthic habitat data that can be used by project developers and regulators to make decisions early in the process of determining project location (i.e., the siting process) that avoid or minimize adverse impacts to sensitive marine benthic habitat. It is presumed that such an approach will help facilitate the licensing process for hydrokinetic and other ocean renewable energy projects within the study area and will assist in clarifying the baseline environmental data requirements described in the U.S. Department of the Interior Bureau of Ocean Energy Management, Regulation and Enforcement (formerly Minerals Management Service) final regulations on offshore renewable energy (30 Code of Federal Regulations 285, published April 29, 2009).

Because projects generally seek to avoid or minimize impacts to sensitive marine habitats, it was not the intent of this project to investigate areas that did not appear suitable for the siting of ocean renewable energy projects. Rather, a two-tiered approach was designed with the first step consisting of gaining overall insight about seabed conditions offshore southeastern Florida by conducting a geophysical survey of pre-selected areas with subsequent post-processing and expert data interpretation by geophysicists and experienced marine biologists knowledgeable about the general project area. The second step sought to validate the benthic habitat types interpreted from the geophysical data by conducting benthic video and photographic field surveys of selected habitat types. The goal of this step was to determine the degree of correlation between the habitat types interpreted from the geophysical data and what actually exists on the seafloor based on the benthic video survey logs. This step included spot-checking selected habitat types rather than comprehensive evaluation of the entire area covered by the geophysical survey. It is important to note that non-invasive survey methods were used as part of this study and no devices of any kind were either temporarily or permanently attached to the seabed as part of the work conducted under this project.

> ***NOTE**: Although the project siting issues related to **benthic habitat characterization are the focus of this project**, a broad range of topics must be considered during the project licensing/permitting process in order to determine the ultimate viability of any marine or hydrokinetic ocean renewable energy project that may be proposed offshore southeastern Florida.*
>
> *Each developer must evaluate the specific project's potential impacts and minimization/mitigation options and conduct site-specific studies necessary to support the licensing/permitting process, including but not limited to: evaluation of the physical and biological coastal/marine environments; performance of site-specific surveys/studies, such as archeological surveys and fishery studies; addressing any use conflict issues, among other possible evaluations and studies that a lead, cooperating or resource management agency at the Federal, State or local level may request to properly evaluate a specific site.*

This page left blank intentionally.

Table of Contents

List of Acronyms

BOEM	Bureau of Ocean Energy Management
CHAPC	coral Habitat Area of Particular Concern
CPCe©	Coral Point Count with Excel extensions
CZMA	Coastal Zone Management Act
DA, LLC	Dehlsen Associates, LLC
DOE	(United States) Department of Energy
DSCE	Deep-Sea Coral Ecosystems
E & E	Ecology & Environment, Inc.
FAU	Florida Atlantic University (Southeast National Marine Renewable Energy Center and Harbor Branch Oceanographic Institute)
FDEP	Florida Department of Environmental Protection
FERC	Federal Energy Regulatory Commission
FFWCC	Florida Fish and Wildlife Conservation Commission
GIS	Geographic Information System
LNG	liquefied natural gas
MMS	(United States Department of the Interior) Minerals Management Service (now BOEM)
NCRI	(Nova Southeastern University) National Coral Reef Institute
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NOAA Fisheries Service	National Oceanic and Atmospheric Administration’s National Marine Fisheries Service
NSU	Nova Southeastern University (Oceanographic Center)
NTL	Notice to Lessee
OCS	Outer Continental Shelf
OTEC	ocean thermal energy conversion
ROV	remotely operated vehicle
SAFMC	South Atlantic Fishery Management Council
USN-SFTC	US Navy South Florida Testing Facility

1 INTRODUCTION

The Gulf Stream, off the southeastern Florida coast, represents the best ocean current resource for renewable energy development in the United States. Various entities have expressed interest in the potential for developing marine current energy or ocean thermal energy conversion (OTEC) projects in offshore southeastern Florida.

In addition to its high current resource, the Outer Continental Shelf (OCS) off southeastern Florida supports the only tropical coral reef system bounding the continental United States. These coral reefs include nearly continuous, linear, nearshore coral reefs that pose potential constraints to landfalls of subsea electrical transmission cables, as well as unique and relatively unexplored deep-water coral communities located in areas with the highest current velocities. These biologically important bottom habitats are protected by various federal and state laws.

Benthic habitat characterization is the focus of this grant work, based on geophysical field investigation and videographic and photographic surveys conducted under this project. This is a screening project aimed at identifying those areas offshore of Palm Beach, Broward, and northern Miami-Dade Counties that appear most viable for the siting of marine or hydrokinetic ocean renewable energy projects, with the objective of assisting project developers in making informed decisions about possible specific sites (pre-screened sites) to consider and that appear viable based on benthic characterization data resulting from this study or from data available from prior studies and investigations and gathered under this grant.

This project seeks to demonstrate to resource management agencies how project proponents would exercise due diligence in evaluating possible pre-screened sites/areas for the development of a proposed project to avoid adverse impacts to the environment and in making a project sustainable over the operational life of the proposed project. In the event that avoidance of such impacts is not possible, minimization and mitigation options should be proposed by the specific project developer and would be subject to regulatory review and approval. Project developers' selection of a specific project site from among pre-screened sites/areas will most likely reduce time/effort that agencies would invest during the review process.

The project team recognizes the importance of conducting other site-specific surveys to determine the ultimate viability of any marine or hydrokinetic ocean renewable energy project that may be proposed offshore southeastern Florida, including archeological surveys, physical oceanographic characterizations, and fishery studies, among possible others. These studies and characterizations will need to be conducted by individual project developers during the project licensing and permitting process; they are not a consideration of this project and thus are not covered as part of this final report. For additional information about criteria to be considered and stakeholders that would likely participate during the licensing and permitting process, refer to Section 5 of this final report.

2 PROJECT TEAM AND PROJECT PURPOSE

2.1 *Project Team*

Dehlsen Associates, LLC (DA, LLC) was awarded a grant by the United States Department of Energy (DOE) Golden Field Office for a project titled "Siting Study for a Hydrokinetic Energy Project Located Offshore Southeast Florida", which corresponds with DOE Grant Award Number DE- EE0002655 resulting from funding Opportunity Announcement Number DE-FOA-0000069 for Topic Area 2 and will be referred to as "the project." The project team includes the following organizations:

Grant Recipient: Dehlsen Associates, LLC
Charles Vinick – Principal Investigator

Cooperating Partners:

- Ecology & Environment, Inc. (E & E)
  Antonino Riccobono, MS – Program Manager

- Nova Southeastern University Oceanographic Center (referred to herein as NSU)
  Charles G. Messing, Ph.D. – Principal Investigator
  Brian K. Walker, Ph.D. – Lead Researcher/GIS Manager

- Florida Atlantic University (Southeast National Marine Renewable Energy Center and Harbor Branch Oceanographic Institute (referred to herein as FAU)
  John K. Reed – Lead Investigator
  Stephanie Rogers – Researcher/Data Manager

2.2 *Purpose of the Project*

The purpose of the project is to enhance the usefulness of survey requirements and regulatory review processes while reducing the time, efforts, and costs associated with siting and permitting of marine and hydrokinetic energy conversion facilities that may be proposed in the Atlantic Ocean offshore southeastern Florida.

The specific objectives of the project included the:

- development of an acceptable bottom habitat survey methodology and siting study framework in consultation and cooperation with those regulatory and resource management agencies with permitting/review authority for marine and hydrokinetic projects on the OCS, offshore southeast Florida; and
- identification of general areas offshore southeastern Florida that appear most suitable for installing marine and hydrokinetic energy facilities, including subsea electrical transmissions cables to shore, based on the distribution of sensitive bottom habitats identified by existing and supplemental surveys conducted for this project. The emphasis was placed on the BOEM (formerly MMS) lease blocks off the coasts of Miami-Dade, Broward, and Palm Beach Counties.

The data collected, analyzed, and reported through this study is intended to be of value to regulatory agencies, industrial developers, and investors in making early siting assessments and decisions based on limited information gathered for this project. However, it is important to note that each project developer must evaluate the specific project's potential impacts and minimization/mitigation options and conduct site-specific studies necessary to support their licensing/permitting process, including but not limited to: evaluation of the biological coastal/marine environment and physical environment; performance of site-specific surveys/studies, such as archeological surveys and fishery studies; addressing any use conflict issues; among other possible evaluations and studies that a lead, cooperating or resource management agency may specifically request.

2.3 Desirable Aspects for Siting

During the selection process, the Dehlsen team considered the input of the regulatory agencies and prospective project developers with interest in the development of marine and hydrokinetic energy projects in areas offshore southeastern Florida, specifically Palm Beach, Broward, and Miami-Dade Counties. Geophysical field information and benthic characterization data resulting from this study will be useful in assisting project developers in making informed decisions about possible specific sites to target or areas to avoid.

2.3.1 Desirable aspects include:

1. focusing on a suitable depth range. Developers indicated that workable water depths are currently between 250 and 400 meters (about 800 to 1,300 feet) for project siting of marine and hydrokinetic projects.
2. focusing on soft bottoms (sediment), which are desirable relative to hard bottom habitats. However, the Dehlsen team recognizes that, although soft bottoms may be less complex, they still may support a variety of species including commercially important ones such as blueline (*Caulolatilus microps)* and golden tilefish (*Lopholatilus chamaeleonticeps*), royal red shrimp (*Pleoticus robustus*) and golden crab (*Chaceon fenneri*) Although the April 2010 Work Plan did not stipulate investigating for the presence, abundance and distribution of tilefish, project developers will have to carry out such activity during project licensing and permitting. Nevertheless, analysis of videotapes recorded during this project noted the occurrence of commercially important species such as tilefish, golden crab, and royal red shrimp.
3. consideration of all nominated MMS (now BOEM) Interim Policy Blocks located within Palm Beach, Broward, and Miami-Dade Counties.
4. consideration of other areas outside of nominated MMS (now BOEM) Interim Policy Blocks that appear desirable for siting projects based on review of existing information.
5. consideration of existing gaps in the reefs, particularly those present in Palm Beach County, and existing cable corridors.
6. consideration of input from agencies at all governmental levels, developers and stakeholders.

2.4 Undesirable Siting Aspects

Areas to avoid are those associated with environmentally sensitive habitats, in particular Essential Fish Habitats and Marine Protected Areas (MPAs), and military and commercial communications facilities and cables.

2.4.1 Essential Fish Habitat (EFH)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA; Public Law 104-208) defines EFH as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” [16 U.S.C. 1802 (10)]. The National Marine Fisheries Service (NMFS) and the South

Atlantic Fisheries Management Council (SAFMC), one of eight regional fisheries management councils, are responsible for managing and protecting fisheries and habitat essential for the survival of managed species within the federal 200-nautical-mile limit off U.S. coasts extending from North Carolina to Key West, Florida. The provisions of the MSFCMA delegate this authority to the U.S. Secretary of Commerce, who acts through NMFS and the SAFMC. As amended by the Sustainable Fisheries Act of 1996, Section 303(a)(7), the MSFCMA includes several mandates for NMFS and SAFMC to identify and protect EFH for all managed species in each Fisheries Management Plan (FMP); minimize to the extent practicable the adverse effects of fishing on EFH, and identify other actions to encourage the conservation and enhancement of EFH (FDOT, 2010).

EFH identified in the FMP Amendments for the SAFMC and pertinent to MHK development off southeastern Florida include live/hard bottoms (see Section 4.2, below), coral and coral reefs, artificial/manmade reefs, *Sargassum* and the water column (NOAA NMFS, 2000), which established the need for developers to avoid whenever possible hard substrate and coral habitats (see Sections 3.1 and 3.2, below). In 1997, NMFS established interim final rules that provided guidance and procedures for implementing the 1996 amendments of the MSFCMA (50 CFR Sections 600.805 - 600.930). These rules also “establish procedures to promote the protection of EFH through interagency coordination and consultation on proposed Federal and state actions” (NOAA NMFS 2000). According to the MSFCMA, the most important provisions for conserving fish habitat “require Federal agencies to consult with NMFS when any activity proposed to be permitted, funded, or undertaken by a Federal agency may have adverse impacts on designated EFH. The consultation requirements in the MSFCMA direct Federal agencies to consult with NMFS when any of their activities may have an adverse effect on EFH. The EFH rules define an **adverse effect** as ‘any impact which reduces quality and/or quantity of EFH...[and] may include direct (e.g., contamination or physical disruption), indirect (e.g., loss of prey, reduction in species’ fecundity), site-specific or habitat wide impacts, including individual, cumulative, or synergistic consequences of actions.’

To incorporate EFH consultations into coordination, consultation and/or environmental review procedures required by other statutes, three criteria must be met:

(1) The existing process must provide NMFS with timely notification of the action;
(2) Notification of the action must include an *EFH Assessment* of the impacts of the proposed action as outlined in the EFH rules; and
(3) NMFS must have completed a written *finding* that the existing coordination process satisfies the requirements of the MSFCMA.

An *EFH Assessment* is a review of the proposed project and its potential impacts to EFH. As set forth in the rules, *EFH Assessments* must include:

(1) a description of the proposed action;
(2) an analysis of the effects, including cumulative effects, of the action on EFH, the managed species, and associated species by life history stage;
(3) the Federal agency’s views regarding the effects of the action on EFH; and
(4) proposed mitigation, if applicable. If appropriate, the assessment should also include the results of an on- site inspection, the views of recognized experts on the habitat or species affects, a literature review, an analysis of alternatives to the proposed action, and any other relevant information” (NOAA NMFS, 2000).

2.4.2 Avoid:

1. or minimize areas with known presence of hard-bottom habitats.

2. or minimize siting, and/or mitigate impacts, within designated Coral Habitat Areas of Particular Concern (CHAPC) and other protected habitats (see Section 3.2, below).
3. duplicating data collection efforts in areas with known geophysical information unless existing data provide insufficient information for decision making. For example, the currently available National Oceanic and Atmospheric Administration (NOAA) bathymetry of the area is too sparse and out of date to determine benthic habitats at the appropriate resolution for a siting study; thus finer resolution surveys are required to determine the nature of benthic habitats.
4. U.S. Department of the Navy's (Navy's) offshore testing range under the jurisdiction of the Naval Surface Warfare Center (NSWC), Carderock Division, except as this area can be used in cooperation with NSWC for testing marine hydrokinetic (MHK) devices.
5. areas with possible mixed use (Use Conflict), such as dumping grounds and fish havens designated by NOAA Fisheries Service.

3 STUDY AREA – OFFSHORE MIAMI-DADE, BROWARD AND PALM BEACH COUNTIES

This study aimed at identifying general areas offshore southeastern Florida (Figure 3-1) that appear most suitable for the mooring and operation of marine and hydrokinetic development projects by establishing a strategy to avoid, minimize, or mitigate project impacts to critical local offshore habitats as described below.

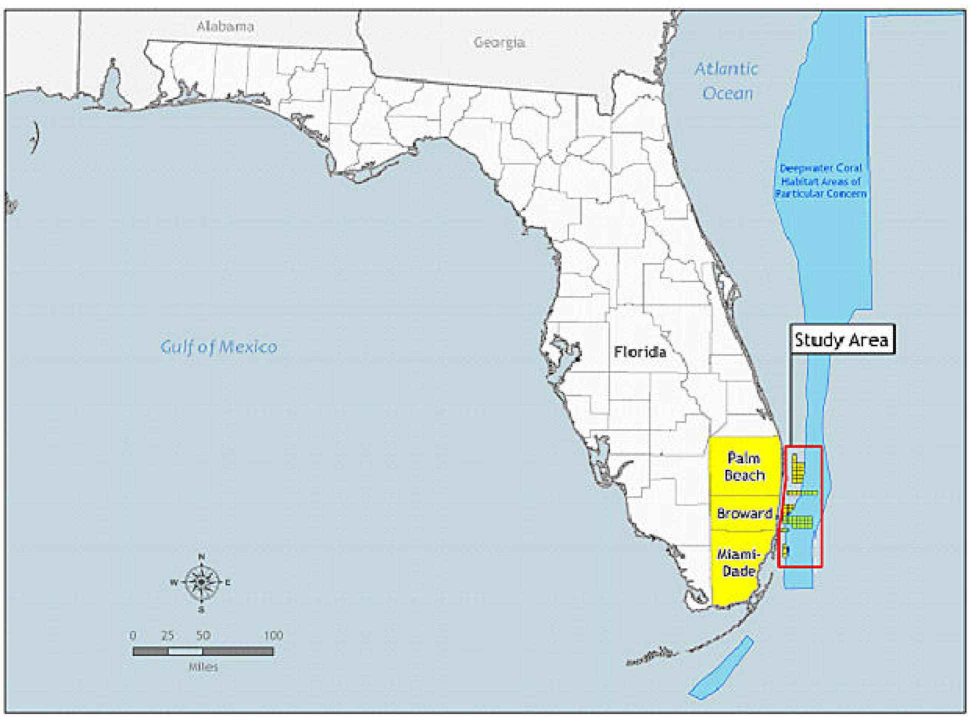

Figure 3-1. Study Area

The Bureau of Ocean Energy Management (BOEM) lease blocks off the southeastern Florida coast are part of a larger area with potential for development of ocean current renewable energy projects, and represent the best ocean current resource for renewable energy development in the United States due to the presence of the Gulf Stream. However, the continental shelf off southeastern Florida supports the only tropical coral reef system bounding the continental United States, as well as extensive but relatively unexplored deep-water coral communities in deeper, outer continental shelf waters.

3.1 Shallow-water coral habitats

This coastal ecosystem includes various, nearly continuous, linear, nearshore, shallow-water (< 30 m) coral reefs that pose potential constraints to landfalls of subsea electrical transmission lines. The shallow-water system consists of a series of shore-parallel reefs and a series of shallow, nearshore ridges (called the "nearshore ridge complex") that lie inshore of the reef complex (Walker *et al*. 2008; Walker 2012). It supports typical Caribbean coral reef fauna of variable composition and density (Walker *et al*. 2009; Gilliam *et al*. 2010). Most of the shallow-water reef system is located inside state waters from the shoreline to approximately 3 miles offshore of the Tri-County area coastline. In addition, deeper-water ecosystems include a shore-parallel ridge in 70 - 90 m depth, the Miami Terrace in 200 – 700 m, and deep-sea coral mounds in >700 m. These deep-water environments support a high diversity of deep-water fish and invertebrates including many commercially valuable and ecologically sensitive species (Reed *et al.* 2006, Reed *et al.* in press).

Federal, state, and local resource protection agencies consider that this reef complex is a unique, biologically important, and irreplaceable ecosystem. These habitats are thus protected by various federal and State of Florida (state) regulations. As demonstrated by recent surveys and environmental permitting efforts conducted for proposed offshore natural gas pipelines, floating liquefied natural gas (LNG) import terminals, and subsea telecommunication cable landfalls along this coastline, these habitats represent potentially significant constraints to the successful siting and regulatory approval of future ocean renewable energy facilities offshore of the southeast Florida coast, including subsea power transmission cables from proposed facilities to the shore location where they would connect to the existing electric grid. However, a number of power cable and communication cable corridors currently exist through nearshore reefs that offer opportunities for marine hydrokinetic (MHK) power transmission to shore (see Section 4.3 below). Previously approved techniques also exist for tunneling under the reef system. Developers will need to consider these existing corridors and tunneling techniques in their submissions to regulatory agencies.

On November 26, 2008, the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries Service) published a final rule in the *Federal Register* designating substrate of suitable quality and availability for southeastern Florida, the Florida Keys, Puerto Rico, and the U.S. Virgin Islands as critical habitat for federally listed (threatened) staghorn and elkhorn corals. In southern Palm Beach County and most of Broward County, much of this substrate occurs in the Atlantic Ocean at depths from 2 to 30 m (~6-98 ft) and has been designated critical habitat for these corals. ''Substrate of suitable quality and availability'' is defined as consolidated hard bottom or dead coral skeleton that is free from fleshy macroalgal and sediment cover. In view of this critical habitat designation, NOAA Fisheries Service, as well as state and local agencies, will require detailed evaluation of alternative routes for electric transmission cables from any MHK developer proposing to connect to the onshore electric transmission system in the tri-county area, unless a project developer proposes to use an existing corridor or adopt other mitigation measures with agency agreement.

3.2 Deep-water coral habitats

The South Atlantic Fishery Management Council (SAFMC) manages benthic habitats in the South Atlantic region through the *Fishery Management Plan for Coral, Coral Reefs, and Live Hard Bottom Habitat*. Regulations implemented through federal fishery management plans for snapper, grouper, coastal migratory pelagics, golden crab, and shrimp seek to reduce or eliminate the impact of fishing and fishing gear on these habitats. In addition, through the Habitat Advisory Panel, the SAFMC has developed and approved standing habitat policies to reduce the impact of non-fishing activities on habitat essential to managed species. In 2010, NOAA established five deep-water Coral Habitat Areas of Particular Concern (CHAPCs) encompassing 62,714 km^2 from North Carolina to south Florida, which will protect much of the known deep-sea coral habitat in this region. This includes portions of the Miami Terrace, a 65-kilometer-long deep-water terrace and escarpment that lies in depths of 200-600 meters (650-2,000 ft) approximately 5-15 miles offshore from Palm Beach to Miami-Dade Counties (see Figure 6-1). NOAA and the SAFMC have previously expressed concern regarding possible damage to DSCE habitat from bottom-disturbing activities in this deep-water area. Although this is an extensive designated area, it spans a variety of habitats, some characterized by protected species such as deep-water mound-building corals, and some not. As a result, on 22 July 2010, NOAA Fisheries Service put into effect a final rule to its Comprehensive Ecosystem-Based Amendment 1 (CE-BA 1), which established allowable gear areas for golden crab and deepwater shrimp fisheries within the CHAPC, permitting continued access to historical fishing grounds that have little or no negative impacts on protected deepwater coral habitat (Gore, 2010).

The protected area designations will require developers to demonstrate site selection and mitigation methods that comply with the intent of the protection designation. In 2009, the State of Florida enacted the Coral Reef Protection Act which authorizes Florida Department of Environmental Protection (FDEP) to protect coral reefs in State waters through the assessment and recovery of damages to affected coral reefs. It provides Florida with the ability to recover monetary damages by imposing a civil penalty schedule for those that do not comply. Hence, any newly proposed efforts will be required to avoidance or minimization of damages to coral reef resources through engineering design.

While the primary area of interest for locating prospective projects is well offshore of the shallow-water reef system, marine and hydrokinetic devices that tie into the onshore electrical transmission grid will require transmission cables to transit these areas to reach the shoreline and ultimately connect to the commercial electrical grid system.

4 COMPILATION OF EXISTING STUDY AREA INFORMATION

The most recent and readily available studies and information on benthic substrate and habitat types in the Atlantic U.S. waters of southeastern Florida (Miami-Dade, Broward and Palm Beach Counties), including those areas covered by BOEM Interim Policy lease blocks nominated offshore of Miami-Dade, Broward and Palm Beach Counties, Florida, were reviewed and compiled in GIS as part of this task.

4.1 Develop GIS Maps with Available Survey Data and Identify Spatial Gaps

A comprehensive GIS database was compiled using relevant data gathered from previous surveys and existing sources for the appropriate spatial extent of the proposed project area. Datasets ranging from administrative boundaries to environmental data were collected in both raster and vector formats or converted into a compatible spatial format using geo-referencing and digitizing techniques. Data sources included NOAA National Geophysical Data Center, which provided bathymetry and other geophysical data. Relevant benthic habitat information was obtained from the NOAA Coastal Services Center. Administrative boundaries including maritime limits, National Marine Sanctuary boundaries, and Marine Managed Area boundaries were gathered from the NOAA Office of Coast Survey. The GIS database was created in ArcGIS 9.3, integrating the most recent and relevant data sources and showing the extent of existing projects and identifying data gaps. The data was catalogued to show the data type, extent, depth range, spatial resolution, source, and date (Table 4-1). These data were the foundation for the site selection procedures.

Table 4-1. Summary of sources consulted.

Num	Content Title	Data Type	Data Extent	Depth Range (m)	Spatial Resolution	Data Source	Date
1	Broward LADS LIDAR Bathymetry	Raster	Broward	0-40	4 m	Broward EPD	Aug-08
2	Broward Benthic Habitat Maps	Polygon	Broward	0-40	1 acre mmu	NCRI/NSUOC	Nov-06
3	Palm Beach LADS LIDAR	Raster	Palm Beach	0-40	4 m	Palm Beach ERM	2002
4	Palm Beach Benthic Habitat maps	Polygon	Palm Beach	0-40	1 acre mmu	NCRI/NSUOC	Sep-07
5	Miami-Dade LADS LIDAR	Raster	Miami-Dade	0-40	4 m	Miami-Dade ERM	2002
6	Miami-Dade Benthic Habitat maps	Polygon	Miami-Dade	0-40	1 acre mmu	NCRI/NSUOC	Jun-09
7	NOAA Hydrographic Multibeam-Miami-Dade	Raster	Government Cut	7-155	0.5 - 4 m	NOAA OCS	Jan-10
8	NOAA Hydrographic LIDAR-Miami-Dade	Raster	Government Cut & North Biscayne Bay	0-15	0.5 - 4 m	NOAA OCS	Jan-10
9	Florida’s Artificial Reefs	Point	Florida	0-128		FFWCC-FWRI	Sep-08
10	NOAA Nautical Chart 11460_1	Raster	Cape Canaveral to Key West	0-max		NOAA OCS	Jul-08
11	Miami-Dade Benthic Habitat Mapping Accuracy Assessment Data	Point	Miami-Dade	0-40		NCRI/NSUOC	Jun-09
12	Reconnaissance Offshore Sand Search	Point	SE Florida	0-90		FL DEP	Aug-07
13	SE FL draft anchorage modifications	Polygon	SE Florida	15-100		NCRI/NSUOC	Mar-10
14	Calypso 0-200m Habitats	Polygon	Port Everglades	0-200		NCRI/NSUOC	Jun-03
15	Calypso 0-200m Tracklines	Polyline	Port Everglades	0-200		NCRI/NSUOC	Jun-03
16	Calypso 0-200m Points	Point	Port Everglades	0-200		NCRI/NSUOC	Jun-03
17	Calypso 0-200m Quantitative Photo Locations	Point	Port Everglades	0-200		NCRI/NSUOC	Jun-03
18	Federal Permitted Dump Sites	Polygon	U.S. Waters	All		NOAA OCS	Mar-10
19	Federal Permitted Submerged Cables	Polyline	U.S. Waters	All		NOAA OCS	Mar-10
20	Calypso 200m-EEZ Habitats	Polygon	Port Everglades	200-750		NCRI/NSUOC	Apr-04
21	Calypso 200m-EEZ Habitatlines	Polyline	Port Everglades	200-750		NCRI/NSUOC	Apr-04
22	Calypso 200m-EEZ Habitat Points	Point	Port Everglades	200-750		NCRI/NSUOC	Apr-04
23	Calypso 200m-EEZ Quantitative Photo Locations	Point	Port Everglades	200-750		NCRI/NSUOC	Apr-04
24	Deep-water Port ROV Habitat Points	Point	Port Everglades	200-300		NCRI/NSUOC	Jun-06
25	Deep-water Port ROV Habitat Lines	Polyline	Port Everglades	200-300		NCRI/NSUOC	Jun-06
26	Deep-water Port Benthic Habitat Polygons	Polygon	Port Everglades	200-300		NCRI/NSUOC	Jun-06
27	Deep-water Port ROV Photo Stations	Point	Port Everglades	200-300		NCRI/NSUOC	Jun-06
28	Deep-water Port Side Scan Targets	Point	Port Everglades	200-300		Intec Engineering	Jun-06
29	Federal Designated Coastal Obstructions	Polygon	US Waters	All		NOAA OCS	Mar-10
30	U.S. Navy South FL Multibeam	Raster	USN-SFTF	15-250	4 m	US Navy	Jul-01
31	U.S. Navy Range SideScan	Raster	USN-SFTF	100-250	1 m	US Navy	Oct-04
32	Reed: Sub Dive Sites	polygon	SE USA	200-914		HBOI- J. Reed	2009
33	Reed: Sub Dive Sites	point	SE USA	200-914		HBOI- J. Reed	2009
34	Reed: COET Turbine ADCP Sites	point	Broward	150-700		HBOI- J. Reed	2009
35	Reed: CFX Cable Survey Sites	point, line	Broward, Palm Beach	200-950		HBOI- J. Reed	2008
36	Reed: Seafarer Pipeline Survey Sites	point	Palm Beach	200-914		HBOI- J. Reed	2008
37	Reed: NOAA Bathmetry Charts	Raster	SE USA	All	Various	HBOI- J. Reed	2009
38	Reed: NURC AUV Multibeam	Raster	Miami Terrace			NOAA NURC- A. Shepard	2007
39	NOAA Hydrographic Florida Hillshaded Bathymetry	Raster	Florida & West Bahamas	All	Various	NCRI/NSUOC from NOAA OSC data	Various
40	Reed: SEAMAP- Florida Hard-bottom Sites 2006	Point	SE Florida	60-275		HBOI- J. Reed	2006
41	SAFMC-CHAPC	polygon	SE USA	200-EEZ		SAFMC-Puglese	2009
42	Port of Miami Proposed Anchorage Modifications	polygon	Miami	36-200		NCRI/NSUOC	2010
43	Port of Palm Beach Proposed Anchorage Modifications	polygon	Palm Beach	36-200		NCRI/NSUOC	2010
44	Port Everglades Anchorage	polygon	Broward	26-200		NCRI/NSUOC	2008

4.2 Develop Common Nomenclature for Mapped Habitat Types

Implementation of ecosystem-based studies requires methods of assessing the quality of habitats in order to deliver high-value information for meeting multiple regulatory and management objectives. Benthic habitats offshore southeastern Florida have been interpreted and denoted in various ways. This lack of common nomenclature could create confusion relative to attribute quality and function. Measures of species assemblage and reference quality will be crucial for supporting assessments of the functional quality of habitats during siting studies.

The objective here was to develop operational language and terminology for the benthic habitats in terms of their ability to support regulatory and policy objectives. Through this process, functional definitions and measures of quality were developed to be more consistent as they relate to ecosystem-based management.

Many deep-water projects and guidelines were reviewed for this section including various deep-water benthic surveys off the southeastern United States; current guidelines by FDEP ('Guidelines for Conducting Offshore Surveys', 2006), MMS (Notice to Lessees No. 2009-39 and No. 2009-40), NOAA, and NOAA Fisheries, and South Atlantic Fishery Management Council, which has operational authority for fisheries and essential fish habitat in the south Atlantic fisheries region from North Carolina to south Florida. We also reviewed NOAA's framework for Coastal and Marine Ecological Classification Standards (CMECS) (http://www.csc.noaa.gov/benthic/cmecs/), which was adopted as an initial guide. This information, along with the previously mapped benthic communities from the GIS database in Section 4.1, was evaluated to determine whether habitat nomenclature applied to different mapped areas could be consolidated under a common scheme. Substantial overlap exists among different habitat types designated by the different agencies, e.g., Live Bottom as designated by MMS (now BOEM) versus Hard Bottom of SAFMC. In particular, common nomenclature was evaluated specifically for offshore southeastern Florida, because nomenclature for different parts of the country will vary according to various regional habitat types.

The following paragraphs discuss several nomenclatural terms that have been applied to deep-water benthic habitats (200-600 m) in the southeastern United States that may be used by offshore marine and hydrokenetic energy projects, and the justifications for our selections.

Live Bottom Habitat.—The BOEM (Gulf of Mexico OCS Region**,** NTL No. 99-G16) defines live-bottom areas (in addition to shallow-water seagrass communities) as those areas that contain biological assemblages consisting of sessile invertebrates living upon and attached to naturally occurring hard or rocky formations with rough, broken, or smooth topography, and areas where the lithotope (i.e., sedimentary environment) favors the accumulation of turtles, fishes, or other fauna. However, extensive portions of hard substrates in the study area support sparse to widely scattered sessile invertebrates, and we do not use the term Live Bottom.

Hard-bottom Habitat.—The SAFMC refers to hard bottom as a class of coral communities occurring in temperate, subtropical, and tropical regions (SAFMC, 1998). Hard bottom is sometimes referred to as live bottom due to the amount of living organisms attached to these substrates. Hard bottoms are cemented or solid substrates that provide anchorage for sessile or semi-sessile organisms (e.g., sponges, stony corals, octocorals, most anemones and crinoids). Note that in this context, coral includes non-accreting taxa such as octocorals (soft corals, gorgonians) and antipatharians (black corals) as well as stony corals and other taxa with solid calcareous skeletons. Hard-bottom habitat includes various sizes of loose rocks (gravel, rubble, cobble, boulders, slabs), pavements, ledges, coral rubble, dead standing coral, and live standing coral. Hard bottom ranges from relatively flat, low-relief surfaces (<0.5 m vertical relief) to tens of meters in relief. Messing et al. (2006a, b) previously reported vertical relief of hard-bottom features (e.g., pavement, boulder, slab) as low relief (<0.5 m), moderate relief (0.5-1.0 m), or high-relief features (>1.0 m). These are relative terms and depend on the size of features within an area and field of view.

The productivity of hard-bottom communities varies depending upon environmental and physical factors including but not limited to depth, current, light penetration, topography, habitat availability and location. Areas of hard bottom provide cover and foraging areas for many fish and invertebrates, including several commercially important species. The importance of hard bottom to fisheries stocks has been recognized, and the SAFMC has designated all natural and artificial hard bottom as Essential Fish Habitat (EFH) and/or Habitat Area of Particular Concern (HAPC). We use the term hard bottom instead of live bottom for all solid and cemented substrates as well as those dominated by gravel, rubble and larger clasts, and the term soft bottom, or soft substrate, for unconsolidated sediments. However, following discussion with BOEM, we also document sessile invertebrate assemblages on sediment (e.g., sea pens) as well as those on hard bottoms that occur over areas of at least several square meters.

Deep-Sea Coral Ecosystems (DSCEs).—Deep-sea coral ecosystems are sometimes referred to as coral banks, bioherms, or lithoherms (Teichert, 1958; Stetson et al., 1962; Neumann et al., 1977; Wilson, 1979; Reed, 1980; Friewald et al. 1997; Fosså et al. 2000; Paull et al., 2000). Rogers (1999) has suggested that deep-water coral banks, which are below effective wave base, fall within the definition of a coral reef based on their physical and biological characteristics. Some deep-water reefs consist of caps of living coral on mounds of unconsolidated mud and coral debris, such as *Oculina* and *Lophelia* coral bioherms (Reed, 2002 b), whereas deep-water lithoherms are defined as high-relief, lithified carbonate limestone mounds rather than unconsolidated mud mounds (Neumann et al., 1977).

The SAFMC Southeast Area Monitoring and Assessment Program (SEAMAP, 2001) deep-water mapping project has documented deep-water, hard-bottom habitat from existing data throughout the South Atlantic Bight and Straits of Florida (Arendt et al., 2003; SAFMC, 2007). SEAMAP has defined deep-water hard bottom using the following subcategories: coral, rock rubble, coral rubble, exposed hard pavement, thinly covered hard substrate, and artificial structures. In addition, a "Special Habitats" category includes the subcategories of canyons, tilefish burrows, consolidated mud, methane seeps, sinkholes, and coral banks (Table 2). SEAMAP considers deep-water corals as Scleractinia (stony corals), Octocorallia (gorgonians), Stylasteridae (lace corals), and Antipatharia (black corals). The NOAA Deep-Sea Coral Ecosystem report (Lumsden et al., 2007) has further defined deep coral communities as assemblages of structure-forming deep corals (including stony corals, octocorals, black corals, gold corals, and lace corals) and other associated species, such as sedentary and mobile invertebrates and demersal fishes.

Table 4-3 lists deep-water, colony-forming corals capable of forming complex 3-dimensional habitats in 200-2000 m off the southeastern United States (Blake Plateau to Straits of Florida). Table 4-4 lists additional sessile and semi-sessile organisms that could indicate hard-bottom substrates in the same region. Sponges (Phylum Porifera, Classes Demospongiae and Hexactinellida) are the primary non-cnidarian group that may contribute substantially to the 3-dimensional complexity of deep-water, hard-bottom communities. Additional mobile invertebrates commonly associated with hard substrates or with organisms such as stony corals, octocorals and sponges on hard substrates include many comatulid (unstalked) crinoids, euryalous ophiuroids (snakestars, basketstars), psolid holothuroids, terebratulid brachiopods, and chirostylid crustaceans (e.g., *Eumunida, Chirostylus*).

Table 4-2. SEAMAP deep-water bottom mapping categories (Arendt et al., 2003).

Category	Subcategory	Relief	Slope (degrees)
Special Habitats	Canyon Tilefish burrows Consolidated mud Methane seeps Sinkholes Coral banks	Low: < 0.5 m Medium: 0.5 to 5 m High: > 5 m	0-10 10-30 >30
Hard Bottom	Live coral Rock/coral rubble Exposed hard pavements (low profile carbonate and phosphorite substrates) Thinly-covered hard substrate with emergent growth (sessile benthic macrofauna indicators) Artificial structures (shipwreck, oil platforms)	Low: < 0.5 m Medium: 0.5 to 5 m High: > 5 m	0-10 10-30 >30
Possible Hard Bottom	Use indirect methods of indicator species to determine possible hard-bottom category, but subcategories cannot be determined		0-10 10-30 >30
Soft Bottom	Unconsolidated sand Unconsolidated mud	Flat Sand waves	

Table 4-3. Deep-water, colony-forming corals capable of forming complex 3-dimensional habitats in 200-2000 m off the southeastern United States (Blake Plateau to Straits of Florida). Common names in parentheses.

Phylum Cnidaria
- Subphylum Anthozoa
  - Class Octocorallia (soft corals, gorgonians)
    - Order Alcyonacea 13 families
      - Family Coralliidae (precious corals)
      - Family Chrysogorgiidae (gold corals)
      - Family Isididae (bamboo corals)
      - Family Paragorgiidae (bubblegum corals)
      - Family Plexauridae (including former Paramuriceidae)
      - Family Primnoidae
      - Family Ellisellidae
      - Family Gorgoniidae
  - Class Hexacorallia (stony corals, anemones, black corals)
    - Order Zoanthidea (colonial anemones)
      - Family Parazoanthidae (*Gerardia* sp.)
    - Order Antipatharia (black corals)
      - Family Antipathidae
      - Family Myriopathidae
      - Family Schizopathidae
      - Family Cladopathidae
      - Family Leiopathidae
    - Order Scleractinia (stony corals)
      - Family Oculinidae (*Madrepora oculata, M. carolinae*)
      - Family Caryophylliidae (*Lophelia pertusa*)
      - Family Dendrophylliidae (*Enallopsammia profunda*)
      - Family Pocilloporidae (*Madracis* spp.)
- Subphylum Medusozoa
  - Class Hydrozoa
    - Order Filifera
      - Family Stylasteridae (lace corals)

Table 4-4. Sessile or semi-sessile organisms other than colonial corals that may indicate hard-bottom substrates in 200-2000 m off the southeastern United States (Blake Plateau to Straits of Florida).

- Phylum Porifera (sponges)
    - Class Hexactinellida (glass sponges)
        - Order Amphidiscosida
        - Order Lyssacinosida
        - Order Lychiniscosida
        - Order Hexactinosida
    - Class Demospongiae
        - Order Astrophorida (5 families)
        - Order Spirophorida (1 family)
        - Order Lithistida (6 families)
        - Order Hadromerida (4 families)
        - Order Halichondrida (2 families)
        - Order Agelasida (1 family)
        - Order Axinellida (6 families)
        - Order Poecilosclerida (8 families)
        - Order Haplosclerida (5 families)
        - Order Dictyoceratida (2 families)
        - Order Dendroceratida (1 family)
        - Order Verongida (2 families)
- Phylum Cnidaria
    - Subphylum Medusozoa
        - Class Hydrozoa
            - Order Leptothecata (thecate hydroids; several families)
    - Subphylum Anthozoa
        - Class Octocorallia
            - Order Alcyonacea (soft corals)
                - Family Alcyoniidae
                - Family Nidaliidae
                - Family Nephtheidae
                - Family Anthothelidae
                - Family Spongiodermatidae
        - Class Hexacorallia
            - Order Scleractinia (solitary stony corals)
                - Family Caryophylliidae (e.g., *Paracyathus, Trochocyathus*)
                - Family Flabellidae (e.g., *Javania*)
                - Family Guyniidae (e.g., *Stenocyathus*)
                - Family Dendrophyliidae (e.g., *Balanophyllia, Bathypsammia*)
            - Order Zoanthidea (zoanthids, colonial anemones; several families)
            - Order Corallimorpharia (corallimorphs)
                - Family Corallimorphidae
            - Order Actiniaria (sea anemones)
                - Numerous families in several orders (e.g., Actinoscyphiidae, Sagartiidae)
- Phylum Arthropoda
    - Subphylum Crustacea
        - Class Maxillopoda
            - Order Pedunculata (stalked and gooseneck barnacles)
                - Family Scalpellidae
- Phylum Echinodermata
    - Class Crinoidea
        - Order Comatulida (feather stars, several families except Atelecrinidae)
    - Class Holothuroidea
        - Order Dendrochirotida (Family Psolidae)
- Phylum Brachiopoda
    - Class Rhynchonellata
        - Order Terebratulida (several families)
- Phylum Bryozoa (most species except a few unattached forms such as *Cupuladria* spp.)

4.3 Map Designated Linear Facility Corridors in Nearshore Areas

Strategically siting marine hydrokinetic development projects in southeastern Florida requires avoidance and/or minimization of impacts to the nearshore coral reef system as outlined in Section 3. The southeastern Florida reef system is a large component of the shallow-water coastal environment from Miami-Dade to Palm Beach counties. The reefs are oriented north-south, parallel to shore; thus planning for placement of submerged cables leading to and from shore needs to include strategies for avoiding or minimizing impacting some portion of these hard-bottom resources. A spatial evaluation of the shallow-water coastal environments indicates that the number of benthic habitats and their morphologies differ from south to north (Walker 2012).

In a study recently conducted to statistically distinguish coral reef ecosystem subregions in southeastern Florida, Walker (2012) identified five distinct regions where the number and extent of habitats significantly differed (Figure 4-1). These areas were defined as follows from south to north: Biscayne, Broward, Deerfield, South Palm Beach, and North Palm Beach. The Biscayne and Broward regions contained large extents of nearshore ridge complex and inner reef habitat. Because these habitats were continuous through the region, avoidance of impacts to coral reef habitats will require that cables be run to shore through an inlet channel or via directional drilling underneath the features to minimize potential impacts to these resources. The Deerfield and Palm Beach regions further north do not contain such large expanses of continuous habitat, which permits a cable shore-approach without significant coral reef habitat impacts.

The Outer Reef traverses all of the coral ecosystem subregions except for North Palm Beach. However, there are several large gaps in this reef that have been identified for telecommunication cabling by the State of Florida (Figure 4-2). The FDEP Sovereignty Submerged Lands Management document identifies these by name and GPS locations (Table 4-4) (Chapter 18-21.004(2) (l), FAC). It identifies five reef gaps for such purpose, including four in Palm Beach County and one in Broward County. Although these areas have been designated as possible corridors through the Outer Reef, it appears as though some are not well designed. The Lake Worth gap is an area where the Outer Reef is not present, although continuous deeper habitats traverse the entire area. It is likely that a shore approach here will still impact these deeper coral reef habitats. Furthermore, the benthic habitat map indicates that the designated South Lake Worth Inlet gap is not completely free of coral reef habitat. The Delray gap also has a significant portion of deeper habitat that must be avoided. Finally, the designated South Broward gap appears to contain a considerable amount of hard-bottom habitat. This designation therefore should be modified to utilize the gaps in the benthic habitat map. Regardless, South Broward is not an ideal location for cabling to shore given the extensive nearshore coral habitat.

It is unclear whether these reef gaps are open for use by electrical cables from hydrokinetic turbine arrays, but they pose an opportunity for developers to investigate. Other gaps along the coast may exist that could be examined for electrical cable use. Considering the current distribution of shallow-water coral reef habitats, cabling to shore in Palm Beach County offers the greatest opportunity to avoid negative impacts to these ecologically sensitive resources.

Table 4-4. Name and location of State of Florida designated reef gaps for telecommunication cables.

Name	LatDM	LonDM
Lake Worth Gap	26 37.659	80 01.341
Lake Worth Gap	26 38.481	80 01.258
South Lake Worth Inlet Gap	26 32.492	80 01.61
South Lake Worth Inlet Gap	26 32.444	80 01.626
Delray Gap	26 27.393	80 02.765
Delray Gap	26 27.641	80 02.726
Sea Turtle Gap	26 22.672	80 03.224
Sea Turtle Gap	26 22.748	80 03.224
South Broward Gap	25 58.438	80 05.278
South Broward Gap	25 58.821	80 05.271
South Broward Gap	25 58.977	80 05.733
South Broward Gap	25 59.132	80 05.997
South Broward Gap	25 59.138	80 06.366
South Broward Gap	25 59.039	80 05.725
South Broward Gap	25 59.205	80 06.06
South Broward Gap	25 59.192	80 06.371

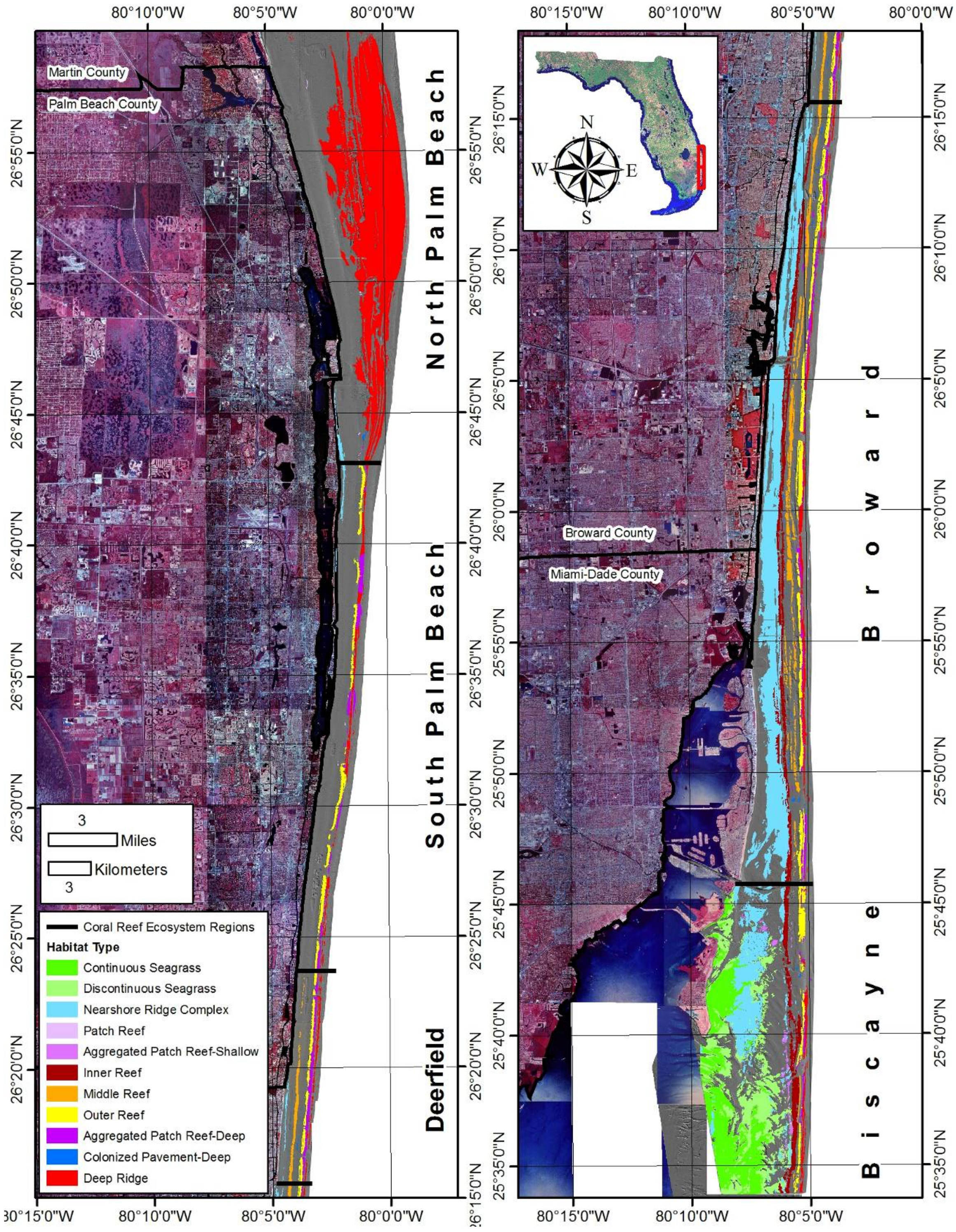

Figure 4-1. Map of the shallow-water coral reef ecosystems in southeastern Florida defined in Walker (2012). The underlying image is hillshaded topography derived from bathymetric lidar data color coded by the southeastern Florida benthic habitats.

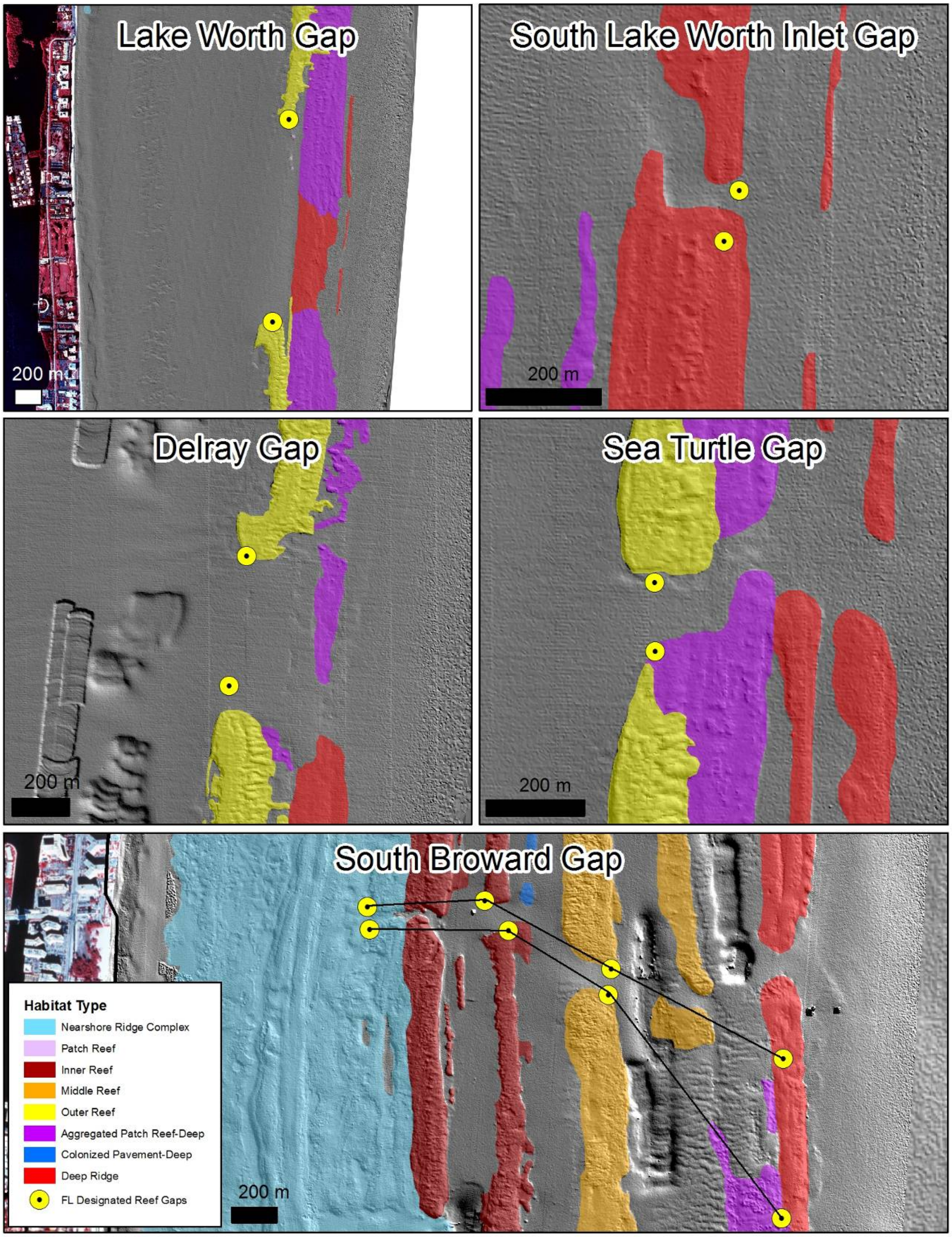

Figure 4-2. Map of the State of Florida (Chapter 18-21.004(2) (l), FAC) designated shallow-water reef gaps in southeastern Florida. Yellow dots are the locations listed in Table 4-1. The underlying image is hillshaded topography derived from bathymetric lidar data color coded by the southeastern Florida benthic habitats (Walker, 2012).

5 SITING STUDY FRAMEWORK AND SURVEY METHODOLOGY

5.1 Survey Work

Offshore survey work under this project was limited to the performance of specific geophysical and benthic video surveys, and included siting study framework and survey methodology. It is important to note that this project used non-invasive survey methods, meaning that no devices of any kind were either temporarily or permanently attached to the seabed during the execution of this project. The intent was to meet or exceed the current guidelines for conducting offshore benthic surveys as required by the following agencies: FDEP Guidelines for Conducting Offshore Benthic Surveys (2006) and BOEM (MMS NTLs No. 2009-G39 and No. 2009-G40). For the purposes of this study and in regard to NTL 2009-G39, the photo-documentation protocol of Attachment 7, Section C, for clearing portions of a lease block was adopted, because it is more appropriate for the purpose of this study than Section B, which is for site-specific clearing.

5.2 Other Facility Siting Criteria Outside the Scope of this Project

Although this project focused on siting issues related to benthic habitat characterization, it is important to note that a broad range of issues must be considered and evaluated during project licensing and the public involvement phase due to their importance in determining the viability of any marine or hydrokinetic project proposed for offshore southeastern Florida. Table 5-1 lists some of the most relevant criteria and stakeholders that will likely play a role in determining the ultimate viability of any marine or hydrokinetic energy project offshore southeast Florida.

5.3 Agency Input

Between March and May 2010, the project team conducted agency stakeholder consultations and shared the siting study approach and framework with the following federal and state agencies, and submitted the resulting information as a Work Plan (first version March 1, 2010, second version April 6, 2010):

- BOEM (formerly MMS)
- FDEP Office of Intergovernmental Programs Offshore Projects Section
- National Oceanic and Atmospheric Administration’s National Marine Fisheries Service (NOAA Fisheries)
- Florida Fish and Wildlife Conservation Commission
- South Atlantic Fishery Management Council
- Florida Department of State - State Historic Preservation Office

The study framework sought to specifically address avoidance of coral and related hard-bottom habitats and focus on more desirable unconsolidated sediments. Although marine archeological resources and other bottom conditions may also affect siting decisions, these resources are less widespread or more easily avoidable than reefs or hard-bottom habitats, which tend to be more continuous and cover larger areas of the seafloor. Such resources will require additional surveys and refined siting once a preferred site for a specific project is selected based on minimization of impacts or possibly avoidance of coral reef and hard-bottom habitats, among other considerations listed in Section 5.2.

Table 5-1. Criteria and considerations for siting of any proposed marine or hydrokinetic project. Abbreviations: FDEP = Florida Department of Environmental Protection; FFWCC = Florida Fish and Wildlife Conservation Commission; BOEM = Bureau of Ocean Energy Management, Regulation, and Enforcement; NGO = non-governmental organization; NOAA = National Oceanic and Atmospheric Administration; SAFMC = South Atlantic Fishery Management Council; USCG = U.S. Coast Guard; USEPA = U.S. Environmental Protection Agency.

Criteria/Issues to Consider	Stakeholders
Survey methodology and framework for specific project	BOEM, State of Florida (FDEP, FFWCC, and others), NOAA Fisheries Service, and SAFMC
Site-specific (for both electric transmission cable corridor and offshore block) characterization studies/evaluations, including but not limited to physical oceanographic characterization studies, meteorology, climate, etc.	BOEM, State of Florida (FDEP, FFWCC, and others), NOAA Fisheries Service, and SAFMC
Existing facility conflicts	U.S. Navy's South Florida Testing Facility Range and Port Everglades
Benthic habitat impacts	NOAA Fisheries Service, State of Florida (FDEP, FFWCC, others), SAFMC, and NGOs
Coral reef habitat impacts	NOAA Fisheries Service, State of Florida (FDEP, FFWCC, and others), SAFMC, and NGOs
Cultural/archeological resources	State Historic Preservation Office (SHPO)
Operational safety	All Stakeholders
Any visibility issues from shore	Public, Property Owners, Counties/Municipalities
Fishing/boating conflicts	SAFMC, Public, Boater/Fishermen Organizations
Other resource use conflicts (e.g., offshore mining of beach-quality sand for beach restoration by coastal cities and communities)	State of Florida (FDEP, FFWCC, and others), U.S. Army Corps of Engineers, Local Governments, BOEM and NOAA Fisheries Service
Impacts to fishery resources (e.g., impingement and entrainment of ichthyoplankton, thermal discharges, and avoidance of resources such as tilefish and golden crab that utilize soft-bottom habitats as Essential Fish Habitats)	NOAA Fisheries Service, State of Florida (FDEP, FFWCC, and others) SAFMC, and NGOs
Vessel traffic conflicts	USCG, Ship Operators, Cruise Line Operators, Boating and Fisherman Organizations
Air quality impacts	USEPA, State of Florida (FDEP, FFWCC, and others), Public
Substrate suitability	All Stakeholders
Proximity to onshore delivery point	All Stakeholders
Public safety	Public, Elected Officials, Counties, Municipalities
Reliability	Project Proponent, Public
Other impacts to activities within State waters	State of Florida (FDEP, FFWCC, and others), Local Governments, and NGOs

5.4 Collection of Information from Gulf Stream Interested Parties

The Dehlsen team conducted a workshop and separate individual interviews with potential commercial marine and hydrokinetic energy developers interested in siting facilities offshore southeastern Florida to collect information on their specific offshore areas of interest, potential array configurations, anchoring/mooring systems, approximate sizes of areas needed for commercial-scale projects, and potential or preferred onshore interconnection points for power delivery.

The workshop, sponsored by FAU, was held on 4 March 2010 to discuss offshore ocean renewable energy and challenges associated with siting such facilities that developers currently face. The workshop was not sponsored under the current DOE grant but was related to topics associated with this grant. The workshop assembled about 50 representatives from industry, utilities, academia, government and NGOs, as well as regulators, consultants, and legal counselors . This discussion targeted common non-proprietary issues encountered by the ocean energy industry, and focused on developing options to address them, including the use of licensed sites for prototype testing, licensing and permitting of proposed facilities, coordination among agencies with regulatory oversight role over proposed projects, use conflicts, environmental and safety factors.

During the workshop, attendees were informed about this grant from the DOE Golden Field Office. To accomplish the goals of this section, we developed a questionnaire and distributed it to potential project developers and utilities interested in siting renewable ocean energy facilities offshore southeastern Florida. The questionnaire (see Appendix) focused on the location and surface area requirements for potential sites under consideration by project developers, utilities and research facilities. Also, individual meetings were held on 4 March 2010 to talk to potential project developers, utilities, and research facilities that have interest in siting offshore renewable marine and hydrokinetic energy projects within the study area of this grant. Follow-up e-mails were also sent to all developers/utilities interested in the geographic area of interest on 8-9 March 2010.

With respect to the U.S. Department of the Interior (USDOI) Minerals Management Service (MMS) [now BOEM] Interim Policy lease blocks nominated offshore southeastern Florida (Figure 5-1), Mr. Gary Goeke of BOEM informed E&E on 9 March 2010 that, although a number of entities had responded to the initial MMS inquiry of interest in 2008, three entities followed through and had been in communication with BOEM regarding projects planned for offshore Palm Beach and Miami-Dade counties: Aquantis (Dehlsen), THOR (Turner Hunt Ocean Renewable part of Vision Energy) and FAU. Table 5-2 lists Interim Policy lease areas offered initially by BOEM.

*Table 5-2. Interim Policy Proposed Lease Project Descriptions: OFFSHORE FLORIDA, 23 July 2008 version. *Where multiple developers are listed for a single PLA, BOEM has received overlapping interest in the proposed lease area. BOEM is working with the listed developers to determine if they are interested in working collaboratively under a single lease.*

Proposed Lease Areas	Developer(s)*	OCS Block(s)	Official Protraction Diagram	Resource	Proposed Activity
Area 1 (3-24 mi. offshore Dania & Hollywood Beaches	Oceana Energy Co.	7054, 7055, 7056, 7104, 7105, 7106	Bahamas NG 17-06	Ocean Current	Data Collection
	Vision Energy LLC	7004, 7005, 7006, 7007, 7051, 7054, 7055, 7056, 7057, 7104, 7105, 7106, 7107	Bahamas NG 17-06	Ocean Current	Data Collection
Area 2 (3-7 mi. offshore Hallandale Beach	Marine Sciences	6001	Bimini NG 17–09	Ocean Current	Data Collection
		6040	Miami NG 17-08		
	Vision Energy LLC	6001	Bimini NG 17–09	Ocean Current	Data Collection
		6040	Miami NG 17-08		
Area 3 (10-13 mi.offshore Hollywood Beach)	Aquantis LLC/Aquantis Development Co., Inc.	7103	Bahamas NG 17–06	Ocean Current	Data Collection & Technology Testing
Area 4 (4-24 mi. offshore Dania & Hollywood Beaches	Florida Power & Light Co.	6702, 6703, 6704, 6705, 6706, 6707, 6708	Bahamas NG 17–06	Ocean Current	Data Collection
	Vision Energy LLC	6702, 6705, 6706, 6707, 6708	Bahamas NG 17–06	Ocean Current	Data Collection

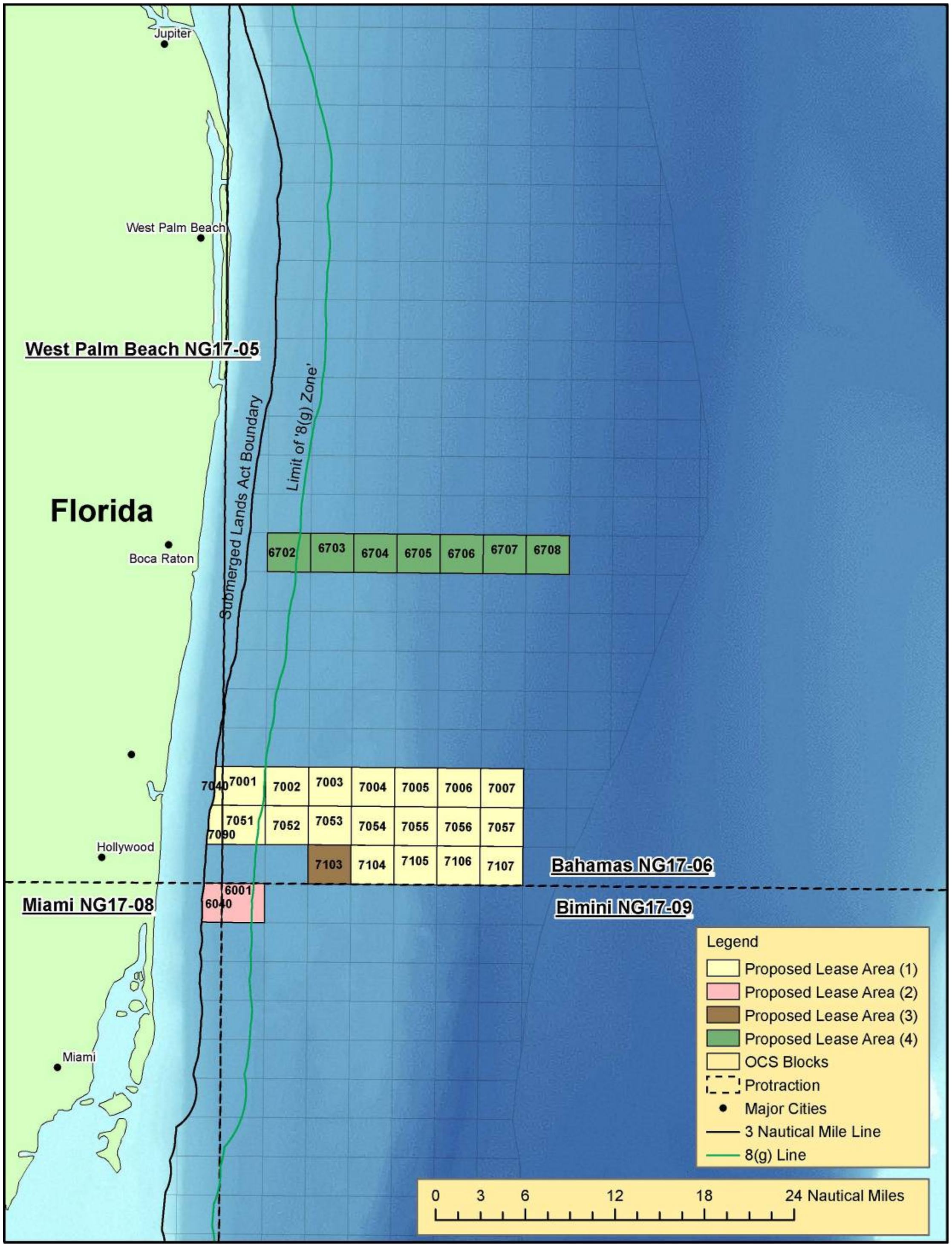

Figure 5-1. Initial MMS Interim Policy Lease Blocks Offer

5.5 Siting Study Framework

Using information collected under this grant, a framework for siting renewable energy projects offshore southeastern Florida was developed with an emphasis on the efficient and effective use of current resources while protecting shallow- and deep-water coral habitats present in some areas as explained in Section 3.

The survey excludes the U.S. Navy's South Florida Testing Facility offshore testing range under the jurisdiction of the U.S. Naval Surface Warfare Center, Carderock Division.

5.6 Consultation with Agencies

The study team consulted with federal, state, and local permitting and resource management agencies throughout the process to ensure that agency requirements (benthic survey equipment/methodologies) are well understood and documented.

5.7 Development Survey Methodology and Scope

Based on the input gathered, a survey methodology and scope was developed and used as described in Section 6 to define the study area(s) for seafloor surveys.

6 FIELD SURVEYS

6.1 Geophysical Survey – Background & Methodology

The Project team selected proposed target areas for geophysical survey in accordance with the 6 April 2010 Work Plan for this project "Siting Study for a Hydrokinetic Energy Project Located Offshore Southeast Florida". The coverage of the geophysical field survey was restricted by the budget approved by DOE to conduct the scope of work specified in the Dehlsen proposal to DOE.

As noted in Section 2.3, we considered the input from the regulatory agencies and prospective project developers during the site selection process. Geophysical and benthic characterization data resulting from this study will assist project developers in making informed decisions about possible specific sites to target or areas to avoid.

6.1.1 Desirable Aspects include:

1. focusing on a suitable depth range. Developers indicated that workable water depths are currently between 250 and 400 meters (about 800 to 1,300 feet) for project siting of marine and hydrokinetic projects. To take advantage of the Florida Current, which is further offshore of Palm Beach County than offshore Broward County, the project team examined lease blocks ranging in depth from ~300 m on the western border of lease blocks to 500 m on the eastern border, including those extending into the coral Habitat Area of Particular Concern (CHAPC).

2. focusing on soft bottoms (sediment), which are desirable relative to hard bottom habitats (but see also Section 2.3.1).

See Section 2.3.1 for additional desirable aspects, and Section 2.4 for areas to avoid or in which to minimize adverse effects.

6.1.2 Areas Targeted for Geophysical Field Investigation

The project team reviewed all the BOEM Interim Policy Blocks proposed offshore Palm Beach, Broward and Miami-Dade Counties. Using the information gathered from developing the GIS database of available data (Section 4.1) and from prospective developers under Section 5.4, three Priority Areas were targeted for the geophysical field investigation off Palm Beach and Broward counties (Figure 6-1). Two Priority Areas were identified offshore Palm Beach County north of the originally designated BOEM Interim Policy Blocks (OCS blocks in Figure 5-1). Blocks now available for consideration by developers are not limited to the Interim Policy Blocks originally designated by BOEM. Priority Area 1 blocks targeted offshore Palm Beach County are 6553, 6554, 6555, and 6556; Priority Area 2 includes blocks 6353, 6354, 6355, and 6356. These blocks span a depth range of 250-500 m directly east of the shallow-water reef gaps identified in Palm Beach County (Figure 4-2, Table 4-4). Both areas are relatively smooth in existing low-resolution NOAA hydrographic survey data, which usually indicates unconsolidated sediment substrates.

Priority Area 3 was identified offshore Broward County and covers BOEM Interim Policy block numbers 7053, 7054, and 7055. Low-resolution NOAA hydrographic survey data suggest that this area lies on the Miami Terrace, which is typically characterized by hard substrates in many of the currently nominated Interim Policy Blocks. Despite the probability that these blocks include extensive hard substrates, the project team chose to sample in this area to verify whether hard bottom habitat is actually present, to correlate substrates with lower resolution NOAA bathymetry, and to recommend protocols for future studies that encounter such habitats. One consideration offshore Broward County is that gaps do not exist in the inner reef and nearshore ridge complex for this area. Horizontal directional drilling or tunneling would be necessary to avoid or minimize impacts to the near-shore coral reef communities. Lease blocks located offshore of Miami-Dade County were omitted from consideration in this study, because existing data indicated close similarities between this area and Broward County, including both the extensive hard substrates of the Miami Terrace and the lack of likely shore approach gaps. Given time and funding constraints, the project team determined that results of investigating the Broward area would be applicable to offshore Miami-Dade County.

Table 6-1 summarizes findings and observations based on review of existing relevant data. If future project developers decide to conduct additional field studies of any of the currently nominated Interim Policy Blocks or any other area offshore Miami-Dade, Broward or Palm Beach Counties, agencies will require detailed field investigations during a project’s licensing process in order to meet all regulatory requirements (refer to Section 5.2).

Table 6-1. Interim BOEM Policy Proposed Lease Blocks Offshore Florida Considered.

Proposed Lease Areas	OCS Block(s)	Official Protraction Diagram	Resource	Proposed Activity	Observations
Area 1 (3 to 24 mi. offshore Dania and Hollywood Beaches)	7054, 7055, 7056, 7104, 7105, 7106	Bahamas NG 17-06	Ocean Current	Data Collection	Within the CHAPC; some blocks appear to include hard bottoms
	7004, 7005, 7006, 7007, 7051, 7054, 7055, 7056, 7057, 7104, 7105, 7106, 7107	Bahamas NG 17-06	Ocean Current	Data Collection	Within the CHAPC; some blocks appear to include hard bottoms. Blocks 7057 and 7107 are within an area designated for dumping of explosives
Area 2 (3 to 7 mi. offshore Hallandale Beach)	6001	Bimini NG 17–09	Ocean Current	Data Collection	Block 6001 is partially within the CHAPC; remainder appears to include hard bottoms
	6040	Miami NG 17-08			
Area 3 (10 to 13 mi. offshore Hollywood Beach)	7103	Bahamas NG 17–06	Ocean Current	Data Collection and Technology Testing	Within the CHAPC; appears to include hard bottoms
Area 4 (4 to 24 mi. offshore Dania and Hollywood Beaches)	6702, 6703, 6704, 6705, 6706, 6707, 6708	Bahamas NG 17–06	Ocean Current	Data Collection	Blocks 6705, 6706, 6707 and 6708 are within the CHAPC. Blocks 6702, 6703, and 6704 are outside the CHAPC boundary but appear to include hard bottoms

6.1.3 Collection of Geophysical Survey Data for Target Areas

Geophysical surveys were conducted under the direction of David F. Naar, Associate Professor, University of South Florida, under contract with Dehlsen. To conduct the geophysical survey, Prof. Naar used a Kongsberg EM 710 FM sweep multibeam backscatter and bathymetry system that operated in the 70 to 100 kHz range to collect the geophysical information in the three Priority Areas. The platform was R/V *Lost Coast Explorer* (Lost Coast Excursions, Miami FL) a 250-ton, 100-ft long Marco built boat with 12-ft draft. Time spent on each major activity was logged as follows: mapping in the three Priority Areas (35 hours), transiting between Priority Areas (7 hours), transiting to and from study areas (46 hours), and sound velocity, calibrations, and problem solving (8 hours).

The swath width was not as wide as anticipated due to three major factors. (1) The "crab" angle for the system in this location of the Gulf Stream (Florida Current) was more significant than anticipated, possibly due to strong southerly winds associated with the presence of hurricane Tomas to the south during November 2010 and a very strong approaching cold front to the northwest. (2) The first area surveyed (Priority Area 2) had primarily very low uniform backscatter intensity (most likely due to fine sediment cover of unknown thickness), which tends to reduce the acoustic sonar swath width. (3) The starboard swath width was reduced due to interference with the ship's keel either while transmitting or receiving.

In an effort to provide a strong stable mount for the sonar below the water line, the sonar was set slightly below the vessel's chine where a bracket was welded directly above for the fabricated schedule 80 steel 8-inch diameter pipe. This "near-the-chine" geometry provided a strong stable location for the sonar mount, which permitted full cruising speeds without concern for vibrations (important when surveying against the Gulf Stream). Unfortunately, the sonar was not quite deep enough to allow the extreme inboard (starboard) transmit and return signals to fully clear the keel despite theoretical calculations made prior to the port side installation of the pole mount in dry dock. This reduced the starboard swath by about 30% of the width compared to the port swath width. Yet, without potentially decreasing stability of the pole mount and increasing cost by spending the additional time (1-2 full days) to remove all the sonar cables from the pipe, fabricate and attach an extender flanged pipe, and then reinstall the sonar, and recalibrate (with no guarantee that the shallow starboard sector would improve), we chose to operate with the stable calibrated geometry with the reduced starboard swath. This required different spacing for the port-to-port and the starboard-to-starboard tracks, which proved to be trivial because the Kongsberg SIS acquisition software allows for different port and starboard track spacing.

The actual survey took a total of 35 hours instead of the anticipated (and budgeted) 24. Priority Area 2 was especially problematic because the uniform and low backscatter intensity returns led to a concern that there was a gain setting or some other unknown problem. Therefore, the swath overlap was increased by making the track line spacing smaller, which equated to 100% overlap in the deeper section. This was useful for cross-checking the data and insuring the backscatter and bathymetry data were correct. Normally, deep to shallow surveys are done parallel to contours. However the east-west geometry of the Priority Areas would have required numerous time-consuming turns to run lines N-S in the Gulf Stream (~3 kts). An east-west “fan” approach with the track lines increasing in spacing from shallow to deep water proved to be the most efficient way to map the remaining boxes. The slight trade-off in this approach was noticed in Priority Areas 1 and 3, where triangular slivers of unmapped areas remain in the NW and SW corners of the western portion of the BOEM blocks. This was not critical to the outcome of the study.

Despite the minor operational limitations described above, the multibeam survey spanned virtually the entire area of each Priority Area, thereby mapping in detail a far greater area than anticipated in the accepted Work Plan.

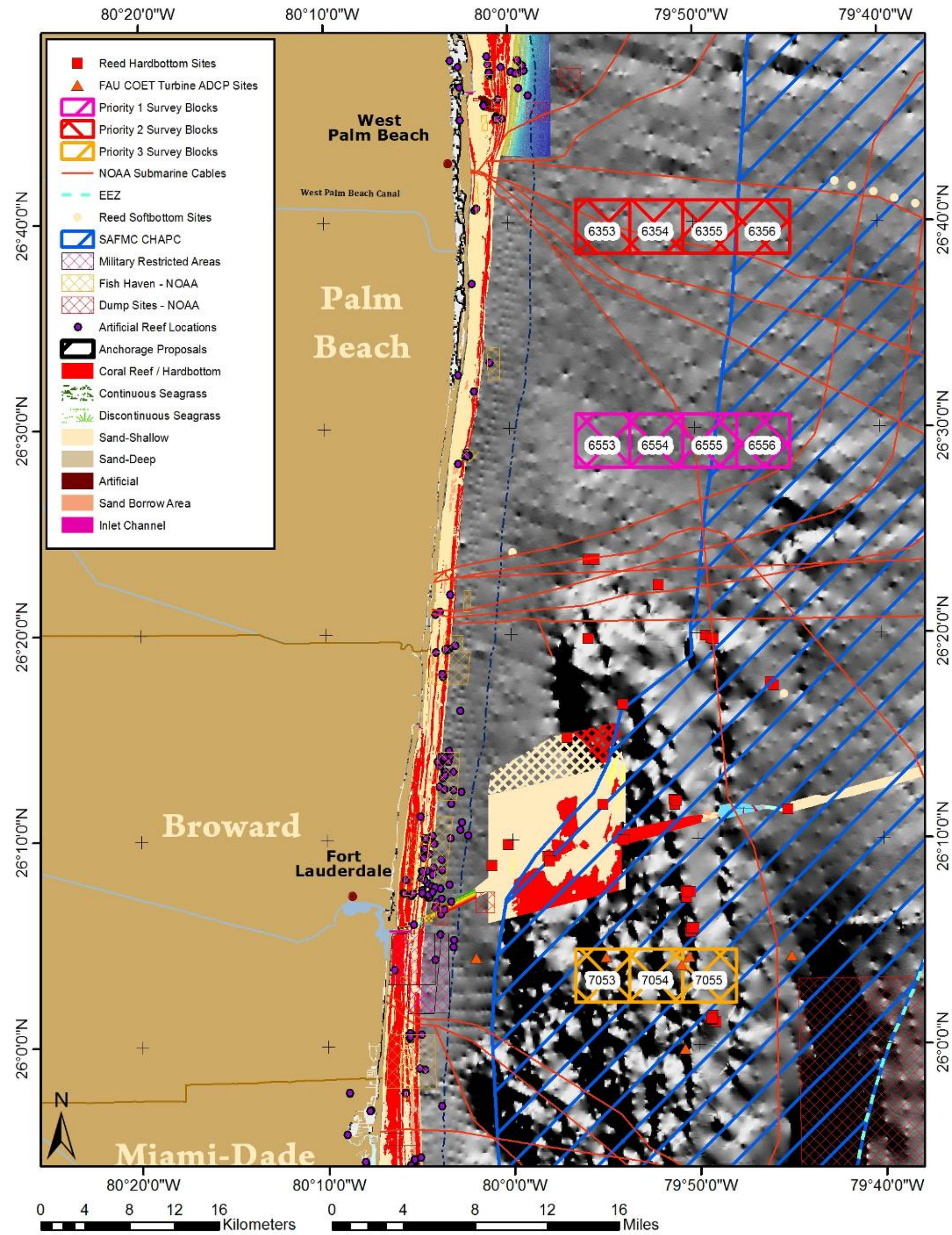

Figure 6-1. Priority Areas 1-3 lease blocks superimposed on existing low-resolution NOAA bathymetry and indicating previously documented seafloor habitats and sites, NOAA submarine cables, and variously restricted areas.

6.2 Geophysical Survey - Results

Geophysical survey data were imported in ArcGIS 9.3 as point data, where each data point had an associated location and depth. Data were interpolated by the Nearest Neighbor algorithm in 3D Analyst and output as a high resolution digital elevation model (DEM). Hillshaded views of each

DEM were created at 45° and 315° sun angle to generate base layers with 3-dimensional perspectives for visualization. Figures 6-2, 6-4 and 6-6 show multibeam seafloor topography surfaces for the three Priority Areas with accompanying depth profiles. Figures 6-3, 6-5 and 6-7 show multibeam backscatter data for the same areas. BOEM blocks and ROV transects are superimposed on each.

6.2.1 Priority Area 1: Southern Palm Beach County

This area extended over four BOEM lease blocks (6553 through 6556) (magenta cross-hatched blocks in Figure 6-1), although the geophysical survey also included the western third of 6557 and most of the eastern half of 6552 (not outlined in Figures 6-2 and 6-3), which were covered as the survey ship turned beyond the survey area to run succeeding swaths. Blocks 6557, 6556 and the eastern ~40% of 6555 lie within the CHAPC (the blue hatched area in Figure 6-1). The smooth multibeam topography suggested that the entire area of the blocks was a gently sloping sediment substrate. However, variations in backscatter imagery suggested several possibly different substrates in blocks 6553, eastern 6556 and, in particular, a different, irregular substrate in a small area in block 6557 east of the defined survey area (Figure 6-3).

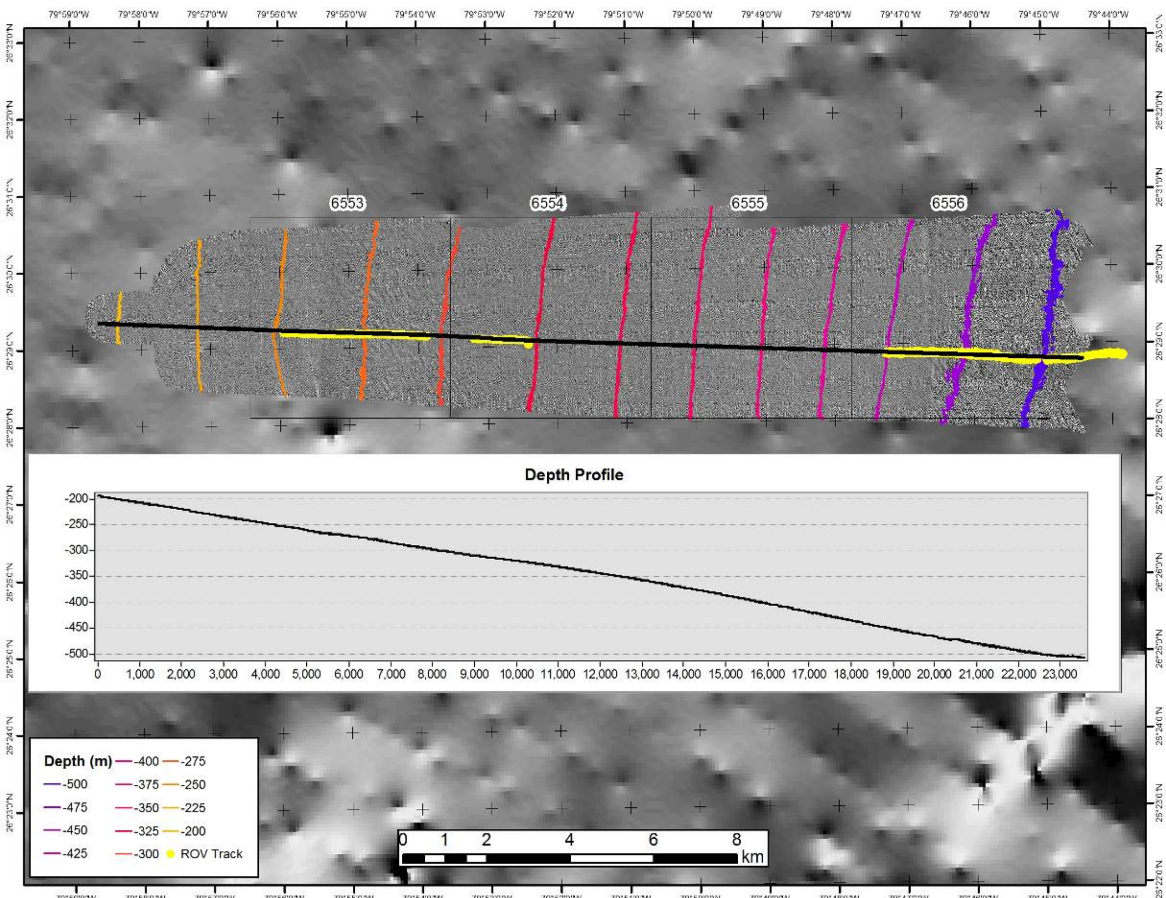

Figure 6-2. Priority Area 1 high-resolution, hillshaded, 3-dimensional image of the multibeam topography data. The black line on the map corresponds to the depth profile in the inset (Y axis = depth in meters; X axis = horizontal distance in meters). Yellow lines illustrate ROV transects.

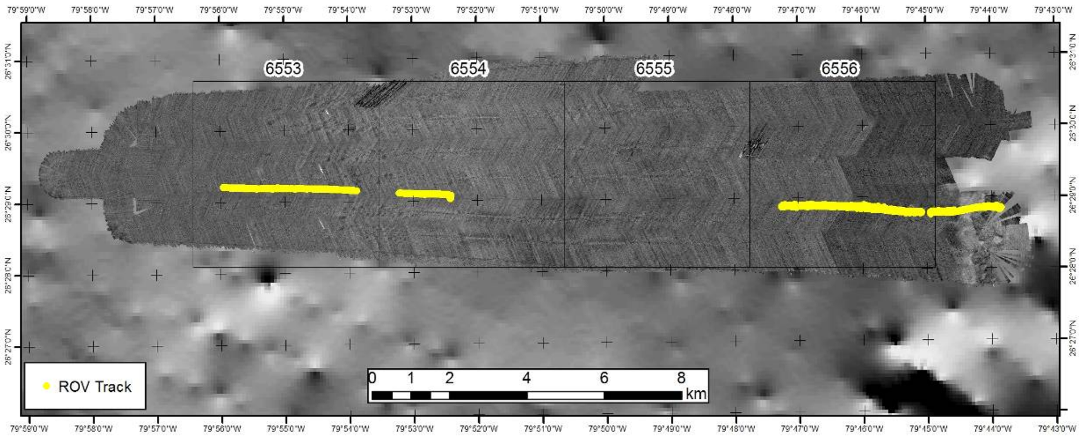

Figure 6-3. Priority Area 1 multibeam backscatter data. Yellow lines illustrate ROV transects.

6.2.2 Priority Area 2: Central Palm Beach County

This site consisted of four BOEM lease blocks, 6353 through 6356, with the latter lying within the CHAPC (northernmost red cross-hatched blocks in Figure 6-1). With the exception of a shipwreck at the western end of the middle transect in block 6355 (not shown in Figures 6-4 or 6-5), no hard substrates were anticipated from the multibeam topography (Figure 6-4). However, backscatter data (Figure 6-5) showed a small distinct spot near the southern boundary of block 6353 that appeared as a depression in the ship track depth profile, and a possibly different substrate straddling the eastern boundary of block 6356.

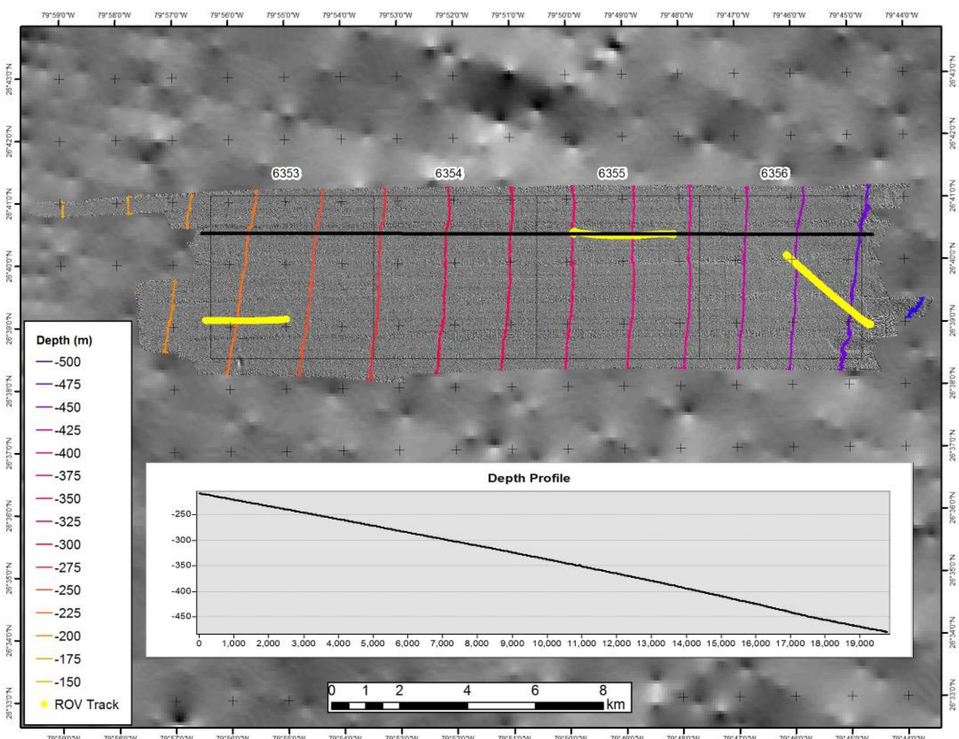

Figure 6-4. Priority Area 2 high-resolution, hillshaded, 3-dimensional image of the multibeam topography data. The black line on the map corresponds to the depth profile in the inset (Y axis = depth in meters; X axis = horizontal distance in meters). The yellow line illustrates the three ROV transects.

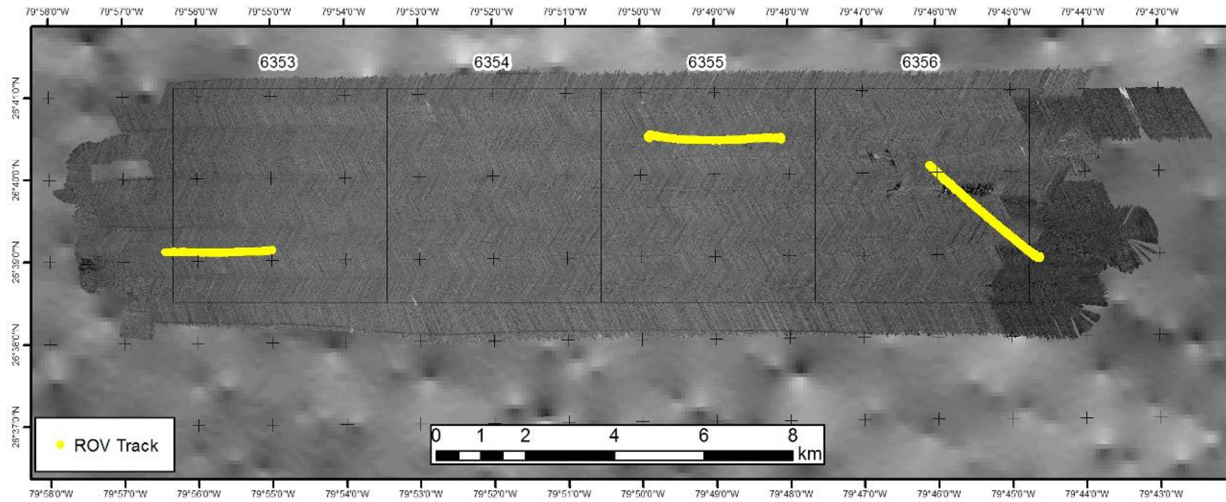

Figure 6-5. Priority Area 2 multibeam backscatter data. Yellow lines illustrate ROV transects.

6.2.3 Priority Area 3—Southern Broward County

This site consisted of three BOEM lease blocks, 7053, 7054, and 7055, which lie completely within the CHAPC (southernmost orange blocks in Figure 6-1). Multibeam topography and backscatter data (Figures 6-6 and 6-7) both suggested substantial areas of irregular hard substrates, including high relief escarpments and sinkholes, as anticipated for this location, which lies within the Miami Terrace. Existing low-resolution NOAA bathymetry in Figure 6-1 clearly shows the northern reach of the Terrace, an elongated, 120-km-long, portion of a drowned carbonate platform that parallels the coast from Broward County to northern Key Largo. This feature covers ~740 km^2, is widest off Miami (22.2 km), and tapers to the north and south where it disappears under prograding sediments (Kofoed & Malloy 1965, Rona & Clay 1966, Malloy & Hurley 1970, Neumann & Ball 1970, Ballard & Uchupi 1971, Mullins & Neumann 1979, Reed *et al*. 2006).

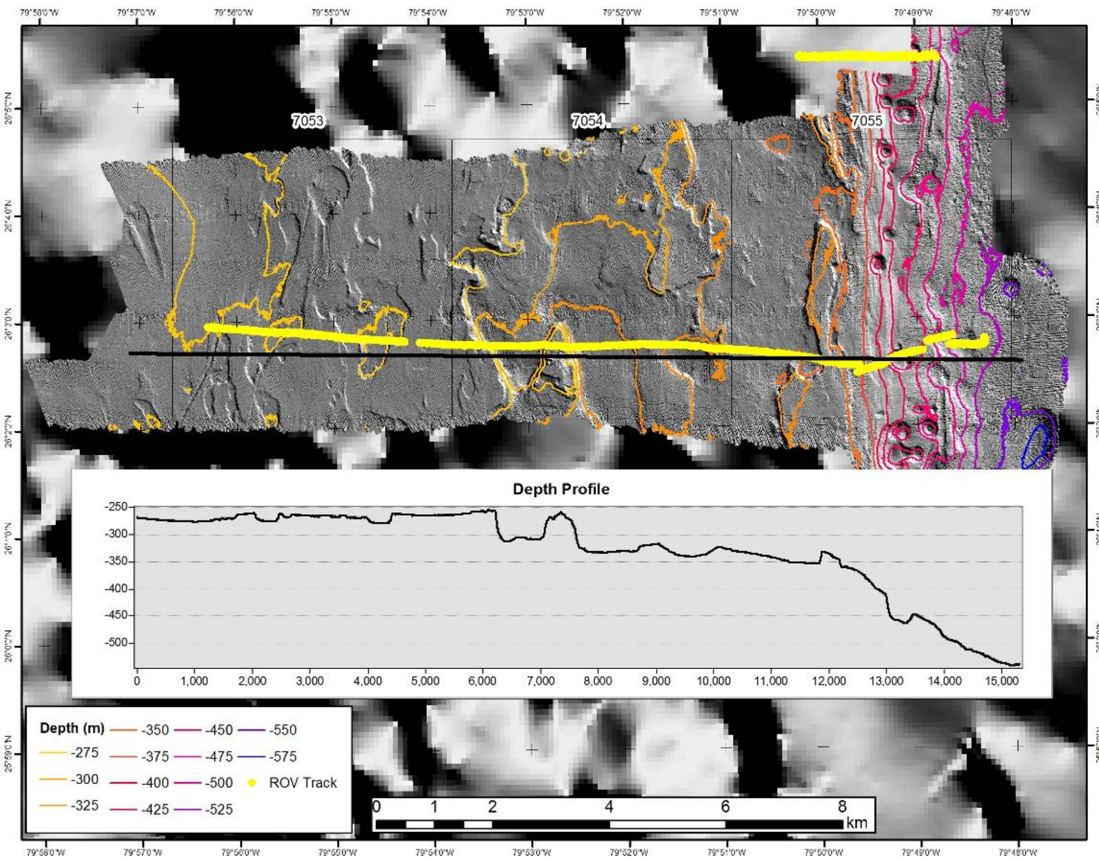

Figure 6-6. Priority site 3 high-resolution, hillshaded, 3-dimensional image of the geophysical data. The black line on the map corresponds to the depth profile in the inset (Y axis = depth in meters; X axis = horizontal distance in meters). The yellow lines illustrate the ROV transects.

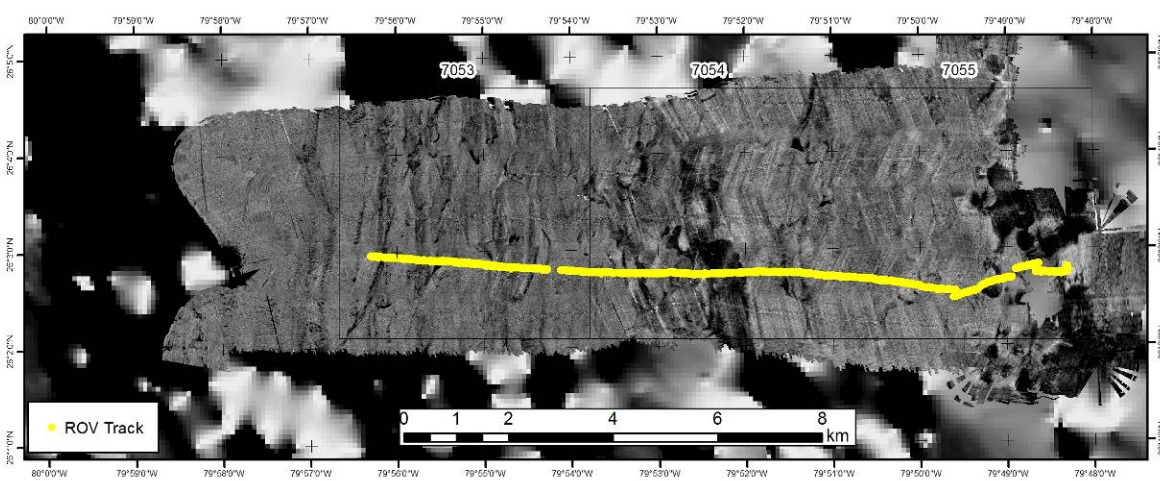

Figure 6-7. Priority Area 3 multibeam backscatter data. The yellow line illustrates the primary ROV transect. The northeastern transect, which lay chiefly beyond the area surveyed by multibeam, is omitted from this image (see Figure 6-6).

6.2.4 Geomorphologic Zone Classification

The benthic habitat map classification was organized by three main components: geomorphologic zone, substrate type, and slope. The geomorphologic zones were identified by previous research (Mullins and Neumann 1979). Most of Priority Areas 1 and 2 were located on the Florida Slope offshore Palm Beach County (Figure 6-8). Priority Area 3 was located on the Miami Terrace, which is much more geographically complex (Figure 6-9). Mullins and Neumann (1979) divided the Miami Terrace into several cross-shelf zones according to their geomorphology as: Upper Terrace, Outer Terrace ridge, and Lower Terrace. This terminology was based on a cross-section across the southern portion of the Miami Terrace; however, it applies to the northern portion as well with some modifications. Differences in the benthic biological communities were evident between these zones; thus they were utilized as a habitat classifier. Differences in biological communities were also evident between two separate platforms of differing depths along the Upper Terrace, which was therefore divided into Inner and Outer Terrace Platforms to distinguish them as separate biological communities. Although not easily recognizable in either the plan-view or 3-dimensional images of multibeam topography (Figures 6-6 and 6-9), the bathymetry of the Outer Terrace Platform generally shoals from south to north across the surveyed area, while the Inner Terrace Platform gently deepens from south to north. It is possible that the two Terrace Platform subdivisions merge north of the survey area and contain similar biological communities.

The area surveyed by multibeam began in ~540 m and ran up the ~40º Lower Terrace and Outer Terrace Ridge across a swath of numerous sinkholes in ~475-360 m before reaching the narrow N-S-oriented crest of the Outer Terrace Ridge in 337 m with up to 20 m local vertical relief. West of this ridge, across the Outer Terrace Platform, the seafloor sloped very gradually upward from 348 m, shoaling only ~20 m overall across a distance of 4.0 nm, although with several broad platforms, depressions and narrow ridges of up to 20-m vertical relief. This gradual slope terminated along the transect line at what appeared to be a spur of Inner Terrace Platform with a vertical relief of ~70 m (~330-260 m). The western margin of this spur dropped to an almost flat stretch of the Outer Terrace Platform about 0.75 nm across in ~310 m before climbing another escarpment of ~60 m vertical relief. Above this feature, the Inner Terrace Platform consisted of chiefly low-relief substrates in 275-250 m with local depressions of 10-m vertical relief that suggested the irregular karstic topography most likely produced by subaerial exposure during the Middle to Late Miocene as reported by Neumann & Ball (1970), Ballard & Uchupi (1971), and Mullins & Neumann (1979).

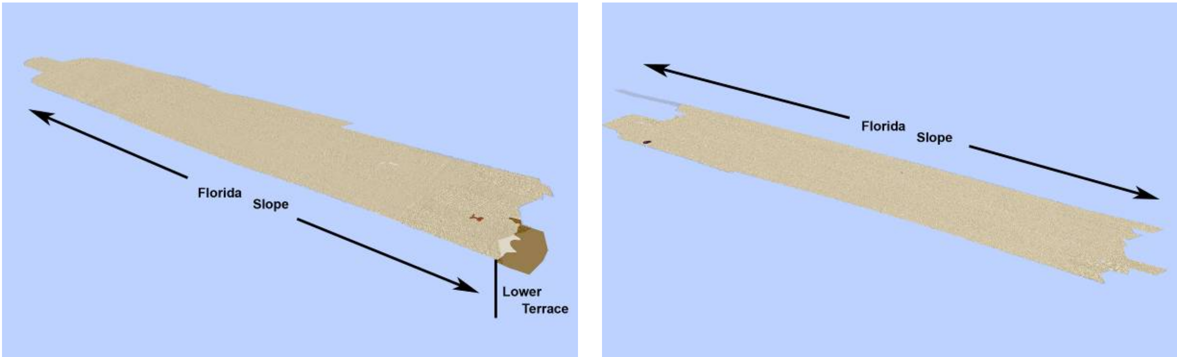

Figure 6-8. Three-dimensional rendering multibeam topography overlain by the benthic habitats illustrating the four major geomorphological features of Priority Areas 1 (left) and 2 (right).

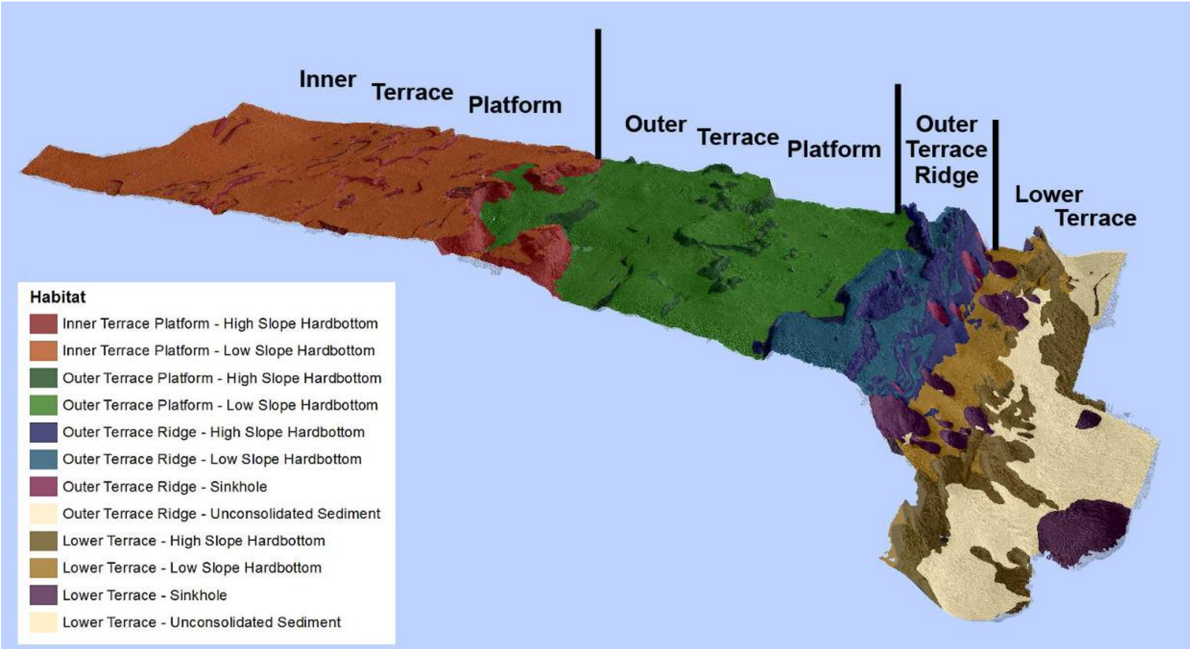

Figure 6-9. Three-dimensional rendering multibeam topography overlain by the benthic habitats illustrating the four major geomorphological features of Priority Area 3.

6.3 Benthic Survey – Background & Methodology

Between 26 January and 31 January 2011, the benthic video and photographic survey was conducted under the direction of Professor Charles Messing, PhD (Nova Southeastern University Oceanographic Center), in cooperation with Brian Walker, PhD (NSU OC), and John Reed, MS (Harbor Branch Oceanographic Institute at Florida Atlantic University) under contract with Dehlsen.

6.3.1 Benthic Survey Equipment

The benthic video survey was carried out aboard the NASA vessel *Freedom Star* (length 53.6 m; beam 11.2 m; draft 3.7 m; displacement 1,052 tons). The survey used the Television Observed Nautical Grappling System (TONGS), a deep-water heavy-lift underwater vehicle owned and operated by the Naval Surface Warfare Center, Carderock Division, South Florida Testing Facility (SFTF), Dania Beach, FL (Figure 6-10). TONGS has a 3,000-m operating depth, 4,500-kg lift capability, and can operate in currents in excess of 5 kt within a 1-m radius on the seafloor for prolonged periods. Underwater position is determined using an ultra-short baseline acoustic tracking system integrated into a differential global positioning system (DGPS), which provides accurate (±1 m) georeferenced bottom positions. TONGS is equipped with 4 color cameras, multiple underwater lights, dual-frequency imaging and search sonar, altimeter and depth sensor. Two cameras are mounted to a pan-and-tilt unit to provide variable camera orientation. TONGS also has two thrusters for orientation and minor positional changes (±10 m). All control, data, and video are multiplexed thru a fiber-optic telemetry system to the surface, providing wide bandwidth and high-quality video (William Baxley, HBOI/FAU, personal communication). For this survey, TONGS was equipped with a Kongsberg OE-1373 high-resolution video camera, OE11242 Flashgun and OE14208 Digital stills camera, the latter provided with a pair of scaling lasers spaced 8 cm apart to permit image area quantification. This specific laser spacing is not a requirement, although frequently used (e.g., Messing et al. 2006 a, b). Much more narrowly separated lasers will not be resolvable when the camera is higher off the bottom; much more widely separated lasers may not both be visible in the image when the camera is closer to the bottom.

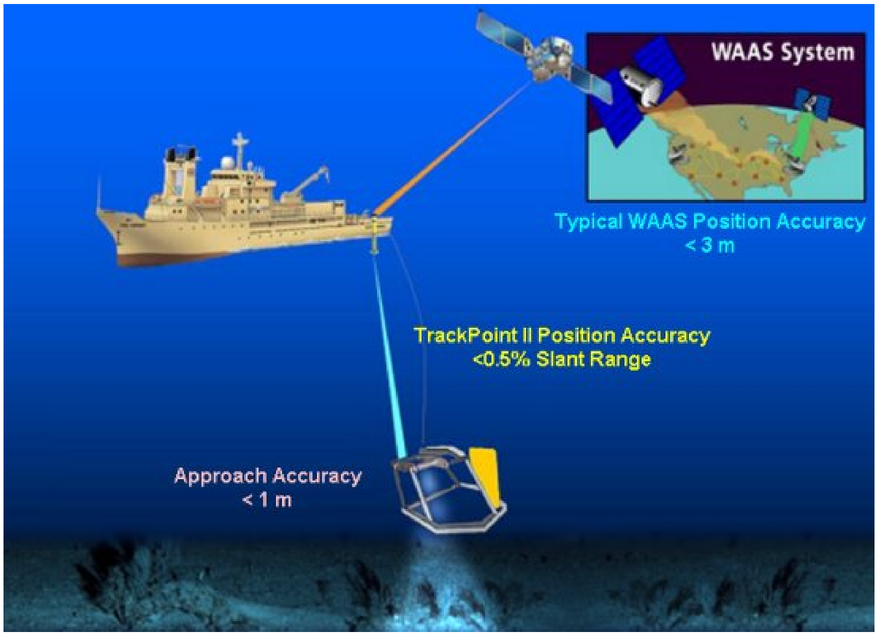

Figure 6-10. Television Observed Nautical Grappling System (TONGS).

6.3.2 Data Collection

Video was run continuously throughout surveys while the ROV was on the bottom (i.e., within 1-2 m of the seafloor. Still images (1-2 MB each) were taken at ~5-min intervals over sediment substrates. Over areas of biological interest on hard substrates, still images were taken repeatedly as soon as the strobe recycled (which ranged from ~5 to over 20 sec) and the ROV moved far enough to avoid overlapping exposures. Images were also taken of specific organisms on all substrates for identification purposes. Transect lines were chosen in order to cover a wide range of topographies and depths (within the range appropriate to the siting study) as reflected by multibeam topography and backscatter data, as well as to accommodate limited available ship time.

Quantitative plan-view digital photography sites (i.e., photostations) were selected on the basis of the presence of high and low slope hard-bottom substrates across geomorphologic zones. The data from the field notes were plotted onto the geophysical data in GIS to guide photostation selection. The field data indicated the extent of hard-bottom substrate along the ROV track. A slope layer was calculated from the geophysical data to distinguish low and high slope areas. Based on the results, it was determined that areas > 5° were considered high slope and areas ≤ 5° were low slope. With the exception of a single site at the far eastern end of Priority Area 1, all quantitative sites were restricted to Priority Area 3 on the Miami Terrace. We originally planned to use ~100 images at a minimum of six sites with satisfactory exposures for quantitative analyses, each series beginning on a habitat of high biological interest. Numbers of images per site were determined pursuant to MMS (now BOEM) guidelines and regulations for assessment of impacts on marine resources and the Florida Fish and Wildlife Conservation Commission (FFWCC) "Guidelines for Conducting Offshore Benthic Surveys" as modified by discussions with MMS. However, a combination of slower than expected camera recycling time plus numerous transitions between low- and high-slope substrates, preliminarily distinguished in multibeam topographic data as less than versus greater than 5° seafloor slope, precluded long enough successive series of images over a single habitat type. As a result, we analyzed quantitative images from a total of 14 sites as follows: 7 Low-Slope sites with 45-73 images each, and 7 High-Slope sites with 27-65 images each (Table 6-2).

Table 6-2. Summary of photostation site images and categorization.

Photostation	Number of Photos	Geomorphologic Zone	Slope
1	57	Inner Terrace Platform	Low
2	54	Inner Terrace Platform	Low
3	45	Outer Terrace Platform	Low
4	37	Inner Terrace Platform	High
5	57	Outer Terrace Platform	Low
6	27	Outer Terrace Platform	High
7	64	Outer Terrace Platform	Low
8	63	Outer Terrace Ridge	Low
9	65	Outer Terrace Ridge	High
10	54	Outer Terrace Ridge	High
11	56	Outer Terrace Ridge	High
12	38	Outer Terrace Ridge	High
13	29	Lower Terrace	High
14	73	Florida Slope	Low

6.3.3. Data Analyses

Following the field surveys, video data were reviewed in the laboratory to confirm organism identifications as far as possible and to define biological zones and benthic habitats. Original field transcripts were summarized to produce habitat descriptions and identify transitions between habitats. Quantitative digital photographs were processed in the laboratory, e.g., to eliminate out-of-focus and excessively dark images and to improve image contrast when necessary. The images varied in brightness and area of cover dependent upon of the height of the ROV off the bottom. Significant shadowing occurred when the ROV was >1 m off bottom. To provide the best image possible, each image was examined in Photoshop. Some were lightened using the Levels/midtone adjustment. Images were then cropped to remove unusable remaining shadowed portions. Images unusable because of dimness, lack of contrast, excessive elevation above bottom, or without visible paired lasers were deleted.

All usable photostation images were analyzed in Coral Point Count with Excel extensions (CPCe)© (Kohler & Gill 2006), a Windows-based software tool for determining benthic habitat and organism cover, area analysis and for image calibration using transect photographs. The relatively low densities of benthic hard-bottom macrofauna anticipated in this study would have required a high number of random points to accurately capture the diversity of organisms and reflect their densities and percent cover. As a result, following successful previous analyses (Messing et al. 2006a, b), images were subjected to a two-stage analysis. Each image was initially analyzed using CPCe software for percent substrate cover (e.g., hard bottom, sediment-veneered hard bottom, sediment) with organisms identified to a general taxonomic level (e.g., sponge, cnidarian, echinoderm) at a density of 50 points per image (Table 6-3). Each image was then re-examined and all organisms larger than ~4 cm enumerated and identified as specifically as possible (e.g., *Pseudodrifa nigra*, *Phakellia* sp., Isididae, anemone sp. 1, unidentified hexactinellid).). Borderline small organisms were measured by magnifying the image (usually to ~50%), spanning the laser dots with a pair of 10-point dividers, and using 0.4 of that length (~3 cm) to decide which animals should be included or omitted. Numbers of encrusting and smaller colonial organisms (e.g., zoanthids) were estimated. Several groups of organisms could not be accurately quantified for several reasons. Although some hydroids (Hydroidolina) were resolvable as individual colonies, many occurred in clusters of overlapping, filmy colonies. The great majority of ophiuroids (Ophiurida; which does not include euryalid snakestars and basketstars) were visible only as arms protruding from crevices, burrows or sediment; in many cases, substantial numbers were out of focus in a given image. Solitary corals (Scleractinia) were chiefly <3 cm across. These three groups were ranked by relative abundance classes (i.e., few, common, abundant) and were not included in quantitative analyses. Image area was calculated by converting image length and width in pixels to centimeters based on the number of pixels equivalent to the 8-cm laser scale. Organism densities per square meter (m^{-2}) were calculated by extrapolating from the number of organisms in the image area. After analysis of each image, the data were saved into an Excel database for analyses of 1) raw percent composition and 2) percent composition per area for each quantitative photo site. Calculations excluded all points categorized as photo effects (i.e., shadow, laser).

The percent cover data from the CPCe image analyses were analyzed using a multivariate approach. Benthic data at the subcategory level (Table 6-3) (excluding fish, human debris, Detritus, Cable, Shadow, and unidentified organism) were analyzed using Bray-Curtis similarity indices (PRIMER v6) for similarity between photostations (Clarke & Gorley 2006). A cluster analysis and corresponding non-metric multi-dimensional scaling (MDS) plot was constructed of the data (square-root transformed) to understand the statistical relationships between sites. Sites were displayed by the map habitat classifications. Similarity percentages (SIMPER) were obtained for the geomorphologic zones and slope classifications to gauge what cover categories contributed most to the site differences between classifications.

Table 6-3. CPCe categories (BOLDFACE CAPS) and subcategories used in the photostation image analyses. (Note that the echiuran was treated as an annelid in both qualitative and quantitative analyses below, according to the most current phylogeny.)

CORAL (COR)	Alcyonacea (ALC)	**BRYZOA (BRY)**
Colonial Dead Coral (DC)	Antipatharia (ANT)	Bryzoa (BRY)
Coral Rubble (CR)	Cerianthidae (CER)	**PORIFERA (POR)**
Lophelia pertusa (LOP)	Corallimorpharia (CRM)	Demospongiae (DEM)
Madracis spp. (MCS)	Gorgonacea (GOR)	Hexactinellida (HEX)
Madrepora spp. (MAD)	Hydroidolina (HYD)	Unidentified Porifera (UPO)
Solitary Coral (SC)	Pennatulacea (PEN)	**UNIDENTIFIED ORGANISM (UND)**
Unidentified Colonial Live Coral (LC)	Stylasteridae (STY)	Unidentified Organism (UND)
ANNELIDA (ANN)	Unidentified Cnidarian (UCN)	**SOFT BOTTOM SUBSTRATE (SB)**
Sabellidae (SAB)	Zoanthidea (ZOO)	Sand-Shell Hash (HAS)
Serpulidae (SER)	**ECHINODERMATA (ECH)**	Soft Bottom Substrate (SB)
Unidentified Annelida (UAN)	Asteroidea (AST)	**HARD BOTTOM SUBSTRATE (HB)**
ARTHROPODA (ART)	Crinoidea (CRI)	Rock Outcrops & Pavement, Sediment Veneer on Hard Bottom, Ledges, Boulders (ROC)
Anomura hermit crab (ANO)	Echinoidea (ECI)	Rubble, Cobble, Gravel (RUB)
Brachyura crab (BRC)	Holothuroidea (HOL)	**CABLE (CB)**
Cirripedia (CIR)	Ophiuroidea (OPH)	Cable (CB)
Galatheidae (GAL)	**ECHIURA (ECR)**	**HUMAN DEBRIS (HUM)**
Isopoda (ISO)	Echiuran (ECR)	Fish/Crab Trap (TRP)
Lobster- Astacidea (LOB)	**MOLLUSCA (MOL)**	Fishing Line/Long Line (FSL)
Shrimp [Penaeidea, Caridea] (SHR)	Bivalvia (BIV)	Other Human Debris (HUM)
CHORDATA (CHO)	Cephalopoda (CEP)	Trawl Gear (TRL)
Fish (FIS)	Gastropoda (GAS)	**NATURAL DETRITUS (DET)**
Urochordata, Ascidiacea (URO)	Polyplacophora (CHI)	Plant/Animal Detritus (DET)
CNIDARIA NON-SCLERACTINIA (CNI)	**BRACHIOPODA (BRA)**	**TAPE, WAND, SHADOW, PHOTO EFFECT (TWS)**
Actinaria Non-Ceriantharia (ACT)	Brachiopoda (BRA)	

6.4 Benthic Survey – Descriptive Results

This section describes the bathymetry, substrates and benthic organism assemblages by Priority Area, transect, and, in the case of Priority Area 3, geomorphologic zone.

6.4.1 Priority Area 1—Southern Palm Beach County.

The three ROV video and still camera transects running through this site were chosen on the combined basis of variations in multibeam topography, backscatter, depth, and limited available ship time. Moving from east to west, the East Transect began eastward of our planned survey area (in block 6557) but was examined in order to groundtruth areas in the multibeam backscatter imagery that suggested a different substrate type than the smooth returns across the rest of the area (Figures 6-3 and 6-11). This area corresponded to the northern end of the Lower Miami Terrace (Figure 6-8). The transect continued westward up the Florida Slope across the boundary between blocks 6657 and 6556 to verify the correspondence between the transitions from rough to smooth multibeam backscatter data and low-relief hard bottom to sediment, and to examine a small area of irregular multibeam topography in block 6556; this proved to be an area of scattered low-relief hard bottom but was too limited in extent for a quantitative photostation. The Middle Transect covered about a third of the width of block 6554 in the western half of the block. The West Transect spanned most of the width of block 6553.

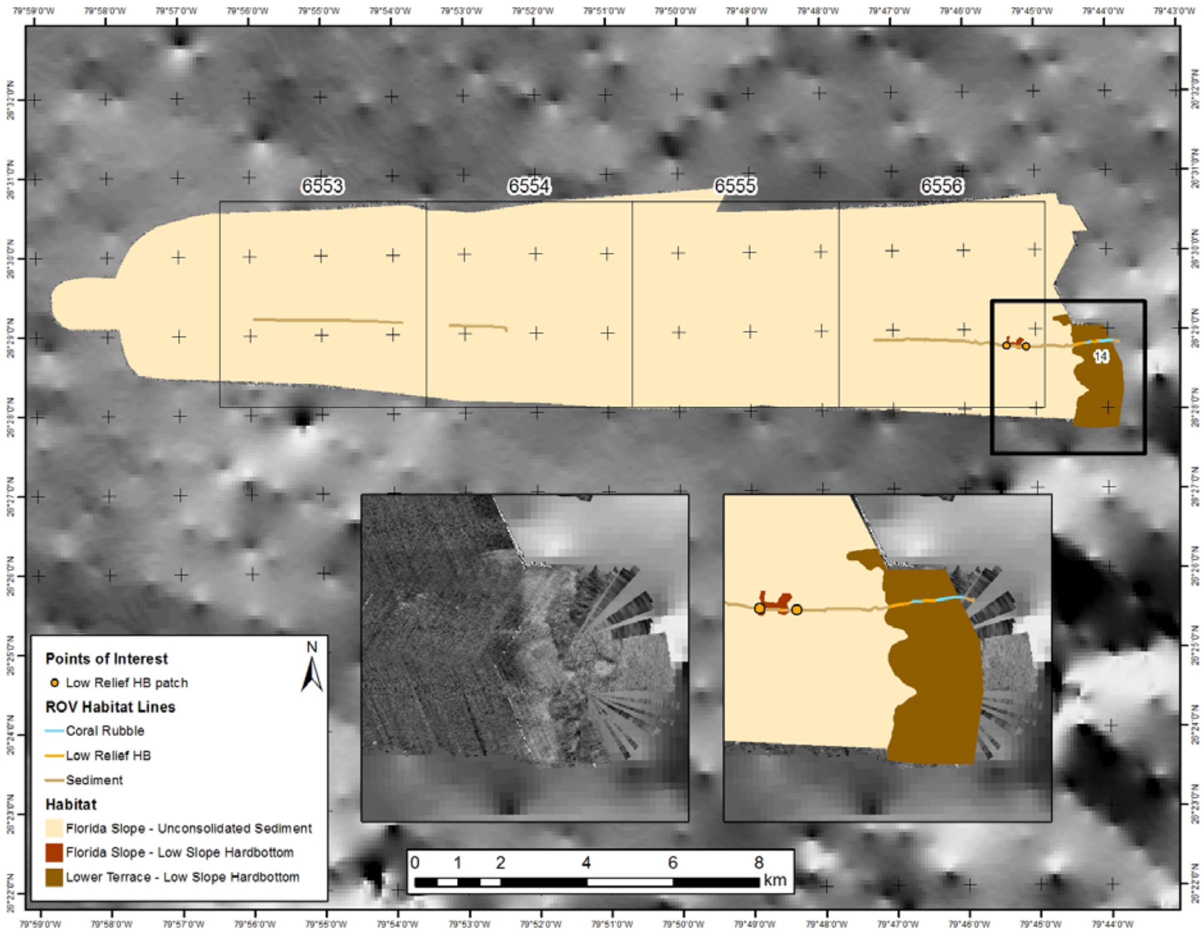

Figure 6-11. Priority Area 1 Benthic Habitat Map. Inserts compare irregular multibeam backscatter data (lower left) with habitat map detail (lower right).

<u>Priority Area 1 East Transect (26.480789 N, 79.730751 W to 26.481275 N, 79.787713 W)</u>.— From the easternmost end of the transect at a depth of 519 m and extending to 503 m, the seafloor consisted of sediment with scattered to abundant azooxanthellate coral rubble (<10 cm; probably *Lophelia pertusa*), scattered phosphoritic limestone gravel (chiefly <3 cm), and areas of low-relief phosphoritic limestone pavement, slabs, cobbles and gravel (Figures 6-11, 6-12); hard-bottom exposures were chiefly less than 20 cm across and rarely up to 1 m across. This habitat is referred to as Lower Terrace Low Slope Hardbottom in Figure 6-11 and indicated in dark brown. Patches of sediment alone were also present. The most abundant organisms were hexactinellid sponges followed by the octocoral *Eunicella* sp. Table 6-4 lists fauna. This list differs slightly from that given in the quantitative analysis below (section 6.2.6) as it includes images not included in that analysis. The extent of putative hard bottom in the multibeam topography and the visual observations of exposed hard substrates corresponded well; both ended near 26.47995 N, 79.74125 W.

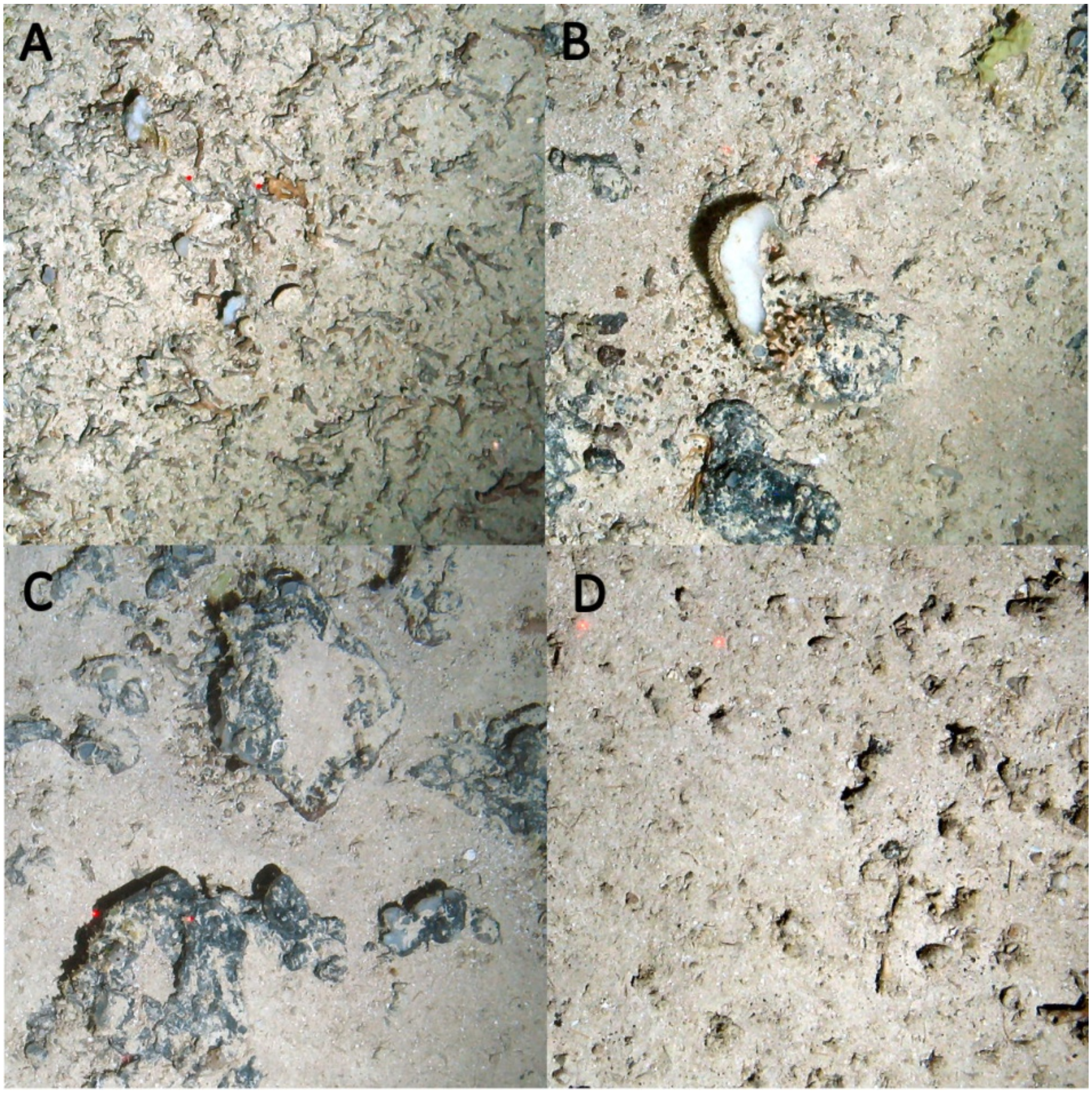

Figure 6-12. Priority Area 1 East Transect hard substrates. A. Coral rubble (probably Lophelia pertusa*). B. Low-relief phosphoritic limestone slabs, rubble and gravel with sponges and zoanthid colony (just to right of white sponge). C. Low-relief barren phosphoritic limestone slabs, cobbles and outcrops. D. Gravel. Scaling lasers 8 cm apart (enhanced in A).*

Table 6-4. Priority Area 1 East Transect. Benthic macrofauna on chiefly hard substrates in quantitative photo transect.

TAXON	TAXON	TAXON
PORIFERA	CNIDARIA	ANOMURA
Unidentified Porifera	OCTOCORALLIA	Unidentified paguroid
DEMOSPONGIAE	*Eunicella* sp.	ASTACIDEA
Phakellia sp.	*Plumarella* sp.	*Nephropsis aculeata*
Unidentified Desmacellidae	ACTINIARIA	ECHINODERMATA
Unidentified demosponge	Unidentified anemone	OPHIUROIDEA
HEXACTINELLIDA	ZOANTHIDEA	Unidentified ophiuroid
Farrea sp.	Unidentified zoanthid	VERTEBRATA
Hertwigia falcifera	HYDROZOA	OSTEICHTHYES
Heterotella sp.	Unidentified Stylasteridae	*Chaunax pictus*
Hyalonema sp.	Unidentified hydroids	*Chlorophthalmus agassizi*
Vazella sp.	BRYOZOA	*Helicolenus dactylopterus*
Unidentified hexactinellid	Unidentified bryozoan	*Nezumia* sp.
	CRUSTACEA	Unidentified eel
	Unidentified shrimp	

Once beyond the mixed gravel, hard bottom and coral rubble habitat, the seafloor became almost exclusively weakly bioturbated sediment dominated by small (~1 cm) fecal casts or short tubes of infauna darker than the surrounding sediment, with scattered to common small low mounds, craters and distinctive burrows of the nephropid lobster, *Nephropsis aculeata* (treated in field notes as *Acanthacaris caeca*) (Figure 6-13A). The ROV crossed the corner of a small area of irregular multibeam topography (brown area in Figure 6-1), which was groundtruthed as scattered gravel and rock rubble patches with one area about 15 m across of phosphoritic limestone cobbles, slabs and rocks up to about 20 cm across (Figure 6-13B). Organisms on hard substrates included an anemone, solitary scleractinian corals, the fan sponge *Phakellia* sp., an ophiuroid, and a small patch of hydroids. Table 6-5 lists organisms observed on sediment substrates.

Figure 6-13. Priority Area 1 East Transect. A. Lobster Nephropsis aculeata *on smooth, weakly bioturbated sediment with infaunal fecal casts or short tubes. B. Low-relief phosphoritic limestone outcrops and gravel in small area of irregular multibeam topography (burnt orange area in Figure 6-11). Scaling lasers 8 cm apart (enhanced in A).*

Table 6-5. Benthic macrofauna observed on chiefly sediment substrates in Priority Area 1 East Transect.

TAXON	TAXON	TAXON
PORIFERA	CARIDEA	CRINOIDEA
HEXACTINELLIDA	*Glyphocrangon* sp.	*Atelecrinus* sp.
Hyalonema sp.	ASTACIDEA	ECHINOIDEA
CNIDARIA	*Nephropsis aculeata*	*Araeosoma ?belli*
Unidentified cerianthids	ANOMURA	VERTEBRATA
Unidentified gorgonian	Unidentified galatheid	CHONDRICHTHYES
PLATYHELMINTHES	BRACHYURA	*Galeus arae*
?Unidentified flatworm	Unidentified Majoidea	Unidentified Rajidae
ANNELIDA	MOLLUSCA	OSTEICHTHYES
?Onuphidae tubes	CEPHALOPODA	*Chaunax pictus*
CRUSTACEA	Unidentified squid	*Chlorophthalmus agassizi*
ISOPODA	Unidentified octopus	*Laemonema* sp.
Bathynomus giganteus	ECHINODERMATA	*Nezumia* sp.
PENAEOIDEA	ASTEROIDEA	*Peristedion* sp.
Pleoticus robustus	Unidentified goniasterid	Unidentified fishes

Priority Area 1 Middle Transect (26.483858 N, 79.87362 W to 26.485243 N, 79.88686 W).—This transect (312-303 m) consisted entirely of unconsolidated sediment: chiefly extensive areas of low irregular ripple marks with coarse lag in troughs alternating with occasional smooth, weakly bioturbated sediment with small mounds, depressions and trails. This substrate (and that in the West Transect, below) reflects the smooth topography recorded by the multibeam. The most common organisms were small asteroids (including *Astropecten* sp.) and fishes: shortnose greeneye (*Chlorophthalmus agassizi*), roughtail cat shark (*Galeus arae*) and blind torpedo (*Benthobatis marcida*) (Figure 6-14). The benthic fauna is similar to that of the West Transect, and the organisms in both are listed together in Table 6-6. The only organisms found in this transect but not in the next are the crabs *Acanthocarpus alexanderi* and *Chaceon fenneri*, and fishes: dragonet *Callionymus* sp. and rattail Macrouridae (probably *Nezumia* sp.).

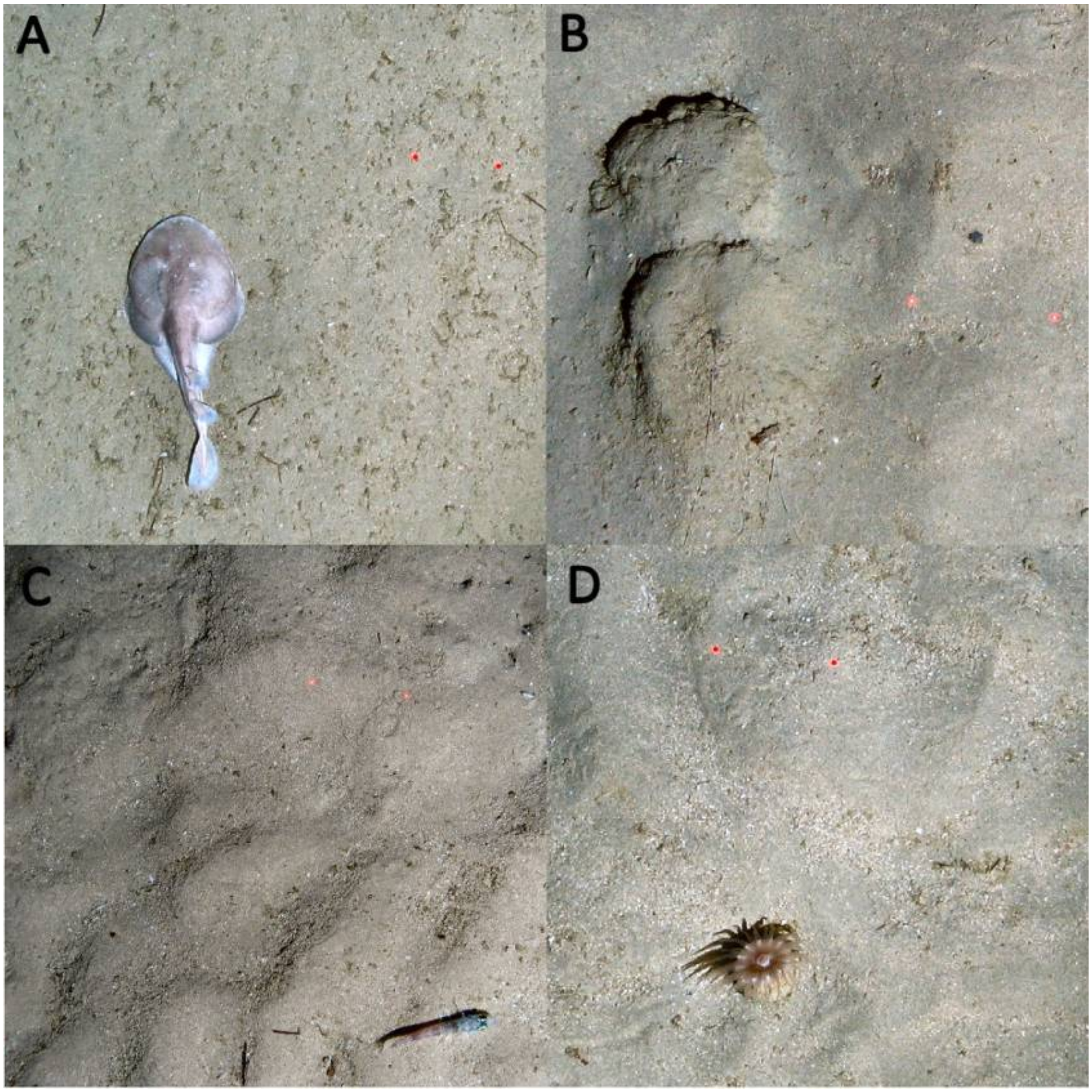

Figure 6-14. Priority Area 1. Middle and West Transect substrates. A. Blind torpedo Benthobatis marcida *on smooth sediment with small dark fecal casts or worm tubes. B. Cake-like probable fecal mounds. C. Shortnose greeneye* Chlorophthalmus agassizi *on sediment with weak, irregular, obsolete ripple marks. D. Sea anemone* Actinauge *sp. on obsolete rippled sediment. Scaling lasers 8 cm apart (enhanced in A & D).*

Priority Area 1 West Transect (26.48587 N, 79.897923 W to 26.486914 N, 79.93254 W).—This transect (290-245 m) also traversed entirely unconsolidated substrate, again dominated by low irregular obsolete ripple marks but alternating with broader smooth, weakly bioturbated areas with sparse to numerous small structures that are likely worm tubes, and fine darker sediment clumps or cakes that appear to be fecal mounds (Figure 6-14B). Although found in both this and the preceding transect, the sea anemone *Actinauge* sp. and many-armed sea star *Coronaster briareus* were the most common organisms in the West Transect. The only taxa noted here and not in the Middle Transect were the sea star *Sclerasterias* sp. and a possible triglid sea robin (Table 6-6).

Table 6-6. Benthic macrofauna observed in Priority Area 1 Middle and West Transects. A question mark preceding a name in this and subsequent tables indicates uncertain identification due to insufficient image resolution.

TAXON	TAXON	TAXON
CNIDARIA	*Cancer borealis*	*Galeus arae*
ACTINIARIA	*Chaceon fenneri*	Unidentified Rajidae spp.
Actinauge sp.	MOLLUSCA	OSTEICHTHYES
CERIANTHARIA	CEPHALOPODA	*Callionymus* sp.
Unidentified cerianthid	Unidentified octopus	*Chlorophthalmus agassizi*
CRUSTACEA	ECHINODERMATA	?*Citharichthys* sp.
PENAEOIDEA	ASTEROIDEA	*Laemonema* sp.
Pleoticus robustus	*Astropecten* sp.	?Ophichthidae
ANOMURA	*Coronaster briareus*	*Nezumia* sp.
Unidentified galatheid	*Sclerasterias* sp.	*Peristedion* sp.
Unidentified paguroid	Unidentified goniasterid	?Triglidae
BRACHYURA	VERTEBRATA	*Urophycis* sp.
Acanthocarpus alexanderi	CHONDRICHTHYES	Unidentified eel
Bathynectes longispina	*Benthobatis marcida*	

6.4.2 Priority Area 2—Central Palm Beach County

This site consists of four BOEM lease blocks located along the Florida Slope, 6353 through 6356, with the latter lying inside the CHAPC (northernmost red cross-hatched area in Figure 6-1). The three video and still camera transects running through this area (Figures 6-4, 6-5 and 6-15) were chosen on the combined basis of variations in multibeam topography, backscatter, depth, and limited available ship time. Moving from east to west, the East Transect ran diagonally SE to NW across most of block 6356. The Middle Transect covered most of the width of block 6355 and terminated at a possible artificial return in the multibeam topography, which proved to be the wreck of a ship (Figure 6-16C). The West Transect spanned the western half of block 6353. With the exception of the shipwreck, no hard substrates were anticipated from the multibeam topography or backscatter data, and none were encountered with the ROV. A small distinct spot near the southern boundary of block 6353 was interpreted as a possible sinkhole in the benthic habitat map (Figure 6-15). It appeared as a depression in the depth profile and was very smooth as if covered by sediments. This area was not visited for confirmation due to time and budget constraints.

<u>Priority Area 2 East Transect (26.649163 N, 79.743468 W to 26.668147 N, 79.768293 W).</u>—With the exception of a few widely isolated phosphoritic rubble clasts no more than ~10 cm across, the substrate along this transect (480-441 m) alternated between expanses of low, obsolete, irregular ripple marks and smooth, weakly bioturbated sediment often with abundant apparent worm tubes. Bioturbation consisted of small mounds, shallow depressions, probable *Nephropsis* burrows, trails, and cake-shaped probable fecal mounds up to ~15 cm across. By far, the most abundant organism was the sea anemone, *Actinauge* sp., which anchors by enveloping a bolus of mud with its pedal disk, but also attaches to the few small rubble clasts observed. Table 6-7 lists all organisms observed.

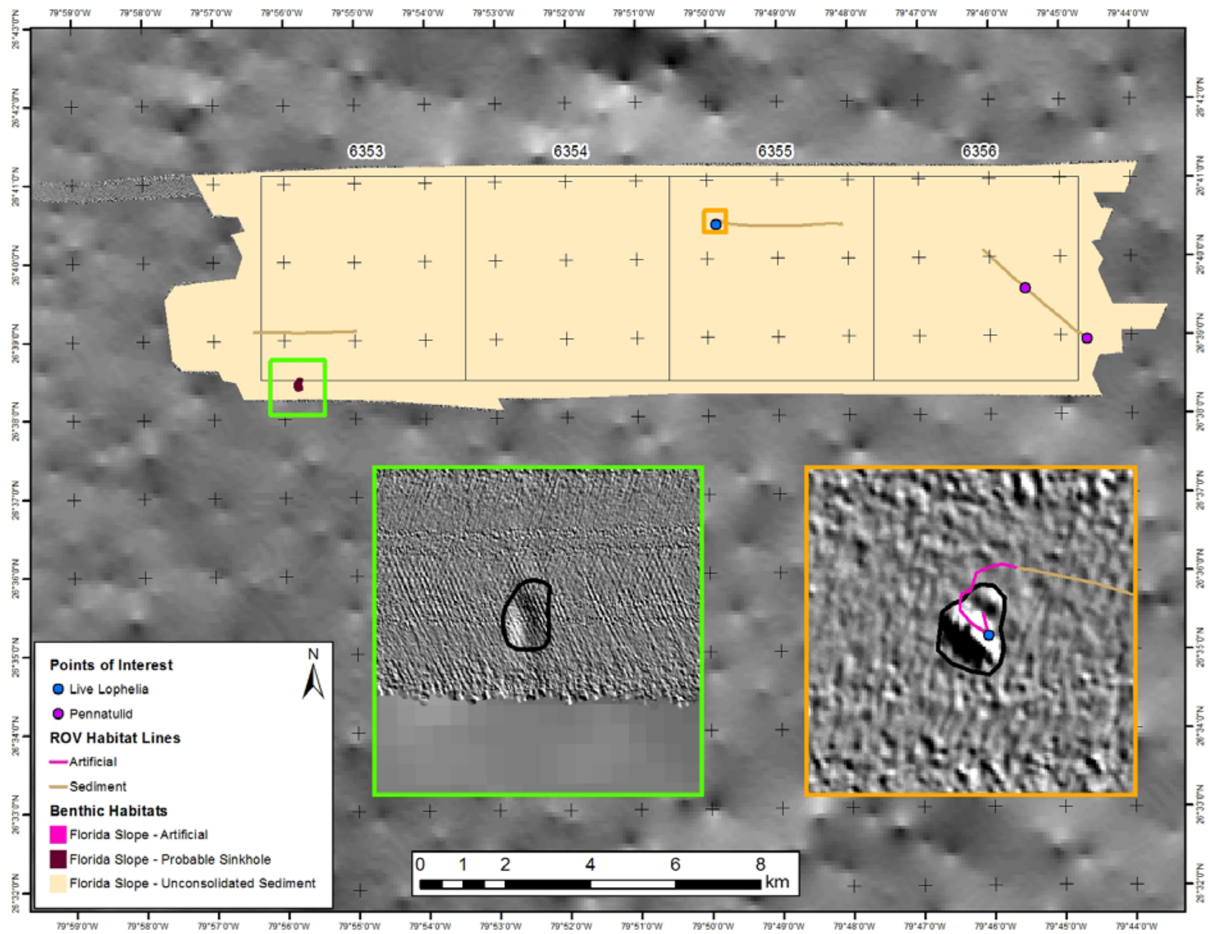

Figure 6-15. Priority Area 2 Benthic Habitat Map. Left insert (green) illustrates a depression in the multibeam that could be a potential sinkhole. Right insert (orange) shows a mound that was confirmed as a shipwreck.

Table 6-7. Benthic macrofauna observed in Priority Area 2 East Transect.

TAXON	TAXON	TAXON
CNIDARIA	ASTACIDEA	VERTEBRATA
OCTOCORALLIA	*Nephropsis aculeata*	CHONDRICHTHYES
?*Anthomastus* sp.	ANOMURA	*Benthobatis marcida*
?Pennatulid	Unidentified galatheid	*Galeus arae*
ACTINIARIA	BRACHYURA	Unidentified Rajidae
Actinauge sp.	*Cancer borealis*	OSTEICHTHYES
CERIANTHARIA	MOLLUSCA	*Chaunax pictus*
Unidentified cerianthid	GASTROPODA	*Chlorophthalmus agassizi*
CRUSTACEA	Unidentified ?buccinid	?*Citharichthys* sp.
PENAEOIDEA	ECHINODERMATA	*Laemonema* sp.
Pleoticus robustus	CRINOIDEA	*Nezumia* sp.
CARIDEA	?Comatulid crinoid	*Peristedion* sp.
Glyphocrangon sp.	ECHINOIDEA	Unidentified fish
	Araeosoma sp.	

Priority Area 2 Middle Transect (26.674161 N, 79.8017 W to 26.674333 N, 79.831281 W).—Initial weak, irregular obsolete ripple marks in 385 m gave way to chiefly featureless almost smooth sediment with scattered shallow depressions, low mounds, probable *N. aculeata* burrows, and possible worm tubes (Figure 6-16A). The most common organisms were royal red shrimp (*Pleoticus robustus*) (Figure 6-16B), asteroids (including Goniasteridae and *Astropecten* sp.) and fishes: *C. agassizi* and *Nezumia* sp. Table 6-8 lists all organisms. A field of scattered small white rocks (< 8 cm across) appeared in advance of a large debris mound of unknown material discolored by possible bacterial mat, followed by the largely barren wreck of a large barge, with an otter trawl hung up on both debris mound and wreck in 346 m. The most common organism associated with the wreck was blackbelly rosefish (*Helicolenus dactylopterus*). Elevated portions of sides of the wreck supported unidentified yellow octocoral fans, sponges, and Venus flytrap anemones (*Actinoscyphia* sp.), with small to large colonies of *Lophelia pertusa* chiefly confined to the upper bow (Figure 6-16C). Other organisms associated with the wreck included squat lobster (*Eumunida picta*), hydroids, worm tubes, *Cancer borealis*, *Laemonema* sp. and a carcharhinid shark.

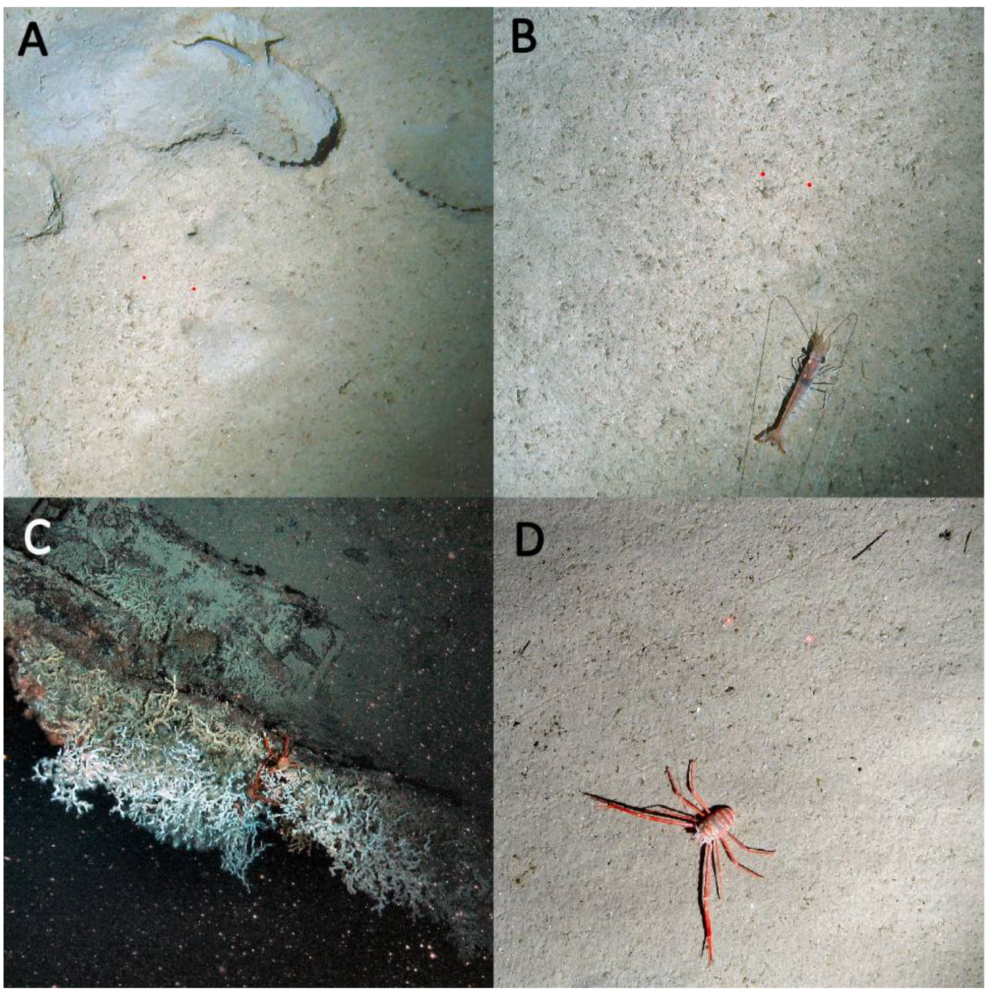

Figure 6-16. A-C. Priority Area 2 Middle Transect. A. Apparently vacant burrow of Nephropsis aculeata*. B. Royal red shrimp,* Pleoticus robustus*, on featureless sediment. C. Azooxanthellate stony coral,* Lophelia pertusa*, with chyrostylid squat lobsters,* Eumunida picta*, on bow of barge wreck. D. Priority Area 2 West Transect. Galatheid squat lobster on featureless sediment. Scaling lasers 8 cm (enhanced in A & B).*

Table 6-8. Benthic macrofauna observed in Priority Area 2 Middle Transect. The anemone Actinauge *sp. (*) was found on small rocks adjacent to the barge wreck.*

TAXON	TAXON	TAXON
CNIDARIA	BRACHYURA	VERTEBRATA
OCTOCORALLIA	*Acanthocarpus alexanderi*	CHONDRICHTHYES
Unidentified soft coral	*Cancer borealis*	*Benthobatis marcida*
ACTINIARIA	*Chaceon fenneri*	*Galeus arae*
Actinauge sp.*	Unidentified Majoidea	Unidentified Rajidae
CERIANTHARIA	MOLLUSCA	OSTEICHTHYES
Unidentified cerianthid	CEPHALOPODA	*Chaunax pictus*
ANNELIDA	Unidentified octopus	*Chlorophthalmus agassizi*
?Unidentified Onuphidae	Unidentified squid	?*Citharichthys* sp.
CRUSTACEA	ECHINODERMATA	*Laemonema* sp.
PENAEOIDEA	CRINOIDEA	?Ophichthidae
Pleoticus robustus	*Democrinus brevis*	*Nezumia* sp.
CARIDEA	ASTEROIDEA	*Peristedion* sp.
Glyphocrangon sp.	*Astropecten* sp.	?Triglidae
ANOMURA	Goniasteridae	
Unidentified galatheid	Unidentified asteroids	
Unidentified paguroid		

Priority Area 2 West Transect (26.652145 N, 79.916533 W to 26.651903 N, 79.940607 W.)—This transect (237-211 m) was entirely almost featureless smooth sediment with scattered depressions, burrows, trails, and qualitatively more *Thalassia testudinum* debris than on preceding transects. A small area of scattered fine black gravel (≤1 cm) appeared near the end of the transect. The most common organisms were galatheid squat lobsters (Figure 6-16D) probably representing two species, the sea star *Coronaster briareus* and the anemone *Actinauge* sp. Table 6-9 lists all organisms in Priority Area 2 West Transect.

Table 6-9. Benthic macrofauna observed in Priority Area 2 West Transect.

TAXON	TAXON	TAXON
CNIDARIA	CRUSTACEA	ECHINODERMATA
OCTOCORALLIA	ANOMURA	ASTEROIDEA
Unidentified pennatulid	Unidentified galatheid	*Astropecten* sp.
ACTINIARIA	Unidentified paguroid	*Coronaster briareus*
Actinauge sp.*	BRACHYURA	Unidentified asteroid
CERIANTHARIA	*Bathynectes longispina*	VERTEBRATA
Unidentified cerianthid	*Cancer borealis*	CHONDRICHTHYES
ANNELIDA	MOLLUSCA	*Benthobatis marcida*
Unidentified ?serpulid	CEPHALOPODA	OSTEICHTHYES
	Unidentified squid	?*Chlorophthalmus agassizi*
		Urophycis sp.

6.4.3 Priority Area 3—Southern Broward County

This area included two transects. The primary transect was a single video and still camera line spanning almost the entire east-west length of the three lease blocks along a line 1.0-1.5 km north of the southern block boundaries from a depth of 510 m to 264 m (Figures 6-6, 6-7 and 6-17). The line crossed much of the width of the northern Miami Terrace and was chosen in order to cover a wide range of topography and depth (within the range appropriate to the siting study) as reflected by multibeam topography, and to avoid the array of US Navy acoustic cables that run across the central and northern portions of the lease blocks. The transect profile was described above and illustrated in Figure 6-6. The second was a 2.5-km portion of an east-west transect surveyed as part of a separate project for the U.S. Navy, 1.5 km north of lease block 7055 and mostly just outside the multibeam survey area. This transect was included to assess additional possible high-relief substrates of the Outer Terrace Ridge and Lower Terrace, which were covered to only a limited extent in the primary transect.

Priority Area 3 Primary transect (26.046768 N, 79.805135 W to 26.049293 N, 79.938357 W).—Most of the multibeam topography suggested relatively low- to moderate-relief substrates with chiefly narrow and primarily north-south oriented features interpreted as high-slope, i.e., > 5º, which encompassed more high-relief substrates (Figure 6-17). The deeper Lower Terrace slope was mapped as unconsolidated sediment chiefly based on previous descriptions. Because the transect only touched the margin of this area, it is uncertain whether or to what degree hard substrates are present.

Priority Area 3 Lower Terrace.—The deeper Lower Terrace slope from 510 to 507 m observed by TONGS consisted of a series of intermixed substrates: low-relief aggregated phosphoritic cobble-rubble fields (20-40% hard bottom) (Figure 6-18A) alternating with areas that included low outcrops (to ~60% cover), a few areas of low- to moderate-relief outcrops, tilted slabs and boulders (to ~70% cover), patches of *Lophelia pertusa* coral rubble in low mounds to ~1 m across (possibly isolated dead thickets), and fields of coral debris that in some places appeared as a continuous sediment-veneered pavement (pale blue dots in Figure 6-17). All were separated by frequently oval patches of rippled or smooth, weakly bioturbated sediment up to several meters across. Largely barren sediment with ripples indicating southbound bottom flow alternated with weakly bioturbated smooth sediment with scattered craters to 467 m. Here, the seafloor transitioned abruptly to hard substrates of the Lower Terrace that ranged from low-relief cobble/rubble (10-30 cm across) fields to moderate- to high-relief phosphoritic boulders, low ledges, overhanging slabs and pavements up to 80-90% cover in 461-443 m, again with ponds and expanses of chiefly rippled sediment. Benthic macrofauna was extremely sparse on low-relief substrates, and more common but still generally widely scattered and patchy on higher relief substrates. The most frequently seen organisms included the anemone *Corallimorphus* sp., isidid bamboo octocorals, golden crab *C. fenneri*, codling *Laemonema* sp., and small mottled rajids.

The transect passed over the edge of a sinkhole in 436 m, characterized by higher relief slabs, boulders and outcrops that gave way to rippled sediment and scattered low-relief hard bottom with coral rubble inside the edge. The eastern slope consisted of fine coral rubble and sediment with small patches of pavement that alternated between rippled and smooth sediment across the sinkhole floor in 450 m. The western portion of the sinkhole transitioned to a smooth pavement thinly veneered with sediment, with small clumps of dead *Lophelia* rubble accumulated on the western slope (Figure 6-18B).

Priority Area 3 Outer Terrace Ridge.—The western margin of the sinkhole, at the transition to the base of the Outer Terrace Ridge, was a steep irregular escarpment of blocks, slabs and boulders from 424 m to 418 m, followed by a flat top of aggregated rubble, slabs and sediment-veneered pavement. The transect confirmed the nature of this habitat inferred from the multibeam data, which was extrapolated to similar returns in this depth zone both north and south of the transect (Figure 6-19). Again, benthic attached organisms, such as stylasterid hydrocorals, isidid octocorals, and sponges were somewhat more common on higher relief substrates. An unidentified rajid skate and greeneye, *C. agassizi* were the most common mobile organisms on the sinkhole floor. Table 6-10 lists organisms found on the Lower Terrace slope from 510 to the western edge of the sinkhole in 418 m.

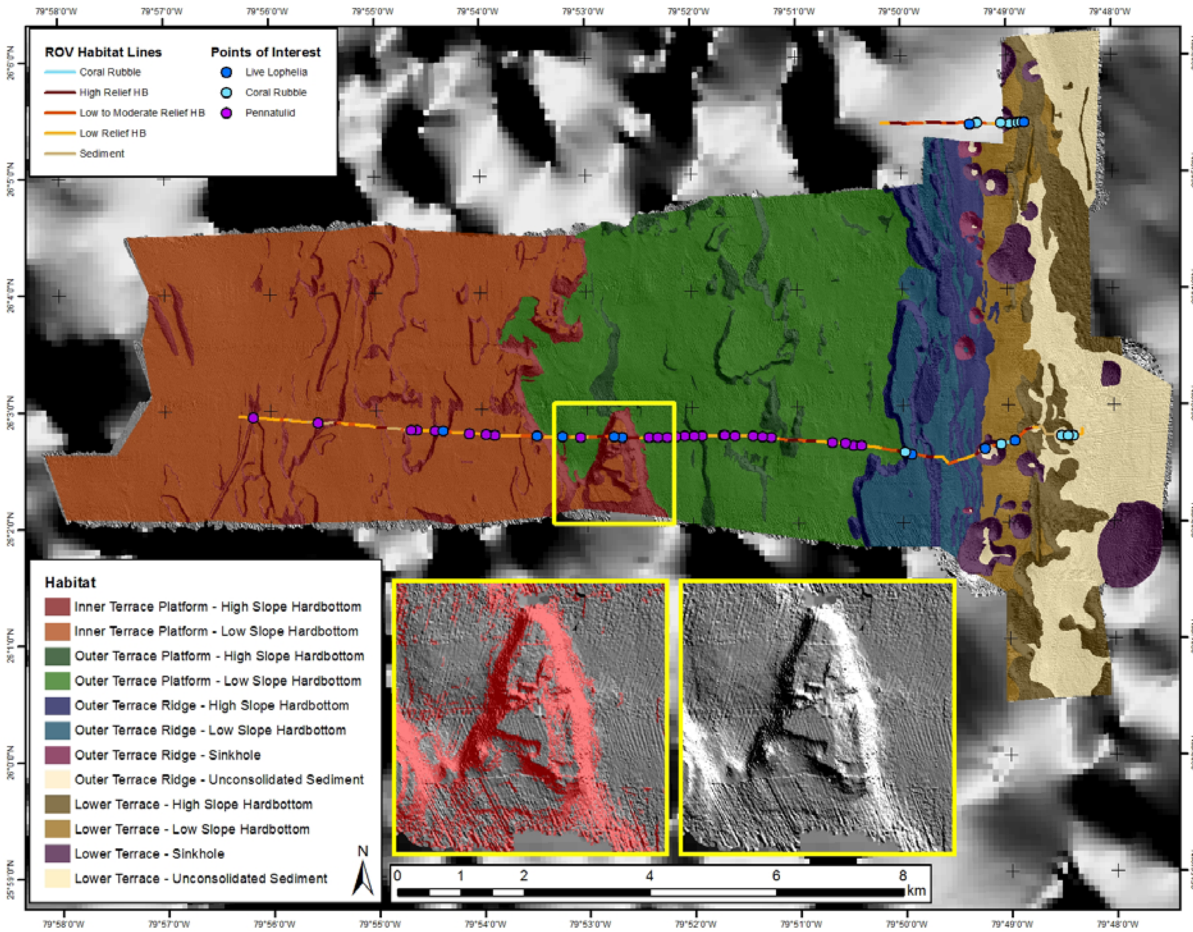

Figure 6-17. Priority Area 3 Benthic Habitat Map showing transect lines and the four major zones. Left insert: Red and pink areas illustrate high-slope (>5º) seafloor areas from geophysical data. Right insert: shows detail of the multibeam topography on which the distinction between low- and high-slope areas was made.

West of the sinkhole, the Outer Terrace Ridge sloped upward as low- to high-relief jointed and irregular pavements with slabs, outcrops, occasional low ledges, cobbles, a few isolated gravel patches, and pools and small expanses of sediment, ending in a steep ledge with large blocks and slabs in 356 m that dropped to abundant cobbles (10-30 cm), larger blocks and slabs. Low- versus high-slope habitats were mapped as noted above on the basis of less than versus greater than 5º seafloor slope (Figure 6-17). The final slope up to the crest of the Outer Terrace Ridge in ~337 m consisted of chiefly low-relief, clean and sediment-veneered, often jointed pavements with several taxa not previously seen on the deeper slopes, e.g., demosponges *Geodia* sp. and Pachastrellidae, and the anemone *Liponema* sp., all of which were characteristic of shallower depths. Attached organisms were more diverse and abundant on the slope above the sinkhole (the unidentified taxa in Table 6-11 likely conceal multiple species) but their distributions remained extremely patchy. Sponges dominated, with patches of stylasterid hydrocorals and, near the top of the slope, numerous small primnoid octocorals (*Plumarella* sp.).

Table 6-10. Benthic macrofauna observed in Priority Area 3 Lower Terrace from the east end of the transect to the western edge of the sinkhole.

TAXON	TAXON	TAXON
PORIFERA	CERIANTHARIA	ECHINODERMATA
DEMOSPONGIAE	Unidentified cerianthid	CRINOIDEA
Phakellia sp.	SCLERACTINIA	?*Comatonia cristata*
Spongosorites sp.	*Lophelia pertusa*	ASTEROIDEA
HEXACTINELLIDA	Solitary corals	Goniasteridae
Aphrocallistes beatrix	ANTIPATHARIA	OPHIUROIDEA
Hyalonema sp.	Unidentified black coral	?*Ophiomusium* sp.
Vazella sp.	HYDROZOA	VERTEBRATA
Unidentified sponge	Unidentified Stylasteridae	CHONDRICHTHYES
CNIDARIA	Unidentified hydroids	*Benthobatis marcida*
OCTOCORALLIA	CRUSTACEA	*Galeus arae*
Anthomastus sp.	PENAEOIDEA	Unidentified Rajidae
Isidella sp.	*Pleoticus robustus*	OSTEICHTHYES
Keratoisis sp.	CARIDEA	*Chaunax pictus*
Plexauridae (yellow fan)	*Glyphocrangon* sp.	*Chlorophthalmus agassizi*
Plumarella sp.	ANOMURA	*Helicolenus dactylopterus*
CORALLIMORPHARIA	Unidentified paguroid	*Laemonema* sp.
Corallimorphus sp.	BRACHYURA	*Nezumia* sp.
	Cancer borealis	*Peristedion* sp.
	Chaceon fenneri	

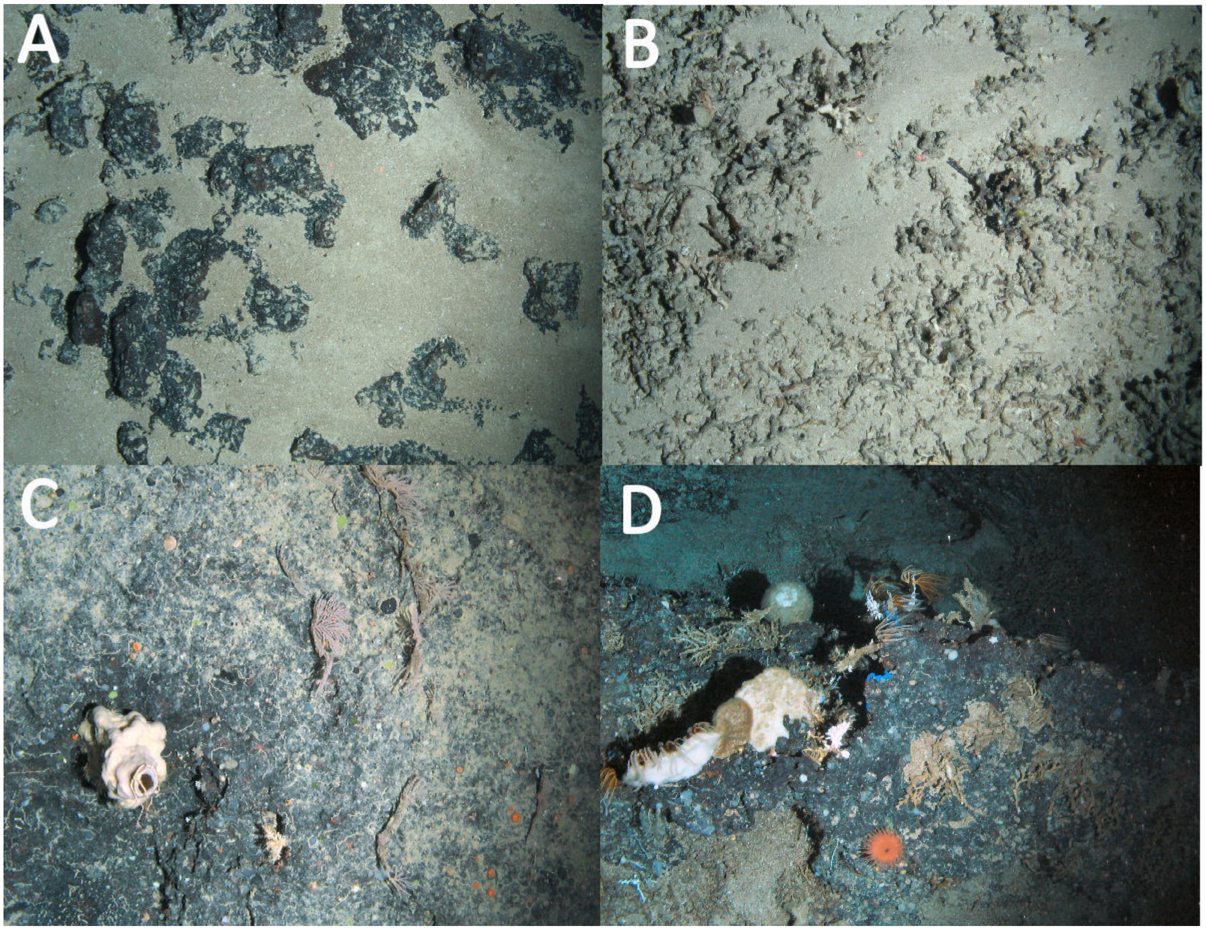

Figure 6-18. A. Low-relief aggregated phosphoritic cobble-rubble field on the deeper Lower Terrace slope in 507-510 m. B. Lophelia pertusa *rubble on the Lower Terrace slope. C. Low-relief pavement near the top of the Outer Terrace Ridge with octocorals (*Plumarella *sp.), orange solitary corals, and white petrosiid sponge. D. Ledge near the top of the Outer Terrace Ridge with sponges, crinoids,* Corallimorphus *sp.(orange) and* Lophelia pertusa *fragments.*

Table 6-11. Benthic macrofauna observed in Priority Area 3 on the Outer Terrace Ridge.

TAXON	TAXON	TAXON
PORIFERA	Unidentified octocoral	ECHINODERMATA
DEMOSPONGIAE	ACTINIARIA	CRINOIDEA
Corallistes sp.	*Actinoscyphia* sp.	*Comatonia cristata*
Geodia sp.	*Liponema* sp.	ASTEROIDEA
Unidentified lithistid	Unidentified orange anemone	Goniasteridae
Phakellia sp.	Unidentified red anemone	*Tosia parva*
Spongosorites sp.	Unidentified anemone	Unidentified asteroids (~4-5 species)
Unidentified Choristidae	CORALLIMORPHARIA	OPHIUROIDEA
Unidentified Desmacellidae	*Corallimorphus* sp.	*Asteroporpa annulata*
Unidentified Pachastrellidae	SCLERACTINIA	Unidentified ophiuroids
Unidentified Petrosiidae	*Lophelia pertusa*	ECHINOIDEA
Unidentified Raspailiidae	Solitary corals	*Araeosoma* sp.
Unidentified spherical astrophorid	ANTIPATHARIA	*Cidaris* sp.
Unidentified white branching sponge	*Leiopathes* sp.	Unidentified echinoid
Yellow encrusting sponge	HYDROZOA	HOLOTHUROIDEA
White wall sponge	Unidentified Stylasteridae	*Psolus* sp.
Unidentified demosponges	Unidentified hydroids	VERTEBRATA
HEXACTINELLIDA	BRYOZOA	CHONDRICHTHYES
Vazella sp.	Unidentfied bryozoan	*Galeus arae*
Unidentified hexactinellid	CRUSTACEA	Unidentified Rajidae
CNIDARIA	ANOMURA	OSTEICHTHYES
OCTOCORALLIA	Unidentified paguroid	*Helicolenus dactylopterus*
Eunicella sp.	BRACHYURA	*Laemonema* sp.
Isidella sp.	*Chaceon fenneri*	Unidentified fish
Pseudodrifa nigra		
Plumarella sp.		

Priority Area 3 Outer Terrace Platform.—The Outer Terrace Platform between the western escarpment of the Outer Terrace Ridge in the middle of block 7055 and the crest of the escarpment at the eastern boundary of the Inner Terrace Platform toward the western margin of block 7054 included a wide diversity of chiefly hard substrates including: a) low-relief, continuous, jointed or broken pavements with occasional abruptly delimited patches of gravel or small cobbles (Figure 6-19A); b) irregular low- to moderate-relief outcrops with sediment pooling in depressions; and c) occasional moderate- to high-relief ledges, jumbled boulders and tilted slabs, with higher relief associated with slopes below ledges (Figure 6-19B). However, much of the area consisted of extensive fields of gravel- to cobble-sized clasts (Figure 6-19C) with occasional patches of exposed hard substrates. Smooth or rippled sediment ranged from extensive areas with no exposed hard substrate through deeply or thinly-veneered pavement, or scattered small to large cobbles, to mixtures of aggregated gravelly hard bottom and more open sediment (Figure 6-19D), with patches of more extensive hard bottom. The multibeam backscatter data did not appear to resolve differences between the sediment substrates and flatter hard bottoms, suggesting that the sediment was likely a relatively thin veneer over buried hard substrate. The approach to the triangular spur of the Upper Terrace consisted of an extensive rippled sediment field with broad sand waves up to 1 m high, passing into increasing density of gravel, rubble and then sediment-veneered pale carbonate pavement overlain with phosphoritic rubble (Figure 6-19E) with proximity to the escarpment slope. Several images, particularly near steep substrates, revealed what appeared to be numerous brachiopod valves, sometimes accompanied by echinoid spines (Figure 6-19E). A unique hard bottom appeared as local low-relief fields of pale bowl-like features 10-20 cm across (Figure 6-19F).

Hard substrates ranged from largely barren with only widely scattered organisms (although close-up images sometimes revealed large numbers of small ophiuroids) (Figure 6-20A), to supporting locally dense assemblages, particularly in areas of higher relief, although no consistency appeared between qualitative densities or composition relative to substrate complexity or topographic relief. For example, a slender white branching sponge was seen in one image toward the western end of the Outer Terrace Platform but nowhere else on apparently similar substrates; isolated colonies of *Lophelia pertusa* (dark blue dots in Figure 6-17) were observed chiefly on higher-relief ledge edges but not on a pinnacle that rose 15 m above the surrounding seafloor; and stylasterid hydrocorals or cidarid echinoids appeared in numbers in a few areas and were absent elsewhere on similar substrates. Nevertheless, the primnoid octocoral, *Plumarella* sp. generally appeared in numbers only near or on apparently elevated exposed substrates, and ledge edges typically supported diverse and often dense assemblages of sponges, stylasterids, and crinoids. Table 6-12 lists organisms observed on the Outer Terrace Platform, including the steep slopes rising to the Inner Terrace Platform.

Organisms characteristic of the Outer Terrace Platform and not previously seen included the soft coral, *Pseudodrifa nigra*, anemones *Actinoscyphia* sp. and Sagartiidae, and echiuran spoonworm *Ochetostoma* sp. (although the latter became far more abundant on the Inner Terrace Platform). The low-relief rubble-cobble fields between escarpments supported a sparse fauna dominated by the anemone *Liponema* sp. with some sponges, abundant ophiuroids, and a few widely scattered large black coral colonies (*Leiopathes* sp.). A sea pen (*Pennatula* or *Ptilosarcus* sp.) was found both on sediment and among gravel and rubble (purple dots in Figure 6-17; Figure 6-20B); it was difficult to determine in some places whether it was anchored in sediment as typical, or clung to hard substrates.

The slopes of the spur and the escarpment at the western margin of the Outer Terrace Platform reached 60° with locally vertical ledges, and consisted chiefly of low-relief, mostly barren pavement with areas of phosphoritic scree, rubble, boulders and irregular phosphoritic outcrops up to ~0.6 m tall on slopes and up to 2.0 m tall on the crest. Much of the pavement was pale limestone, in places overlain with contrasting phosphoritic gravel, rubble or cobbles (Figure 6-19E). Abrupt changes in slope and major local zones of high-relief conformed well with multibeam topography. The eastern slope of the triangular spur rose from 328 to 264 m and dropped on its western side back to the Outer Terrace Platform in 299 m. The western escarpment rose from 300 m at the base to a crest in 252 m.

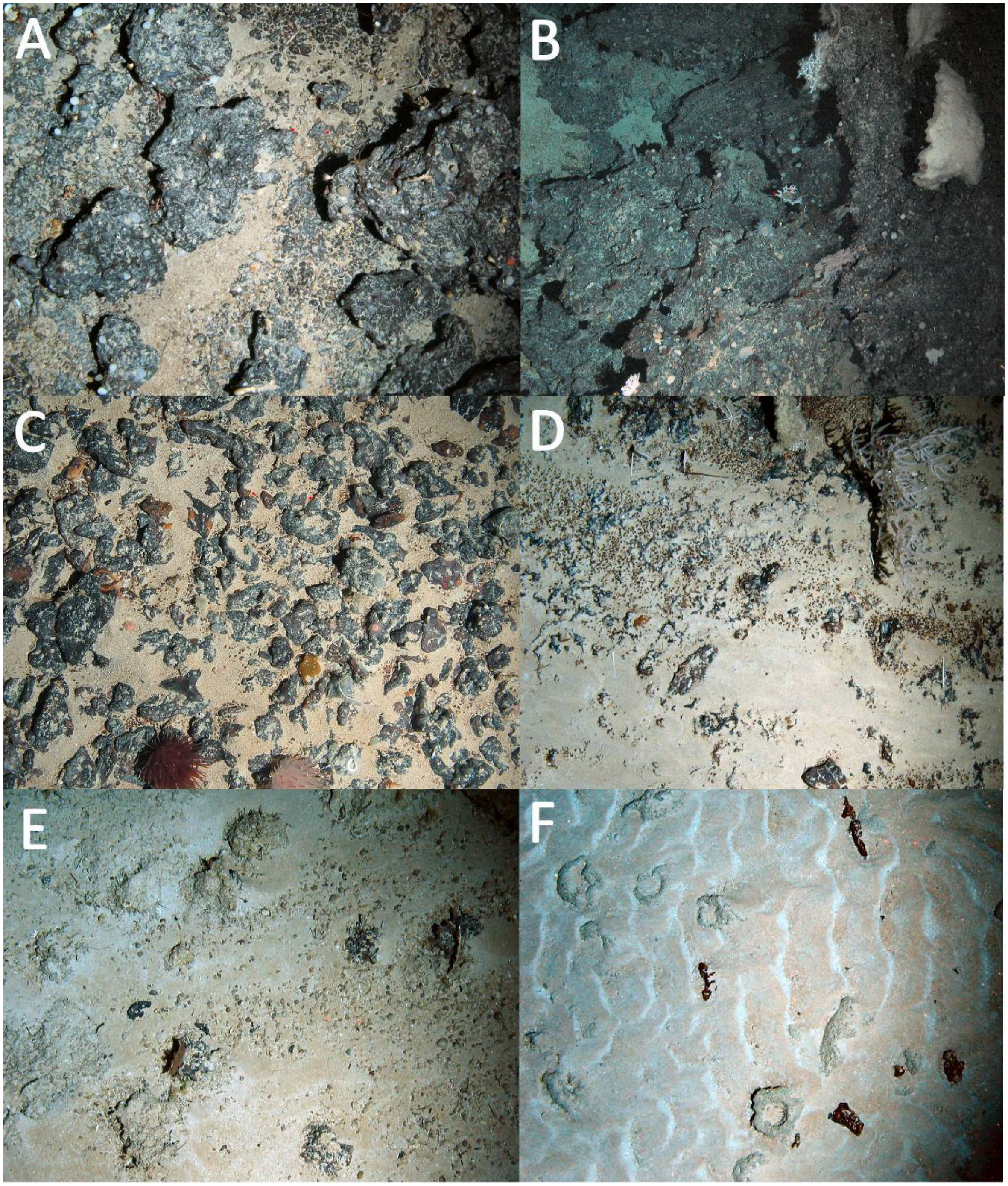

Figure 6-19. Outer Terrace Platform. A. Sediment-veneered pavement with slab-like low-relief outcrops, patchy gravel and small cobbles. B. Series of ledges with Lophelia pertusa *(small white colony, upper center), octocoral* Plumarella *sp. and large white* Phakellia *sp. sponges. C. Anemones* Liponema *sp. (bottom) on low-relief rubble mixed with gravel. D. Sediment-veneered pavement with gravel; pachastrellid sponge and black coral* Leiopathes *sp. at top right. E. Pale sediment-veneered limestone pavement with a few small black phosphoritic clasts, gravel, and scattered brachiopod valves. F. Unusual bowl-like outcrops of pale limestone on rippled, sediment-veneered hard bottom.*

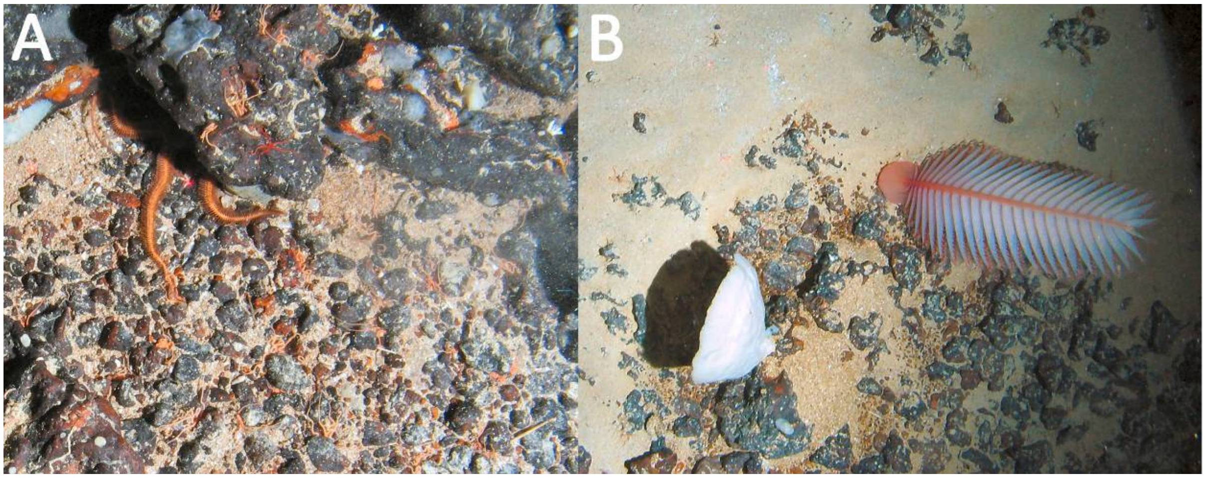

*Figure 6-20. Outer Terrace Platform. A. Abundant ophiuroids belonging to three species. B. Sea pen (*Pennatula *or* Ptilosarcus *sp.) apparently on sediment-veneered hard bottom, accompanied by the fan sponge* Phakellia *sp.*

Table 6-12. Benthic macrofauna observed in Priority Area 3 on the Outer Terrace Platform.

TAXON	TAXON	TAXON
PORIFERA	ACTINIARIA	ASTEROIDEA
DEMOSPONGIAE	*Actinoscyphia* sp.	Goniasteridae
Geodia sp.	*Liponema* sp.	Unidentified asteroids (~1)
Unidentified lithistid	Unidentified Sagartiidae	OPHIUROIDEA
Phakellia sp.	Unidentified anemone	*Asteroporpa annulata*
Spongosorites sp.	CORALLIMORPHARIA	Unidentified Asteroschematidae
Unidentified Desmacellidae	*Corallimorphus* sp.	Unidentified ophiuroids
Unidentified Pachastrellidae	SCLERACTINIA	ECHINOIDEA
Unidentified Raspailiidae	*Lophelia pertusa*	*Araeosoma* sp.
Unidentified spherical astrophorid	Solitary corals	*Cidaris* sp.
Brown encrusting sponge	ANTIPATHARIA	*Echinus* sp.
White wall sponge	*Leiopathes* sp.	*Stylocidaris* sp.
Unidentified demosponges	HYDROZOA	Unidentified echinoid
HEXACTINELLIDA	Unidentified Stylasteridae	VERTEBRATA
Aphrocallistes beatrix	Unidentified hydroids	CHONDRICHTHYES
Farrea sp.	ANNELIDA	*Benthobatis marcida*
Vazella sp.	*Ochetostoma* sp.	*Galeus arae*
Unidentified hexactinellid	CRUSTACEA	Unidentified Rajidae
CNIDARIA	ANOMURA	OSTEICHTHYES
OCTOCORALLIA	*Eumunida picta*	*Chaunax* sp.
Eunicella sp.	Unidentified paguroid	*Chlorophthalmus agassizi*
Isidella sp.	BRACHYURA	*Helicolenus dactylopterus*
Pseudodrifa nigra	*Cancer borealis*	*Laemonema* sp.
Plumarella sp.	ISOPODA	*Nezumia* sp.
Unidentified octocoral	*Bathynomus giganteus*	*Polymixia* sp.
Pennatula sp. (or *Ptilosarcus* sp.)	ECHINODERMATA	Unidentified Scorpaenidae
	CRINOIDEA	Unidentified fish
	Comatonia cristata	

Priority Area 3 Inner Terrace Platform.—The Inner Terrace Platform above the escarpment was characterized by low-relief, highly irregular phosphoritic outcrops, pavement and aggregated cobble substrate accounting for ~40-90% of cover, with sediment pooling in depressions (Figure 6-21). A phosphoritic ledge in 255 m dropped ~0.6 m to a distinctly different pale limestone pavement, which rapidly transitioned again to low-relief phosphoritic irregular outcrops. Much of the western Inner Terrace Platform was vast fields of phosphoritic gravel, rubble and cobble-sized clasts on sediment, with hard substrates accounting generally for 10-50% of cover, but interspersed with areas of more extensive low-relief pavement, outcrops, slabs and narrow low ridges. The transect also crossed two depressions with vertical relief of up to 10 m (floor in 273 m) bordered by ledges and irregular high-relief outcrops and boulders, and floored by expanses of rippled sediment and fields of gravel- to rubble-sized clasts on sediment. The westernmost portion of the transect was dominated by sediment substrates alternating between smooth, with unidentified tufts (possibly polychaete tubes), and rippled, but still interspersed with fields of sparse to dense gravel- to cobble-sized clasts, and low-relief pavements and irregular outcrops infrequently reaching ~0.6 m vertical relief with sediment pooling in depressions.

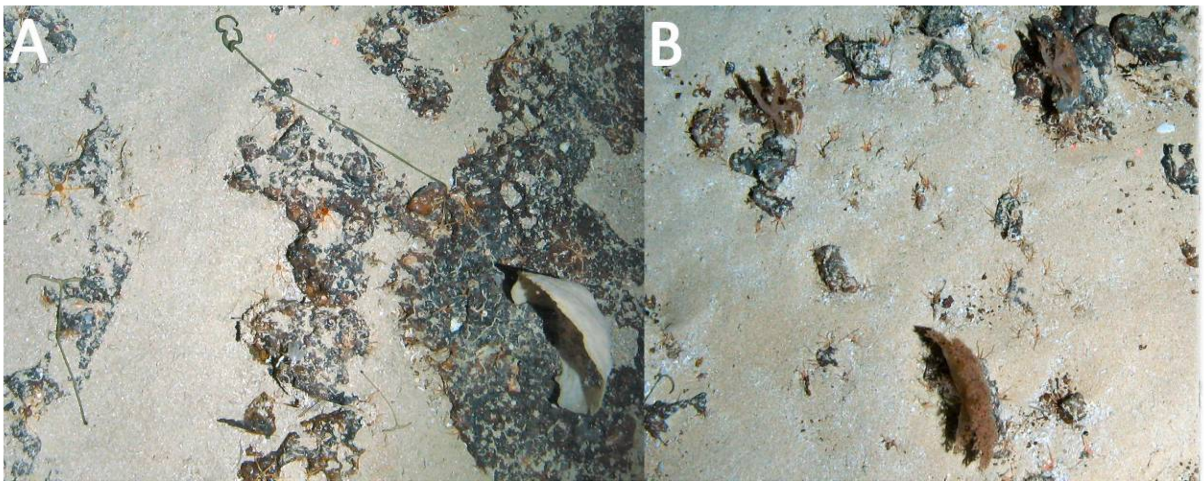

*Figure 6-21. Inner Terrace Platform. A. Several echiuran worms ?*Ochetostoma *sp., fan sponge* Phakellia *sp. and numerous ophiuroids on low-relief, sediment-veneered pavement. B. Several soft corals* Pseudodrifa nigra *on phosphoritic rubble.*

Most hard substrates supported sparse assemblages of benthic macrofauna except for occasional local increases on low-relief substrates and typical often denser concentrations on local high-relief substrates (boulders and edges of ledges and raised slabs). Dominant organisms included fan sponges (*Phakellia* sp.), the echiuran *Ochetostoma* sp. (Figure 6-21A), and the anemone *Liponema* sp., with local increases in pink-lipped sagartiid anemones, soft corals (*Pseudodrifa nigra*) (Figure 6-21B) and sea pens, and enormous concentrations of ophiuroids. The shallowest, westernmost colony of *Lophelia pertusa* was observed on the rugged western lip of one of the sediment-floored depressions in 261 m, accompanied by sponges, black corals, hydroids and octocorals. Species richness clearly declined toward the western end of the transect; several taxa not previously seen or characteristic of the Outer Terrace Platform were observed only once or rarely. Table 6-13 lists fauna observed on the Inner Terrace Platform, including the top of the triangular spur described above.

Table 6-13. Benthic macrofauna observed in Priority Area 3 on the Inner Terrace Platform. Asterisks indicate taxa observed once or rarely.

TAXON	TAXON	TAXON
PORIFERA	Unidentified Sagartiidae	ECHINODERMATA
DEMOSPONGIAE	Unidentified stripe-disk anemone*	CRINOIDEA
Geodia sp.	CORALLIMORPHARIA	*Comatonia cristata*
Phakellia sp.	*Corallimorphus* sp.	Unidentified comatulid*
Unidentified Desmacellidae	CERIANTHARIA	ASTEROIDEA
Unidentified lithistid*	Unidentified cerianthid	Goniasteridae*
Unidentified Pachastrellidae*	SCLERACTINIA	*Tremaster mirabilis*
Unidentified Petrosiidae*	*Lophelia pertusa**	Unidentified asteroids
Unidentified Raspailliidae	Unidentified solitary corals	OPHIUROIDEA
Slender branching sponge*	ANTIPATHARIA	*Astroporpa annulata**
Spherical white sponge	*Leiopathes* sp.	?*Ophiomusium lymani*
White encrusting sponge*	Unidentified black coral*	Unidentified ophiuroids
Yellow encrusting sponge	HYDROZOA	ECHINOIDEA
Unidentified demosponges	Unidentified Stylasteridae	*Cidaris* sp.
HEXACTINELLIDA	Unidentified hydroids	*Echinus* sp.*
*Aphrocallistes beatrix**	ANNELIDA	HOLOTHUROIDEA
Farrea sp.	? *Ochetostoma* sp.	*Psolus* sp.*
Vazella sp.*	MOLLUSCA	VERTEBRATA
CNIDARIA	GASTROPODA	CHONDRICHTHYES
OCTOCORALLIA	*Calliostoma* sp.	Unidentified Rajidae
?*Anthomastus* sp.*	CRUSTACEA	OSTEICHTHYES
Eunicella sp.	ANOMURA	*Chlorophthalmus agassizi*
Isidella sp.*	Unidentified galatheoid*	*Helicolenus dactylopterus* *
Pennatula or *Ptilosarcus* sp.	Unidentified paguroid	*Laemonema* sp.
Plumarella sp.*	BRACHYURA	*Polyprion americanum* *
Pseudodrifa nigra	*Bathynectes longispina**	Unidentified Scorpaenidae*
ACTINIARIA	*Cancer borealis**	Unidentified fish*
Actinoscyphia sp.	?*Rochinia* sp.*	
Liponema sp.		

<u>Priority Area 3 Northeastern transect (26.090555 N, 79.836766 W to 26.090425 N, 79.813007 W)</u>.—This transect was surveyed from west to east (opposite the preceding transects) and spanned both high- and low-slope portions of the Outer Terrace Ridge and Lower Terrace. Although mostly outside the multibeam survey area, it was added to incorporate additional high-slope, high-relief habitat with extensive enough still photographic coverage for quantitative analyses. From the western end of the transect in 292 to 349 m, the seafloor sloped chiefly downward in a series of drop offs, ledges, steep high-relief slopes of boulders, tilted slabs and irregular outcrops, including an escarpment of ~25 m. These were interspersed with low- to moderate-relief, sediment-veneered, often broken pavements and slabs, with or without overlying rubble; some irregular isolated table-like ledges; deeply eroded "ironshore"-like hard bottom, and short patches of barren rippled or smooth sediment, sometimes with gravel. Much of the initial portion of the transect was continuous pale pavement overlain in many places with either a coarse shelly hash or phosphoritic rubble, or both (Figure 6-22A).

Below this depth, perhaps corresponding to the transition between the Outer Terrace Ridge and the Lower Terrace (although this could not be confirmed because the transect was outside the multibeam survey), high-relief substrates were fewer and further apart, and were separated by a) low- to moderate-relief broken or jointed, sediment-veneered, pavements with sediment pooling in depressions; b) slabs; c) patches of gravel and rubble on sediment, and d) more frequent entirely sediment substrates. *Lophelia pertusa* coral rubble first appeared in 409 m and continued intermittently to at least 474 m in a sinkhole (the eastern half of which is mapped at the upper left of Figure 6-17). The sinkhole slopes included broken and tilted slabs and cobbles, largely barren pavement, some ledges and boulders, with sediment, rubble, cobbles and coral rubble in the deeper portions. The easternmost end of the transect in 451 m was a combination of rippled and smooth gravelly sediment, small areas of scattered cobbles, largely barren hard bottom, deeply eroded cobbly hard bottom, and broken slabs.

Some areas of sea floor along this transect were largely or completely barren of macrofauna, with contrasting and often dense aggregations along and near the edges of ledges, overhanging pavement and other locally high-relief substrates (Figure 6-22B). Demosponges were the most diverse and abundant organisms (e.g., *Phakellia* sp., Raspailiidae, Pachastrellidae, Lithistida), accompanied by hexactinellid sponges, stylasterids, the anemone *Liponema* sp., local concentrations of the octocorals *Isidella* sp. or *Plumarella* sp., and locally dense populations of ophiuroids (Table 6-14).

Figure 6-22. Priority Area 3 northeast transect. A. Coarse shelly hash including echinoid spines on low-relief pavement with a gastropod (possibly Sconsia *sp.), solitary corals and ophiuroids. B. High-relief tilted phosphoritic slabs with a variety of sponges including lithistids (fluted plates) and a spherical astrophorid.*

Table 6-14. Benthic macrofauna observed in Priority Area 3 along the Northeastern Transect.

TAXON	TAXON	TAXON
PORIFERA	*Keratoisis* sp.	BRACHYURA
DEMOSPONGIAE	*Pseudodrifa nigra*	*Bathynectes longispina*
Corallistes sp.	*Plumarella* sp.	*Chaceon fenneri*
Phakellia sp.	Unidentified octocoral	ECHINODERMATA
Spongosorites sp.	ACTINIARIA	CRINOIDEA
Unidentified Desmacellidae	*Liponema* sp.	*Comatonia cristata*
Unidentified Lithistida	Unidentified red anemone	Unidentified comatulid
Unidentified Lithistida (vase)	Unidentified Sagartiidae	ASTEROIDEA
Unidentified Pachastrellidae	CORALLIMORPHARIA	Goniasteridae
Unidentified Petrosiidae	*Corallimorphus* sp.	*Tosia parva*
Unidentified Raspailliidae	SCLERACTINIA	*Tremaster mirabilis*
Unidentified brown encrusting sponge	*Lophelia pertusa*	Unidentified asteroids (~4-5 species)
Unidentified spherical astrophorid	Solitary corals	OPHIUROIDEA
Unidentified white amphitheater sponge	ANTIPATHARIA	?*Ophiomusium lymani*
Unidentified white branching sponge	?*Leiopathes* sp.	Unidentified ophiuroids
Unidentified white conulose sponge	Unidentified black coral	ECHINOIDEA
Brown encrusting sponge	HYDROZOA	*Cidaris* sp.
White wall sponge	Unidentified Stylasteridae	*Echinus* sp.
Unidentified demosponges	Unidentified hydroids	VERTEBRATA
HEXACTINELLIDA	BRYOZOA	CHONDRICHTHYES
Aphrocallistes beatrix	Unidentfied bryozoan	*Benthobatis marcida*
Farrea sp.	MOLLUSCA	OSTEICHTHYES
Hertwigia falcifera	GASTROPODA	?*Aulopus* sp.
Heterotella sp.	?*Sconsia* sp.	?*Aldrovandia* sp.
Vazella sp.	CRUSTACEA	*Beryx decadactylus*
Unidentified hexactinellid	CARIDEA	*Chaunax pictus*
CNIDARIA	Unidentified caridean shrimp	*Chlorophthalmus agassizi*
OCTOCORALLIA	ANOMURA	*Helicolenus dactylopterus*
Anthomastus sp.	*Eumunida picta*	*Laemonema* sp.
Eunicella sp.	Unidentified galatheoid	*Nezumia* sp.
?*Eunicella* sp. (branched)	Unidentified paguroid	Unidentified Scorpaenidae
Isidella sp.		

<u>Priority Area 3 – Selected Habitat Details.</u>—Figures 6-23 and 6-24 illustrate enlarged areas of Figure 6-17 showing details of the distribution of a few selected organisms in different portions of the primary transect. Such mapping details may provide useful insights into habitat use by different taxa. Figure 6-23 shows the western portion of the Outer Terrace Platform and the spur and eastern portion of the Inner Terrace Platform, and illustrates observations of the stony coral *Lophelia pertusa* and the sea pen *Pennatula* sp. or *Ptilosarcus* sp. *Lophelia pertusa* is chiefly confined to steeply sloping (i.e., High Slope) substrates. It was observed on more gradually sloping (i.e., Low Slope) substrates only at the top of elevated topography—the crest of the spur and top of the east-facing escarpment of the Inner Terrace Platform. By contrast, the sea pen was regularly distributed on Low Slope (and low relief) areas of the Outer Terrace Platform. As this species usually anchors in unconsolidated sediment, its distribution here may reflect the alternating distributions of exposed versus buried hard substrates. Figure 6-24 focuses on the Outer Terrace Ridge and Lower Terrace Slope, and illustrates the distributions of several other associated taxa in addition to *Lophelia pertusa* and the coral rubble. Bamboo octocorals (Isididae) occurred across several habitat types, whereas the primnoid octocoral *Plumarella* sp. was restricted to the highest elevations, and golden crabs were restricted to the deeper reaches of the Lower Terrace Slope.

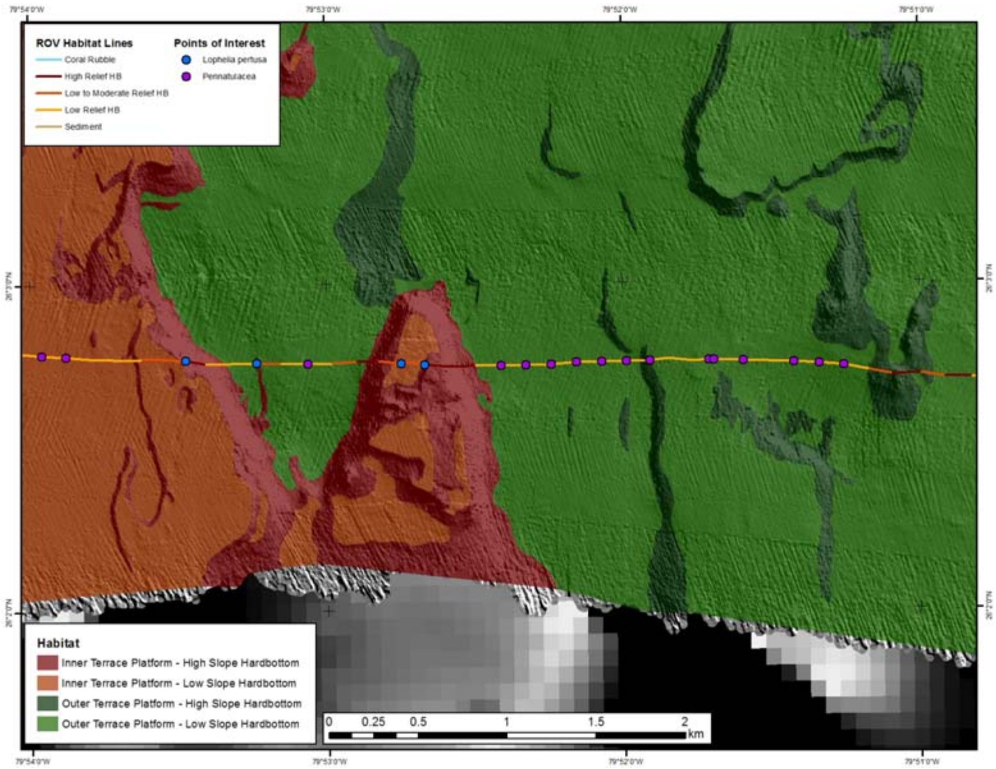

Figure 6-23. Detail of western portion of Outer Terrace Platform and eastern portion of Inner Terrace Platform showing observations of sea pens (Pennatulacea) and Lophelia pertusa.

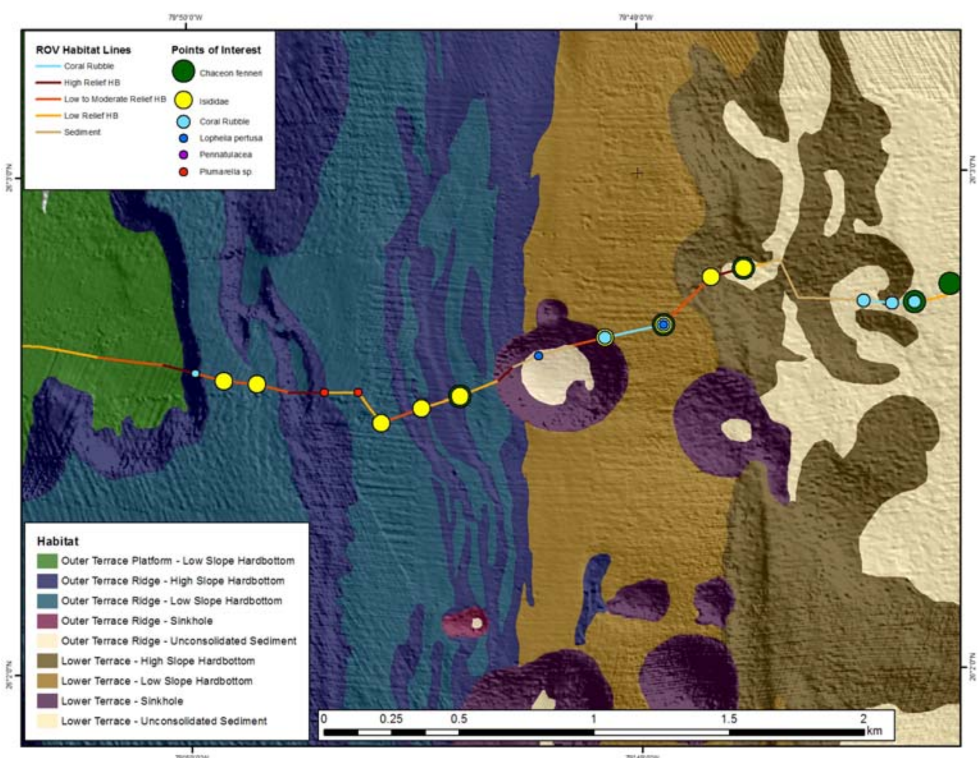

*Figure 6-24. Detail of Outer Terrace Ridge and Lower Terrace Slope showing observations of selected corals (*L. pertusa*), octocorals (Isididae,* Plumarella *sp., and* Chaceon fenneri.

6.5 Benthic Video Survey – Quantitative Results

As noted above in section 6.4.1, a single small area at the easternmost end of Priority Area 1 was examined quantitatively (Figure 6-11). No hard bottom sites were found within Priority Area 2; no quantitative analyses were carried out for this area. All other hard-bottom photostation sites were located in Priority Area 3 on hard substrates on the Miami Terrace and included six sites identified as low-relief and seven as high-relief (Figure 6-25, Table 6-15). Photostations 1-8 were taken along the primary transect and included six low-relief and two high-relief stations. Of the low-relief sites, two were taken on the Inner Terrace Platform (stations 1, 2), three on the Outer Terrace Platform (stations 3, 5 and 7), and one on the Outer Terrace Ridge (station 8). The two high-relief stations were taken on the Inner Terrace Platform spur (station 4) and on the Outer Terrace Platform (station 6). Five additional high-relief stations were taken on the northeastern transect, stations 9-12 on the Outer Terrace Ridge and station 13 on the Lower Terrace (Figure 6-25).

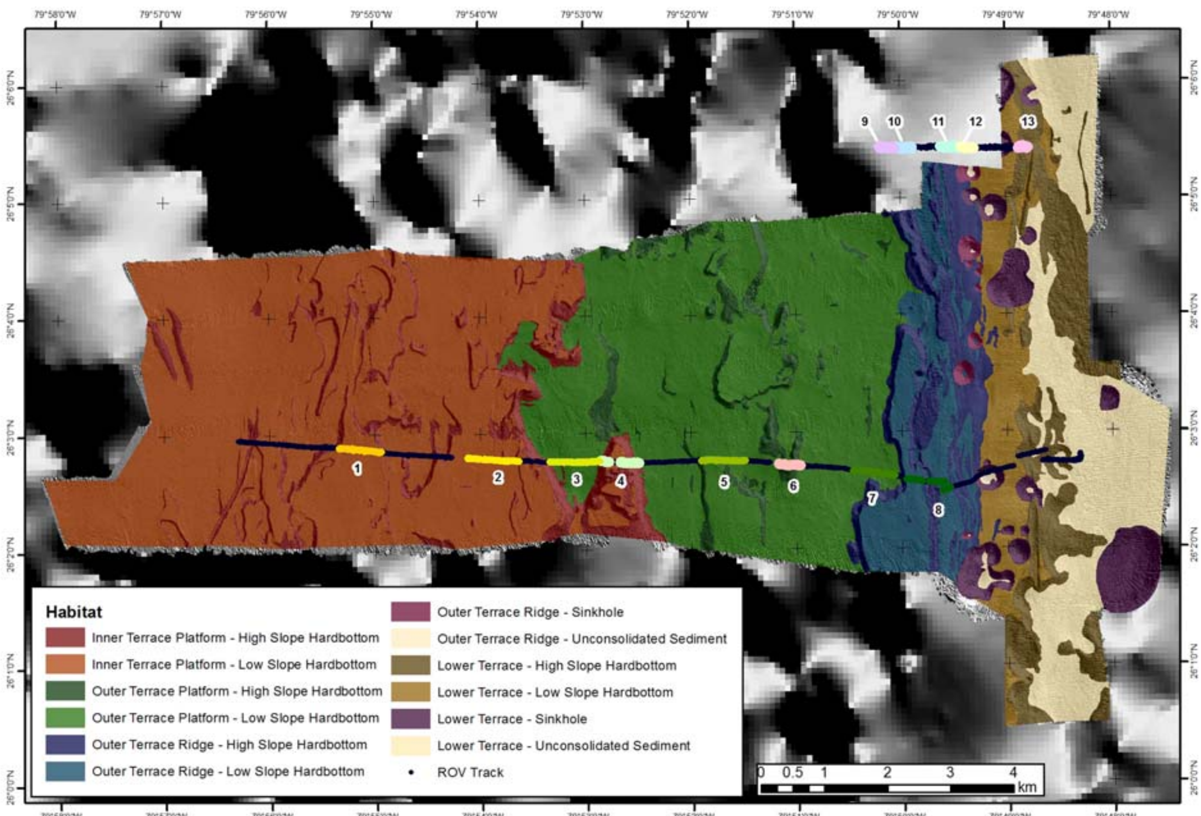

Figure 6-25. Priority Area 3 photostations. Yellow and green sites are low-relief (stations 1-3, 5, 7, 8); high-relief sites are pale blue, pink and tan (stations 4, 6, 9-13).

Table 6-15. Priority Area 3 quantitative photostation data. Image count does not omit images eliminated because of poor lighting, or distance from seafloor.

PhotoSta	First image			Last image			Image
	N Lat	N long	Depth (m)	N Lat	N long	Depth (m)	Count
1	26.04764848	-79.91569309	273	26.04814522	-79.92240276	291	57
2	26.04615729	-79.89393873	269	26.04663654	-79.90202649	279	54
3	26.04606807	-79.88116764	324	26.04602551	-79.88909965	314	55
4	26.04575535	-79.87499447	353	26.04609735	-79.88103781	304	47
5	26.07501807	-79.86778008	298	26.07512574	-79.86628983	303	72
6	26.04522629	-79.84937567	353	26.04547852	-79.85286455	353	29
7	26.07717467	-79.8386136	381	26.07754514	-79.83657302	385	73
8	26.04598391	-79.85815935	344	26.04599257	-79.86512087	335	57
9	26.09064797	-79.83661019	339	26.09038832	-79.83420291	370	65
11	26.09060386	-79.8269394	382	26.09045581	-79.82388354	442	56
10	26.09048055	-79.83405798	376	26.09058908	-79.83144676	315	54
12	26.09050616	-79.82370406	439	26.09033749	-79.8216275	443	39
13	26.09026546	-79.81456462	485	26.09041288	-79.81304509	500	29

Multivariate statistics were used to evaluate the similarities of biological composition and cover among photostations. These methods “base their comparisons of two (or more) samples on the extent to which these samples share particular species, at comparable levels of abundance” (Clarke and Warwick 2001). They are based on similarity indices, which facilitate clustering of the data into similar groups, and mapping the data in ordination plots, which illustrates the samples’ relationship to one another (Clarke and Warwick 2001). The similarities can be illustrated in a dendrogram (Figure 26) that shows the relationship between the sites in terms of their similarities. Figure 6-26 illustrates the dendrogram of a Bray-Curtis similarity index analysis (PRIMER v6) for similarities of organism composition and cover among photostations using data at the subcategory level (Table 6-3) (excluding fish, human debris, Detritus, Cable, Shadow, and unidentified organisms). The data can also be illustrated in the form of a Multidimensional scaling (MDS) plot that maps the relationship between sites and fits it to a two dimensional image. The distance between sites illustrates their level of similarity; hence very similar sites will cluster closely together and vice versa. The similarity levels from the dendrogram can be overlain on the MDS plot to better understand the spatial relationship of the clusters at a given similarity level. Figure 6-27 shows the same analysis in the form of an MDS plot. Both illustrate the close similarities among the Outer Terrace Ridge High-Slope hard-bottom sites (red circles), and among these and the Outer Terrace Ridge Low-Slope site (green circle). The Inner Terrace Platform Low-Slope sites (green triangles) and two of the three Outer Terrace Platform Low-Slope sites (green squares) also clustered together. However, a third Outer Platform site (7) clusters most closely with the most adjacent site (8), a Low-Slope habitat on the Outer Terrace Ridge, reflecting the former’s close proximity to our delineation of the western boundary of the Outer Terrace Ridge, suggesting that our boundaries, which are based on previous work and our multibeam data, might be modified following detailed faunal analysis. Interestingly, Low-Slope site 14, distantly located at Priority Area 1, returned as closely similar to the Low-Slope sites on the Outer Terrace Platform. Photostation 6, the only site characterized as High-Slope on the Outer Terrace Platform, returned as most closely similar to the Low-Slope sites of both Inner and Outer Terrace Platforms. One possible explanation is that this site, located between the major escarpments along the eastern margin of the Inner Terrace Platform and western edge of the Outer Terrace Ridge, may not be elevated enough, despite its characterization as High-Slope (based on multibeam data), to expose its resident fauna to the flow environment characteristic of the High-Slope habitats of the Outer Terrace Ridge. Conversely, photostation 4 on the Inner Terrace Platform clustered with the Outer Terrace Ridge stations, perhaps due to its location on the elevated spur that likely exposed it to a flow environment more similar to that of the Outer Terrace Ridge. Finally, photostation 13 is a distinct outlier, not surprising given its location in substantially deeper water on the Lower Terrace.

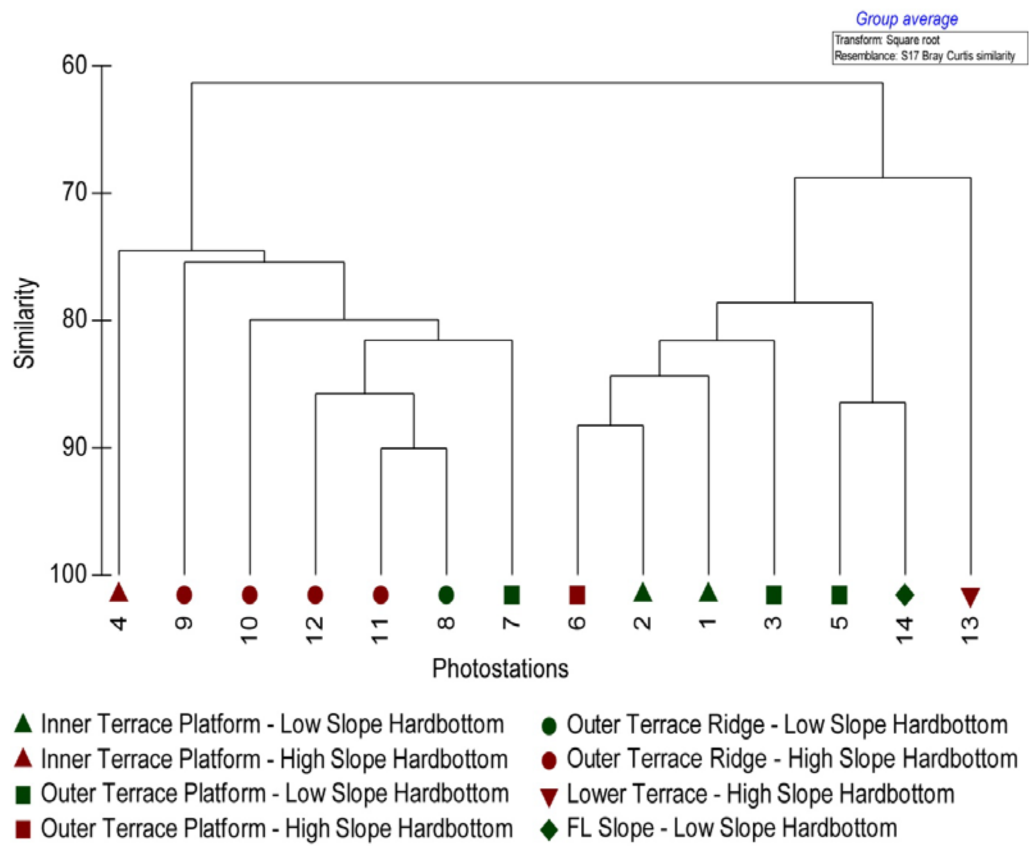

Figure 6-26. Dendrogram of Bray-Curtis similarity cluster analysis results of benthic cover image analysis. Photostations displayed by habitat. Shape indicates zone: Triangles = Inner Terrace Platform, squares = Outer Terrace Platform, circles = Outer Terrace, upside down triangle = Lower Terrace, and diamond = FL slope. Color indicates slope: Green = Low (< 5°), red = high (> 5°).

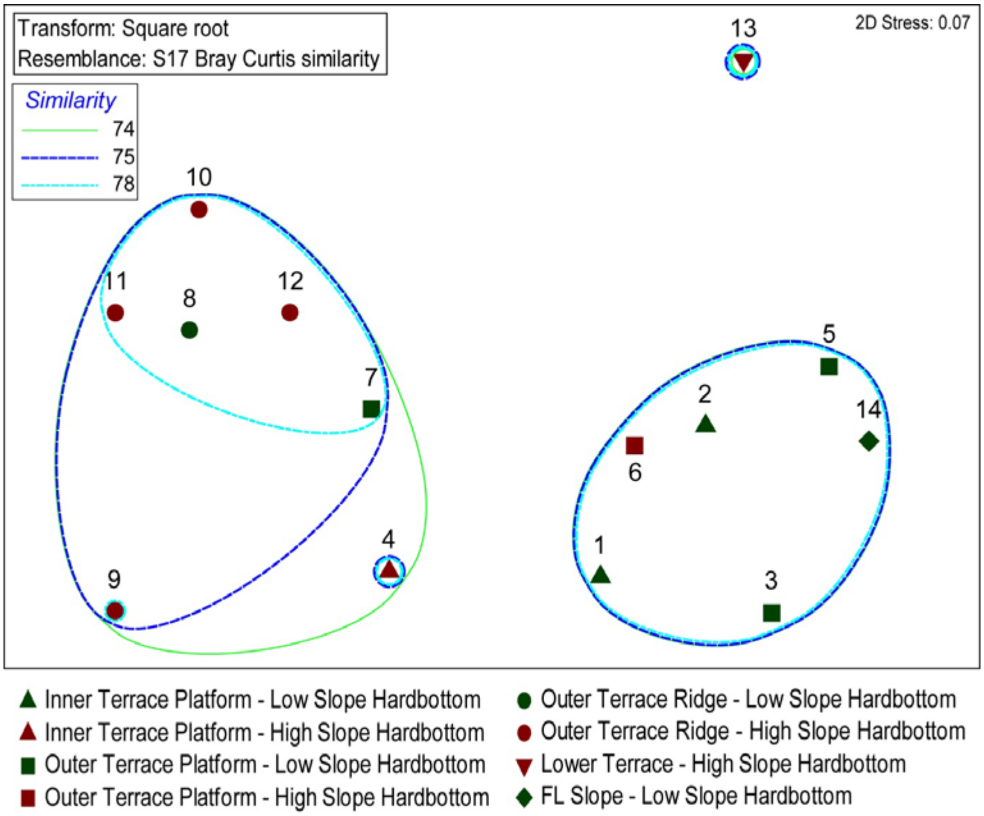

Figure 6-27. Multidimensional scaling (MDS) plot of Bray-Curtis similarity matrix of photostation benthic cover data. Outlines represent 74%, 75%, and 78% similarity from the cluster analysis. Photostations displayed by habitat. Shapes and colors as in Figure 6-26.

6.5.1 Priority Area 1.

The summary of CPCe analysis of benthic cover at photostation 14 using 50 points per image is given with Priority Area 3 low-relief stations in Table 6-17 below. Only scleractinian coral subcategories are shown. Total area covered was 73 m^2. Percent cover was chiefly unconsolidated sediment (79.1%) with 2% shell hash and 0.4% scleractinian coral rubble. Of hard bottom, 12.0% was extended solid substrate (e.g., outcrops, pavement) and 6.2% gravel/rubble/cobble. Sponges (Porifera) accounted for 0.17% of cover, the most of any living organism category. Quantitative analysis of still images indicated an overall density of 2.1 organisms m^{-2}, with the fauna dominated by a variety of hexactinellid sponges and the small unbranched gorgonian octocoral *Eunicella* sp., followed by stylasterid hydrocorals (Table 6-16, Figure 6-28). *Eunicella* sp. was the most abundant individual taxon, with a density across all images of 0.53 m^{-2}.

Table 6-16.Macrofaunal organism densities at the Priority Area 1quantitative photostation. Numbers are organisms per square meter (m^{-2}). Totals for Demospongiae and Hexactinellida are sums that include species listed below each.

Total image area (m^2):	**73.0389**		
Arthropoda	**0.0274**	Lithistida sp. 1	0.0137
Eumunida picta	0.0274	Pachastrellidae	0.0411
Bryozoa	**0.0137**	Raspailiidae	0.0137
Cnidaria	**1.0132**	Unident. Demospongiae	0.0411
Actiniaria unid.	0.0548	**Hexactinellida**	**0.8899**
Eunicella sp.	0.5340	Euritidae/Farreidae	0.0958
Hydroidolina	0.0411	*Hertwigia falcifera*	0.2191
Scleractinia (solitary)	0.0548	*Hyalonema* sp.	0.0958
Stylasteridae	0.2601	*Hyatella* sp.	0.0137
Zoanthidae	0.0685	Unident. Hexactinellida	0.4518
Porifera	**1.0268**	*Vazella* sp.	0.0137
Demospongiae	**0.1369**	**Unknown organisms**	**0.0411**
Desmacellidae	0.0274	**Total**	**2.1222**

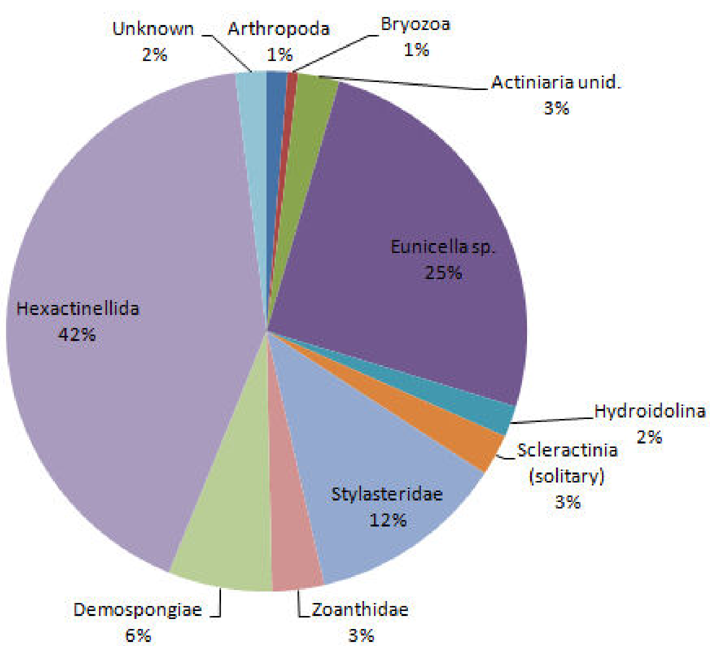

Figure 6-28. Macrofaunal organism densities (in m^{-2}) at the Priority Area 1quantitative photostation expressed as percentages of total benthic density (data from Table 6-16).

6.5.2 Priority Area 3.

Table 6-17 summarizes the CPCe analysis of benthic cover at the six low-relief stations using 50 points per image. Only scleractinian coral subcategories are shown. Percent cover by hard substrates varied widely, with a maximum of 87.9% at Outer Terrace Ridge station 8 (almost entirely extended hard substrate rather than clasts), 49.7% and 31.7% at Inner Terrace Platform stations 1 and 2, respectively, and 34.4, 18.2 and 77.6% at Outer Terrace Platform stations 3, 5 and 7. The high percentage of hard bottom cover at the latter was not surprising given its close proximity to the western slope of the Outer Terrace Ridge (Figure 6-25). Clastic hard bottom (gravel/rubble/cobble) accounted for a maximum of 13.2% at station 3 and no more than 3.6% at any other site. Soft substrates were almost entirely fine sediment with shell hash contributing at most 2.5% overall (station 7), again not surprising as one component was brachiopod shells derived from species found only on hard substrates. The greatest percentages of living organisms were non-scleractinian cnidarians with a maximum of 0.7% (station 1; chiefly the soft coral *Pseudodrifa nigra*), and demosponges with a maximum of 0.6% (station 8). Scleractinian corals accounted for at most 0.08% of cover, only as dead rubble (station 2).

Table 6-17. Summary of substrate percent cover at the six low-relief photostations in Priority Area 3on the primary transect and one photostation (14) in Priority Area 1. Subcategories are shown only for scleractinian corals. Cells with values other than zero are highlighted in grey.

PHOTOSTATION	**1**	**2**	**3**	**5**	**7**	**8**	**14**			
Number of frames	57	54	45	57	64	63	73			
Total points	2850	2700	2250	2850	3200	3150	3650			
Total points (minus tape+wand+shadow)	2826	2668	2248	2786	3133	3145	3489			
MAJOR CATEGORY (% of transect)								**MEAN**	**STD. DEV.**	**STD. ERROR**
CORAL (COR)		0.075			0.032		0.401	0.073	0.148	0.056
Coral Rubble (CR)		0.075					0.401	0.068	0.150	0.057
Solitary Coral (SC)					0.032			0.005	0.012	0.005
CNIDARIA NON SCLERACTINIA (CNI)	0.743	0.600	0.623	0.395	0.447	0.254	0.029	0.441	0.244	0.092
ECHINODERMATA (ECH)	0.142	0.375	0.089	0.431	0.160	0.095		0.184	0.158	0.060
PORIFERA (POR)	0.283	0.187	0.044	0.179	0.192	0.636	0.172	0.242	0.187	0.071
UNIDENTIFIED ORGANISM (UND)		0.037					0.057	0.014	0.024	0.009
SOFT BOTTOM SUBSTRATE (SB)	49.151	66.979	61.877	80.797	21.545	11.097	81.055	53.214	27.670	10.458
HARD BOTTOM SUBSTRATE (HB)	49.682	31.747	37.367	18.198	77.561	87.886	18.229	45.810	27.646	10.449
CABLE (CB)					0.064			0.009	0.024	0.009
HUMAN DEBRIS (HUM)						0.032	0.057	0.013	0.023	0.009
Tape, Wand, Shadow, Photo effect (TWS)	0.842	1.185	0.089	2.246	2.094	0.159	4.411	1.575	1.509	0.570
Sum (excluding tape+shadow+wand)	100	100	100	100	100	100	100			

Table 6-18 summarizes the results of macrofaunal density analyses for the low-slope stations. Ophiuroids, which could not be counted accurately due to their large numbers, usually small sizes, and frequently semicryptic habits (e.g., with only one or a few arms exposed), are not included in density analyses. The pie diagrams of densities as percentages of total fauna do not include fishes. Specific genera or (when known) species are distinguished when they were found at an overall density greater than 0.1 m^{-2} at that station. Again, note that organism identifications may differ from those described above in the qualitative section, as the latter also include organisms reported on videotape, and in still images not included in the quantitative analysis. Area covered ranged from 80.6 m^2 at station 1 to 123.3 m^2 at station 3. Figure 6-29 shows macrofaunal organism densities (in m^{-2}) expressed as percentages of abundance.

Station 1 on the Inner Terrace Platform (the westernmost site) covered 80.6 m^2 with an overall density of 9.9 organisms m^{-2}, dominated by unidentified hexactinellid sponges and the soft octocoral *Pseudodrifa nigra*. The annelid tentatively identified as *Ochetostoma* sp. is an echiuran spoonworm; the phylum Echiura has been reconsidered as a clade of polychaetes within the phylum Annelida. Station 2, also on the Inner Terrace Platform, covered 81.1 m^2 with 7.2 organisms m^{-2} and exhibited a more even proportional distribution of densities among major taxa, with the octocoral *Eunicella* sp., the soft coral *Pseudodrifa nigra*, the anemone *Liponema* sp. and unidentified hexactinellid sponges all accounting for between 13 and 16% of organisms.

All three Low-Slope stations on the Outer Terrace Platform supported substantially lower organism densities than those on the Inner Terrace Platform, despite covering larger areas. Station 3 covered 123.3 m^2 with 2.8 organisms m^{-2}, with about 50% of the fauna divided almost equally among *Eunicella* sp., *Liponema* sp. and *P. nigra*. Station 5 covered 112.0 m^2 with 3.6 organisms m^{-2}. Here, stylasterids accounted for the greatest proportion of benthos (20%), followed by *Liponema* sp. (18%), *P. nigra* (13%) and other cnidarians (12%), the latter chiefly *Eunicella* sp. and pennatulids. Station 7, just west of the Outer Terrace Ridge, covered 102.0 m^2 with 5.1 organisms m^{-2} dominated by stylasterids (24%), followed by *Liponema* sp. (15%), and about equal proportions of unidentified demosponges, cidarid urchins, solitary corals and *Eunicella* sp. (8-10%). Station 8, on the Outer Terrace Ridge, covered 118.3 m^2 and supported the greatest density of all Low-Slope stations, 7.7 organisms m^{-2}. Here, stylasterids accounted for the greatest abundance (33%).

Table 6-18. Macrofaunal densities at Priority Area 3 low-slope stations. Numbers are organisms per square meter (m^{-2}). Ophiuroids are omitted.

Photostation	1	2	3	5	7	8
Total image area (m^2):	80.560	81.052	123.269	112.005	102.022	118.297
Annelida	**0.385**	**0.271**	**0.024**			
?*Ochetostoma* sp.	0.385	0.271	0.024			
Arthropoda	**0.012**	**0.012**	**0.122**	**0.027**		**0.025**
Cirripedia				0.018		
Eumunida picta			0.008			
Paguroidea	0.012	0.012		0.009		0.017
Paguroidea 1			0.114			0.008
Bryozoa						**0.025**
Chordata	**0.062**	**0.049**	**0.041**	**0.036**	**0.029**	**0.059**
Actinopterygii				0.009		0.008
Ascidiacea			0.008			0.008
Chlorophthalmus agassizi	0.012			0.009	0.029	
Laemonema sp.	0.050	0.037	0.032	0.018		0.042
Scorpaenidae		0.012				
Cnidaria	**2.383**	**3.899**	**1.963**	**1.161**	**2.745**	**3.567**
Actiniaria 1 (?*Actinauge* sp.)		0.074	0.032			
Actiniaria 2		0.173				
Unident. Actiniaria	0.248	0.333	0.122	0.009	0.098	0.245
Actinoscyphia sp.	0.025	0.086	0.008			
Anthomastus sp.				0.018		
Corallimorphidae	0.012	0.025		0.009	0.020	
Eunicella sp.	0.149	0.753	0.381	0.045	0.412	0.127
Hydroidolina		0.037	0.016		0.010	0.034
Isididae			0.008			0.101
Liponema sp.	0.248	0.728	0.511	0.357	0.637	0.085
Octocorallia, gorgonacea				0.009		
Pennatulacea			0.024	0.045		
Plexauridae (Paramuriceidae)						0.042
Primnoidae		0.012				0.287
Pseudodrifa nigra	1.527	0.938	0.414	0.250	0.157	0.017
Unident. Sagartiidae	0.050	0.123	0.032		0.020	
Scleractinia (solitary)	0.025	0.086	0.105		0.343	0.507
Stylasteridae	0.074	0.444	0.300	0.402	1.039	2.096
Zoanthidea	0.025	0.086	0.008	0.018	0.010	0.025
Mollusca	**0.137**	**0.012**		**0.027**	**0.010**	**0.017**
Calliostoma sp.	0.074					
Pleurotomariidae	0.012					

	1	2	3	5	7	8
	80.560	81.052	123.269	112.005	102.022	118.297
Unident. Gastropoda	0.025			0.018	0.010	
Polyplacophora						0.017
Scaphella junonia	0.025	0.012				
Cephalopoda				0.009		
Echinodermata	**0.298**	**0.382**	**0.211**	**0.152**	**0.529**	**0.626**
Asteroidea	0.012	0.025	0.016		0.010	0.008
Cidaridae	0.186	0.234	0.032	0.080	0.353	0.414
Coelopleurus floridanus						0.017
Comatonia cristata		0.049	0.154	0.018	0.059	0.161
Democrinus cf. *brevis*	0.012				0.020	
Unident. Echinoidea	0.012					
Echinus sp.	0.025		0.008	0.009	0.010	
Euryalidae		0.037		0.009	0.039	0.008
Goniasteridae	0.012	0.025		0.027	0.020	0.008
Linckia sp.						0.008
Psolidae	0.025					
Sclerasterias sp.		0.012		0.009	0.020	
Tremaster mirabilis	0.012					
Porifera	**1.949**	**1.184**	**0.324**	**0.420**	**1.068**	**2.147**
Astrophorida			0.008			0.135
Axinellidae	0.012					
Desmacellidae	0.050	0.099	0.041		0.010	0.025
Geodiidae	0.012	0.025		0.018	0.020	0.017
Lithistida sp. 1				0.009	0.118	0.068
Lithistida sp. 2						0.101
Pachastrellidae		0.012		0.009	0.098	0.051
Phakellia sp.	0.025	0.012	0.016	0.179	0.088	0.372
Raspailiidae					0.010	0.169
Spongosorites					0.039	0.017
Unident. Demospongiae	0.273	0.210	0.057	0.134	0.421	0.642
Euritidae/Farreidae	0.062	0.012	0.008	0.018	0.118	0.025
Hyalonema sp.						0.008
Vazella sp.						0.008
Unident. Hexactinellida	1.514	0.814	0.195	0.054	0.147	0.507
Unknown organism	**0.037**			**0.018**		**0.025**
Total	**9.906**	**7.193**	**2.823**	**3.553**	**5.117**	**7.684**

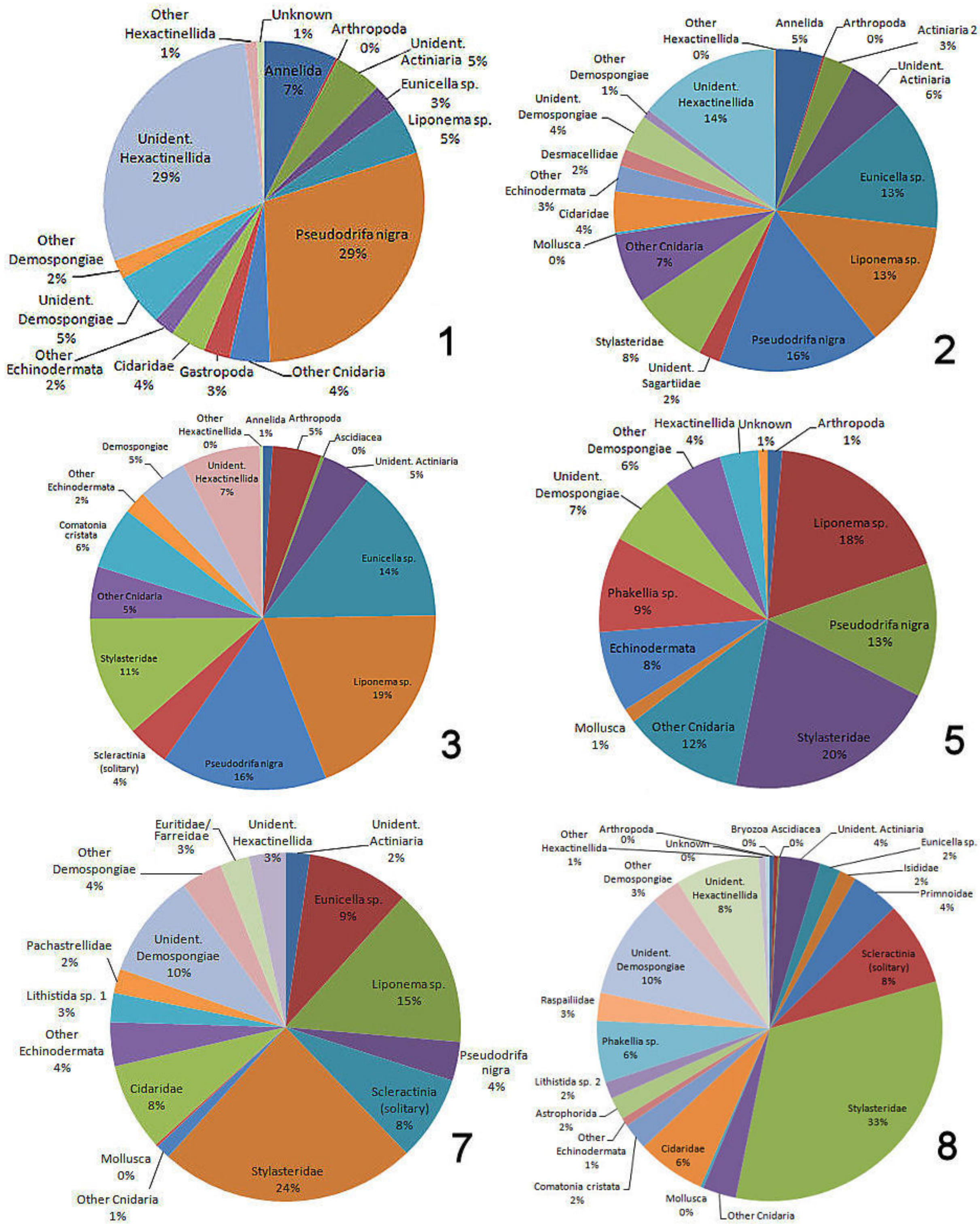

Figure 6-29. Priority Area 3 primary transect low-slope quantitative photostations 1, 2, 3, 5, 7 and 8. Macrofaunal organism densities (in m^{-2}) expressed as percentages of total organism abundance (data from Table 6-18). Font in this and Figures 6-30 and 6-31 size varied among pie diagrams to keep labels from overlapping.

Table 6-19 summarizes the CPCe analysis of benthic cover at the seven high-slope stations using 50 points per image. With the exception of scleractinian coral subcategories, only major categories are shown. Percentage cover of hard substrate was greatest (83.0-95.0%) at the four sites (stations 9-12) on the Outer Terrace Ridge on the northeast transect, lower on the two primary transect stations—70.2% at station 4 and 44.8% at station 6—and lowest on the Lower Terrace station 13 (24.3%). The great majority of hard bottoms comprised extended solid substrates (i.e., outcrops, pavement, ledges, boulders) with gravel/rubble/cobble substrates accounting for a maximum of 10.5% of total cover at station 9. Unconsolidated sediment accounted for almost all of the remaining substrates with the exception of station 13 where dead coral (chiefly *Lophelia pertusa* rubble) accounted for 14.4%. The greatest percentage cover attributed to living organisms was non-scleractinian cnidarians (chiefly octocorals), which accounted for 1.85% of cover at station 4. Living scleractinian coral accounted for at most 0.15% (station 6) and dead standing coral 0.56% at station 13.

Table 6-19. Summary of substrate percent cover at high-relief photostations in Priority Area 3. Stations 4 and 6 are on the primary transect; stations 9-13 on the northeast transect. Subcategories are shown only for scleractinian corals. Cells with values other than zero are highlighted in grey.

PHOTOSTATION	**4**	**6**	**9**	**10**	**11**	**12**	**13**			
Number of frames	37	27	65	54	56	38	29			
Total points	1850	1350	3250	2700	2800	1900	1450			
Total points (minus tape+wand+shadow)	1843	1330	3239	2625	2753	1834	1432			
MAJOR CATEGORY (% of transect)								**Mean**	**Std.Dev.**	**Std.Error**
CORAL (COR)	0.434	0.150		0.724	0.291	0.654	14.385	2.377	5.302	2.004
Dead Standing Coral (DC)						0.055	0.559	0.088	0.209	0.079
Coral Rubble (CR)	0.434			0.648	0.254	0.545	13.827	2.244	5.114	1.933
Lophelia (LOP)		0.150		0.076	0.036			0.038	0.058	0.022
Madrepora (MAD)						0.055		0.008	0.021	0.008
CHORDATA (CHO)					0.036	0.055		0.013	0.023	0.009
CNIDARIA NON-SCLERACTINIA (CNI)	1.845	0.451	0.185	0.267	0.073	0.164	0.489	0.496	0.614	0.232
ECHINODERMATA (ECH)	0.217		0.556	0.305	0.109			0.169	0.208	0.079
PORIFERA (POR)	0.271	0.075	1.111	0.610	1.090	0.164	0.349	0.524	0.428	0.162
SOFT BOTTOM SUBSTRATE (SB)	27.021	54.511	2.995	14.248	9.263	15.921	60.475	26.348	22.549	8.523
HARD BOTTOM SUBSTRATE (HB)	70.212	44.812	95.029	83.848	89.030	83.043	24.302	70.039	26.055	9.848
CABLE (CB)					0.109			0.016	0.041	0.016
NATURAL DETRITUS (DET)			0.123					0.018	0.047	0.018
Tape, Wand, Shadow, Photo effect (TWS)	0.378	1.481	0.338	2.778	1.679	3.474	1.241	1.624	1.164	0.440
Sum (excluding tape+shadow+wand)	100	100	100	100	100	100	100			

Table 6-20 summarizes the results of macrofaunal density analyses for the high-slope stations. Organisms are treated as in Table 6-18. Figures 6-30 and 6-31 shows macrofaunal organism densities (in m^{-2}) expressed as percentages of abundance. Area covered ranged from 59 m^2 at station 12 to 133.5 m^2 at station 11. Of the two high-slope sites on the primary transect, station 4, on the spur of the Inner Terrace Platform, covered 68.7 m^2, had an overall density of 4.1 organisms m^{-2}, and was dominated by stylasterid hydrocorals, the soft coral *Pseudodrifa nigra*, primnoid octocorals (*Plumarella* sp.) and demosponges (most commonly Raspailiidae). Station 6, on a slope in the middle of the eastern portion of the Outer Terrace Platform, covered 131.3 m^2, had an overall density of 5.0 organisms m^{-2}, and was dominated by the plexaurid octocoral *Eunicella* sp., the soft coral *P. nigra*, and stylasterids. The category "Other Cnidaria" here consists chiefly of anemones and solitary corals. There were 0.21 fishes m^{-2} at this station, chiefly Scorpaenidae, which were more than three times as abundant as at any other high-slope station.

Of the five high-slope sites on the northeast transect from west to east, station 9 covered 103.1 m^2 and had an overall density of 10.2 organisms m^{-2}. The small unbranched plexaurid octocoral *Eunicella* sp. was by far the most abundant organism (4.9 m^{-2}), accounting for 50% of all macrobenthos. Station 10 covered 112.2 m^2 and had an overall density of 7.65 organisms m^{-2}, again with *Eunicella* sp. the most abundant organism (32%). Station 11 covered 133.5 m^2 with overall density of 5.8 organisms m^{-2}. Unidentified demosponges were proportionally the most abundant organisms (46%). Although numerous sponges could not be identified from either photographs or video, stations 10 and 11 appeared to have the greatest sponge species richness of any of the high-slope sites. Station 12, apparently on the eastern crest of the Outer Terrace Ridge, covered 59.1 m^2 with an overall density of 3.89 organisms m^{-2}. Primnoid octocorals (*Plumarella* sp.), which are most commonly found on and near ledge edges and other projecting high-relief substrates, were proportionally most abundant (31%). Station 13, on the Lower Terrace, covered 41.5 m^2 with an overall density of 9.1 organisms m^{-2} and was dominated by small solitary corals (57%).

Table 6-20. Macrofaunal densities at Priority Area 3 high-slope stations. Numbers are organisms per square meter (m^{-2}). Ophiuroids are omitted.

Photostation	**4**	**6**	**9**	**10**	**11**	**12**	**13**
Total image area (m^2)	**68.663**	**131.315**	**103.072**	**112.177**	**133.489**	**59.099**	**41.455**
Arthropoda	**0.015**	**0.023**	**0.019**	**0.036**	**0.045**	**0.034**	**0.048**
Bathynectes longispina			0.010				
Crustacea					0.007		
Eumunida picta	0.015	0.023		0.009	0.015		
Paguroidea			0.010	0.009	0.007	0.034	0.024
Penaeidae				0.018	0.015		0.024
Bryozoa		**0.008**	**0.019**	**0.018**	**0.112**	**0.017**	
Chordata	**0.044**	**0.206**	**0.107**	**0.009**	**0.022**	**0.051**	**0.072**
Actinopterygii	0.015					0.017	
Ascidiacea			0.078			0.017	
Chlorophthalmus agassizi			0.010				
Elasmobranchii					0.007		
Helicolenus dactylopterus		0.008			0.007	0.017	0.024
Laemonema sp.	0.029	0.038	0.019	0.009	0.007		0.048
Scorpaenidae		0.160					
Cnidaria	**2.709**	**3.869**	**6.850**	**4.466**	**1.985**	**2.538**	**8.057**
Actiniaria 2				0.009		0.034	
Actiniaria unid.	0.029	0.038	0.116	0.027	0.015		0.072
Actinoscyphia sp.	0.015	0.038					
Antipatharia		0.008					
Bathypathes alternata				0.009	0.022	0.034	
Corallimorphidae	0.029		0.039	0.027		0.017	0.121
Eunicella sp.	0.146	1.325	4.958	2.318	0.352	0.051	0.024
Hydroidolina		0.008	0.019	0.027		0.017	0.145
Isididae			0.010			0.068	0.024
Liponema sp.	0.175	0.129	0.223	0.089	0.112	0.017	
Lophelia pertusa	0.015			0.009			0.024
Madrepora oculata						0.017	0.096
Octocorallia, gorgonacea			0.010	0.009		0.305	0.941
Pennatulacea				0.009			
Primnoidae	0.495	0.053		0.071	0.105	1.117	1.303
Pseudodrifa nigra	0.772	0.891	0.417	0.098			0.024
Sagartiidae	0.015	0.091	0.010	0.009			0.096
Scleractinia (solitary)	0.058	0.807	0.437	0.464	0.479	0.372	4.776
Stylasteridae	0.961	0.480	0.611	1.293	0.891	0.491	0.386
Zoanthidae					0.007		0.024

	4	**6**	**9**	**10**	**11**	**12**	**13**
	68.663	**131.315**	**103.072**	**112.177**	**133.489**	**59.099**	**41.455**
Echinodermata	0.233	0.617	1.184	1.284	0.180	0.152	0.048
Araeosoma sp.	0.029	0.008			0.007		
Asteroidea	0.160	0.168	0.165	0.125			
Cidaridae			0.611	0.401	0.022		
Coelopleurus floridanus	0.015						
Comatonia cristata	0.029	0.404	0.398	0.660	0.142	0.135	0.048
Echinoidea				0.009			
Echinus sp.				0.036			
Euryalidae		0.008					
Goniasteridae		0.015		0.027		0.017	
Linckia sp.			0.010				
Psolidae					0.007		
Sclerasterias sp.		0.015		0.009			
Tremaster mirabilis				0.018			
Mollusca	**0.044**		**0.010**	**0.018**	**0.015**		**0.096**
Cephalopoda				0.009			
Gastropoda	0.044		0.010	0.009	0.015		0.096
Porifera	**0.990**	**0.236**	**1.979**	**1.819**	**3.379**	**1.100**	**0.748**
Demospongiae	**0.655**	**0.221**	**1.717**	**1.471**	**3.049**	**0.795**	**0.145**
Desmacellidae	0.058	0.152	0.107	0.018	0.022		
Geodiidae	0.015			0.009			
Leiodermatium sp.					0.015	0.034	
Lithistida sp. 1			0.058	0.232	0.120	0.017	
Pachastrellidae	0.058	0.023	0.039	0.027	0.007	0.017	
Phakellia sp.	0.044	0.008	0.194	0.107	0.292	0.118	0.048
Raspailiidae	0.102	0.015	0.747	0.259	0.030	0.034	
Spongosorites sp.				0.009	0.015		
Unident. Demospongiae	0.379	0.023	0.572	0.811	2.547	0.575	0.096
Hexactinellida	**0.335**	**0.015**	**0.107**	**0.116**	**0.150**	**0.034**	**0.000**
Euritidae/Farreidae	0.044	0.015	0.107	0.107	0.105		
Unident. Hexactinellida	0.291						
Vazella sp.				0.009	0.045	0.034	
Unknown animal	**0.029**	**0.015**			**0.037**		
Total	**4.063**	**4.973**	**10.168**	**7.649**	**5.776**	**3.892**	**9.070**

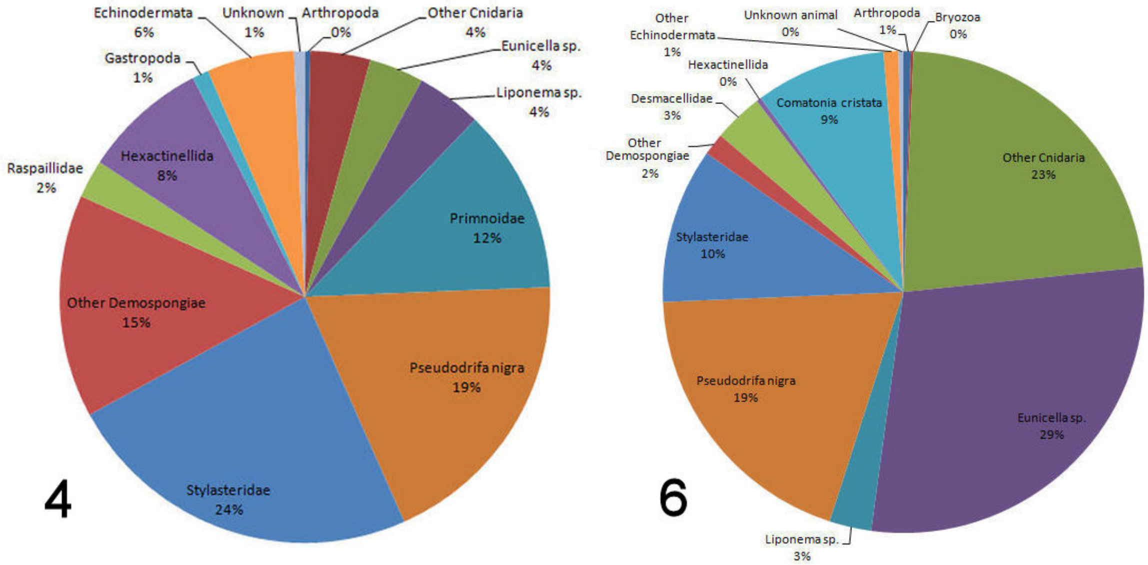

Figure 6-30. Priority Area 3 primary transect high-slope quantitative photostations 4 and 6. Macrofaunal organism densities (in m^{-2}) expressed as percentages of total organism abundance (data from Table 6-20).

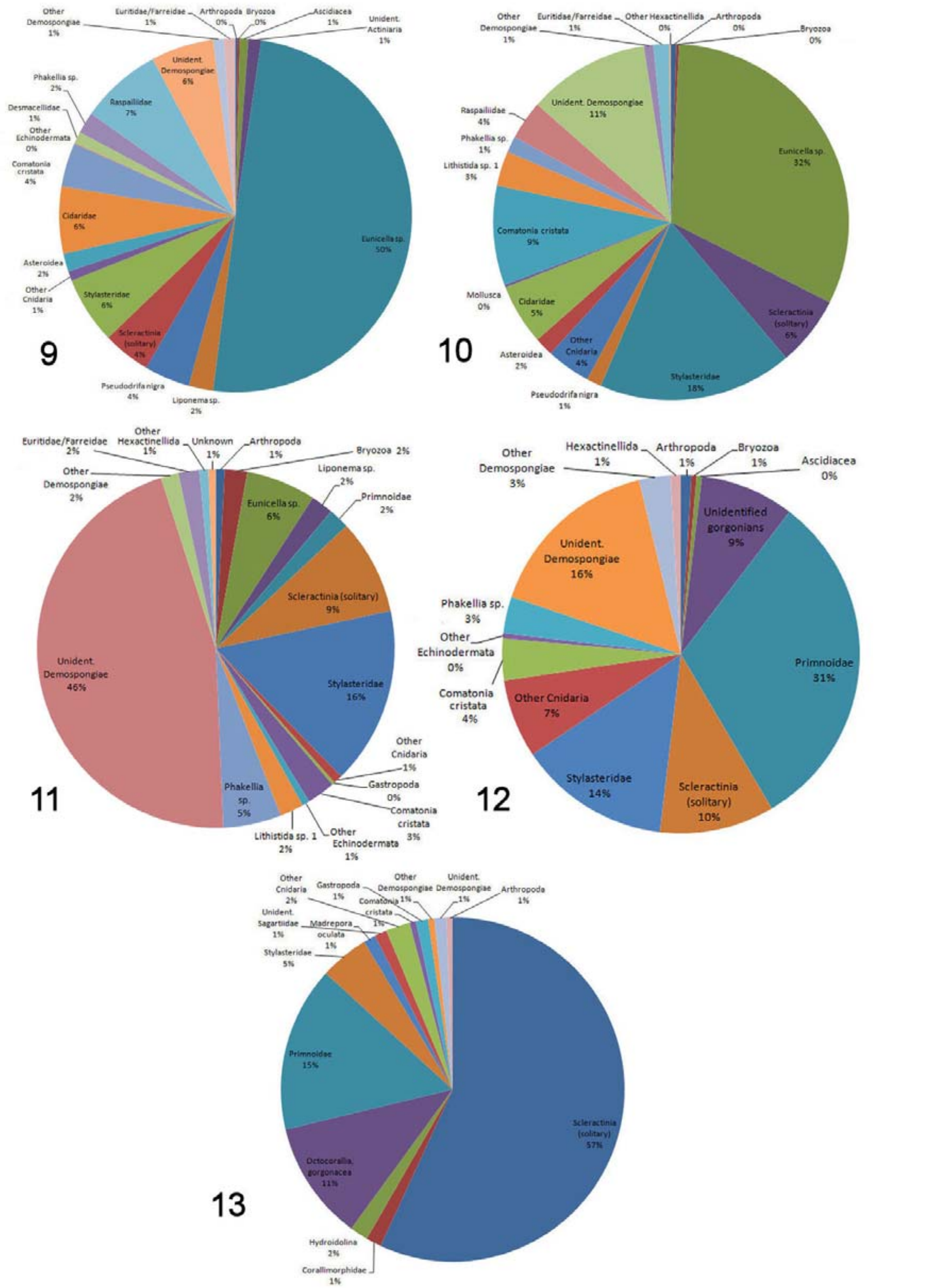

Figure 6-31. Priority Area 3 northeast transect high-slope quantitative photostations 9 through 13. Macrofaunal organism densities (in m^{-2}) expressed as percentages of total organism abundance (data from Table 6-20).

7 CONCLUSIONS

With respect to the specific objectives set out in section 2.2, the project team assembled a seafloor survey methodology and siting framework that can be used by developers of marine and hydrokinetic projects on the outer continental shelf off southeastern Florida in consultation and cooperation with regulatory and resource management agencies that have the permitting and review authority for such projects.

The project team also identified two major areas offshore southeastern Florida that appear suitable for installing commercial scale marine and hydrokinetic energy facilities, including subsea electrical transmissions cables to shore, and one major area that appears unsuitable for such applications. The seafloor of Priority Areas 1 and 2 off Palm Beach County are almost entirely unconsolidated sediment (except for a small area at a depth at or near the current preferable maximum for such projects) that do not support complex three-dimensional benthic biological assemblages. Both areas are adjacent to coastal environments that have gaps in environmentally sensitive hard-bottom habitats that offer shore access for subsea electrical transmissions cables. On the other hand, Priority Area 3 off Broward County lies on the geologically and biologically complex Miami Terrace, which supports rich assemblages of macrobenthic organisms, including a variety of deep-water corals and lies within the federally designated Coral Habitat of Particular Concern. Shore access for transmission cables is also limited here by the extensive coast-parallel system of reefs and ridges of the northern reaches of the Florida Reef Tract.

The benthic descriptive and quantitative survey results described herein demonstrate a practical application of the protocols developed during this project, and represent guidelines for future surveys. It remains for MHK developers to consult with appropriate agencies (e.g., through EFH Assessments) about what patterns of benthic assemblage composition and diversity, and what organism densities and construction-associated impacts and adverse effects, determine whether proposed sites can be mitigated or must be avoided. Similarly, these protocols were developed with agency and industry input. Once vetted by regulatory agencies and DOE, it would be an appropriate next step to solicit feedback from all potential stakeholders. That additional review process lies outside the scope of this project.

8 DISSEMINATION OF RESULTS

Results and methodologies associated with this project have so far been disseminated via the following presentations. Additional presentations at national and international meetings are anticipated as those venues become scheduled.

Reed JK, Messing C, Walker B, Brooke S, Brouwer M, Correa T, and Farrington S. 2010. Distribution and characterization of deep-water reef and hard-bottom habitats off eastern Florida. Renewable Ocean Energy and the Marine Environment: Responsible Stewardship for a Sustainable Future, Nov. 2010, Florida Atlantic University. Abstract, p. 42. HBOI Miscellaneous Contribution Number 687.

Riccobono A. 2010. “Siting Study Framework and Survey Methodology for Marine and Offshore Hydrokinetic Energy Projects Offshore Southeast Florida.” Renewable Ocean Energy & the

Marine Environment: Responsible Stewardship for a Sustainable Future, 3-5 Nov 2010. Florida Atlantic University.

Walker BK. 2011. "Spatial Planning to Inform Renewable Alternative Energy Siting Off Florida." 26th U.S. Coral Reef Task Force (USCRTF) Meeting, Special Session: Spatial Planning on the Florida Reef Tract - Pieces of the Coastal and Marine Spatial Planning (CMSP) Puzzle. 21 October 2011, Ft. Lauderdale, FL.

The final report will be accessible on the websites of Nova Southeastern University and Florida Atlantic University.

9 PROTOCOLS – Benthic Environmental Assessment Protocols for Marine and Hydrokinetic Development Projects Offshore Southeastern Florida

9.1 Introduction

Protocols described herein:

- apply to the identification of general areas offshore southeastern Florida (Figure 9-1) to determine the suitability for the mooring and operation of marine and hydrokinetic development projects;
- apply to the establishment of strategies for avoiding or minimizing project impacts to critical habitats such as hard bottom and deep-sea coral and sponge habitat, as described below, and
- apply to the performance of specific offshore geophysical and benthic video surveys using non-invasive methods (i.e., no devices of any kind either temporarily or permanently attached to the seabed).

These protocols derive from the results of this project coupled with those of previous deep-water surveys and environmental assessments of proposed LNG pipelines and cables offshore southeastern Florida (Reed 2004, 2006; Reed et al. 2005, 2006, 2008, 2011; Reed and Farrington 2010; Messing et al. 2006 a, b). These surveys are generally required by agencies such as the U.S. Army Corps of Engineers (COE), National Marine Fisheries Service (NMFS), regional fishery management councils, Florida Fish Wildlife Conservation Commission (FFWCC), and other state agencies, to determine if hard-bottom habitats (also referred to as live bottom) are present within areas proposed for development, such as pipeline or cable rights-of-way (ROW), within U.S. Federal waters, i.e., all submerged lands between the Florida State 3-nm limit and the U.S. Exclusive Economic Zone (EEZ). The protocols for such surveys have been designed to adhere in part to those outlined by the *Guidelines for Conducting Offshore Benthic Surveys* (DEP Office of Intergovernmental Programs Offshore Projects Section, 2006) and as applied herein and by Messing et al. (2006 a, b) and Reed et al. (2008).

In general, areas of interest are chosen by spatially evaluating all known and available regional data. Stakeholders (e.g., agencies, other local developers, and those who make use of the resource) are engaged in advance to provide knowledge about any potential conflicts in the proposed areas of interest and to provide input on the proposed work plan. Then, detailed high-resolution multibeam or side-scan sonar surveys are conducted on these focused areas followed by high-resolution video and digital still camera transects to assist with site selection in order to avoid or minimize impact to hard-bottom habitats. If potential hard-bottom is present, and unavoidable impacts are likely at the proposed site, mitigation measures and surveys of alternative sites may be required. Transect spacing for the surveys may require approval by various agencies.

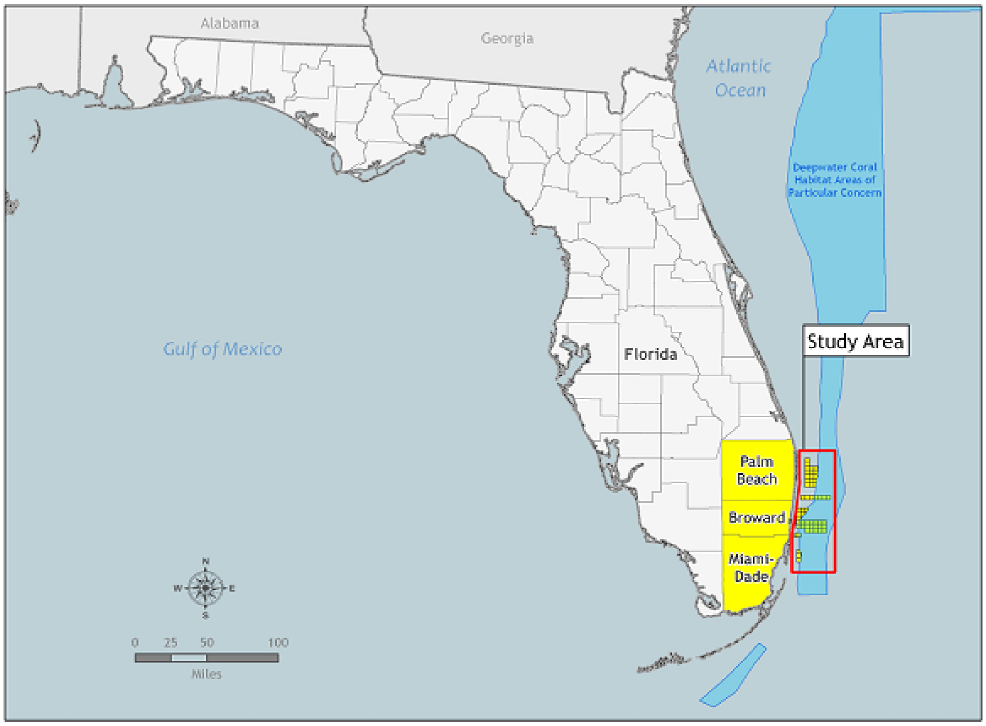

Figure 9-1. Areas offshore southeastern Florida to which protocols apply (red box).

9.2 Compilation of Existing Information

The most recent and readily available information on benthic substrates, benthic habitat, and marine biota in the region of interest should be reviewed and analyzed prior to designing a geophysical and benthic video/photographic survey to select siting options.

Datasets ranging from administrative boundaries to environmental data should be compiled in both raster and vector formats or converted into a compatible spatial format using geo-referencing and digitizing techniques. Data sources should include the NOAA National Geophysical Data Center, which can provide available bathymetry and other geophysical data. Relevant benthic habitat information may be obtained from the NOAA Coastal Services Center and published scientific literature. Administrative boundaries, including maritime limits, National Marine Sanctuary boundaries, and Marine Managed Area boundaries, may be obtained from the NOAA Office of Coast Survey. The information should be compiled, analyzed, and summarized in a planning report.

Publications on deep-sea coral and sponge ecosystems that occur off southeastern Florida are limited. Although these ecosystems are widespread in the area (Arendt et al. 2003, Hain and Corcoran 2004, Partyka et al. 2007, Reed et al. in press), the region is poorly explored and their precise extent is unknown. Only a few, limited areas of deep-sea habitat have been remotely mapped off Florida (Reed et al. 2005b; Grasmueck et al. 2006, 2007; Messing et al. 2006 a, b; Reed 2008), and the percentage of seafloor explored visually with human-occupied submersibles and ROVs remains small.

9.3 Agency and Stakeholder Input

It is recommended that Key Project Development Team members establish agency and stakeholder consultations early in project development and share information about proposed objectives, plans and schedules so that proper feedback about the siting study is secured from all applicable federal and state agencies. Agency and stakeholder input should be integrated prior to completing any field work plan that includes geophysical and benthic surveys. In this region of the southeastern U.S., we suggest that the following agencies be consulted during early planning phases, in addition to regional non-governmental stakeholders (see abbreviations on page vi):

- BOEM
- FERC
- FDEP Office of Intergovernmental Programs Offshore Projects Section
- National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries)
- Florida Fish and Wildlife Conservation Commission
- South Atlantic Fishery Management Council
- Florida Department of State - State Historic Preservation Office

There are other stakeholders that also participate in the permitting and licensing process. Please refer to Section A.9 for additional information.

9.4 Protocol Terminology

Potential developers should follow habitat terminology used by agencies. The South Atlantic Fisheries Management Council (SAFMC) refers to hard bottom as a class of benthic communities occurring in temperate, subtropical, and tropical regions (SAFMC, 1998). Hard bottom is sometimes referred to as live bottom due to the amount of living organisms attached to these substrates. Hard bottom provides anchorage for sessile or semi-sessile organisms (e.g., corals, sponges, anemones and crinoids). Hard-bottom habitat includes various sizes of loose rock (gravel, rubble, cobble, boulders, slabs), rock pavement, ledges, coral rubble, and standing coral (live or dead). Hard bottom slopes range from relatively flat, low-relief surfaces (<0.5 m vertical relief) to sheer vertical escarpments tens of meters in relief. Vertical relief of bottom features (e.g., pavement, boulder, slab) were reported in the Calypso LNG pipeline and deep-water port reports as low- (<0.5 m), moderate- (0.5-1.0 m), and high-relief (>1.0 m) (Messing et al. 2006a, b). However, these values are arbitrary, and the low-to-high relative terms depend on the size of features within an area and field of view. Soft substrates were defined as unconsolidated sediments.

NOAA defines 'deep-sea corals' as an assemblage of scleractinian corals, zoanthids, black corals, octocorals, and hydrocorals belonging to the phylum Cnidaria (Etnoyer et al. 2006, Lumsden et al. 2007). Deep-sea coral ecosystems (DSCEs) occur locally at depths of 50 to >1000 m and consist of structure-forming, deep-water corals and other associated structure-forming species such as sponges, bryozoans, and hydroids, all of which may provide habitat to hundreds of species of invertebrates and demersal fishes (Lumsden et al. 2007, Partyka et al. 2007, Messing et al. 2008).

The SAFMC Southeast Area Monitoring and Assessment Program (SEAMAP 2001) deep-water mapping project and the Southeastern United States Deep-Sea Corals Initiative (SEADESC) have documented deep-water, hard-bottom habitat from existing data throughout the South Atlantic Bight and Straits of Florida (Arendt et al. 2003, Partyka et al. 2007). SEAMAP has subdivided deep-water hard bottom habitat as follows: coral, rock rubble, coral rubble, exposed hard pavement, thinly covered hard substrate, and artificial structures. In addition, a "Special Habitats" category includes the subcategories of canyons, tilefish burrows, consolidated mud, methane seeps, sinkholes, and coral banks (see Section 4.2 and Table 4-2 above).

The importance of hard bottom to fisheries stocks has been recognized, and the SAFMC has designated all natural and artificial hard bottom as Essential Fish Habitat (EFH) and/or Habitat Area of Particular Concern (HAPC).

9.5 Geophysical Methods

We recommend high-resolution bathymetric (multibeam or side-scan sonar) surveys of future cable, pipeline routes, and energy projects in all federal waters. Geophysical field information will be useful in assisting project developers in making informed decisions about possible specific sites to target areas for potential development or areas to avoid. Such surveys will at least provide data to eliminate unsuitable areas, such as obvious high-relief features, from consideration and permit focusing on areas potentially suitable for development. Although unconsolidated sediment substrates are biologically less complex and therefore more desirable relative to hard-bottom habitat, it is critical to recognize that these substrates support a variety of species, potentially including commercially important taxa such as blueline (*Caulolatilus microps)* and golden tilefish (*Lopholatilus chamaeleonticeps*), royal red shrimp (*Pleoticus robustus*) and golden crab (*Chaceon fenneri*), or 3-dimensional habitat-forming taxa such as sea pens (Pennatulacea). Project developers will have to investigate the presence, abundance and distribution of these species during project licensing and permitting as well.

The geophysical survey should provide full coverage of the areas of interest. Survey lines should have sufficient overlap to provide the most precise results, avoid data gaps, and provide cross-checking between lines for quality control. For dual-frequency sidescan surveys, line spacing must provide suitable overlapping coverage for both the low and high-frequency data channels.

Surveys should collect both bathymetry and backscatter information. The bathymetry will provide depth information, whereas the backscatter will provide some indication of seafloor hardness. This may be helpful in distinguishing low-relief hard-bottom from unconsolidated sediments in some cases. Data should be provided in vector and raster forms. Vector data should be processed to generate high-resolution images in standard GIS formats (e.g., geotif). Bathymetric data should be used to create high-resolution digital elevation models (DEMs) and hillshaded scenes to visualize topography. DEMs can be used to visualize backscatter data, create contours, and illustrate seafloor profiles. Geophysical data should be provided to the agencies in hard copy and electronic format.

Sub-bottom profiling could also be used to provide additional information on sediment thickness and presence of hard bottom.

9.6 Benthic Surveys

Visual inspection is required to document the presence of deep-water, hard-bottom substrate, which provides essential habitat for sponge and coral communities. Bathymetric data (e.g., multibeam, side scan) must be visually groundtruthed to confirm the extent of such habitat. For example, during previous surveys by submersible or remotely operated vehicle (ROV) in this region, visual inspection of all high-relief bathymetric features were verified as hard-bottom habitat, whereas low-relief, flat seafloors could be either unconsolidated sediment or hard substrate (e.g., Reed et al. 2008). Some areas of relatively flat bottom may have a thin veneer of sediment overlying rock pavement but still provide habitat for sessile, benthic species such as sponges and coral. As an example, sonar data provided during the CFX-1 cable survey showed an extensive area of apparent soft-bottom habitat

(Site HB-4, 6540 m length) which in fact was hard bottom and coral rubble verified by ROV video (Reed et al. 2008). Direct visual observation is therefore necessary to verify the presence and extent of deep-water, hard-bottom habitat.

Protocols for benthic video surveys by submersible and/or ROV should adhere in part and as applicable to those outlined by the *Guidelines for Conducting Offshore Benthic Surveys* (DEP Office of Intergovernmental Programs Offshore Projects Section, 2006) and as applied herein and by Messing et al. (2006 a & b) and Reed et al. (2008).

Video and photographic transects from either an ROV or manned submersible should be used to document and characterize the benthic habitat and biota at all sites where there could be potential benthic impact, including deployment areas, actual facility location sites, and cable-to-shore routes. High-resolution video and digital still camera surveys should be conducted at the proposed and alternative sites that are selected based on the literature search and geophysical surveys. Transect spacing of the video/photo surveys may require approval by various agencies, such as offsets of ±300 m for cable routes in areas of potential hard-bottom habitat, and a 1-nmi x 1-nmi grid around a fixed facility site.

For pre-site selection and for post-deployment monitoring, ROV/submersible transects should be made at an approximate speed of <0.25 m s^{-1} (0.5 knot). During transects, the vehicle should remain <1 m off bottom whenever possible in order to identify objects of interest in the video. Continuous video should be recorded for the duration of each dive to provide a complete record of *in situ* observations. Throughout the dive, a biologist knowledgeable in the regional deep-water fauna should provide audio descriptions of the habitat and biota on the videotape. These data should be entered into an Excel spreadsheet or Access database and include date, georeferenced coordinates, time (every 2-5 min), depth (m), height off bottom (m), ROV/sub heading, course over ground (COG), speed, habitat descriptions (habitat type, geomorphology, estimated percent cover), and biota descriptions (species, estimated sizes, and relative abundances). The high-definition, high-quality color video camera should be mounted on a pan and tilt platform and be provided with good lighting to avoid shadows. The camera must have a set of parallel lasers a known distance apart for scale. The camera angle is typically 25-35^{o} for a good field of view, which should range from 1-3 m in width, and which can be determined by the scaling lasers. Scaling lasers are typically set 8 cm apart, but this is not a precise requirement.

A high-quality digital still camera, positioned straight down, ~1 m off bottom, and also equipped with scaling lasers, should be used for quantitative photographic transects. Still images should be captured at 5-10-min intervals while over sediment habitat and continuously over all hard-bottom habitat (no fewer than 3-4 min^{-1}). Representative sites for each hard substrate habitat type (e.g., rock pavement, rock ledge, rock rubble/cobble, standing coral, coral rubble) should be selected for quantitative analysis based on apparent substrate composition, geomorphology (structure, relief, and slope), depth range, biological complexity, and diversity relative to surrounding substrates. Approximately 100 images should be taken of each representative habitat type. If the habitat is too limited in extent to allow 100 photos, as many as possible non-overlapping image should be made.

Data derived from the video and digital still images will be used to carry out GIS mapping of deep-water habitats. Video and photographic data will be used to confirm organism identifications as far as possible and to define biological zones and benthic habitats. In many cases deep-water organisms cannot be identified from video or images below major taxonomic categories (e.g., family, class, order), and often require specimens for species-level classification. Data should be summarized to produce habitat descriptions and identify transitions between habitats.

Quantitative digital images should be first analyzed to eliminate out-of-focus and too distant-from-bottom images. Image contrast and light balance may be improved when necessary by using

Photoshop© or similar software. All images that overlap another portion of the bottom should be omitted from analysis. Software such as Coral Point Count with Excel extensions (CPCe)© (Kohler and Gill, 2006) can be used to quantify percent cover of bottom types and faunal densities (see Methods section in report above).

The relatively low densities of benthic hard-bottom macrofauna anticipated in deep-water habitats off southeastern Florida require an excessive number of random points in order to accurately capture the diversity of organisms and reflect their densities and percent cover. As a result following discussions with, and agreement by, agency representatives, Messing et al. (2006 a,b) and this study subjected quantitative images to a two-stage analysis: randomized counts of 50 points per frame for percent cover of substrate type and major taxonomic group, and absolute counts of all organisms greater than ~3 cm in size. Each image was initially analyzed using CPCe software for percent biological (e.g., sponge, cnidarian, echinoderm) and substrate cover (e.g., hard-bottom, sediment-veneered hard-bottom, sediment) at a density of 50 points per image. Organisms were identified to the most detailed taxonomic level possible with visual identification. Each image was then re-examined and all organisms larger than ~3 cm counted and identified as specifically as possible. Image area was calculated in CPCe software by converting image length and width in pixels to centimeters based on the number of pixels equivalent to a known object in the image, i.e., the 8-cm laser scale in the digital still images. Organism densities per square meter were calculated by extrapolating the number of organisms for the calculated image area. After CPCe analysis of each image, the data was saved into an Excel spreadsheet for analyses of: 1) raw percent composition, and 2) percent composition per area for each site.

9.7 Benthic Habitat Mapping

Geophysical and benthic video data associations should be interpreted into a benthic habitat map of the area of interest. All previous regional research on the biological communities should be reviewed as part of this process, and previous mapping efforts should be incorporated where possible. Mapping should attempt to discern as fine of a characterization as possible at a scale most appropriate to the data. A benthic habitat map composed of all three vector types (points, lines, and polygons) will be the most informative way to illustrate the mapping data. Polygons can be made of the entire mapped area. However, visually confirmed areas must be distinguished from those extrapolated from geophysical data, i.e., by lines along groundtruthing (ROV or submersible) transects. It is recommended that segments along the transect lines be categorized by the habitat they span. This will help illustrate the finer scale variability in habitats not captured in the polygon mapping. It is also recommended to add points of major interest encountered during the visual surveys to the map. This is especially relevant in instances where species of interest are encountered (e.g., tilefish, coral). Polygons in areas without high-resolution geophysical data should be distinguished.

9.8 Additional Considerations

For examining Right of Ways (ROWs), typical survey corridors (i.e., 150 ft to either side of a cable route) may not be sufficient in this region, as cables and pipes will drift from their deployment location at the surface under the influence of the strong Florida Current until they settle on the bottom. Recent surveys have also encountered deployed facilities such as cables where none were recorded in standard sources.

High surface velocities associated with the Florida Current/Gulf Stream (sometimes >150 cm sec^{-1}), strong bottom currents (to 50 cm sec^{-1}), and local high-relief rock and coral habitat (vertical escarpments to 70-m and coral mounds to 150-m vertical relief) create an exceedingly difficult work environment for ROVs or submersibles. As a result, it is critical that platforms proposed for benthic video and photographic surveys be powered sufficiently to operate under such hydrodynamic conditions in topographically complex environments. As alternatives, manned submersibles typically have restricted operational time constraints (typically 7 out of 24 hours) but once launched are able to operate near the bottom unaffected by high surface currents. ROVs are capable of much longer continuous periods of operation but offer more limited bottom views and are difficult to maneuver and maintain position due to the effect of currents on the tether cable. ROV tether diameter and power is important, as thicker tethers generate a substantially greater drag, making it difficult or even impossible for insufficiently powered or weighted ROVs to reach bottom at depths of several hundred meters.

9.9 Other Facility Siting Criteria Outside the Scope of this Protocol

Although these protocols focus on siting issues related to benthic habitat characterization, it is important to note that a broad range of issues must be considered and evaluated during project licensing and the public involvement phase due to their importance in determining the viability of any marine or hydrokinetic project proposed for offshore southeastern Florida. Table 9-1 lists some of the most relevant criteria and stakeholders that will likely play a role in determining the ultimate viability of any marine or hydrokinetic energy project offshore southeastern Florida.

Table 9-1. Additional Criteria and Considerations for the Siting of Any Proposed Marine or Hydrokinetic Project. NGO = non-governmental organization; USCG = U.S. Coast Guard; USEPA = U.S. Environmental Protection Agency. Other abbreviations as in Section 9.3.

Criteria/Issues to Consider	Stakeholders
Survey methodology and framework for specific project	BOEM, State of Florida (FDEP, FFWCC, and others), NOAA Fisheries Service, and SAFMC
Site-specific (for both electric transmission cable corridor and offshore block) characterization studies/evaluations, including but not limited to physical oceanographic characterization studies, meteorology, climate, etc.	BOEM, State of Florida (FDEP, FFWCC, and others), NOAA Fisheries Service, and SAFMC
Existing facility conflicts	U.S. Navy's South Florida Testing Facility Range and Port Everglades
Benthic habitat impacts	NOAA Fisheries Service, State of Florida (FDEP, FFWCC, others), SAFMC, and NGOs
Coral reef habitat impacts	NOAA Fisheries Service, State of Florida (FDEP, FFWCC, and others), SAFMC, and NGOs
Cultural/archeological resources	State Historic Preservation Office (SHPO)
Operational safety	All Stakeholders
Any visibility issues from shore	Public, Property Owners, Counties/Municipalities
Fishing/boating conflicts	SAFMC, Public, Boater/Fishermen Organizations
Other resource use conflicts (e.g., offshore mining of beach-quality sand for beach restoration by coastal cities and communities)	State of Florida (FDEP, FFWCC, and others), U.S. Army Corps of Engineers, Local Governments, BOEM and NOAA Fisheries Service
Impacts to fishery resources (e.g., impingement and entrainment of ichthyoplankton, thermal discharges, and avoidance of resources such as tilefish and golden crab that utilize soft-bottom habitats as Essential Fish Habitats)	NOAA Fisheries Service, State of Florida (FDEP, FFWCC, and others) SAFMC, and NGOs
Vessel traffic conflicts	USCG, Ship Operators, Cruise Line Operators, Boating and Fisherman Organizations
Air quality impacts	USEPA, State of Florida (FDEP, FFWCC, and others), Public
Substrate suitability	All Stakeholders
Proximity to onshore delivery point	All Stakeholders
Public safety	Public, Elected Officials, Counties, Municipalities
Reliability	Project Proponent, Public
Other impacts to activities within State waters	State of Florida (FDEP, FFWCC, and others), Local Governments, and NGOs

9.10 Summary of Offshore Survey Protocols for Facility Siting

In general, high-resolution multibeam or side-scan sonar surveys followed by high-resolution video and digital still camera transects will assist with site selection in order to avoid or minimize impact to hard-bottom habitats. If potential hard-bottom is present and unavoidable, potential impacts at the proposed site may require mitigation measures and alternative site surveys may be surveyed.

1) Evaluate existing data (i.e., geophysical, biological, archeological) in the areas of interest prior to the initial planning of geophysical and benthic video/photographic survey activities.
2) Early agency and stakeholder consultation.
3) Conduct high-resolution multibeam or side-scan sonar survey to assist with site selection in order to avoid or minimize impact to possible hard-bottom habitat.
4) Evaluate alternative sites if unavoidable impacts are likely at proposed site.
5) Survey proposed and alternative sites with high-resolution video and digital still cameras. Transect spacing of the video/photographic surveys may require approval by various agencies and may include offsets of ±300 m for cable routes in areas of potential hard-bottom habitat and 1-nmi x 1-nmi grids around turbine or other fixed facility sites.
6) A biologist knowledgeable in the regional deep-water fauna should provide descriptions of the habitat and biota on the videotape during the survey; these data must be georeferenced and entered into an Excel spreadsheet or Access database.
7) Still images should be captured at 5-10-min intervals while over sediment habitat and continuously over all hard-bottom habitat (no less than 3-4 min^{-1}).
8) Images must be georeferenced and stored in digital format for analysis.
9) Digital still images should be analyzed using CPCe software (or similar) to determine percent cover of hard bottom substrates and major taxonomic groups in areas of biological interest.
10) Images should be analyzed in greater detail to determine faunal composition and organism densities in areas of biological interest.
11) Field notes and video/photo data should be reviewed and summarized to identify habitats and faunal distributions.
12) Summaries should be compiled in GIS format and used to produce habitat maps.

10 SOURCES CITED

Arendt MD, Barans CA, Sedberry GR, Van Dolah RF, Reed JK & Ross SW. 2003. Summary of seafloor mapping and benthic sampling in 200-2000m from North Carolina through Florida. Final rept. Deep-water Mapping Project Phase II. SAFMC. Charleston, SC.

Ballard RD & Uchupi E. 1971. Geological observations of the Miami Terrace from the submersible Ben Franklin. *Mar. Technol. Soc. J.* 5(2):.43-48.

Clarke KR & Warwick RM. 2001. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. 2nd edition: PRIMER-E, Plymouth, UK, 172 pp.

Clarke KR & Gorley RN. 2006. PRIMER v6: User manual/tutorial, PRIMER-E, Plymouth UK, 192 pp.

Etnoyer P, Cairns SD, Sanchez JA, Reed J, Lopez J, Schroeder W, Brooke S, Watling L, Baco-Taylor A, Williams G, Lindner A, France S, and Bruckner A. 2006. Deep-sea coral collection protocols. *NOAA Technical Memorandum NMFS-OPR-28*, 53 p.

FDOT [Florida Dept. Transportation] 2010. Essential Fish Habitat Assessment: Crosstown Parkway Extension from Manth Lane to US Hwy 1, St. Lucie Co., FL. Financial Project Number: 410844-1-A8-01. Federal Project Number: 7777-087-A.

Gilliam D. 2010. Southeast Florida Coral Reef Evaluation and Monitoring Project 2009 Year 7 Final Report. Florida DEP report #RM085, Miami Beach, FL, p. 42.

Grasmueck M, Eberli G P, Viggiano D, Correa T, Rathwell G, and Luo J. 2006. Autonomous underwater vehicle (AUV) mapping reveals coral mound distribution, morphology, and oceanography in deep water of the Straits of Florida. *Geophys. Research Letters* 33:L23616, 6 p.

Grasmueck M, Eberli GP, Correa T, Viggiano D, Luo J, Wyatt G, Wright A, Reed J, and Pomponi S. 2007. AUV-based environmental characterization of deep-water coral mounds in the Straits of Florida. *2007 Offshore Technology Conference*, Houston, Texas, 12 p.

Hain, S. and Corcoran E, eds. 2004. 3. The status of the cold-water coral reefs of the world. In *Status of coral reefs of the world: 2004. Vol. 1*, C. Wilkinson (ed), 115-135. Perth: Australian Institute of Marine Science.

Kofoed JW & Malloy RJ. 1965. Bathymetry of the Miami Terrace. *Southeastern Geology* 6(3): 159-165.

Kohler KE & Gill SM. 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. *Computers and Geosciences* 32 (9): 1259-1269.

Lumsden SE, Hourigan T, Bruckner A, Dorr F. (eds.) 2007. The state of deep coral ecosystems of the United States. NOAA Tech. Memorandum CRCP-3. Silver Spring, MD.

Malloy RJ & Hurley RJ. 1970. Geomorphology and geologic structure: Straits of Florida. *Geological Society of America Bulletin* 81:1947-1972, 1 map.

Messing CG, Walker BK, Dodge RE, Reed JK & Brooke SD. 2006a. Calypso LNG Deepwater Port Project, Florida, Marine Benthic Video Survey. Submitted to Ecology and Environment, Inc. & SUEZ Energy North America, Inc. 40 pp. + appendices.

Messing CG, Walker BK, Dodge RE & Reed JK. 2006b. Calypso U.S. Pipeline, LLC, Mile Post (MP) 31 - MP 0, Deep-water Marine Benthic Video Survey. Submitted to SUEZ Energy North America, Inc. 64 pp. + appendices.

Mullins HT & Neumann AC. 1979. Geology of the Miami terrace and its paleo-oceanographic implications. *Marine Geology* 30:205-232.

Neumann AC & Ball MM. 1970. Submersible observations in the Straits of Florida: geology and bottom currents. *Bulletin Geological Society of America* 81:2861-2874.

NOAA NMFS [National Oceanic and Atmospheric Administration, National Marine Fisheries Service] 1999 [Revised 4/2000]. Essential Fish Habitat: New Marine Fish Habitat Conservation

Mandate for Federal Agencies. NMFS Habitat Conservation Division, Southeast Regional Office, St. Petersburg, FL 33702 [http://www.safmc.net/Portals/0/EFH/EFHMandate.pdf]

Partyka ML, Ross SW, Quattrini A, Sedberry G, Birdsong T, Potter J, and Gottfried S. 2007. Southeastern United States deep-sea corals (SEADESC) initiative: a collaborative effort to characterize areas of habitat-forming deep-sea corals. *NOAA Technical Memorandum OAR OER 1*, 176 p.

Reed JK. 2004. Deep-water coral reefs of Florida, Georgia, and South Carolina: A summary of the distribution, habitat, and associated fauna. South Atlantic Fishery Management Council, Charleston, SC.

Reed JK. 2006. Results of the deep-water submersible survey of the proposed Seafarer natural gas pipeline route from Mile Post 0 (U.S.-Bahamas EEZ) to Mile Post 12. Characterization of benthic habitat and biota with documentation of hard/live bottom habitat. February 28 – March 7, 2006, R/V *Seward Johnson, Johnson-Sea-Link* I Manned Submersible. A report to ENSR Corporation for Seafarer Inc., April 28, 2006, 257 pp.

Reed J K. 2008. WAITT Catalyst One Project, AUV sonar survey of Florida's deep water coral reefs, expedition science summary report. WAITT Institute for Discovery. Accessed 25 August 2009. http://wid.waittinstitute.org/

Reed JK, Pomponi S, Wright A, Weaver D, and Paull C. 2005a. Deep-water sinkholes and bioherms of South Florida and Pourtales Terrace- Habitat and Fauna. Bulletin of Marine Science 77:267-296.

Reed JK, Shepard A, Koenig C, Scanlon K, and Gilmore G. 2005b. Mapping, habitat characterization, and fish surveys of the deep-water *Oculina* coral reef Marine Protected Area: a review of historical and current research. Pp. 443-465, *In* A Freiwald, J Roberts (eds), Cold-water Corals and Ecosystems, Proceedings of Second International Symposium on Deep Sea Corals, Sept. 9-12, 2003, Erlanger, Germany, Springer-Verlag, Berlin Heidelberg.

Reed JK, Weaver DC & Pomponi SA. 2006. Habitat and fauna of deep-water *Lophelia pertusa* coral reefs off the southeastern U.S.: Blake Plateau, Straits of Florida, and Gulf of Mexico. *Bull. Mar. Sci.* 78(2):343-375.

Reed JK, Duncan L, Furman B. 2008. Results of the deep-water benthic video survey of the Colombia-Florida Express 1 (CFX-1 BC-1) Telecom Cable Route. Characterization of benthic habitat and biota with documentation of hard/live bottom habitat along the CFX-1 cable route within U.S. Federal waters from the Florida State 3-nm boundary to the U.S.-Bahamas EEZ boundary off eastern Florida.

Reed JK and Farrington S. 2010. Distribution of deep-water commercial fisheries species-golden crab, tilefish, royal red shrimp- in deep-water habitats off eastern Florida from submersible and ROV dives. South Atlantic Fishery Management Council and NOAA National Marine Fisheries Service. 163 pp.,

Reed JK, Messing CG, Walker B, Brooke S, Correa T, Brouwer M and Udouj T.(in press) Habitat characterization, distribution, and areal extent of deep-sea coral ecosystem habitat off Florida, southeastern United States. Journal of Caribbean Science.

Rona PA & Clay CS. 1966. Continuous Seismic Profiles of the Continental Terrace off Southeast Florida. *Bulletin Geological Society of America* 77(1):31-44.

[SAFMC 1998] South Atlantic Fishery Management Council. 1998. Final Habitat Plan for the South Atlantic Region: Essential Fish Habitat Requirements for Fishery Management Plans of the South Atlantic Fishery Management Council, SAFMC, Charleston, S.C., 457 p.

[SAFMC, 2007] South Atlantic Fishery Management Council. 2007. Comprehensive Ecosystem Amendment 1. Establish and protect expanded deepwater Coral HAPCs. Joint Meeting of the Habitat and Environmental Protection Advisory Panel and Coral Advisory Panel, Nov. 7-8, 2007, Charleston, SC.

SEAMAP. 2001. Southeast Area Mapping and Assessment Program- South Atlantic (SEAMAP-SA). Distribution of Bottom Habitats on the Continental Shelf from North Carolina through the Florida Keys. SEAMAP-SA Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission, Washington, DC. 166 pp.

Walker BK. 2012. Spatial Analyses of Benthic Habitats to Define Coral Reef Ecosystem Regions and Potential Biogeographic Boundaries along a Latitudinal Gradient. *PLoS ONE*7: e30466.

Walker BK, Jordan LKB, Spieler RE. 2009. Relationship of Reef Fish Assemblages and Topographic Complexity on Southeastern Florida Coral Reef Habitats. *J. Coastal Research* 53:39-48.

Walker BK, Riegl B & Dodge RE. 2008. Mapping coral reef habitats in southeast Florida using a combined technique approach. *J. Coastal Research* 24:1138-1150.

11 ADDITIONAL REFERENCES ON THE STRAIT OF FLORIDA

Adams CE and Weatherly GL. 1981. Suspended-Sediment Transport and Benthic Boundary-Layer Dynamics. Developments in Sedimentology 32:1-18.

Adams CE and Weatherly GL. 1981. Suspended-sediment transport and benthic boundary-layer dynamics. Marine Geology 42(1-4):1-18.

Agassiz A. 1888. Three cruises of the United States Coast and Geodetic Survey Steamer “Blake”, vol. 2. Houghton Mifflin, Boston. 220 pp., figs. 195-545.

Anselmetti FS, Eberli GP and Zan-Dong Ding 2000. From the Great Bahama Bank into the Straits of Florida: A margin architecture controlled by sea level fluctuations and ocean currents. *Geol. Soc. Amer. Bulletin* 112:829-844.

Atkinson LP, Berger T, Hamilton P, Waddell E, Leaman K and Lee TN. 1995. Current meter observations in the Old Bahama Channel. *J. Geophys. Res.* 100 (1995): 8555–8560.

Ayers, MW, and OH Pilkey. 1981. Piston core and surficial sediment investigations of the Florida-Hatteras slope and inner Blake Plateau. In Environmental Geologic Studies on the Southeastern Atlantic Outer Continental Shelf, 1977-78, ed. P. Popenoe, 5-1 to 5-89.

Baringer MO and Larsen JC. 2001. Sixteen Years of Florida Current Transport at 27N. *Geophysical Research Letters.* 28(16): 3179-3182.

Baringer, MO and Molinari RL. 1999. Atlantic Ocean baroclinic heat flux at 24-26°N. *Geophysical Research Letters*. 26(3):353-356.

Bartoli G, Sarnthein M, Weinelt M, Erlenkeuser H, Garbe-Schönberg D and Lea DW. 2005. Final closure of Panama and the onset of northern hemisphere glaciations. *Earth and Planetary Science Letters* 237(2005):33–44.

Baumiller TK & Messing CG. 2007. Stalked crinoid locomotion, and its ecological and evolutionary implications. *Palaeontologia Electronica* 10(1) 2A:10p, 12MB; http://palaeo-electronica.org/paleo/2007_1/crinoid/index.html

Baumiller TK, Mooi R & Messing CG. 2008. Urchins in the meadow: paleobiological and evolutionary implications of cidaroid predation on crinoids. *Paleobiology* 34(1): 35–47.

Bayer FM. 1964. The genus *Corallium* (Gorgonacea: Scleraxonia) in the western north Atlantic Ocean. *Bull. Mar. Sci*. 14(3):465–478.

Bayer FM. 1971. New and unusual mollusks collected by R/V John Author Elliott Pillsbury and R/V Gerda in the tropical western Atlantic. *Bull. Mar. Sci*. 21(1):111-236.

Bergman K and Eberli G. 2003. Caribbean Tectonics Responsible for Intensification of Middle Miocene Gulf Stream Flow but not for Pliocene Weakening. EGS-AGU-EUG Joint Assembly, Nice, France, 6-11 April 2003; abstract #7812.

Betzler C, Pfeiffer M and Saxena S. 2000, Carbonate shedding and sedimentary cyclicities of a distally steepened carbonate ramp (Miocene, Great Bahama Bank). *International Journal of Earth Science* 89:140-153.

Boehlert GW. 1987. A review of the effects of seamounts on biological processes. pp. 319-334 IN: Keating BH, Fryer P, Batiza R & Boehlert GW. (eds.) Seamounts, Islands and Atolls. Geophysical Monographs no. 3. AGU, Washington, DC.

Bogle MA. 1975. A review and preliminary revision of the Aglaopheniinae (Hydroida: Plumulariidae) of the tropical Western Atlantic. Unpublished M.S. Thesis, University of Miami, Miami, FL. ix + 308 p.

Boning, CW, Doscher R and Budich RG. 1991. Seasonal transport variation in the western subtropical North Atlantic - experiments with an eddy-resolving model. *Journal of Physical Oceanography.* 21: 1271-1289.

Brooke SD, Messing CG, Reed JK & Gilmore RG. 2006.Exploration of deep-sea coral ecosystems along the east coast of Florida. *11th Intl. Deep-Sea Biology Symposium*, Southampton, UK.

Brooks IH and Niiler PP. 1975. The Florida Current at Key West: summer 1972. *J. Mar. Res.* 33(1975):83–92.

Brooks RA, Nizinski MS, Ross SW, Sulak KJ (2007) Frequency of sublethal injury in a deepwater ophiuroid, *Ophiacantha bidentata*, an important component of western Atlantic *Lophelia* reef communities. *Marine Biology* 152: 307-314.

Cairns SD. 1979. The deep-water Scleractinia of the Caribbean Sea and adjacent waters. *Studies on the fauna of Curaçao and other Caribbean Islands*. No. 180. 341 p.

Cairns SD. 1981. Marine flora and fauna of the northeastern United States: Scleractinia. NOAA Tech Rep NMFS Circ no 438, 14 pp

Cairns SD. 1986. A revision of the Northwest Atlantic Stylasteridae (Coelenterata: Hydrozoa). *Smithsonian Contributions to Zoology*. No. 418. iv +131 pp.

Cairns SD & Chapman RE. 2001. Biogeographic affinities of the North Atlantic deep-water Scleractinia. Pp. 30-57 in Willison JHM. et al. (eds) *Proc. First Internatl. Sympos. Deep-sea Corals.* Ecology Action Centre, Nova Scotia Museum, Halifax.

Cairns SD & Stanley GD Jr. 1981. Ahermatypic coral banks: living and fossil counterparts. *Proc. Fourth International Coral Reef Sympos., Manila* 1:611-618.

Carew JL & Mylroie JE. 1995. Quaternary tectonic stability of the Bahamian archipelago: evidence from fossil coral reefs and flank margin caves. *Quarternary Research* 14(2):145-153.

Carpenter KE. (ed.) 2002. *The living marine resources of the Western Central Atlantic. FAO species identification guide for fishery purposes*. Spec. Publ. no. 5, vol. 1. FAO, Rome. xiv + 599 pp.

Collins WT & McConnaughey R. 1998. Acoustic Classification of the Sea Floor to Address Essential Fish Habitat and Marine Protected Area Requirements. *Proc. 1998 Can. Hydrogr. Conf.*, Victoria, March 1998, pp. 369-377.

Cronin TM. 1983. Bathyal ostracodes from the Florida-Hatteras slope, the Straits of Florida, and the Blake Plateau. Marine Micropaleontology 8(2):89-119.

David J, Roux M, Messing CG & Améziane, N. 2006. Revision of the pentacrinid stalked crinoids of the genus *Endoxocrinus* (Echinodermata, Crinoidea), with a study of environmental control of characters and its consequences for taxonomy. *Zootaxa* 1156:1-50

Domning DP. 1999. Fossils explained 24: Sirenians (seacows). *Geology Today* 1999:75-79.

Druffel ERM, Griffin S, Witter A, Nelson E, Southon J, Kashgarian M & Vogel J. 1995. *Gerardia*: bristlecone pine of the deep-sea? *Geochimica et Cosmochimica Acta* 59:5031-5036.

Düing W. 1973. Some evidence for long-period barotropic waves in the Florida Current. *J. Phys. Oceanogr*. 3(3):343-346.

Düing W. 1975. Synoptic studies of transients in the Florida Current. *J. Mar. Res*. 33(1):53-73.

Düing W. & Johnson D. 1971. Southward Flow under the Florida Current. *Science* 173(3995):428–430.

Düing W and Johnson D. 1972. High resolution current profiling in the Straits of Florida. Deep Sea Research and Oceanographic Abstracts 19(3):259-260.Duing, W., Mooers, C.N.K. & Lee, T.N. 1977. Low-frequency variability in the Florida Current and its relations to atmospheric forcing from 1972 to 1974. *J. Mar. Res.* 35(1):129-161.

Düing W, Mooers CNK and Lee TN. 1977. Low-frequency variability in the Florida Current and relations to atmospheric forcing from 1972 to 1974. *J. Mar. Res.* 35**:**129–161.

Eberli GP, Swart PKS & Malone M., et al. 1997. Proceedings ODP Leg 166: Initial Reports, pp. 850.

Emery KO & Uchupi E. 1972. Western North Atlantic Ocean: topography rocks structure water life and sediments. *Mem. 17 Amer. Assoc. petrol. Geol*. 532 p.

Emiliani C, Hudson JH, Shinn EA & George RY. 1978. Oxygen and Carbon Isotopic Growth record in a Reef Coral from the Florida Keys and a Deep-Sea Coral from Blake Plateau. Science 202:627-629.

Featherstone CM, Messing CG and McClintock JB. 1998. Dietary composition of two bathyal stalked crinoids: *Neocrinus decorus* and *Endoxocrinus parrae* (Echinodermata: Crinoidea: Isocrinidae). pp. 155-160. IN: Mooi R & Telford M (eds) *Echinoderms: San Francisco*. Balkema, Rotterdam.

Fell JW. 1976. Yeasts in oceanic regions. In: Jones EBG (ed) *Recent Advances in Aquatic Mycology*. Elek Science, London: 93-124.

Finkl CW and Charlier R. 2009. Electrical power generation from ocean currents in the Straits of Florida: Some environmental considerations. Renewable and Sustainable Energy Reviews 13(9):2597-2604.

Fratantoni PS, Lee TN, Podesta GP, and Muller-Karger FE. 1998. The Influence of Loop Current Perturbations on the Formation and Evolution of Tortugas Eddies in the Southern Straits of Florida. *Marine Science Faculty Publications.* University of South Florida, Scholar Commons @USF. Paper 52. http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1051&context=msc_facpub

Freeman-Lynde RP & Ryan WBF. 1987. Subsidence History of the Bahama Escarpment and the Nature of the Crust Underlying the Bahamas. *Earth and Planetary Science Letters* 84:457-470.

Fuglister FG. 1951. Multiple currents in the Gulf Stream System. *Tellus* 3:230-233.

Galstoff PS. 1954. Historical Sketch of the Explorations in the Gulf of Mexico, Galstoff, PS, (ed.), In Gulf of Mexico and Its Origin, Waters, and Marine Life. *Fishery Bulletin of the Fish and Wildlife Service* 55:3-36.

Gardner WD, Richardson MJ and Cacchione DA. 1989. Sedimentological effects of strong southward flow in the Straits of Florida. Marine Geology 86(2-3): 155-180.

Gomberg D. 1976. Geology of the Pourtalès Terrace Straits of Florida. Ph.D. Dissertation Univ. Miami Florida 371 p.

Grimmer JC, Holland ND and Messing CG. 1984. Fine structure of the stalk of the bourgueticrinid sea lily *Democrinus conifer* (Echinodermata: Crinoidea). *Marine Biology* 81:163-176.

Gyory J, Rowe E, Mariano AJ, Ryan EH. [No date] "Surface Currents in the Caribbean Sea: The Florida Current." Ocean Surface Currents.
http://oceancurrents.rsmas.miami.edu/caribbean/florida.html
Additional links at: http://oceancurrents.rsmas.miami.edu/caribbean/florida_2.html
Retrieved 9 June 2011.

Halpern JA. 1970. Goniasteridae (Echinodermata: Asteroidea) of the Straits of Florida. *Bull. Mar. Sci.* 20(1):193-286.

Hatcher BG & Scheibling RE. 2001. What determines whether deep-water corals build reefs: Do shallow reef models apply? Pp. 6-18 in Willison JHM et al. (eds), *Proc. First Internatl. Sympos. Deep-sea Corals.* Ecology Action Centre, Nova Scotia Museum, Halifax.

Henderson GM, Lindsay FN. & Slowey NC. 1999. Variation in bioturbation with water depth on marine slopes: a study on the Little Bahamas Bank. *Marine Geology* 160:105–118.

Hine AC & Neumann AC. 1977. Shallow-carbonate-bank margin growth and structure, Little Bahama Bank, Bahamas. *American Association of Petroleum Geologists Bulletin* 61:376-406.

Hine AC, Wilber RJ, Bane JM, Neumann AC & Lorenson KR. 1981. Offbank transport of carbonate sands along open, leeward bank margins: Northern Bahamas. *Marine Geology* 42:327-348.

Holthuis LB. 1971. The Atlantic shrimps of the deep-sea genus *Glyphocrangon* A. Milne Edwards, 1881. *Bull. Mar. Sci.* 21(1):267-373.

Holthuis LB. 1974. The lobsters of the superfamily Nephropidea of the Atlantic Ocean (Crustacea: Decapoda). *Bull. Mar. Sci.* 24(4):723-884.

Hoskin CM, Reed JK & Mook DH. 1986. Production and off-bank transport of carbonate sediment, Black Rock, southwest Little Bahama Bank. *Marine Geology* 73:125-144.

Hurley RJ and Fink LK. 1963. Ripple marks show that countercurrent exists in Florida Straits. *Science* 139(3555): 603-605.

Johns WE & Schott F.1987. Meandering and transport variations of the Florida Current. *J. Phys. Oceanogr.* 17(8):1128-1147.

Johns WE, Townsend TL, Fratantoni DM and Wilson WD. 2002. On the Atlantic inflow to the Caribbean Sea. Deep Sea Research Part I: Oceanographic Research Papers 49(2) 211-243.

Jordan G. 1954. Large sink holes in Straits of Florida. *Bull. Am. Ass. Petrol. Geol.* 38:1810-1817.

Jordan G & Stewart H Jr. 1961. Submarine topography of western straits of Florida. *Bull. Geol. Soc. Am.* 72:1051-1058.

Jordan GF, Malloy RJ & Kofoed JW. 1964. Bathymetry and geology of Pourtales Terrace, Florida. *Marine Geology* 1: 259-287.

Kameo K and Sato T. 2000. Biogeography of Neogene calcareous nanofossils in the Caribbean and the eastern equatorial Pacific — floral response to the emergence of the isthmus of Panama. *Marine Micropaleontology* 39: 209-218.

Kielmann J & Düing W. 1974. Tidal and sub-inertial fluctuations in the Florida Current. *J. Phys. Oceanogr.* 4(2):227-236.

Land LA, Paull CK & Hobson B. 1995. Genesis of a submarine sinkhole without subaerial exposure: Straits of Florida. *Geology* 23:949-951.

Land L & Paull C. 2000. Submarine karst belt rimming the continental slope in the Straits of Florida. *Geo-Marine Letters* 20:123-132.

Larsen JC. 1992. Transport and heat flux of the Florida Current at 27°N derived from cross-stream voltages and profiling data: theory and observations. *Phil. Trans. Roy. Soc. Lond. A.* 338:169-236.

Larsen JC & Sanford TB. 1985. Florida Current volume transport from voltage measurements. *Science* 227:302-304.

Lavoie DL. 1991. Geoacoustic Environments: (1) Northern Little Bahama Bank, (2) Transect Between the Bahamas and King's Bay, Georgia. Final Report. Naval Oceanographic and Atmospheric Research Lab, Stennis Space Center, MS. 40 pp. http://handle.dtic.mil/100.2/ADA247912

Leaman KD & Molinari RL. 1987. Topographic modification of the Florida Current by Little Bahama and Great Bahama Banks. *J. Physical Oceanography* 17(10):1724-1736.

Leaman KD, Molinari RL & Vertes PS. 1987. Structure and variability of the Florida Current at 27^{o}N: April 1982-July 1984. *J. Phys. Oceanogr.* 17(5):565-583.

Leaman KD, Johns E and Rossby T. 1989. The average distribution of volume transport and Potential Vorticity with temperature at three sections across the Gulf Stream. *J. Phys. Oceanogr.* 19: 36-51.

Leaman, KD, Vertes PS, Atkinson LP, Lee TN, Hamilton P and Waddell E. 1995. Transport, potential vorticity, and current/temperature structure across Northwest Providence and Santaren Channels and Florida Current off Cay Sal Bank. *J. Geophys. Res.* 100 (1995):8561–8569.

Lee TN. 1975. Florida current spin-off eddies. Deep Sea Research and Oceanographic Abstracts 22(11):753-765.

Lee TN and Mayer A. 1977. Low-frequency current variability and spin off eddies on the shelf off southeast Florida. *J. Mar. Res.* 35(1977):193–220.

Lee TN & Mooers CNK. 1977. Near-bottom temperature and current variability over the Miami slope and Terrace. *Bull. Mar. Sci*. 27(4): 758-775.

Lee TN, Schott F & Zantopp R. 1985. Florida Current: low-frequency variability as observed with moored current meters during April 1982 to June 1983. *Science* 227: 298-302.

Lee TN & Williams E. 1988. Wind-forced transport fluctuations of the Florida Current. *J. Phys. Oceanogr*. 18:937-946.

Lee TN & Williams E. 1999. Mean distribution and seasonal variability of coastal currents and temperatures in the Florida Keys with implications for larval recruitment. *Bull. Mar. Sci.* 64:35-56.

Lee TN, Rooth C, Williams E, McGowan M, Szmant AF, Clarke ME. 1992. Influence of Florida Current, gyres and wind-driven circulation on transport of larvae and recruitment in the Florida Keys coral reefs. Continental Shelf Research 12(7-8):971-1002.

Lee TN, Leaman K, Williams E, Berger T and Atkinson L. 1995. Florida current meanders and gyre formation in the southern Straits of Florida, *J. Geophys. Res.* 100(C5):8607–8620.

Lee TN, Johns WE, Zantopp RJ & Fillenbaum ER. 1996. Moored observations of Western Boundary Current variability and thermohaline circulation at 26.5deg.N in the Subtropical North Atlantic. *J. Phys. Oceanogr.* 26: 962-983.

Leichter JJ, Stewart HL & Miller SL. 2003. Episodic nutrient transport to Florida coral reefs. *Limnol. Oceangr*. 48(4):1394-1407.

Llewellyn G & Messing CG. 1993, Compositional and taphonomic variations in modern crinoid-rich sediments from the deep-water margin of a carbonate bank. *Palaios*, 8:554-573.

Major RP and Wilber RJ. 1991. Crystal habit, geochemistry, and cathodoluminescence of magnesian calcite marine cements from the lower slope of Little Bahama Bank. *Geol. Soc. Amer. Bull.* 103:461-471.

Mangarella PA and Heronemus WE. 1979. Thermal properties of the Florida Current as related to Ocean Thermal Energy Conversion (OTEC). *Solar Energy* 22(6):527-533.

Masaferro JL and Eberli GP. 1999. The structural evolution of southern Great Bahama Bank, southern Bahamas. *In*: P. Mann (ed.) *Caribbean Basins, Sedimentary Basins of the World, 4.* Elsevier, Amsterdam, p. 167-193.

Masaferro JL, Poblet J, Bulnes M, Eberli GP, Dixon TH and McClay K. 1999. Paleogene – Neogene/present day(?) growth detachment folding in the Bahamian foreland in the Cuban fold and thrust belt. *Journal of the Geological Society*. 156: 617-631.

Mayer DA, Leaman KD and Lee TN. 1984. Tidal motions in the Florida Current. *J. Phys. Oceanogr.* 14 (1984):1551–1559.

Meinen CS, Baringer MO and Garcia RF. 2010. Florida Current transport variability: An analysis of annual and longer-period signals. Deep Sea Research Part I: Oceanographic Research Papers 57(7): 835-846.

Messing CG. 1978. A revision of the comatulid genus *Comactinia* A.H. Clark (Echinodermata: Crinoidea). *Bull. Mar. Sci*. 28:49-80.

Messing CG. 1981. Reclassification and redescription of the comatulid *Comatonia cristata* (Hartlaub) (Echinodermata: Crinoidea). *Proc. Biol. Soc. Washington* 94:240-253.

Messing CG. 1984. Brooding and paedomorphosis in the deep-water feather star *Comatilia iridometriformis* A.H. Clark (Crinoidea: Comatulida). *Marine Biology* 80:83-91.

Messing CG. 1985. Submersible observations of deep-water crinoid assemblages in the tropical western Atlantic Ocean. pp. 185-193 IN: Keegan, B.F. and O'Connor, B.D.S. (eds.) *Proc. Fifth Intl. Echinoderm Conf.*, Galway. Balkema, Rotterdam.

Messing CG. 1997. Biozonation on deep-water carbonate mounds and associated hardgrounds in the northeastern Straits of Florida. *Geological Society of America, Southeastern Section, Abstracts with Programs* 29(3): 58.

Messing CG. 2004. Biozonation on deep-water carbonate mounds and associated hardgrounds along the western margin of Little Bahama Bank, with notes on the Caicos Platform island slope. Pp. 107-115 IN Lewis, R.D. & Panuska, B.C. (eds.) *11th Symposium on the Geology of the Bahamas and other Carbonate Regions*, Gerace Research Center, San Salvador, Bahamas.

Messing CG, Neumann AC & Lang JC. 1990. Biozonation of deep-water lithoherms and associated hardgrounds in the northeastern Straits of Florida. *Palaios* 5:15-33.

Messing CG & Rankin D. 1995. Local variations in skeletal contribution to sediment by a modern stalked crinoid (*Chladocrinus decorus*)(Echinodermata) relative to distribution of a living population. *Geol. Soc. Amer. Abstr. with Progr.* 27(6): A136.

Messing CG, David J, Baumiller TK, Roux M & Ameziane N. 2001. Stalk growth rates of Isocrinidae: a summary of a decade of *in situ* experiments. p. 125 In: Barker M (ed) *Echinoderms 2000; Proc. 10th Internatl. Echinoderm Conf., Dunedin, N.Z., 2000*. Balkema, Rotterdam.

Messing CG, Moyer R, Gilliam DS, Walker B, Dodge RE & Shaul R. 2003. Deep-Water Biological Habitat Survey Report for the Tractabel Calypso Natural Gas Pipeline: Extension of existing survey to 200 m depth. Ecological Services Program, URS Corporation, Miami Springs, FL 33166. 31 pp. + map.

Messing CG, Gilliam DS, Walker BK, Moyer R, Dodge RE & Shaul R. 2003. Deep-water biological habitat survey report for the Blue Marlin natural gas pipeline. Submitted to: Gary D. Goeke, Ecology and Environment, Inc. 36 pp.

Messing CG, Walker BK, Dodge RE, Reed JK & Brooke SD. 2006. Calypso LNG Deepwater Port Project, Florida, Marine Benthic Video Survey. Submitted to Ecology and Environment, Inc. & SUEZ Energy North America, Inc. 40 pp. + appendices.

Messing CG, Walker BK, Dodge RE & Reed JK. 2006. Calypso U.S. Pipeline, LLC, Mile Post (MP) 31 - MP 0, Deep-water Marine Benthic Video Survey. Submitted to SUEZ Energy North America, Inc. 64 pp. + appendices.

Messing CG, David J, Roux M, Améziane N & Baumiller TK. 2007. In situ stalk growth rates in tropical western Atlantic sea lilies (Echinodermata: Crinoidea). *J Exp. Mar. Biol. Ecol.* 353 (2007) 211–220.

Meyer DL, Messing CG and Macurda DB JR. 1978. Zoogeography of tropical western Atlantic Crinoidea. *Bull. Mar. Sci.* 28:412-441.

Meyerhoff AA & Hatten CW. 1974. Bahamas salient of North America: Tectonic framework, stratigraphy and petroleum potential. *American Association of Petroleum Geologists Bulletin* 58:1201-1239.

Milliman JD, Manheim FT, Pratt RM, Zarudski EF (1967) Alvin dives on the continental margin off the southeastern United States, July 2-13, 1967. Tech Rep Woods Hole Oceanogr Inst 67-80, 48 pp.

Minter LL, Keller G & Pyle T. 1975. Morphology and sedimentary processes in and around Tortugas and Agassiz Sea Valleys southern Straits of Florida. *Mar. Geol*. 18:47-69.

Molinari RL, Wilson WD & Leaman K. 1985. Volume and heat transports of the Florida Current: April 1982 through August 1983. *Science* 227:292-294.

Montgomery RB. 1938. Fluctuations in the monthly sea level on the eastern U.S. Coast as related to dynamics of the western North Atlantic Ocean, *Journal of Marine Research*, 1:32-37.

Mullins HT. 1983. Modern carbonate slopes and basins of the Bahamas: Platform margin and deep-water carbonates. *SEPM Short Course Notes* 12:1-138.

Mullins HT & Lynts GW. 1977. Origin of the northwestern Bahama Platform: review and reinterpretation. *Geological Society of America Bulletin* 88:1447-1461.

Mullins HT & Neumann AC. 1977. Deep carbonate bank margin structure and sedimentation in the northern Bahamas. *Society of Economic Paleontologists & Mineralogists Special Publication* no. 27: 165-192.

Mullins HT & Neumann AC. 1979. Deep carbonate bank margin structure and sedimentation in the northern Bahamas. *SEPM Special Publ*. (27):165-192.

Mullins HT, Newton CR, Heath K, Van Buren HM. 1981. Modern deep-water coral mounds north of Little Bahama Bank: criteria for recognition of deep-water coral bioherms in the rock record. *Journal of Sedimentary Petrology* 51(3):999-1013.

Mullins HT, Heath KC, Van Buren HM and Newton CR. 1984. Anatomy of a modern open-ocean carbonate slope: northern Little Bahama Bank. *Sedimentology* 31:141-168.

Neumann AC, Kofoed JW and Keller GH. 1977. Lithoherms in the Straits of Florida. *Geology* 5(1):4-10.

Neuweiler F, Rutsch M, Geipel G, Reimer A and Heise K-H. 2000. Soluble humic substances from *in situ* precipitated microcrystalline calcium carbonate, internal sediment, and spar cement in a Cretaceous carbonate mud-mound. *Geology* 28:851-854.

Niiler PP & Richardson WS. 1973. Seasonal variability of the Florida Current. *J. Mar. Res.* 31:144-167.

Olson DB, Brown OB and Emerson SR. 1983. Gulf Stream frontal statistics from Florida Straits to Cape Hatteras derived from satellite and historical data, *Journal of Geophysical Research.* 88:4569-4577.

Partyka, M.L., S.W. Ross, A.M. Quattrini, G.R. Sedberry, T.W. Birdsong, J. Potter, S. Gottfried. 2007. Southeastern United States Deep-Sea Corals (SEADESC) Initiative: A collaboration to characterize areas of habitat forming deep-sea corals. NOAA Technical Memorandum OAR OER 1, 176 pp.

Paull CK, Chanton J, Martens C, Fullagar P, Neumann A & Coston J. 1991. Seawater circulation through the flank of the Florida Platform: evidence and implications. *Mar. Geol*. 102:265-279.

Paull CK, Freeman-Lynde R, Bralower T, Gardemal J, Neumann A, D'Argenio B & Marsella E. 1990**.** Geology of the strata exposed on the Florida Escarpment. *Mar. Geol*. 91:177-194.

Paull CK, Neumann AC, Ende BA am, Ussler W & Rodriguez NM. 2000. Lithoherms on the Florida-Hatteras slope. *Marine Geology* 136:83-101.

Pilskaln CH, Neumann AC & Bane JM. 1989. Periplatform carbonate flux in the northern Bahamas. *Deep-Sea Research* 36:1371-1406.

Pourtalès LF de. 1868. Contributions to the fauna of the Gulf Stream at great depths. *Bull. Mus. Comp. Zool. Harvard* 1(6):103-141.

Pourtalès LF de. 1871. Deep-sea corals. *Illustrated catalogue of the Mus. Comp. Zool*. 2(4):1-99.

Pourtalès LF de. 1874. Crinoids and Corals. Zoological Results of the "Hassler" Expedition. *Illus. Cat. Mus. Comp. Zool. Harvard Coll*. 8:25-50.

Quinn JF. 1979. The systematics and zoogeography of the gastropod family Trochidae collected in the Straits of Florida and its approaches. *Malacologia* 19(1):1-62

Reed JK. 2002. Comparison of deep-water coral reefs and lithoherms off southeastern USA. *Hydrobiologia* 471:57-69.

Reed JK, Pomponi S, Frank T, Widder E (2002) Islands in the Stream 2002: Exploring Underwater Oases. Mission Three Summary: Discovery of new resources with pharmaceutical potential; vision and bioluminescence in deep-sea benthos. NOAA Ocean Exploration web site: http://oceanexplorer.noaa.gov/explorations/02sab/logs/summary/summary.html, 29 pp, HBOI DBMR Misc Cont No 208

Reed JK & Gilmore R. 1982. Nomination of a Habitat Area of Particular Concern (HAPC). Pages L-20-42 *in* Brawner J (ed) *Fishery management plan, final environmental impact statement for coral and coral reefs*. Gulf of Mexico and South Atlantic Fishery Management Councils, 337 p.

Reed JK & Hoskin CM. 1987. Biological and geological processes at the shelf edge investigated with submersibles. Pages 191-199, *in Scientific applications of current diving technology on the U.S. Continental Shelf*. NOAA Symp. Ser. Undersea Res., Vol. 2.

Reed JK & Wright A. 2004. Final cruise report. Submersible and scuba collections on deep-water reefs off the east coast of Florida, including the Northern and Southern Straits of Florida and Florida Keys National Marine Sanctuary for biomedical and biodiversity research of the benthic communities with emphasis on the Porifera and Gorgonacea, May 20- June 2, 2004. Conducted by the Center of Excellence, HBOI and FAU, pp 54

Reed JK, Wright A & Pomponi S. 2004. Medicines from the deep sea: exploration of the northeastern Gulf of Mexico. Pages 58-70 i*n Proc. Amer. Acad. Underwater Sci. 23rd annual scientific diving symposium*, March 11-13, 2004, Long Beach, California.

Reed JK & Ross S. 2005. Deep-sea reefs off the southeastern USA: recent discoveries and research. *Current- J. Mar. Education* 21: 33-37.

Reed JK, Pomponi SA, Weaver D, Paull CK, Wright AE. 2005. Deep-water sinkholes and bioherms of South Florida and the Pourtalès Terrace—Habitat and Fauna. *Bull. Mar. Sci.* 77(2):267-29

Richardson WS, Schmitz WJ Jr & Niiler PP. 1969. The velocity structure of the Florida Current from the Straits of Florida to Cape Fear. *Deep-Sea Res.* 16 (Suppl.):225-234.

Roberts JM, Wheeler AJ, Freiwald A (2006) Reefs of the deep: the biology and geology of cold-water coral ecosystems. Science 312:543-547

Rogers AD (1999) The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. Intl Rev Hydrobiol 84:315-406

Rosenthal Y, Boyle EA & Slowey N. 1997. Temperature control on the incorporation of magnesium, strontium, fluorine, and cadmium into benthic foraminiferal shells from Little Bahama Bank: Prospects for thermocline paleoceanography. *Geochimica et Cosmochimica Acta* 61(17):3633-3643.

Ross SW (2006) Review of distribution, habitats, and associated fauna of deep-water corals reefs on the southeastern United States continental slope (North Carolina to Cape Canaveral, FL). Report to the South Atlantic Fishery Management Council, Charleston, SC. 36 pp

Ross SW, Nizinski MS (2007) State of Deep Coral Ecosystems in the US Southeast Region: Cape Hatteras to southeastern Florida. p.233-270, Ch 6 In: Lumsden SE, Hourigan TF, Bruckner AW, Dorr G (eds.). The State of Deep Coral Ecosystems of the United States. NOAA Technical Memo. CRCP-3, Silver Spring, MD 365 pp

Ross SW, Quattrini AM (2007) The Fish Fauna Associated with Deep Coral Banks off the Southeastern United States. Deep-Sea Research Part I 54(6): 975-1007.

Schmitz WJ Jr & Richardson WS. 1968. On the transport of the Florida Current. *Deep-Sea Res.* 15:679-693.

Schmitz WJ and Richardson PL. 1991. On the sources of the Florida Current. *Deep-Sea Res.* 38 (Suppl.):379-409.

Schmitz WJ Jr, Luyten JR and Schmitt RW. 1993. On the Florida Current T/S envelope. *Bulletin of Marine Science of the Gulf and Caribbean.* 53(1):1048-1065.

Schott FA & Zantopp RJ. 1985. Florida Current: seasonal and interannual variability. *Science* 227:308-311.

Schott F, Lee TN and Zantopp R. 1988. Variability of structure and transport of the Florida Current in the period range of days to seasonal. *Journal of Physical Oceanography*, 18, 1209-1230.

Seim HE, Winkel DP, Gawarkiewicz G & Gregg MC. 1999. A benthic front in the Straits of Florida and its relationship to the structure of the Florida Current. *J. Phys. Oceanogr*. 29:3125-3132.

Shay LK, Cook TM, Haus BK, Martinez J, Peters H, Mariano AJ, An PE, Smith S, Soloviev A, Weisberg R and Luther M. 2000. VHF radar detects oceanic submesoscale vortex along the Florida coast. *EOS* 81(19): 209–213.

Shay LK, Cook TM and An PE. 2003. Submesoscale coastal ocean flows detected by very high frequency radar and autonomous underwater vehicles. *J. Atmos. Oceanic Technol.* 20:1583-1599.

Sheridan RE. 1974. Atlantic continental margin of North America, pp. 391-407 IN Burke, C.A. & Drake, C.L. (eds.) *Geology of Continental Margins*. Springer-Verlag, NY.

Shinn EA, Reich CD, Locker SD & Hine AC. 1996. A giant sediment trap in the Florida Keys. *J. Coast Res*. 12:953-959.

Shoosmith DR, Baringer MO & Johns WE. 2005. A continuous record of Florida Current temperature transport at 27°N. *Geophysical Research Letters* 32: L23603, doi:10.1029/2005GL024075

Siegler VB. 1959. Reconnaissance survey of the bathymetry of the Straits of Florida. Univ. Miami Marine Lab. Tech. Rept., 59-3, 9 pp.

Smith JE, Risk MJ, Schwarcz HP, McConnaughey TA. 1997. Rapid climate change in the North Atlantic during the Younger Dryas recorded by deep-sea corals. *Nature* 386:818-820.

Smith NP. 1982. Upwelling in Atlantic shelf waters of south Florida. *Florida Sci*. 45(2):125-138.

Soto L. 1985. Distributional Patterns of Deep-Water Brachyuran Crabs in the Straits of Florida. *Journal of Crustacean Biology* 5(3):480-499.

Soto LA. 1991. Zoogeographic status of the deep brachyuran fauna of the Straits of Florida. *Bull. Mar. Sci*. 49(1-2):623-637.

Squires DF. 1963. Modern tools probe deep water. *Nat. Hist*. 72(6);22-29.

Staiger JC. 1970. The distribution of the benthic fishes found below two hundred meters in the Straits of Florida. Ph.D. Dissertation, Univ. of Miami. 245 p.

Stetson TR, Squires DF & Pratt RM. 1962, Coral banks occurring in deep water on the Blake Plateau, *American Museum Novitates* no. 2114:1-39.

Stimpson W. 1871. Preliminary report on the Crustacea dredged in the Gulf Stream in the Straits of Florida, by L.F. de Pourtales, Assist. U.S. Coast Survey. *Bulletin of the Museum of Comparative Zoology, Harvard* 2: 109-160.

Teichert C. 1958. Cold- and deep-water coral banks. *Bull. Amer. Assoc. petrol. Geol.* 42: 1064-1082.

Uchupi E. 1969. Morphology of the continental margin off southeastern Florida. *Southeastern Geology* 11:129-134.

Wang J & Mooers CNK. 1997. Three-dimensional perspectives of the Florida Current: transport, potential vorticity, and related dynamical properties. *Dyn. Atmos. & Oceans* 27:135-149.

Weatherly GL. 1977. Bottom Boundary Layer Observations in the Florida Current. Bottom Turbulence, Proceedings of the 8th International Liege Colloquium on Ocean Hydrodynamics. Elsevier Oceanography Series 19:237-254.

Winkel DP, Gregg MC and Sanford TB. 2002. Patterns of shear and turbulence across the Florida Current. *J. Phys. Oceanogr*. 32:3269-3285.

Worthington LV and Kawai H. 1972. Comparisons between deep sections across the Kuroshio and the Florida Current and Gulf Stream, in Kuroshio, its Physical Aspects, H Stommel and K Yoshida (eds.), University of Tokyo Press, Tokyo, pp. 371-385.

Wunsch C, Hansen DV, and Zetler BD. 1969.Fluctuations of the Florida Current inferred from sea level records, *Deep-Sea Research.* 16 (Suppl.):447-470.

APPENDIX

Questionnaire Distributed on March 4, 2010

QUESTIONNAIRE FOR PROJECT DEVELOPERS

What is the purpose of the questionnaire?

Dehlsen Associates, LLC in partnership with Florida Atlantic University Center for Ocean Energy Technology, Nova Southeastern University Oceanographic Center, and Ecology and Environment, Inc has been awarded a grant by the United States Department of Energy (DOE) Golden Field Office for a project titled "***Siting Study for a Hydrokinetic Energy Project Located Offshore Southeast Florida".***

The purpose of the project is to develop acceptable bottom habitat survey methodologies in consultation with the regulatory and resource management agencies with permitting/review authority for marine and hydrokinetic projects that may be proposed on the Outer Continental Shelf offshore southeast Florida. The project seeks to increase regulatory certainty and reduce the time, effort, and costs associated with siting and permitting these facilities.

One of the objectives of the project is to identify general areas offshore southeast Florida that appear most suitable for installing marine and hydrokinetic energy facilities, including subsea electric transmissions cables to shore, based on the distribution of sensitive bottom habitats currently mapped or identified by field surveys to be conducted during this study. To collect as much information as possible and to target relevant areas offshore southeast Florida, ***one of the tasks of the grant is to gather information from project developers interested in siting facilities offshore Miami-Dade, Broward and Palm Beach Counties.*** The information gathered from this survey will be used to help define the spatial extent of the grant-funded field surveys. Questions regarding this questionnaire can be directed to Antonino Riccobono of Ecology and Environment, Inc. at (954) 270-6675 or ariccobono@ene.com.

No.	Question	Response
1	***Optional Information*** Developer & Project Name	
2	For project location, please provide lease block number or coordinates, if possible. If lease block number/ coordinates are not available, please generally describe project location using known shoreline point as reference	
3	Provide approximate seabed area required for the implementation of the project (acres or # of MMS Blocks)	
4	Is the required seabed area described above suitable for a "prototype" or for a full scale "commercial" project?	
5	Provide approximate depth range (feet) for the project area under consideration	
6	Has a site location alternatives analysis been conducted for the project?	
7	Has any permitting or consultation been initiated for the project? If yes, when was it initiated?	
8	***Optional Information*** Contact Information for person with technical knowledge of the project	