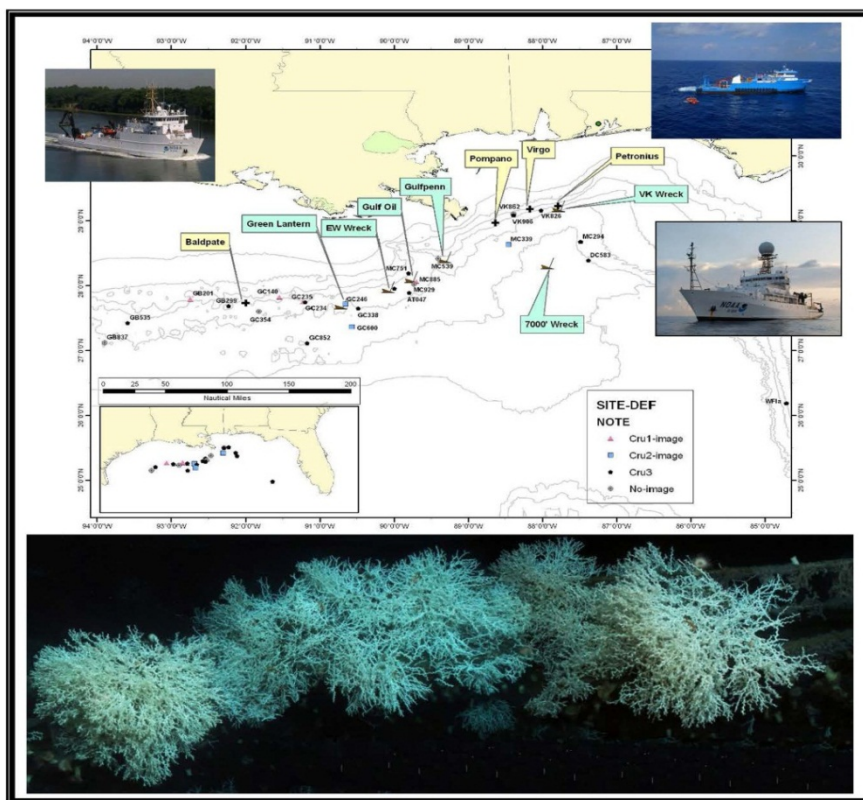


Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard-Bottom Habitats with Emphasis on Coral Communities: Reefs, Rigs, and Wrecks—“Lophelia II”

Interim Report



U.S. Department of the Interior
Bureau of Ocean Energy Management
Gulf of Mexico OCS Region

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Interim Report

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1 INTRODUCTION

1.1 OVERVIEW

This document represents TDI-Brooks' Interim Report for the *Lophelia* II Project, Contract M08PC20038, issued by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement (now the Bureau of Ocean Energy Management [BOEM]) "Exploration and Research of Northern Gulf of Mexico Deepwater Natural and Artificial Hard Bottom Habitats with Emphasis on Coral Communities: Reef, Rigs, and Wrecks. This report provides detailed information regarding field sampling, sampling activity, and sample analyses. Results will possibly be revised. This report is a preliminary product of Contract M08PC20038.

1.2 BACKGROUND

Over the last half century, offshore exploration for hydrocarbons in the northern Gulf of Mexico (GoM) has advanced from the bay and inner shelf to the continental slope/continental rise transition. Geophysical and geotechnical data collected in support of both exploration and production have been largely responsible for the foundation of our present understanding of slope geology. This database emphasizes the extremely complex geological framework of the northern GoM's continental slope and the surprisingly important role that the expulsion of subsurface fluids and gases has in shaping surficial geology and biology of the modern seafloor. Regional topography of the slope consists of basins, knolls, ridges, and mounds derived from the dynamic adjustments of salt to the introduction of large volumes of sediment over long time scales. Superimposed on this underlying topography is a smaller class of mounds, flows, and hard grounds that are the products of the transport of fluidized sediment, mineral-rich formation fluids, and hydrocarbons to the present sediment-water interface. The geologic response to the expulsion process is related both to the products being transported and the rate at which they arrive at the seafloor. Mud volcanoes and mudflows are typical of rapid flux settings where fluidized sediment is involved. Slow flux settings are mineral-prone. Authigenic carbonate mounds, hard grounds, crusts, and nodules are common to settings where hydrocarbons are involved.

Recent manned submersible and remotely operated vehicle (ROV) dives to the middle and lower continental slope confirm the existence of these hard substrates to the deepest parts of the slope. Direct observation and sampling of expulsion sites started in the mid-1980s on the upper slope. We now know from analysis of 3D-seismic data and submersible-ROV dives that numerous expulsion sites with hard substrates provide habitat for deep water corals over the slope's full depth range.

In the context of this study, deep hardground communities of the GoM comprise all of the biological communities inhabiting natural or artificial hard substrates, excluding the chemosynthetic seep communities. These communities consist of foundation species, those species that form large complex habitats at these sites, and their associated fauna ranging in size from large mobile fishes to microscopic meiofauna. The most prominent foundation species in these communities are the deep-water ("cold-water") corals. The terms "deep-water corals" and "cold-water corals" include relatives of the tropical reef-forming scleractinian corals, but also refer to a variety of other cnidarian taxa, including antipatharians (black corals), gorgonians (including bamboo corals), alcyonaceans (soft corals), and stylasterine hydrocorals. Other taxa,

including anemones and sponges, are also significant contributors to the biogenic framework of these deep-water reef systems.

In the GoM, deep-water corals are commonly found on seep-related authigenic carbonates, but have also been observed on anthropogenic structures, ship wrecks and oil platforms in particular. The most common species of reef-forming deep-water coral in the GoM is *Lophelia pertusa* (= *prolifera*). This species was first recovered in the late 1800s by the United States Coast and Geodetic Survey Steamer *Blake*.

Increasing industry activity in deepwater has resulted in the creation of numerous platforms in water depths exceeding 300m. In areas where hard substrates are limiting, these platforms may significantly increase the potential range of corals and other hardground fauna. Growth of *Lophelia pertusa* has been noted on the Pompano platform in VK 989. In addition, the Joliet platform in GC 184 near Bush Hill and the Neptune platform near the large *L. pertusa* site in VK 826 are very likely to host coral populations. This study will focus on the exploration and characterization of these communities and examination of their potential connection to other coral populations and surrounding deep-water communities.

1.3 OBJECTIVES OF THE PROJECT

A primary goal of this study is to obtain a robust predictive capability for the occurrence of rich cnidarian (primarily scleractinian coral) hard ground communities in the deep GoM. To achieve this long-term goal, this study will accomplish three interrelated and interdependent objectives:

- Discover and describe new locations at greater than 300m depth in the GoM with extensive coral community development, particularly including *Lophelia pertusa*.
- Gain a more comprehensive understanding of the fundamental processes that control the occurrence and distribution of *Lophelia* and other extensive coral communities at depths greater than 300 m in the GoM through both laboratory experiments and field data collection.
- Document and understand the relationship between coral communities on artificial and natural substrates with respect to community composition and function, phylogeographic and population genetics, and growth rates of the key cnidarian foundation fauna.

Upon meeting these three interrelated objectives, we will have obtained an understanding of the biology and biogeography of *Lophelia* in the GoM that will result in a quantum increase in our ability to predict the occurrence of *Lophelia* at additional sites, based on data such as bathymetry, current models, 3D seismic profiles, and known occurrence of source populations.

1.3.1 Biological Objectives

- To discover and characterize new sites
 - Characterize key sites at the largest scale with HR bathymetry, SSS, 3D seismic data and current models
 - Characterize the coral density at the 10-m to 100-m scale with randomized photo transects and general site descriptions
 - Characterize the community composition at the 1m- to 10-m scale at significant coral sites (human-made and natural) with analysis of close-up imagery, replicate photomosaics and quantitative community collections
- Analyze connectivity among humanmade and natural sites with comparative community, phylogeographic and population genetic analysis
- Compare the structure, species richness and diversity of communities tightly associated with *Lophelia* at humanmade and natural sites
- Experimentally determine the tolerance and growth response of *Lophelia* to temperature, pH/alkalinity, dissolved oxygen, and current
- Characterize and constrain growth rates of key species of colonial cnidarians (pioneer colonies) using analysis of images on human-made structures of known age
- Characterize key variables (temperature, currents, larval seasonal distribution development and sediment quality) at sites with the most significant coral communities over one year at two to four sites

1.3.2 Other Objectives

- Historical shipwreck component. Study of up to six shipwrecks to determine their identity, site boundaries, National Register eligibility, preservation state and stability, associated biological communities and artificial reef effects.
 - Determine the rate of deterioration of test coupons at platforms or shipwrecks
- Coordination with USCG
- Deepwater commercial fisheries review that impact hardbottom communities

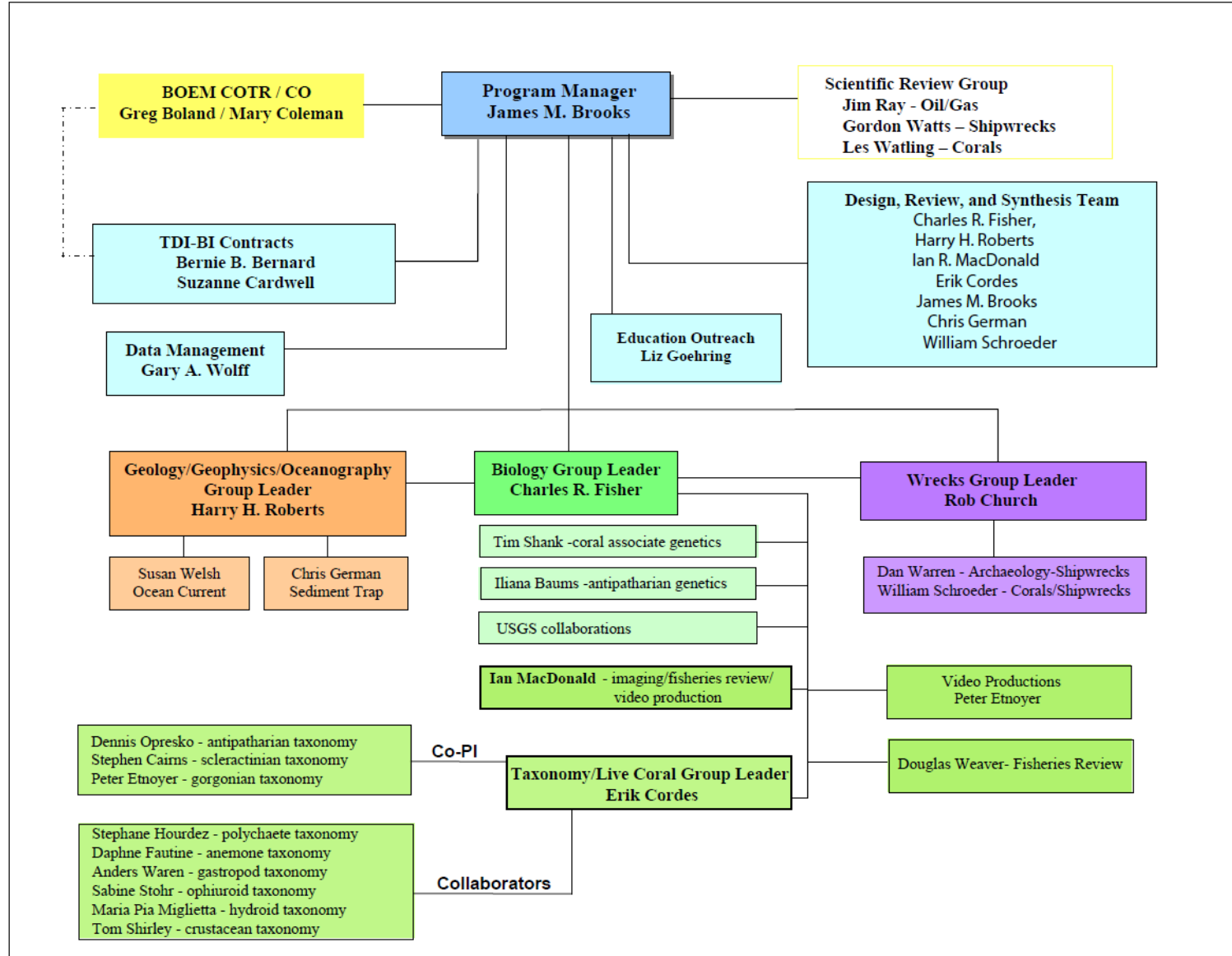


Figure 1-1. Program organization.

2 CRUISE OVERVIEWS

The *Lophelia* II project involves exploration and research of the northern GoM deepwater natural and artificial hard bottom habitats with emphasis on coral communities with archeological studies of 4–6 shipwrecks. To date, there have been three cruises completed. The first *Lophelia* II cruise took place in September 2008, and the second cruise in June 2009. Cruise 3, August–September 2009, returned to known sites and the newly-discovered sites targeted by Cruise 1 and 2 for further exploration.

2.1 CRUISE 1

The *Lophelia* II Cruise 1 was conducted on the NOAA Ship *Nancy Foster* from September 2, 2008 to October 2, 2008, and was the first cruise conducted for this contract. The cruise mobilized and embarked from Galveston, Texas, and returned to Gulfport, Mississippi, for the second leg. The second leg concluded on 2 October 2008, and demobilized in Pascagoula, Mississippi.

Table 2-1 lists sites that were visited during Legs 1 and 2 (Figures 2-1, 2-2).

Table 2-1.

Sites Occupied During Cruise 1

Leg 1 Sites	Leg 2 Sites
EW1008, EW Wreck	AT47
MC497, <i>Gulfpenn</i>	EB478
MC796, <i>Gulfoil</i>	EW 1009
GC245, <i>Green Lantern</i>	GB201
	GB535
	GC140
	GC201
	GC234
	GC246
	MC539
	MC751
	MC885
	VK906

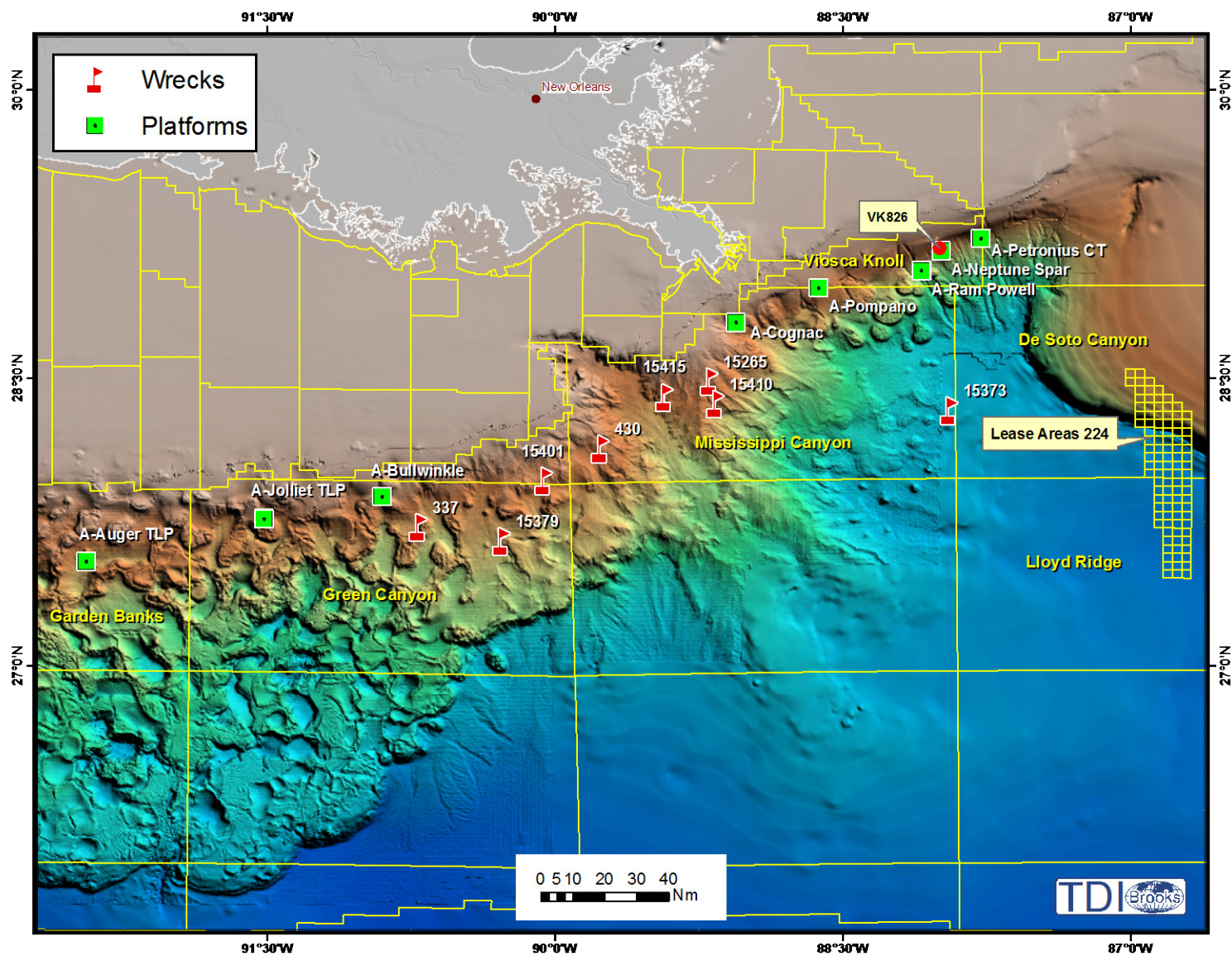


Figure 2-1. Sites of interest—Cruise 1.

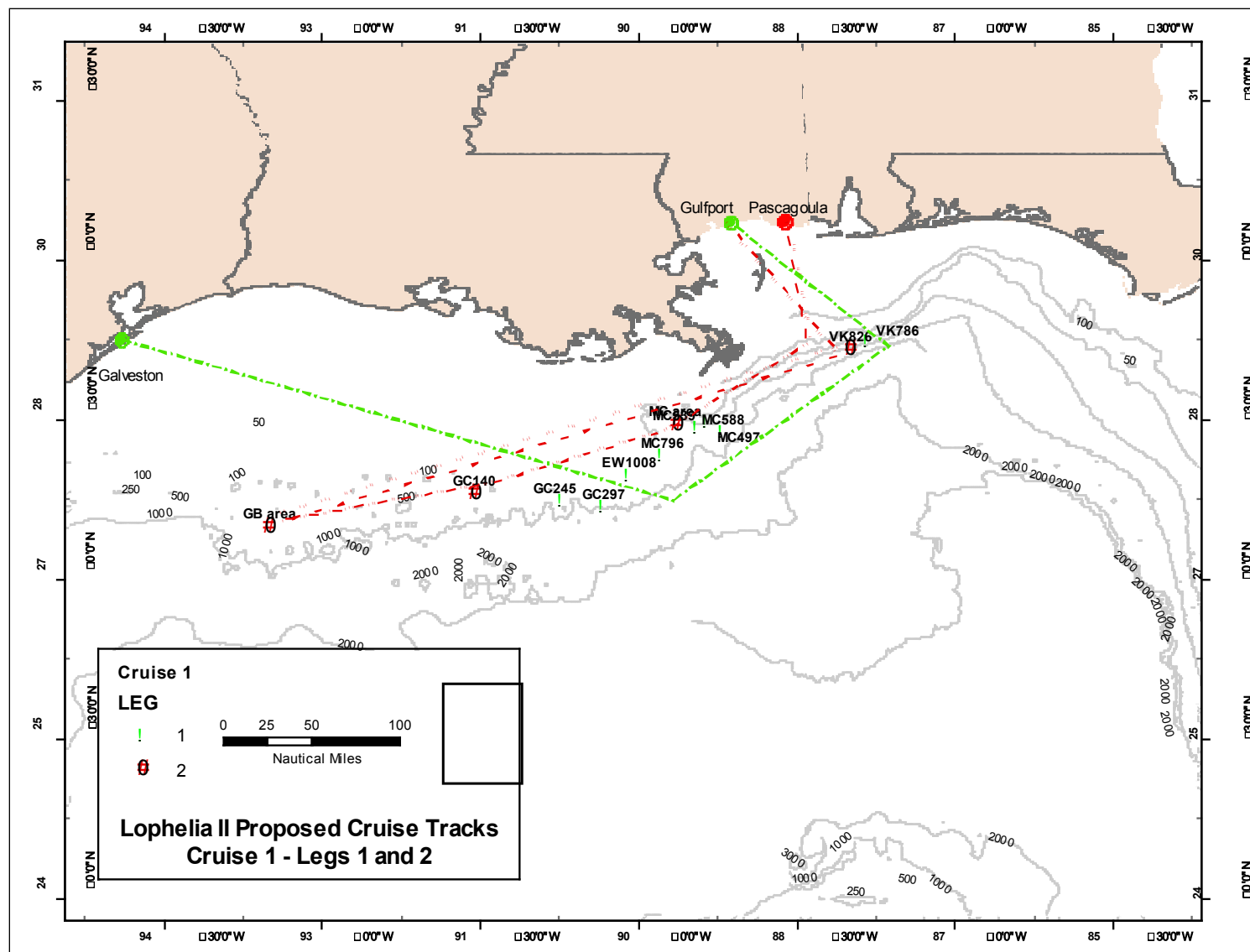


Figure 2-2. Cruise tracks for Leg 1 and Leg 2.

2.2 CRUISE 2

The *Lophelia* II Cruise 2 was conducted on the TDI-BI Ship *Brooks McCall* from 17 June–1 July, 2009, and was the second cruise conducted for this contract. The cruise mobilized and embarked from Freeport, Texas, and demobilized in Gulfport, Mississippi. The primary objective was to conduct exploratory surveys of suspected deep-sea coral communities with the WHOI AUV *Sentry* (Figure 2-3).

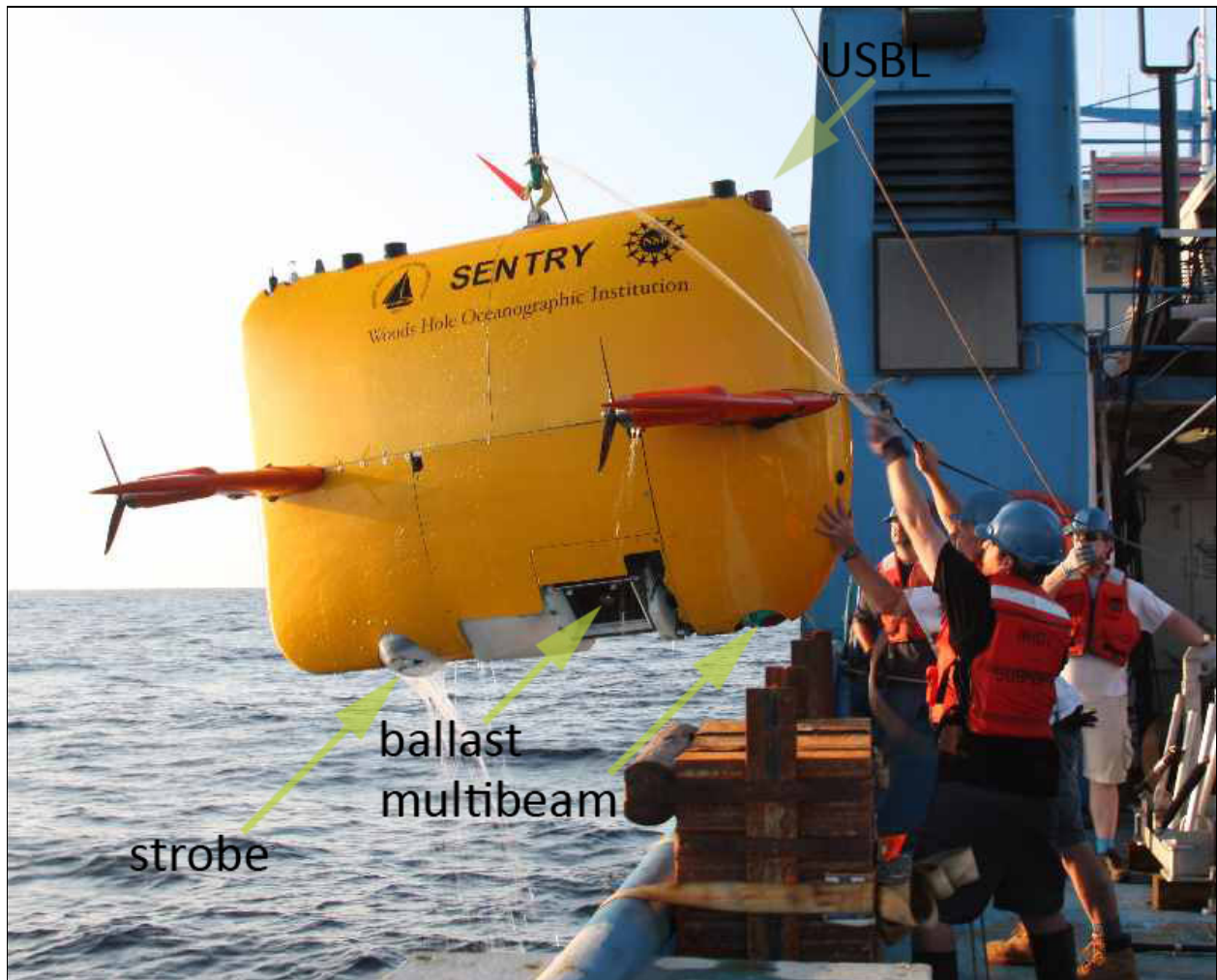


Figure 2-3. The AUV *Sentry* being recovered onto the R/V *Brooks McCall* following a successful dive.

Table 2-2 lists sites that were occupied during Cruise 2. The cruise track and site locations are shown in Figure 2-4. Surveys have been completed at targeted features in the following lease blocks: GB837, GB535, and GC600.

Table 2-2.

Sites Occupied During Cruise 2

Dive	Site	Lat	Lon	Depth m	Photographs	Comments
017	test					Self-terminate above bottom
018	test				49	Strobe not synched with camera shallow test West Flower Gardens
019	GB837	27.11967	93.89694	865.6		Weight fell off on 3rd line
020	GB837	27.11967	93.89694	865.6		Camera did not work
021	GB535	27.43115	93.59861	585.0	691	Phins (INS) inoperable compass substituted
022	GC600	27.36639	90.56417	1,248.8		Self-terminate above bottom 450m
023	GC600	27.36639	90.56417	1,248.8	163	Camera stopped after 10 min.
024	GC246	27.71133	90.67600	755.0	570	Camera took ~800 pics then quit weight fell at start of multibeam
025	MC885	28.08250	89.71850		3800	Photo-survey complete showing gorgonians and small <i>Lophelia</i> colonies. Unprogrammed weight drop before multibeam started
026	MC657	28.34364	87.93010	~2,000	5160	Completed dense mosaic of shipwreck site with multibeam data. Ship was clearly and completely
027	MC339	28.63251	88.44917	1,398.5	~4000	Completed multibeam and photo survey of mound slopes. No problems or delays with vehicle. No coral or sea fans noted.
028	VK826	29.14200	88.03783	610.0	>5000	Completed multibeam and photo survey of most of knoll area. All systems functional to end of dive. Anticipate good coverage.

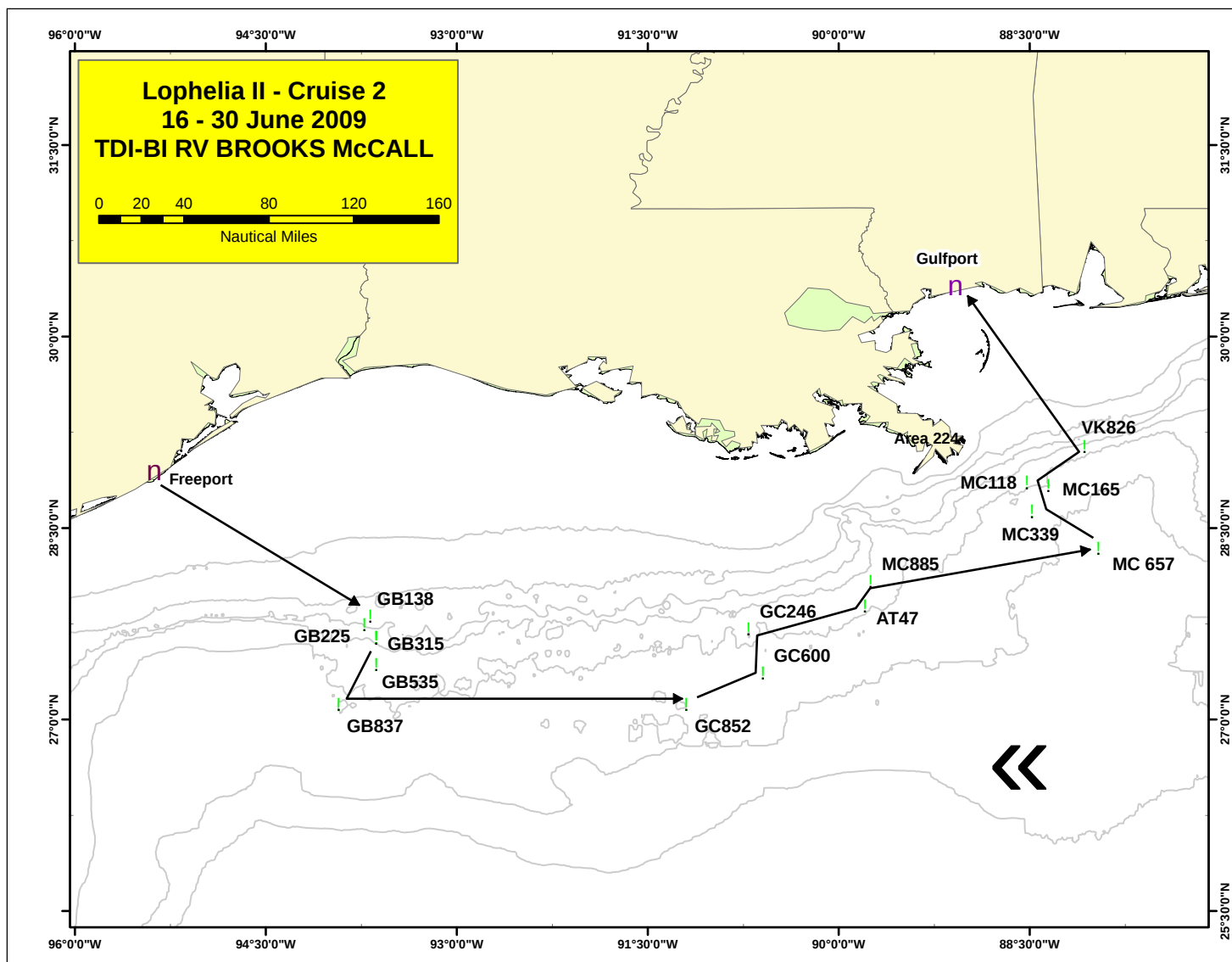


Figure 2-4. Sites visited, Cruise 2.

2.3 CRUISE 3

Cruise 3 was completed on NOAA Ship *Ronald H. Brown* 19 August–12 September 2009. The cruise mobilized in Key West, Florida. One mid-cruise personnel transfer took place on 5 September. The cruise demobilized in Pensacola, Florida, on 12 September 2009.

This cruise employed the ROV *Jason II* to explore new sites, make a variety of deployments and collections, and conduct a variety of studies on natural deep water coral reefs and deep water shipwrecks (Figure 2-5). This was a 25-day cruise with 21 ROV dives and an at-sea personnel transfer.



Figure 2-5. Illustration of the *Jason II*/Medea ROV (WHOI).

Jason II was used to: explore 10 new sites (Table 2-3) for the occurrence of deep water coral reefs; make collections of *Lophelia* and other corals for genetic and physiological studies; make

collections of communities associated with *Lophelia* and other corals for ecological studies; collect quantitative digital imagery for characterization of sites and coral communities; collect spatially explicit physical near bottom oceanographic data; deploy cameras and microbial arrays; reposition larval traps and current meters; collect push cores; and conduct a series of linked archeological and biological investigations on deep water shipwrecks. In addition to launching and recovering *Jason II*, elevators were deployed and recovered twice, four moorings (two larval traps and two current meters) were deployed, and Conductivity-Temperature-Depth (CTD) casts were conducted (Figure 2-6).

Table 2-3.

Sites Characterized Listed in Chronological Order

Dive	Site	Dates	Times	Depth m	Lat-D	Long-D	Comments
J2-453	Fla Slope-1	8/20-8/21	2130-1600	450	26.184100	-83.292583	
J2-454	DC-583	8/22-8/23	1720-0745	2500	28.385493	-86.611932	Aborted but dive number unchanged
J2-456	MC-294	8/23-8/24	2140-0745	1360	28.674300	-87.518917	
J2-457	AT-047	8/24-8/25	1630-0730	863	27.879200	-88.212217	
J2-458	GC-235	25-Aug	1643-2230	530	27.737033	-90.812733	Aborted: Hydraulic Failure
J2-459	GB-299	8/26-8/27	0830-0740	410	27.692450	-91.777100	
J2-460	GB-535	8/27-8/28	1636-1216	600	27.422880	-87.402863	
J2-461	GC-852	29-Aug	0118-2020	1400	27.124667	-90.835833	
J2-462	GC-338	30-Aug	0851-2030	900	27.670000	-89.520320	Aborted: OcTan Failure
J2-463							Aborted: jelly
J2-464	MC-751	8/31-9/1	1324-1206	460	28.189667	-88.202167	
J2-465	VK-906	9/1-9/2	2031-2000	400	29.069000	-87.622833	
J2-466	VK-826	9/3-9/4	1119-0805	510	29.156933	-87.989333	
J2-467	VK-826						
J2-468	VK-786	9/5-9/6	2030-0810	612	29.218833	-86.223667	VK Wreck
J2-469	MC-657	9/6-9/7	1714-0800	2256	28.343167	-86.069500	7,000ft Wreck
J2-470	EW1008	9/7-9/8	2025-0830	610	29.142000	-88.037833	EW Wreck
J2-471	GC245	9/8-9/9	1644-1210	627	27.389500	-93.600167	<i>Green Lantern</i>
J2-472	MC497	9/9-9/10	2108-0815	554	28.440333	-88.680000	<i>Gulfpenn</i>
J2-473	VK-906	9/10-9/11	1633-0815	490	29.065500	-87.618333	
J2-474	VK-826	11-Sep	1259-2312	510	29.156933	-87.989333	

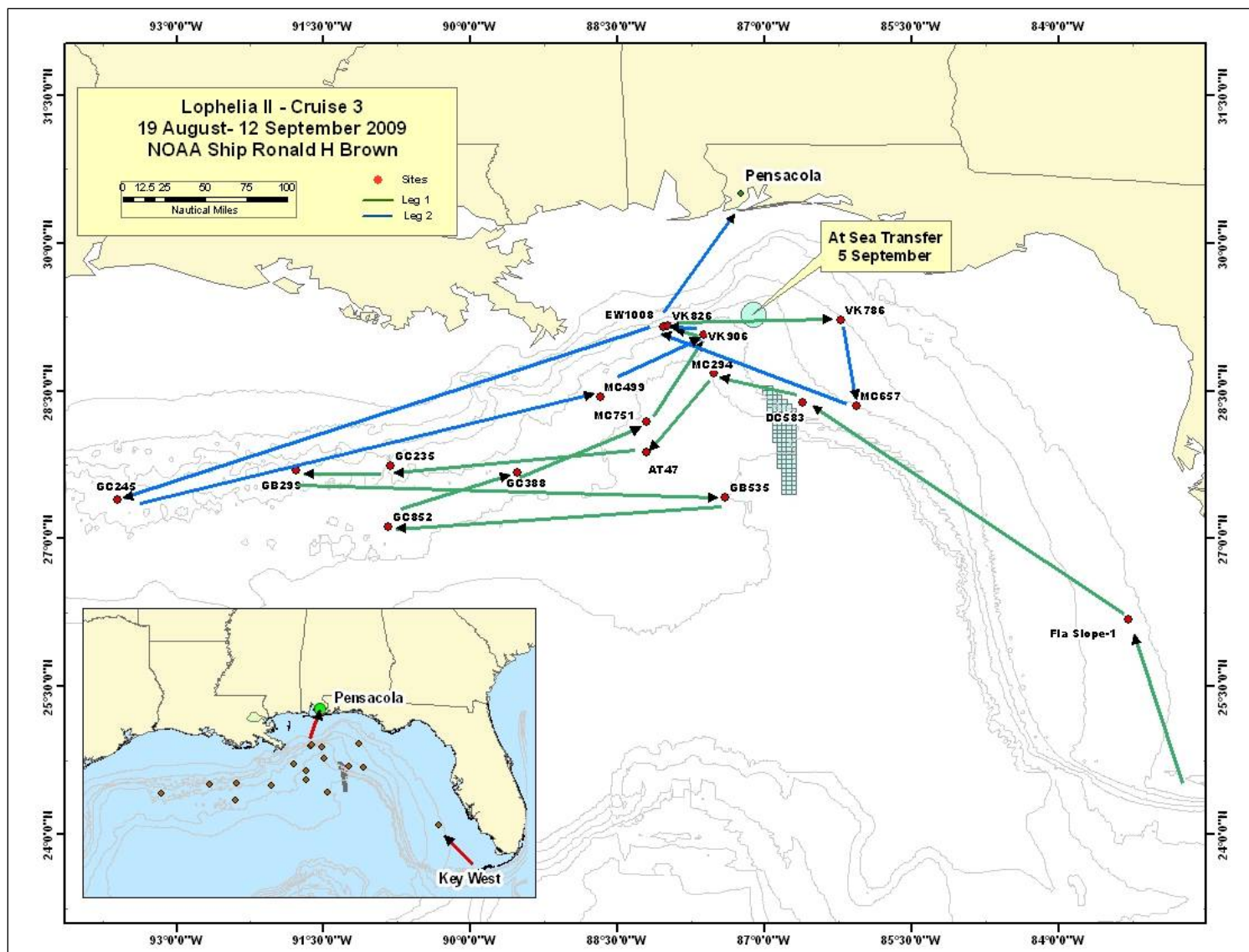


Figure 2-6. *Lophelia* II Cruise 3 track of *Ronald H. Brown*

3 OIL PLATFORM ROV SURVEY

Early in this project the team chose four platforms to survey (Figure 3-1) for live coral colonization using the criteria: 1) arrangements can be made with the operators to conduct the necessary operations, 2) are located in areas determined to be of special interest to our studies of population connectivity among known and potential deep coral communities in the GoM, and 3) represent a range of ages in order to generate a range of growth rates for pioneer colonies. We found that most platform operators preferred that work on these platforms be conducted using their ROV capabilities.

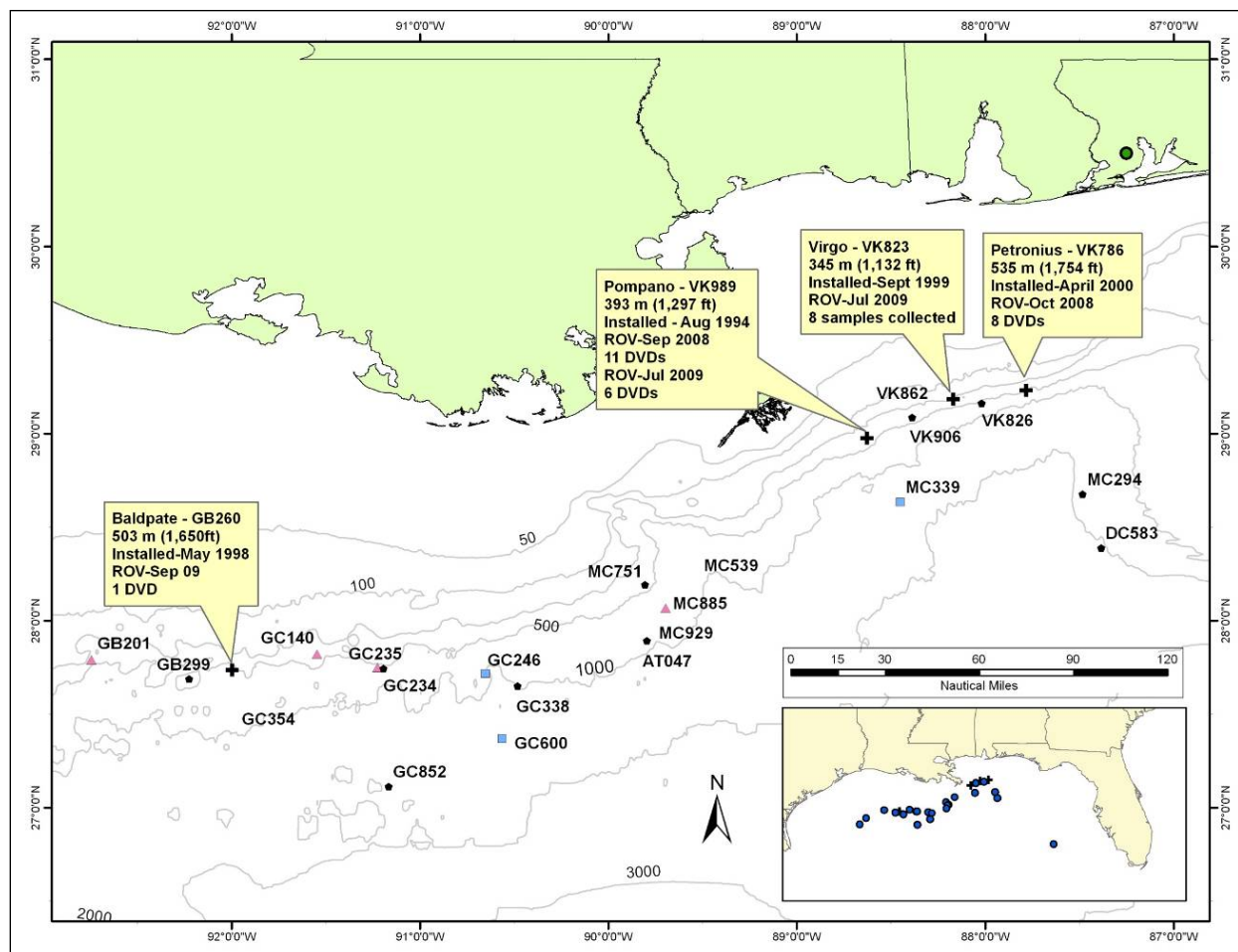


Figure 3-1. Platforms.

3.1 PLATFORMS

Following are the four platforms and characteristics, as well as a record of data collection.

3.1.1 Virgo Fixed Platform

The Virgo field, situated on Viosca Knoll Block 823, offshore of Louisiana, is located in 1,132 feet of water (345 m) in the GoM. The field began production in 1997 and has produced roughly 23,000 barrels of oil since 2001.

The Virgo Fixed Platform is located in 1,130 feet of water (344 m) on Viosca Knoll Block 823. Elf Exploration, Inc., operator, has a 64% interest in association with Coastal Oil & Gas Corporation (16.2%), Pogo Producing Company (10.8%) and Nippon Oil and Gas Exploration USA (9%).

The Virgo structure is a four leg 12-skirt pile. It has a 200 MMcf/d of gas and 15,000 barrels of oil condensate capacity. The platform, consisting of a four-leg jacket, weighs more than 24,000 tons (21,772 tonnes) and features legs 60–120 inches in diameter. At the time of its construction, the Virgo fixed platform was the third largest structure of its size in the GoM and the fourth largest in the world.

Collection: corals collected 22 Jul 2009, DVD.

3.1.2 Pompano

- Operator: BP
- Water Depth: 393 m / 1,297 ft

Last Updated: Oct 9, 2009 (view update history)



One of the first deepwater projects in the GoM, Pompano is being used as a production hub for area fields. Located in 1,300 feet (396 m) of water.

Collection: 14 July 2009, DVD.

3.1.3 Petronius

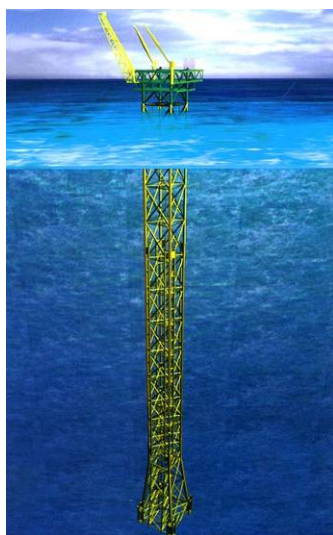
The Petronius field, discovered in 1995, is located in Viosca Knoll Block 786, approximately 130 miles (208 km) south-east of New Orleans and named after Petronius, the Roman writer. It lies in water depths of 1,754ft (535 m). The field was discovered in 1995 and contains estimated recoverable reserves of 80–100 million barrels of oil equivalent. Petronius is a deepwater compliant tower oil platform. The cost of the project has been put at \$500 million. Texaco (the operator) owns 50% of the field and the remaining 50% is owned by Marathon.

A compliant piled tower design, it is 609.9 m (2,001 ft) high, and was arguably the tallest free-standing structure in the world, until surpassed by the Burj Khalifa Tower (Dubai) in 2008, although this claim is disputed since only 75 m of the platform are above water. The multi-deck topsides are 64 m by 43 m by 18.3 m high and hold 21 well slots, and the entire structure weighs around 43,000 tons. The compliant tower design is more flexible than conventional land structures to cope better with sea forces. It can deflect (sway) in excess of 2% of height. Most buildings are kept to within 0.5% of height in order to have occupants not feel uneasy during periods of movement. Around 8,000 m³ (50,000 barrels) of oil and 2,000,000 m³ (70 million cubic feet) of natural gas are extracted daily by the rig.



Collection: N/A

3.1.4 Baldpate



Baldpate is a 1,902 ft tall (579.7 m) offshore compliant tower oil platform near the coast of Louisiana.

Baldpate is located in 1,650ft of water, in Garden Banks (GB) block 260, 120 miles off the Louisiana coast. This is the first free-standing offshore compliant tower ever, as well as one of the tallest free-standing structures in the world. The tip of the flare boom extends 1,902ft above the seafloor.



Collection: 9-27-2008 DVD

3.2 POMPANO OCEANEERING ROV SURVEY CONCLUSIONS

Observations and conclusions are presented below (Figure 3-2) for the Pompano platform.

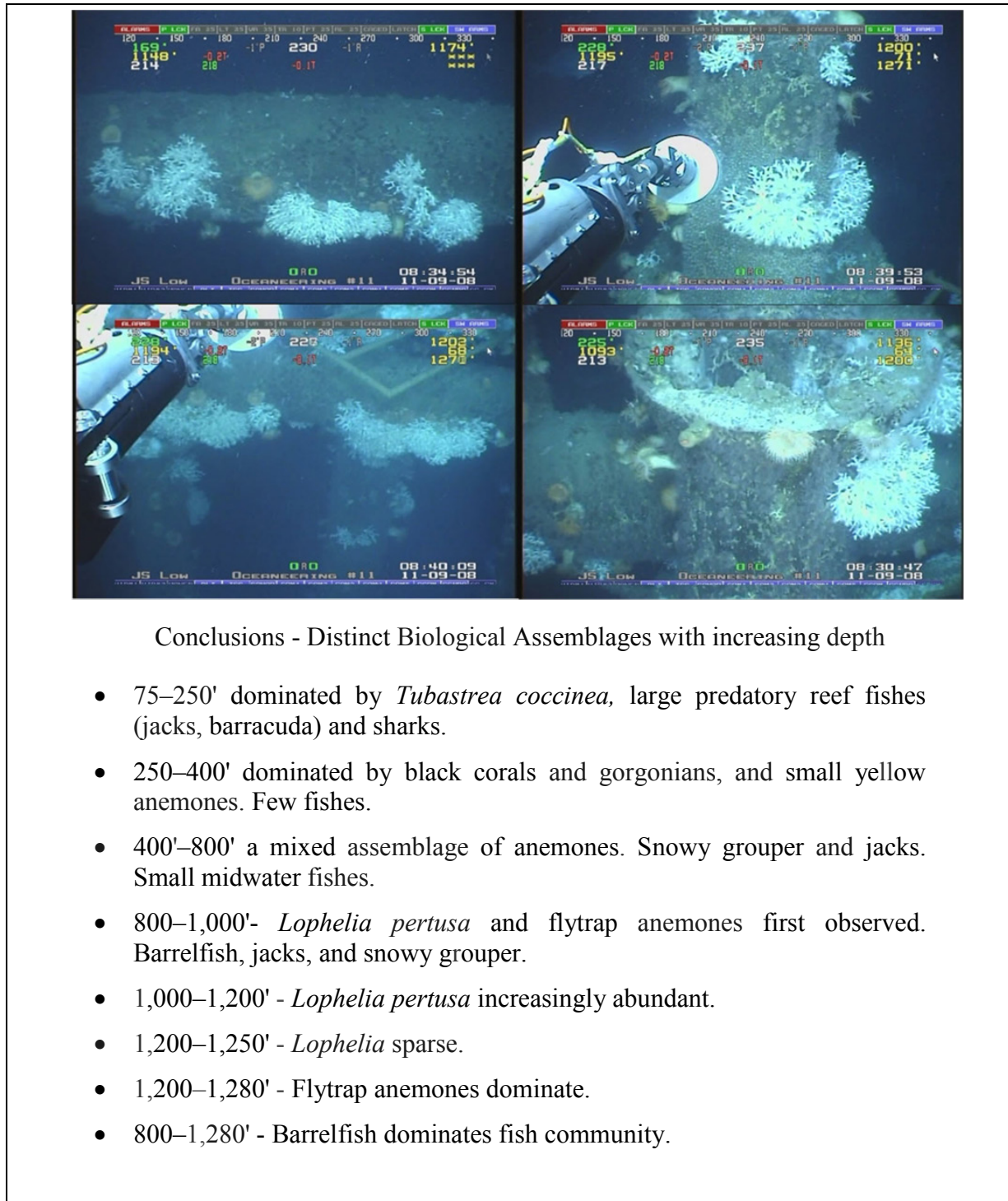


Figure 3-2. Still images from BP's Pompano compliant tower platform. ROV survey by Oceaneering, Inc.

4 SITE SELECTION

Selection of sites for the study of natural and artificial hard bottom habitats that may support deep water coral communities is fundamental to the success of this proposed research program. Following the successful *Alvin* (2006) and *Jason II* (2007) dives associated with the Chemo III project, we now have increased our confidence of locating natural hard bottom areas associated with fluid-gas expulsion. These sites occur to the deepest parts of the continental slope. The manned submersible and ROV dives provided field verification of hard bottom conditions predicted from the analysis of seafloor reflectivity or surface amplitude derived from 3D-seismic data.

4.1 CURRENT STATUS

For the 3D-seismic analysis, reflection strength (amplitude) and phase were determined by using a 10-millisecond window from the sediment-water interface into the shallow subsurface. This window translates into an interval approximately 7.6 m (25 ft) thick. Phase is a seismic attribute related to amplitude and has a sawtooth appearance resulting from amplitude maxima and minima. Phase reversal may help indicate gas contained in near-surface sediments. As applied in the study, phase helps define “fast” (usually hard bottom) and “slow” (usually soft, gas charge bottom). Early appraisals of surface reflectivity (amplitude) from regional 3D-seismic data sets indicated that the continental slope of the northern GoM was punctuated with seafloor bright spots (Figure 4-1). Research conducted since the early 1990s indicates that seafloor bright spots can be correlated to localized surface areas of fluid-gas expulsion and hard bottom conditions (Figure 4-2).

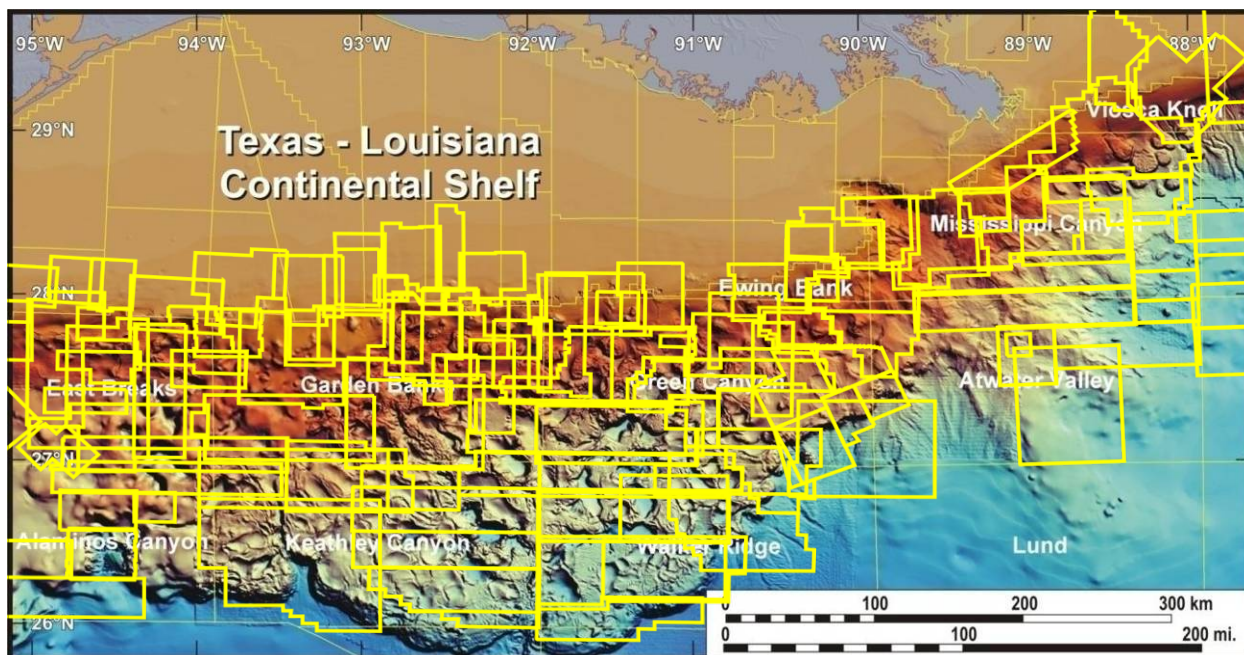


Figure 4-1. Seafloor reflectivity anomalies as observed with 3D-seismic data.

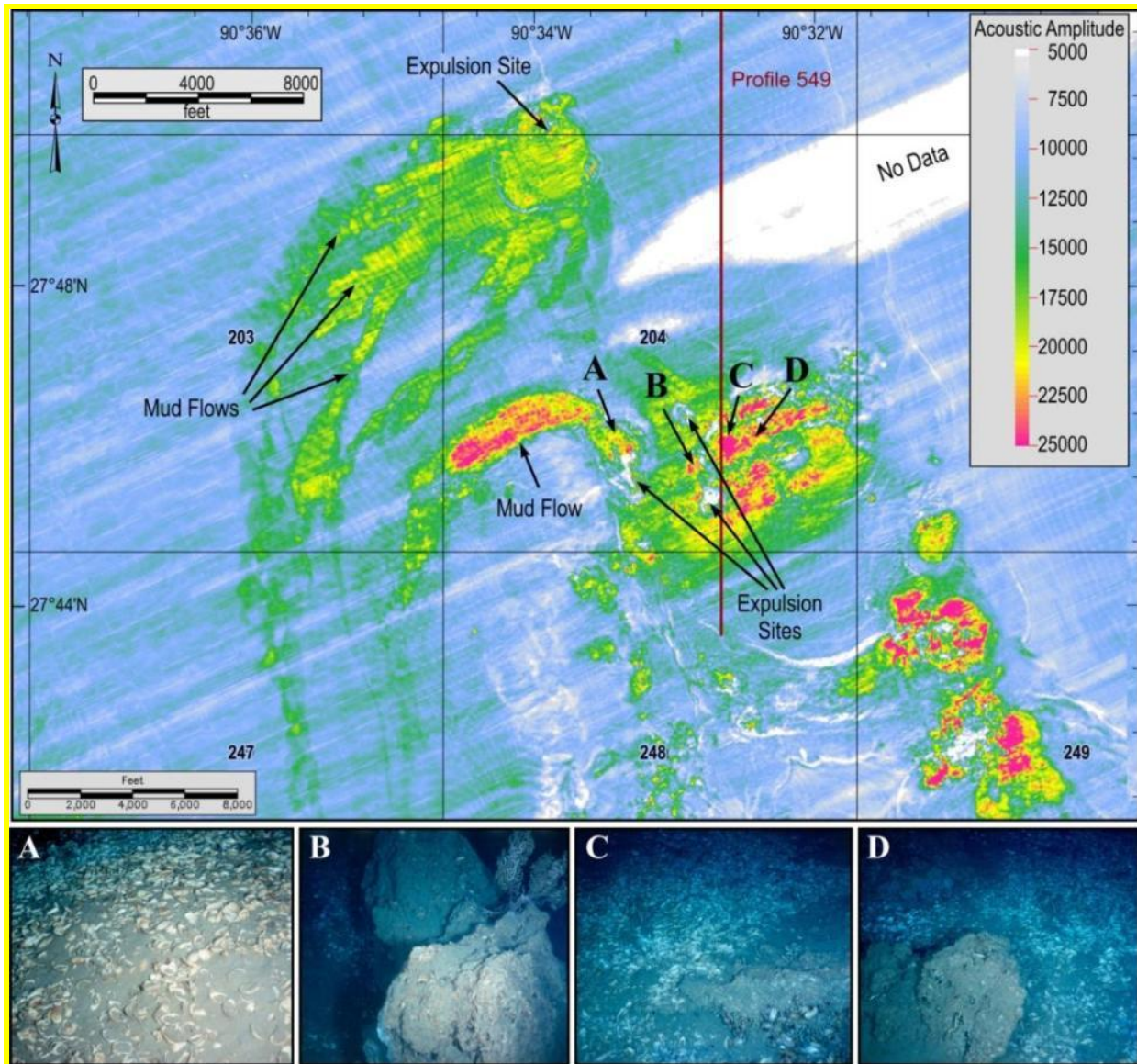


Figure 4-2. Surface reflectivity (correlation to seabed).

4.2 SITE SELECTION CRITERIA

- Depth Range 1: Shelf Edge to 1,000 m
- Depth Range 2: 1,000 m to 2,000 m
- Hard Bottom (Surface Reflectivity Anomaly)
- Rough Bottom (Topographic Highs)
- Variable Bathymetric Configurations
- Special Steep Slope Settings (Concentration of Deep Ocean Currents)

Based on these criteria, the sites to study were formulated (Table 4-1) and resulted in new prospective sites (Table 4-2).

Table 4-1.

Sites Visited: *Lophelia* Project

site	lat	long	depth	Jason Cruise	Sentry Cruise		Nancy Foster Cruise	
					photo	multibeam	video	multibeam
GC140	27.82024	91.54463	259				x	x
VK862	29.10713	88.38459	317					x
GB299	27.68562	92.22344	355	x				
VK906	29.08513	88.38475	380	x			x	x
Wfla	26.18411	84.70741	425	x				
MC751	28.19113	89.80375	450	x			x	x
VK826	29.16112	88.01688	457	x	x	x		x
GC234	27.74695	91.22447	500				x	x
GC354	27.60053	91.82379	515					x
GB201	27.79033	92.74300	525				x	x
GC235	27.74278	91.19191	530	x				
GB535	27.42574	93.58819	530	x	x	x		x
EW1009	27.95454	89.99404	556					x
MC885	28.06465	89.69509	627		x			x
MC539	28.41319	89.40154	630					x
MC929	28.02051	89.72825	633					x
GC246	27.71487	90.64978	811		x			x
AT047	27.88999	89.79425	835	x				x
GB837	27.11972	93.89694	880			x		
GC338	27.64876	90.47948	939	x				
GC600	27.36639	90.56417	1250		x	x		
MC294	28.67433	87.481	1400	x				
GC852	27.11175	91.16488	1410	x				
MC339	28.63278	88.44917	1425		x			
DC583	28.38714	87.38143	2440	x				

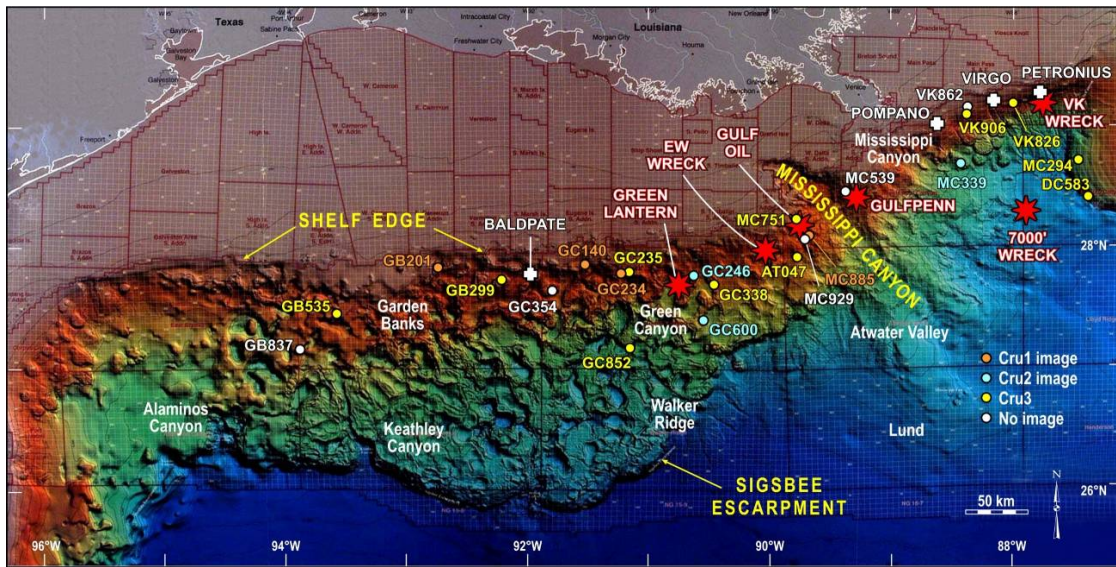
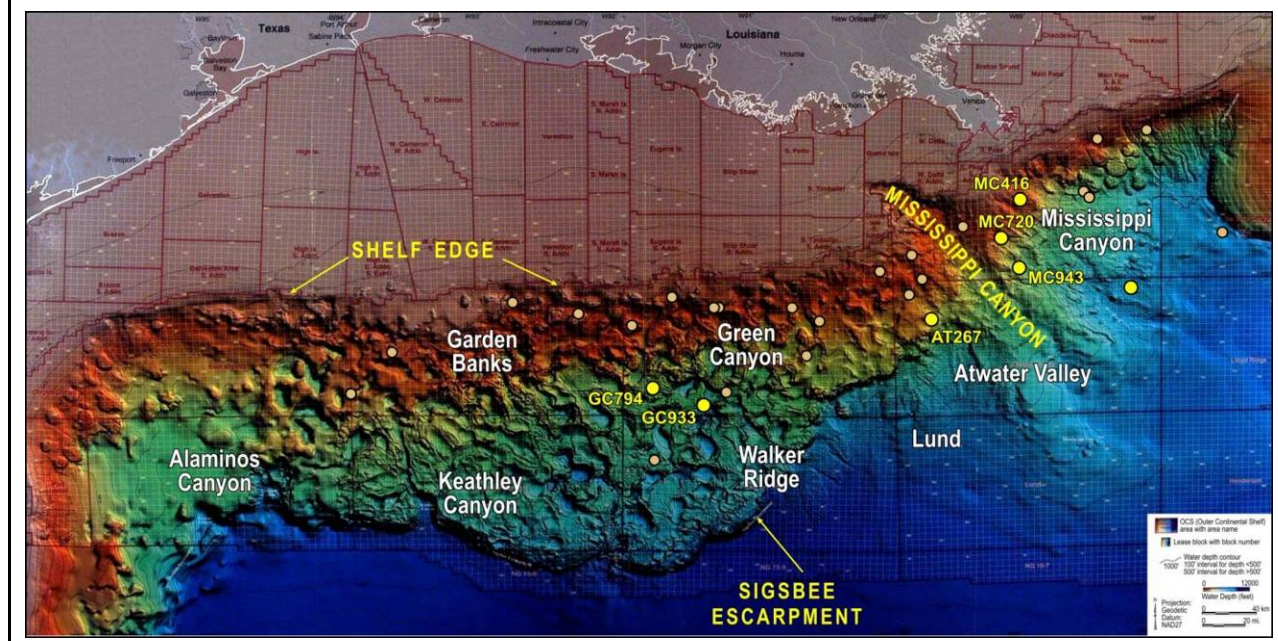


Table 4-2.

New Prospects for *Lophelia* Sites

SITES	WATER DEPTH	KEY CHARACTERISTICS
MC 416	640 m	Low Sloping Seafloor, Hard Bottom, Good Migration Pathways from Shallow Salt
MC 720	1051 m	Multiple Migration Pathways, Hard Bottom, Mounds
MC 943	1350 m	Discrete Seafloor Mound, Clear Migration Pathway, Hard Bottom
AT 267	1050 m	Clear Migration Pathway, Hard Bottom, Rough Bottom
AT 81	2286 m	Hard Bottom, Small Mound
GC 794	1540 m	Complex Area, Seep Mound, Adjacent Topographic Highs, Hard Bottom
GC 933	1958 m	Steep Slope, Hard Bottom



5 SITE EXPLORATION RESULTS OVERVIEW: MACROBIOLOGY

At this point in the program, after three field efforts, we have collected additional information on 25 natural sites, six wrecks and four platforms (Figure 5-1) and have extensive imaging on a number of these (Figure 5-2). We had previous information concerning several of these sites from previous work in the region; however, the majority of these sites had not been imaged before this study. It should also be noted that there were additional sites discovered during the *Lophelia* I project with limited occurrence of corals that we have chosen not to study further as part of this project.

Active Sites

- 25 natural
- 6 wrecks
- 4 rigs

Samples from

- 15 natural
- 5 wrecks
- 1 rig

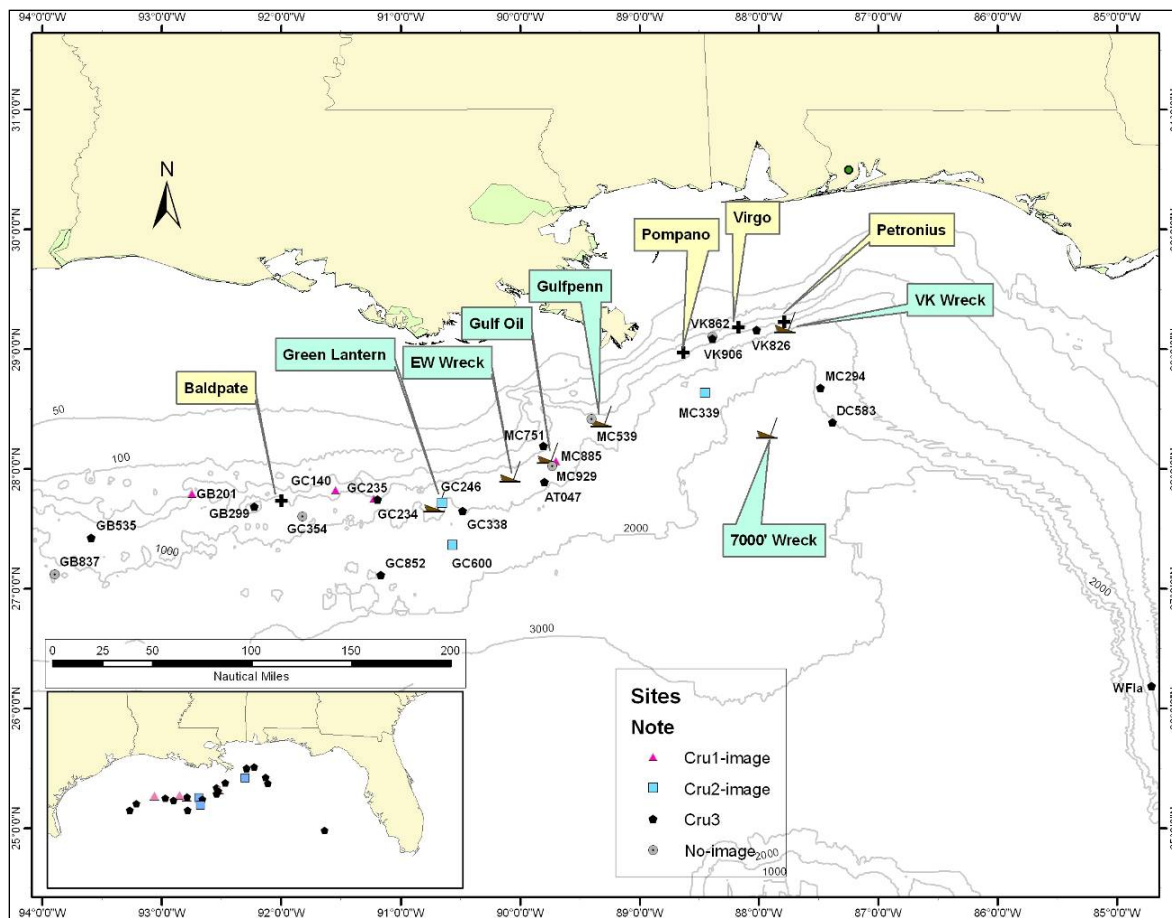


Figure 5-1. Active sites.

Site Considerations:

- Depths (ranges)
- Geography
- Key species
 - (Pop gen #s)
- Diversity
- Deeper “reefs”
- Special features
- Logistics

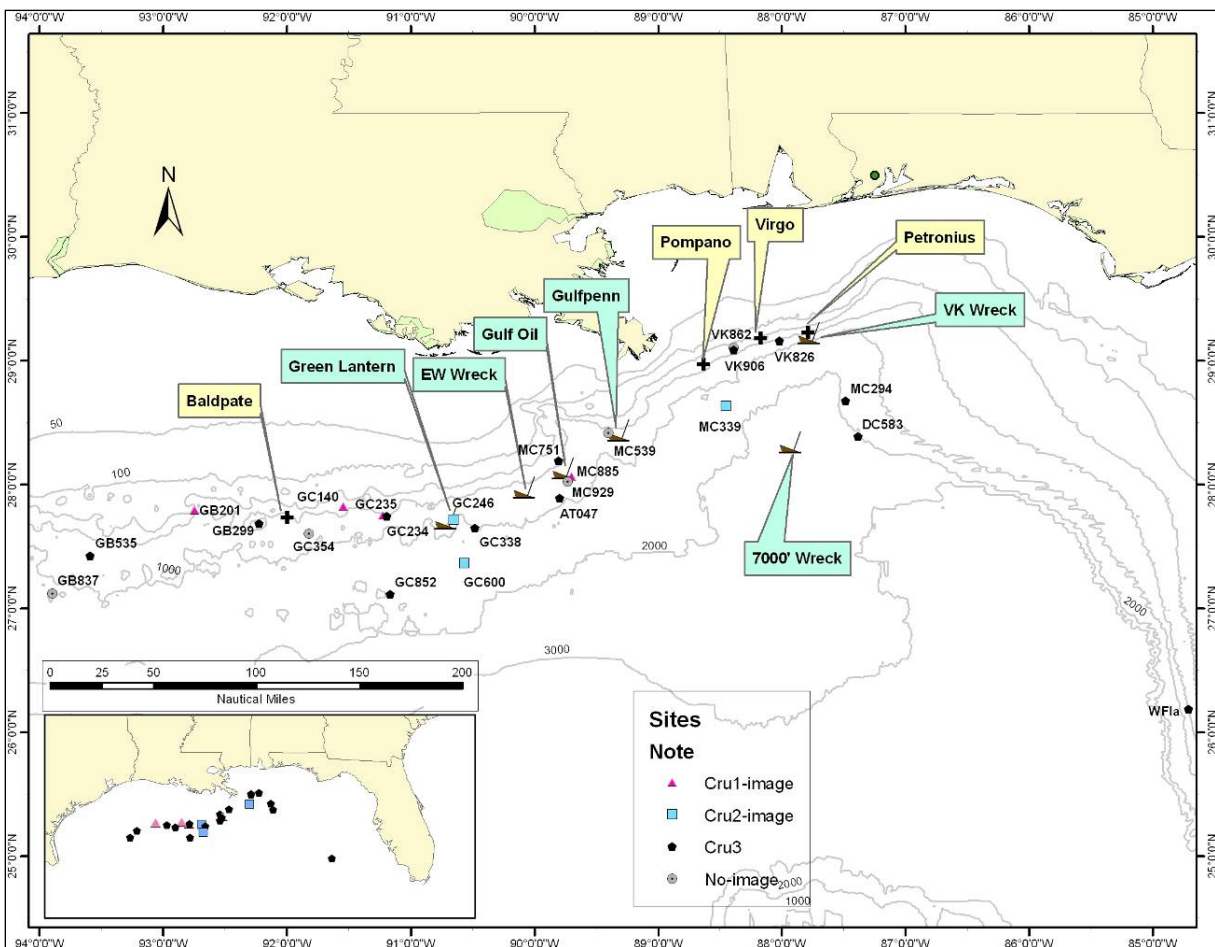


Figure 5-2. Site images.

There are three “species” that we have identified for in-depth population level analyses, *Lophelia pertusa*, *Callogorgia* spp, and *Leiopathes* spp, and we have discovered numerous additional sites where we can continue to make collections for this aspect of the project.

Lophelia pertusa has been confirmed at 14 sites, ranging in depth from 317 to 627m and over a wide E-W distribution range (Figure 5-3). There are sufficient colonies present for population genetic sampling at seven sites, including sites at the far eastern and western ends of our explorations.

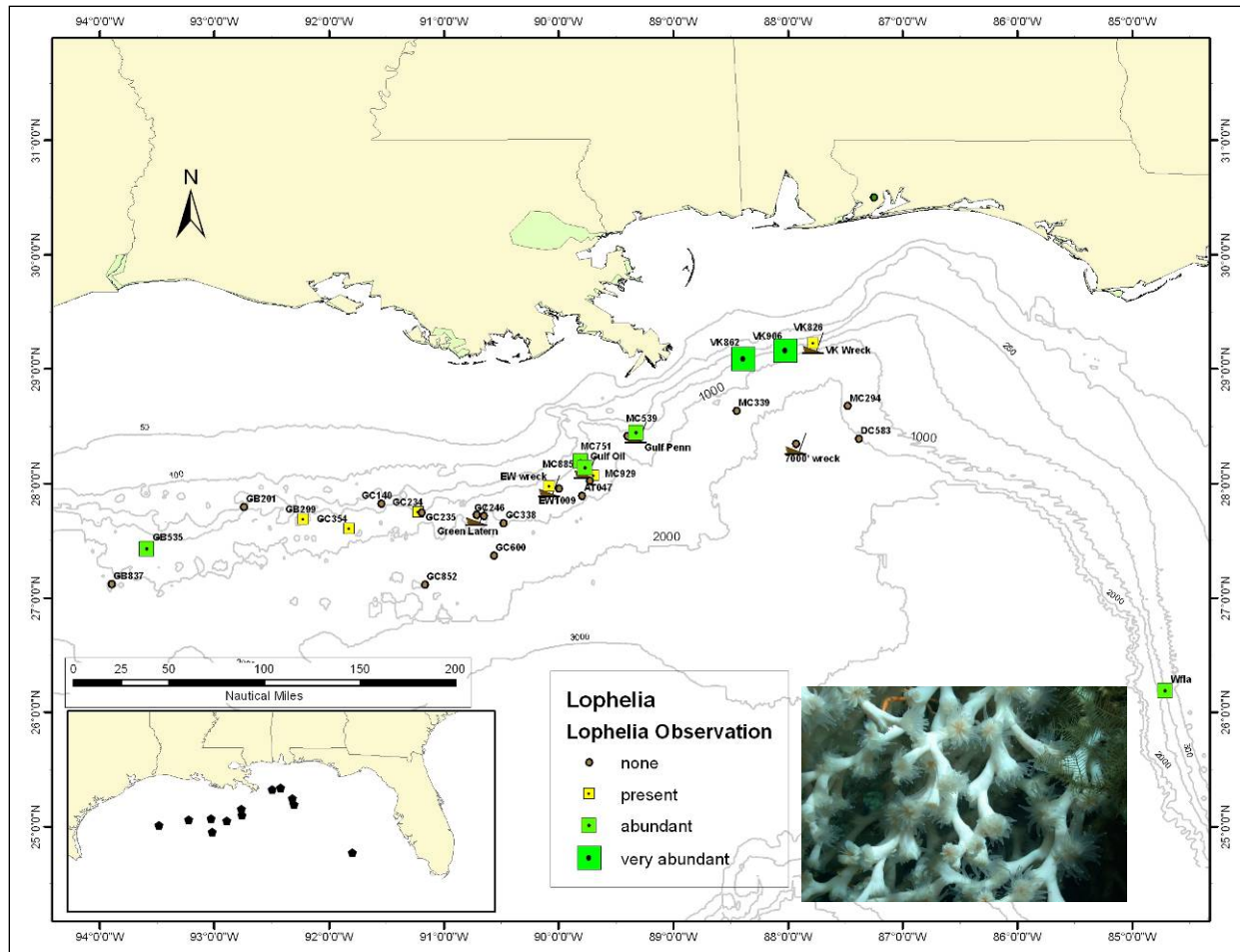


Figure 5-3. *Lophelia* observations.

- *Lophelia*
- Confirmed at 14 sites
- Pop gen #s at 7
- 317 to 627 m depths
- Great E-W distribution
- (missing middle)

Leiopathes sp. has been confirmed at eight sites over a depth range of 259 to 627m (Figure 5-4). Like *Callogorgia*, it is known to occur at shallower sites, not included in the mandate for this study. We have identified six sites with sufficient colonies for population genetic sampling, including the eastern-most site with *Lophelia*. Co-occurrence of sufficient numbers of at least

two of these species at seven of our study sites will facilitate efficient use of our 2010 submersible assets for genetic studies.

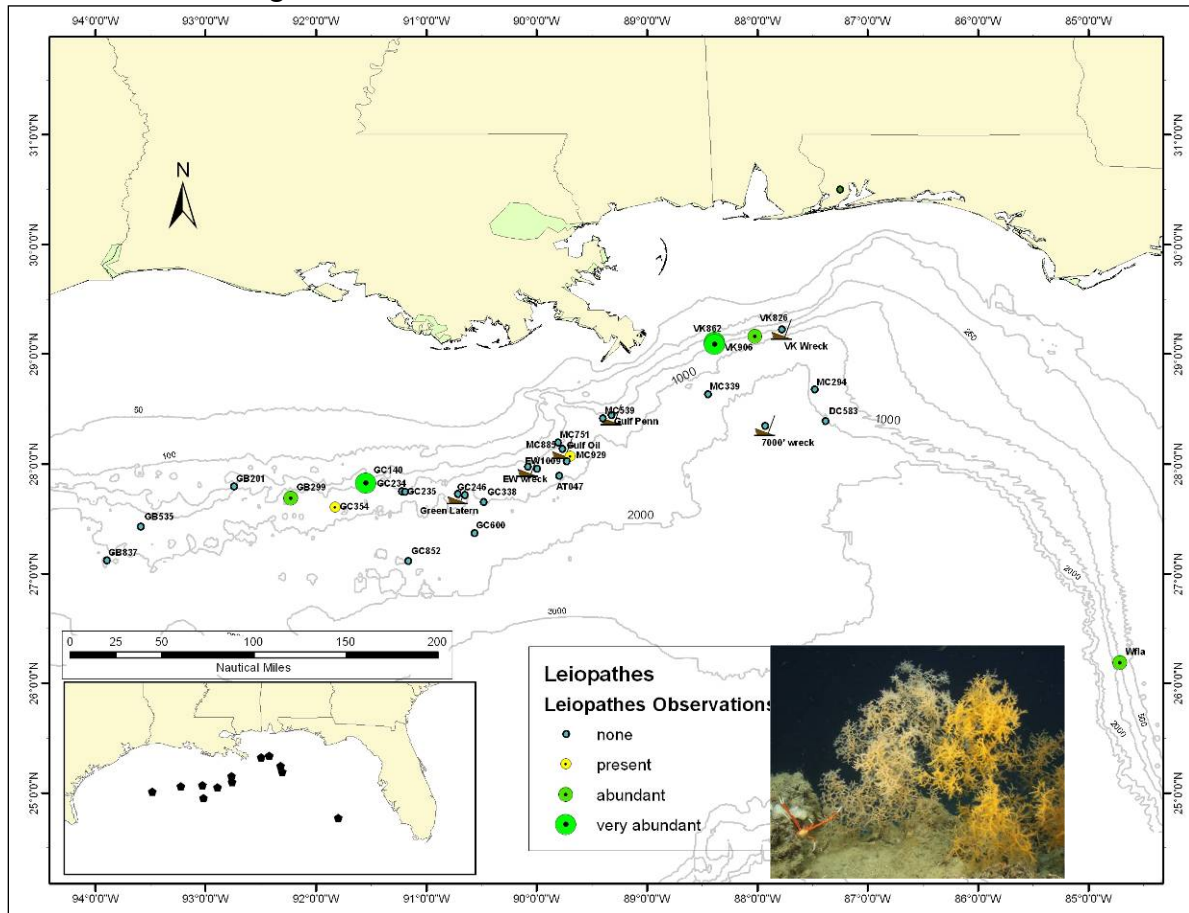


Figure 5-4. *Leiopathes* observations.

Leiopathes

- Confirmed at 8 sites
- Pop gen #s at 6
- 259 to 627 m depths
- Nice E-W distribution
- (missing middle)

Callogorgia spp have been confirmed at 12 sites over a depth range of 259 to 939 m (Figure 5-5). It is known to occur at shallower sites, not included in the mandate for this study. We have identified seven sites with sufficient colonies to sample for population genetic analyses; however we have not found *Callogorgia* spp on either the West Florida Slope, or in the western most Garden Banks sites.

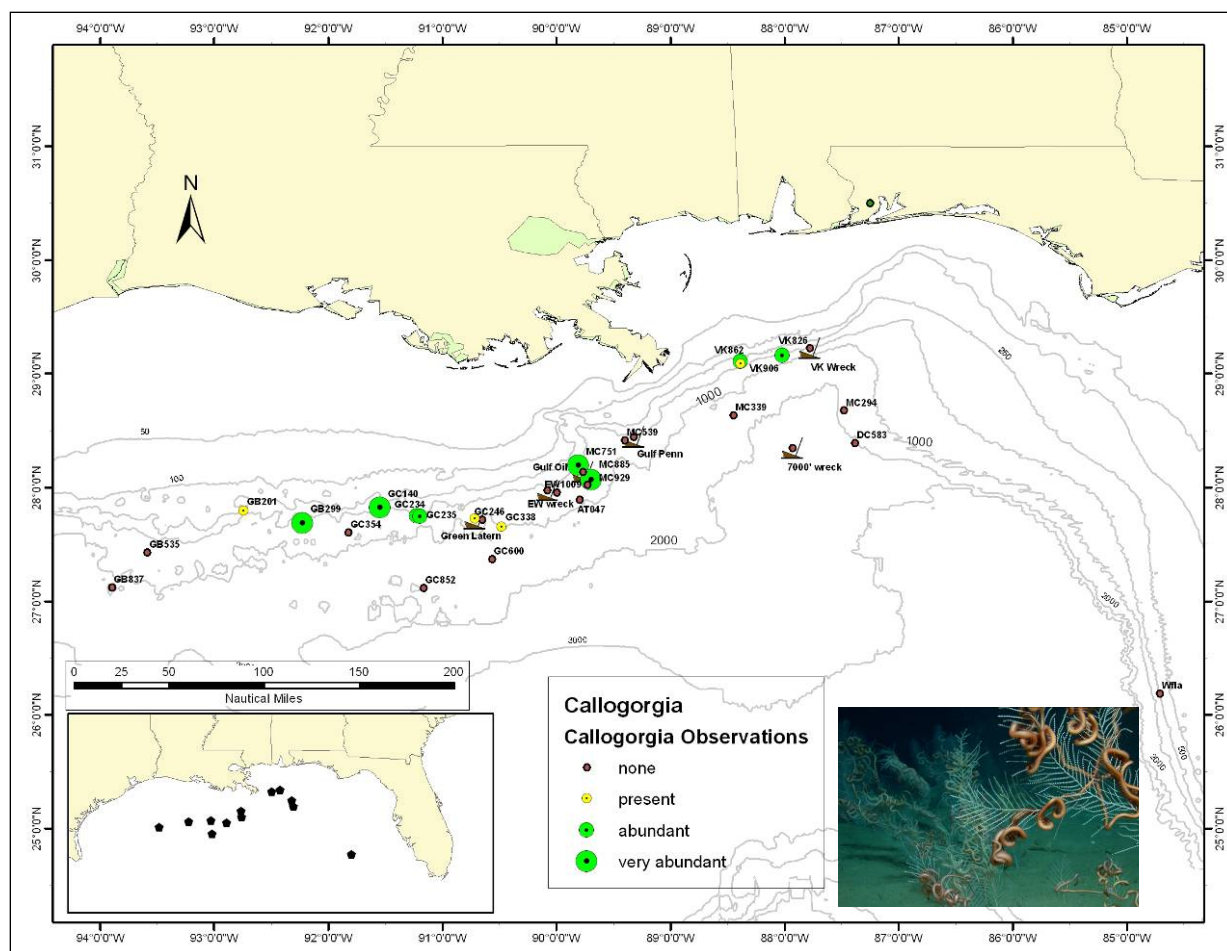


Figure 5-5. *Callogorgia* observations.

Callogorgia

- Confirmed at 12 sites
- Pop gen #s at 7
- 259 to 939 m depths
- Mostly mid-Gulf dist.

At least two key species are abundant at many sites. All three are abundant at VK 826 and VK862/906 (Table 5-1, Figure 5-6).

Table 5-1.

Species Abundance

		Loph.	Leiop.	Callag.	Other soft
Site	Depth				
GC140	259		XXX	XXX	X
VK862	317	X	XXX	XX	X
GB299	355	X	XX	XXX	XX
VK906	380	XXX	XXX	X	D
WFla	425	XX	XX		XX
MC751	450	XX		XXX	XX
VK826	457	XXX	XX	XX	D
GC234	500	X		XX	X
GC235	530			XX	
GB535	530	XX	X		D
GULFPENN	554	XX			
GULFOIL	600	XX			
MC885	627	X	X	XXX	
Baldpate		XX			
Pompano		XX			



Leiopathes

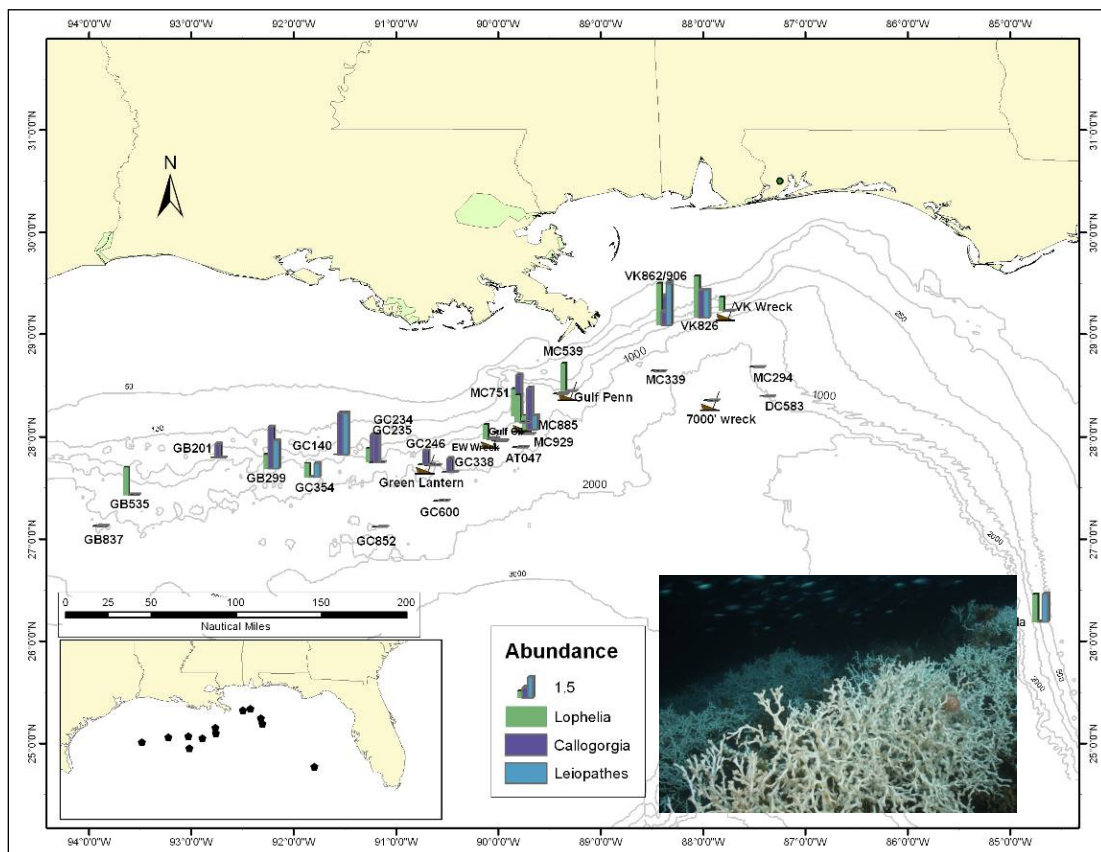


Figure 5-6. Species abundance.

5.1 SITE OVERVIEW

Although more dialog with BOEM and among investigators will be necessary to decide on the dive sites for the 2010 expedition, several sites have characteristics that suggest they will be seriously considered. These sites are discussed from east to west, not in order of priority, below.

5.1.1 West Florida Slope

Although the area visited by both the BOEM and USGS teams on the West Florida Slope (Figure 5-7) is outside of the area of prime interest in this project, there are several reasons that another visit to this area is appropriate for this project. First, its geographic location, over 200 miles to the east and south of our next eastern most site, suggests that it will provide important information about connectivity of the key populations we are studying using population genetic tools, and both *Lophelia* and *Leiopathes* are present in abundance in this area. Second, the preliminary results suggest that the associated communities may be intermediate to those in the central GoM and the West Atlantic, so this site will provide information on connectivity between the GoM and open Atlantic.

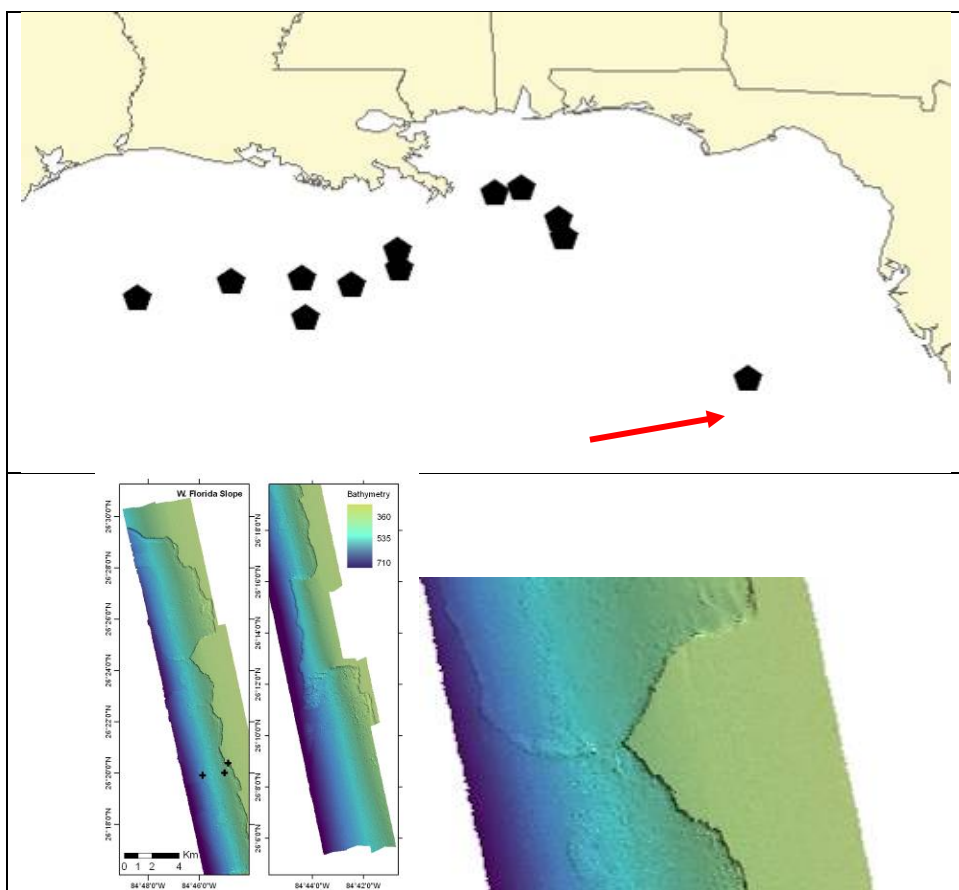


Figure 5-7. West Florida Slope (multibeam data processing courtesy S. Ross lab).

The western-most site is important for population genetics and

- Community connectivity
- A fairly extensive area: Good for genetic analyses
- Both *Lophelia* and *Leiopathes* abundant: *Callogorgia*?
- Nice depth range and interesting occurrence patterns:
- Need a closer look at water chemistry, temperature patterns, etc.

5.1.2 DC583

Sites like DC583 on the Florida Escarpment have extensive deep hard ground communities and the presence of a new species of mussel here suggests they may be oceanographically isolated from better known portions of the Florida Escarpment and also from the deep water sites previously visited in Chemo III. This area may continue to provide access to new species of hard ground fauna (Figure 5-8).

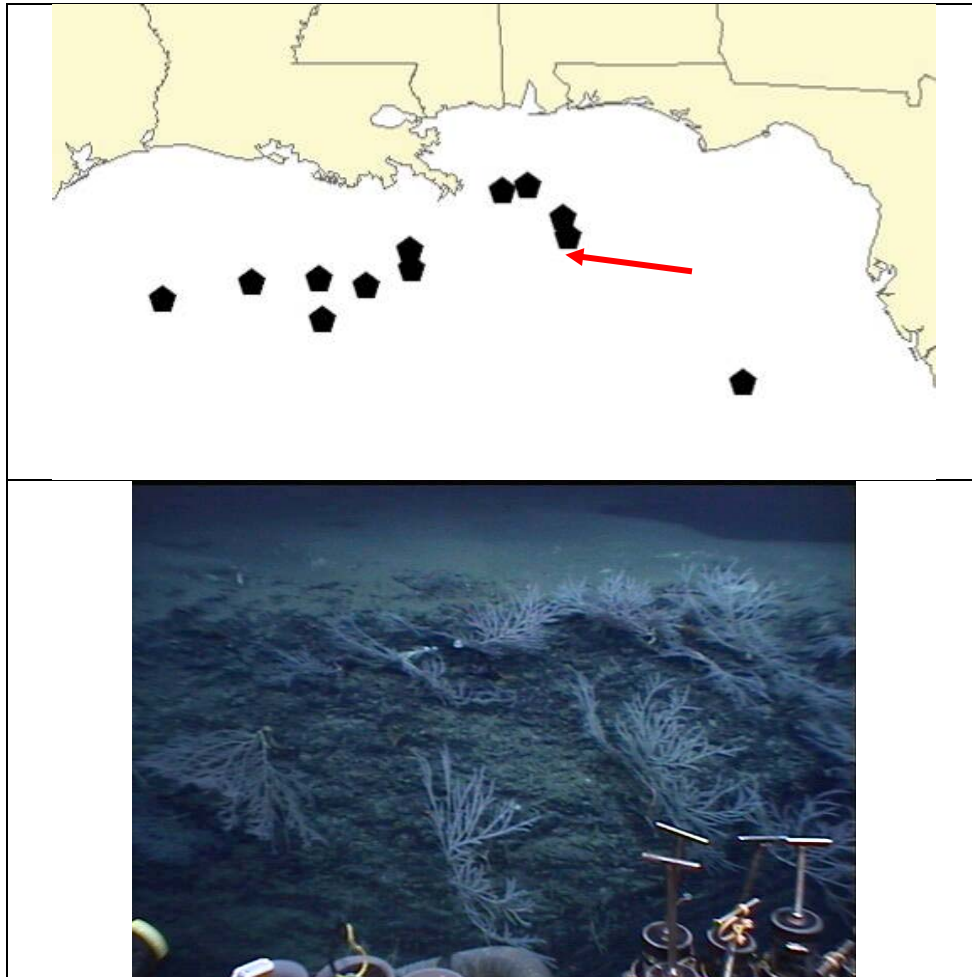


Figure 5-8. DC583.

Deepest study site (2240m)

- Good diversity of soft corals
- Some dense soft coral aggregations
- New species of seep mussel:
- Oceanographically isolated

5.1.3 VK826

VK826 is perhaps the best known *Lophelia* reef site in the GoM and there is abundant data from this site on all scales. Currently two moorings are deployed at this site and other previous moorings have provided a wealth of oceanographic data for this site. The site was very well mapped by the AUV *Sentry*. All key species are present at this site (Figure 5-9).

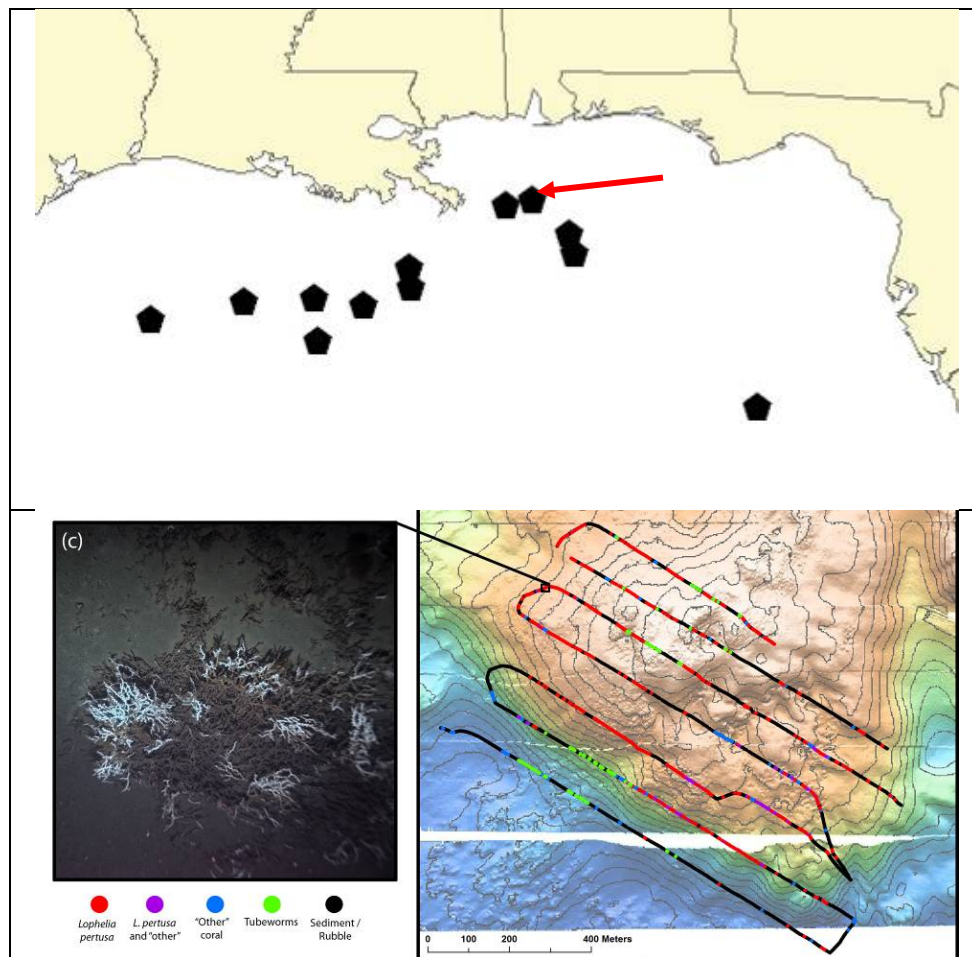


Figure 5-9. VK826.

We have an excellent *Sentry* map with co-located pictures

- Lots of long term data: past present and future
- All three key species present and abundant
- Very good spatially constrained genetic collections

5.1.4 VK862/906

VK862/906 are two sites, separated by about a mile, with very different geology and water chemistry, but can be visited during a single dive. Although the 862 sites were previously known, the mounds in VK906 were discovered during the *Jason II* operations in 2009 and the abundance of key species, diversity of habitats, and rather unique water chemistry and geology make this one of the highest priority sites for continued study (Figure 5-10).

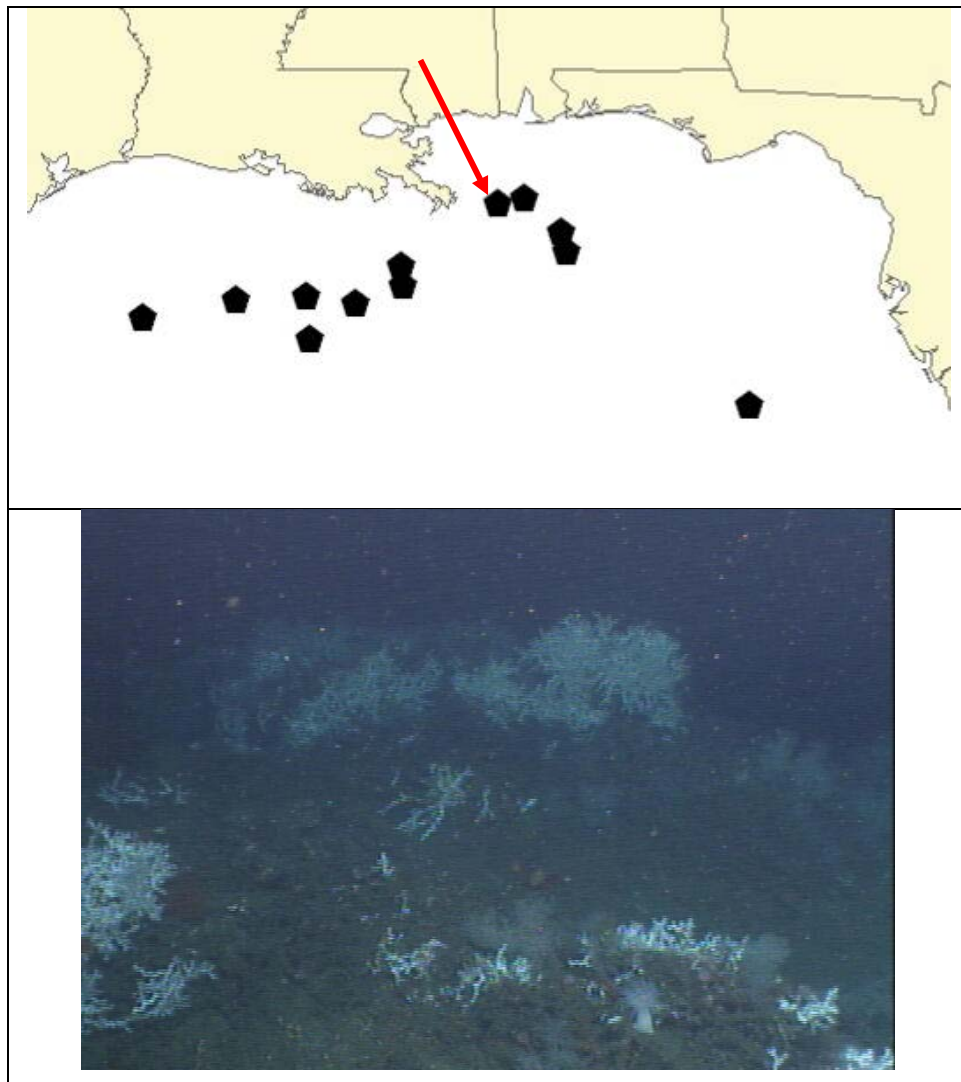


Figure 5-10. VK862/906.

Lophelia mounds

- All three key species are present and abundant
- Very good start on spatially-constrained genetic collections
- Nice depth range, includes shallowest natural *Lophelia*

5.1.5 MC751

MC751 harbors abundant *Lophelia* and *Callogorgia* colonies as well as a nice diversity of soft corals (Figure 5-11). It also has areas where *Lophelia* and chemosynthetic tube worms co-occur, making it an ideal site at which to further explore the nutritional and compositional links between the communities associated with these two types of foundation fauna. There is a sediment trap/larval trap mooring currently at this site.

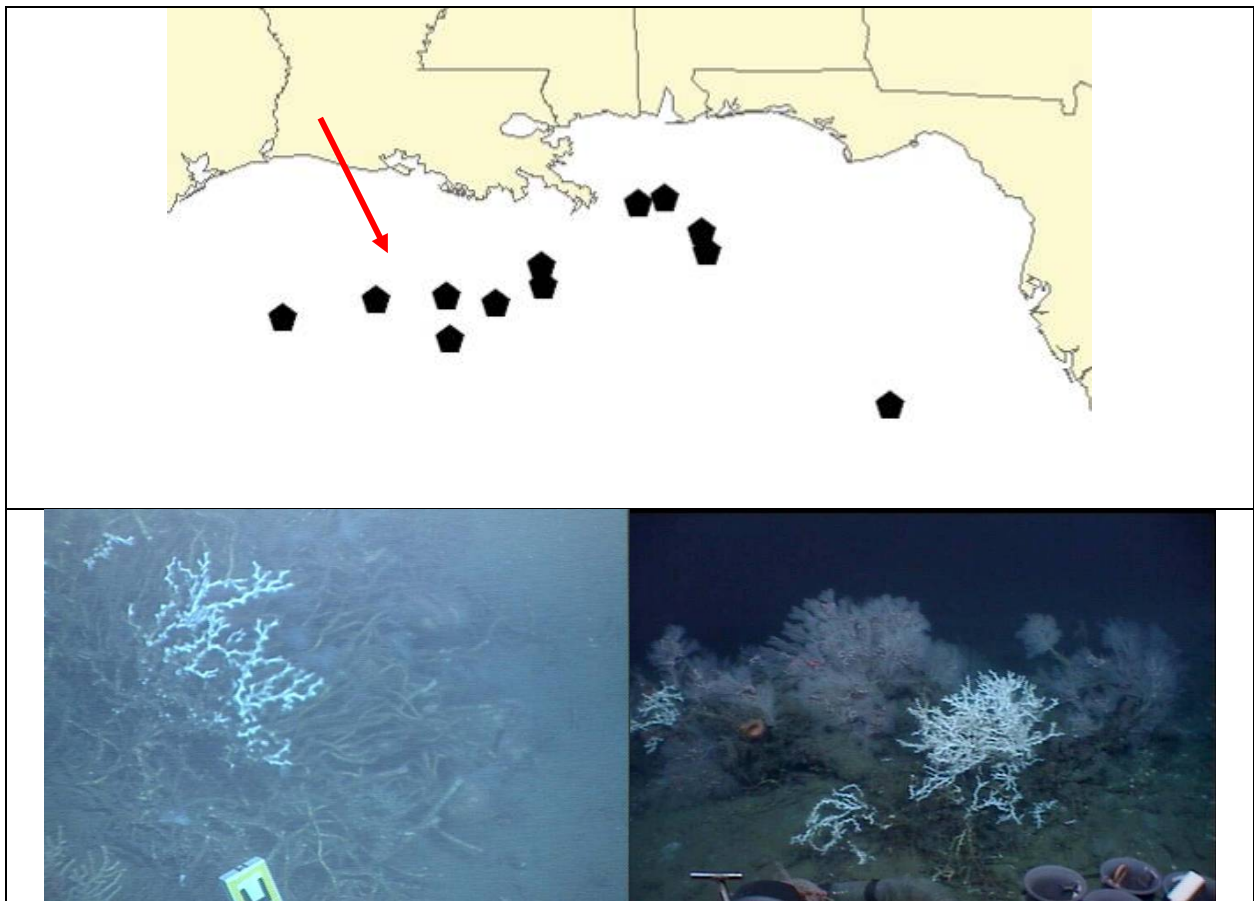


Figure 5-11. MC751.

Have sediment trap mooring down

- Abundant *Lophelia* and *Callogorgia* and other soft corals
- *Lophelia* intermixed with tube worms on cm scale:
- Prime site to detect any input of seep productivity (if it exists)

5.1.6 MC855

Although we did not dive on MC885 during this study, it was visited as part of the *Lophelia* I project. This site (Figure 5-12) hosts the deepest currently-known occurrence of both *Lophelia* and *Leiopathes* in the GoM, as well as *Madrepora* and abundant *Callogorgia*. *Madrepora* is also known from MC 118, in the area of the NOAA Hydrate Observatory site, where there may be additional oceanographic data available. Depending on success in discovery of other sites in this area and depth range, we will consider further work at one or both of these sites.

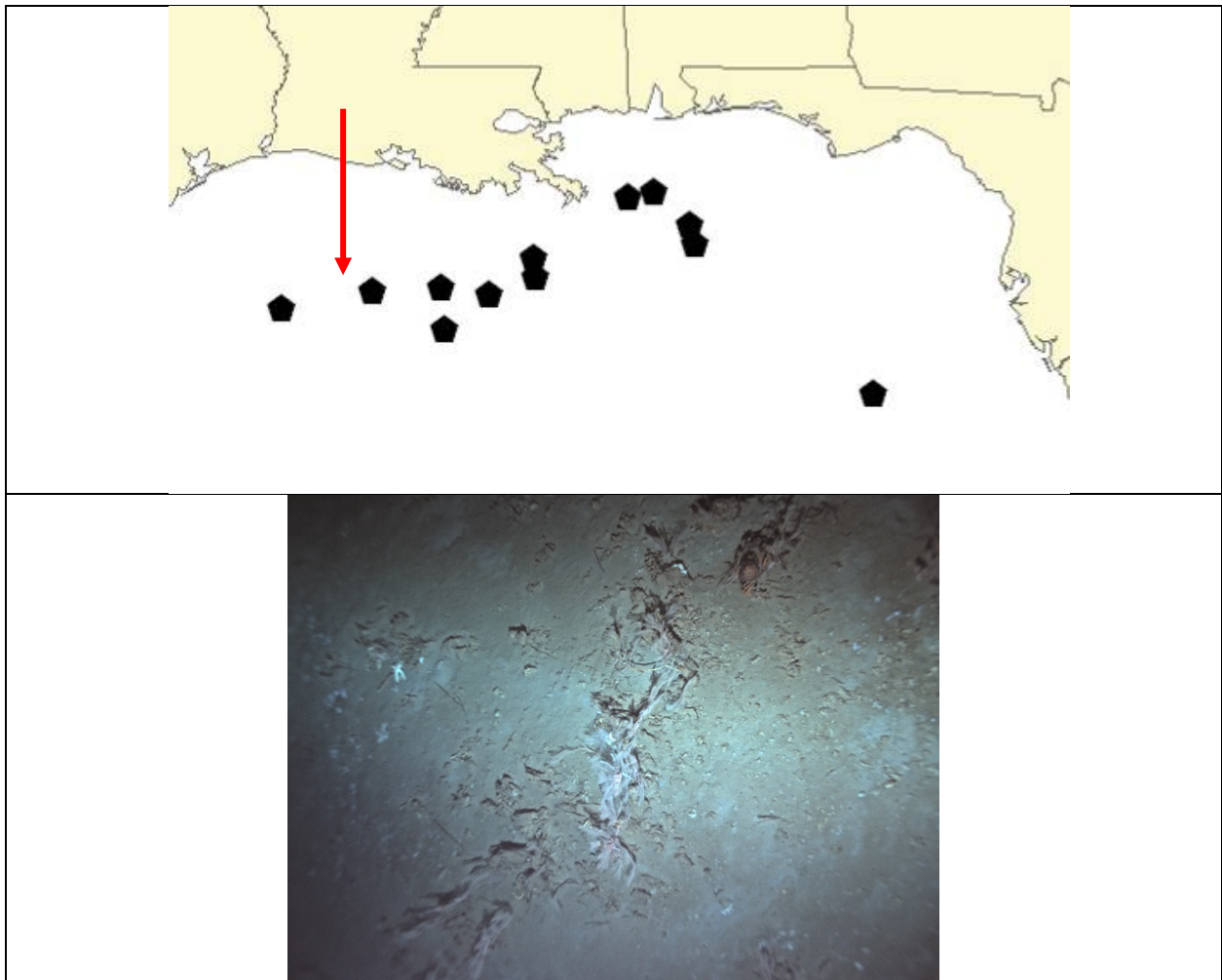


Figure 5-12. MC855.

Deepest abundant *Callogorgia* site (627m)

- *Lophelia* and *Leiopathes* also present;
 - Deepest occurrence for both
- *Madrepora* also present
- Included in *Lophelia* I and visited by *Sentry* in 2009

5.1.7 Gulfoil

The *Gulfoil* wreck was confirmed during the first cruise of this project, but was not visited during the *Jason II* expedition in 2009 (Figure 5-13). It is a priority site for the wreck-related biological studies because it will provide replicate transects and push cores for the reef effect components and is the deepest site with abundant *Lophelia* currently known in the GoM. It is also a priority for the archeological component.

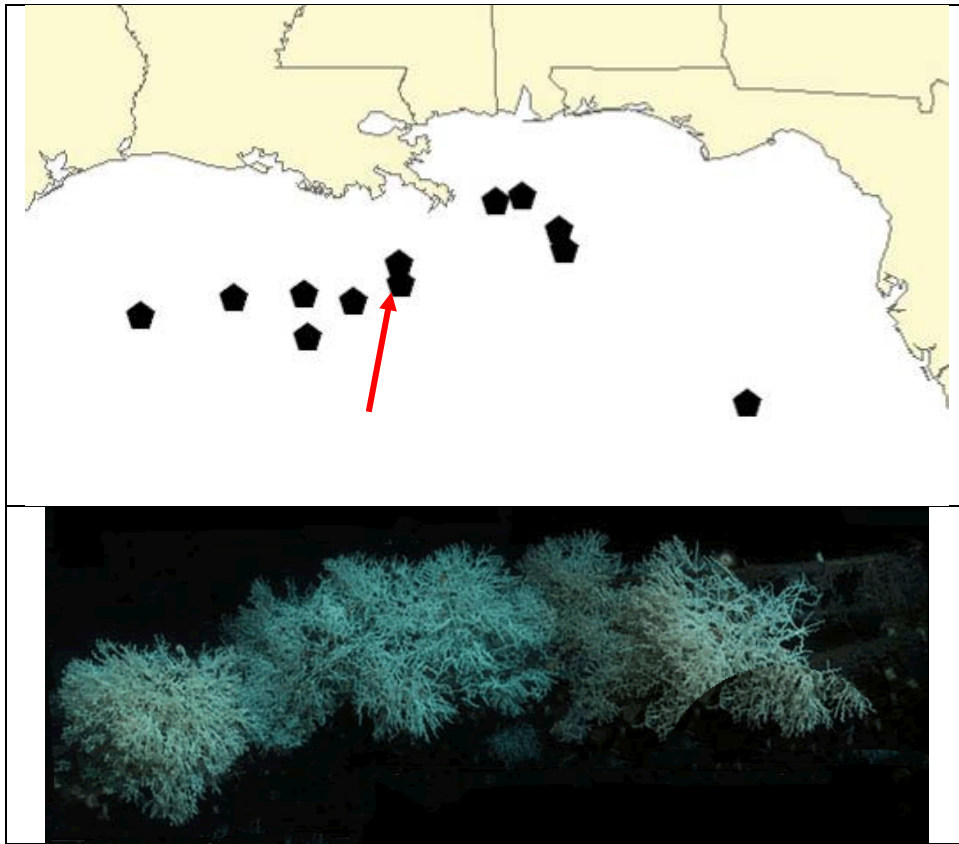


Figure 5-13. The location of *Gulfoil*.

- Deepest abundant *Lophelia* site (600 m)
- Good replicate site for reef effect studies:
- Infauna (cores) and megafauna (transects)

5.1.8 GC852: (1,400m)

Nice deep gorgonian and hard coral diversity (Figure 5-14)

- None of the key popgenetic species present
- We have good maps, collection, etc:
- No additional bottom work needed
- Have current meter deployed
- Additional water column work beneficial?

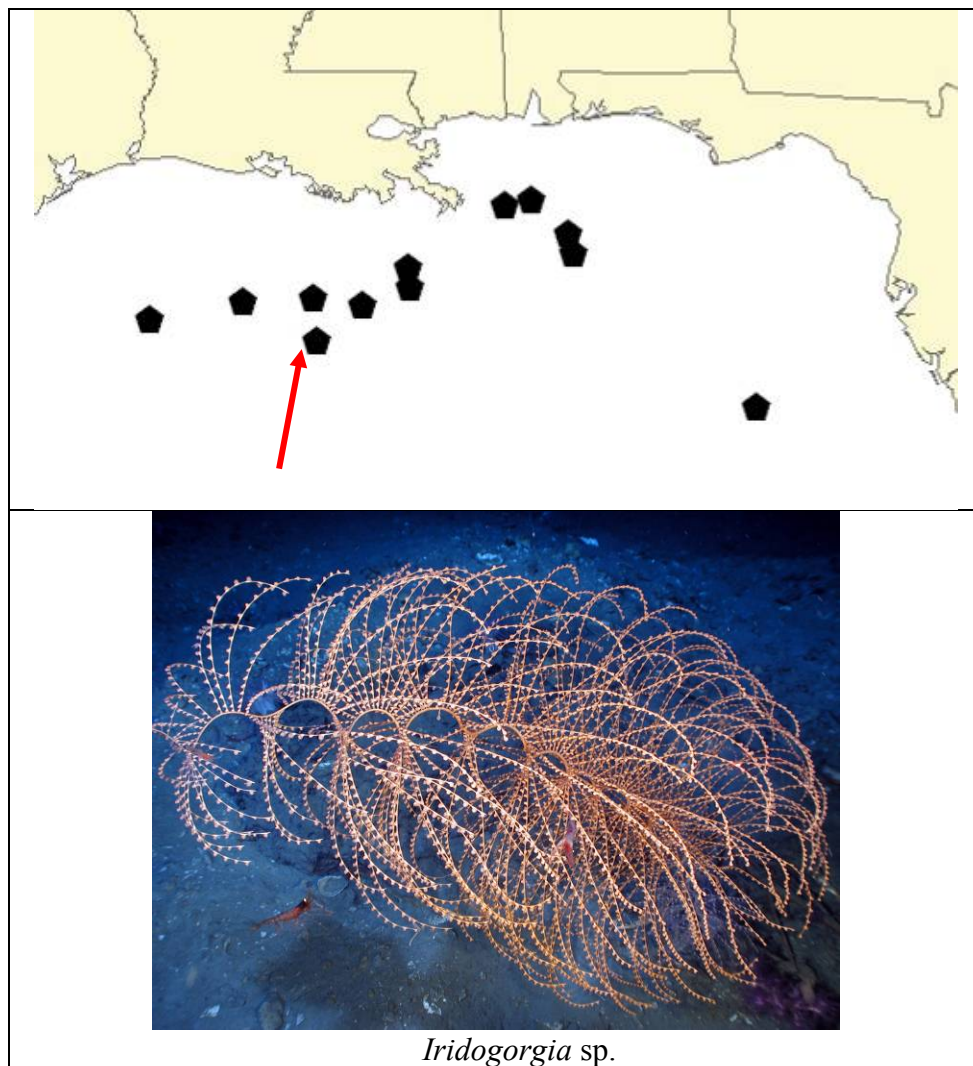


Figure 5-14. GC852.

5.1.9 Shallower GC sites (140, 234, 235, 338):

A number of sites in the Green Canyon (GC) lease area are worth considering (Figure 5-15), and this area may also yield better sites with additional explorations. Although we have a current meter deployed at the GC852 site, it is unlikely we will need to conduct additional dives to this site as it has been well mapped, well explored, and sufficiently sampled. GC234 and 235 have been visited either as part of previous studies or during this project or both. Both have scattered but sparse *Lophelia* and abundant *Callogorgia* and well-established seep communities. GC338 is the deepest currently known *Callogorgia* site and also hosts a diversity of soft corals. Of all of these, GC140 is perhaps the most potentially informative if additional work is done here for the current project. It is the shallowest site visited with sufficient *Callogorgia* and *Leiopathes* for genetic sampling and its proximity to Bush Hill (where *Lophelia* is known to occur), suggests that a depth transect covering nearby hard grounds could be informative, especially if correlated with water column work.

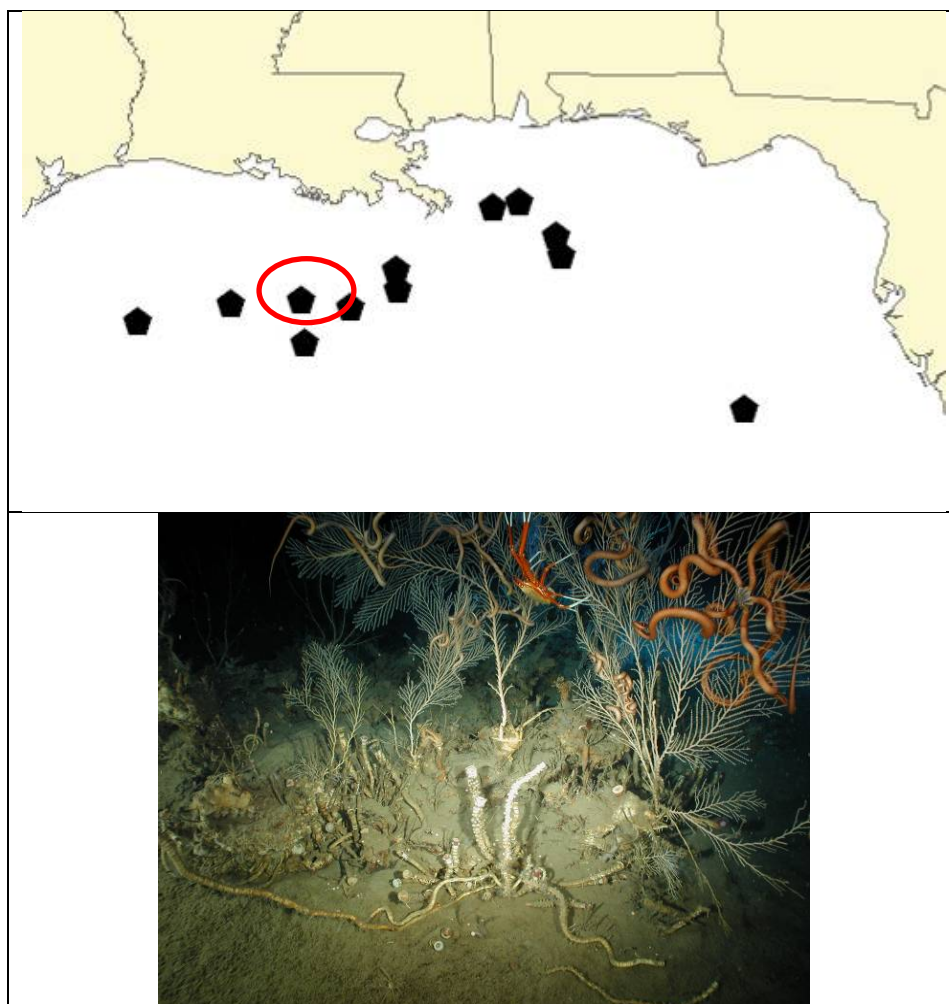


Figure 5-15. Shallower Green Canyon(GC) sites.

Characteristics:

- GC 234: Scattered *Lophelia*, Abundant *Callogorgia*
- GC 235: Abundant *Callogorgia*
- GC 338: Deepest *Callogorgia* (938m), diversity of soft corals
- GC 140: Shallowest *Callogorgia* and *Leiopathes*:
 - Both abundant
 - Perhaps can go down slope to first *Lophelia* occurrence?
 - Interesting water column work site?

5.1.10 GB299

GB [Garden Banks] 299 is the furthest west site with abundant *Callogorgia* and *Leiopathes*. *Lophelia* is rare but present (one small colony seen) but there are abundant other soft corals present (Figure 5-16).

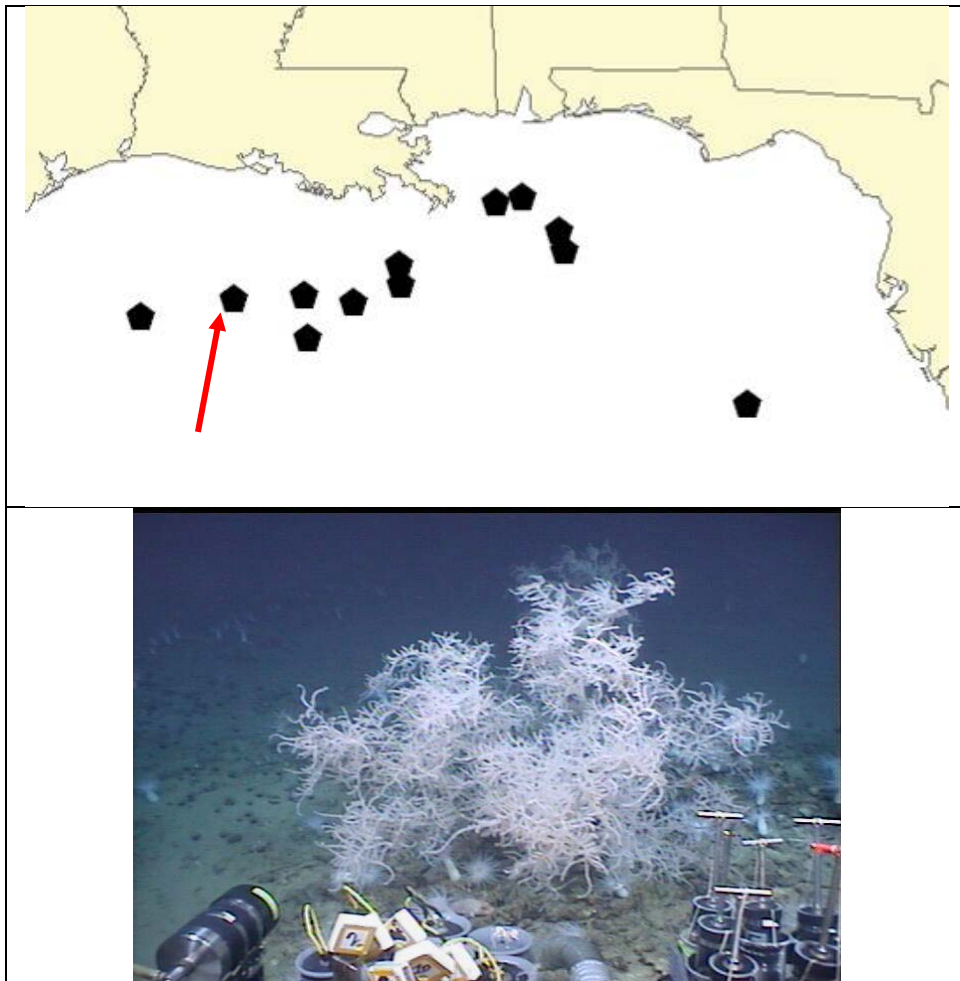


Figure 5-16. Garden Banks (GB) 299.

5.1.11 GB535

In the Garden Banks area, GB535 (Figure 5-17) stands out among the sites we have visited. It is the furthest west site with abundant *Lophelia*, and the reason for the apparent absence of *Callogorgia* or *Leiopathes* is not understood. There are additional areas of the site visible on the 3D seismics that warrant exploration and additional sampling here for the population genetic study of *Lophelia* suggests this is a high priority site for additional submersible work. Another site in this region, GB299 has abundant *Leiopathes* and *Callogorgia*, but *Lophelia* is very rare (Figure 5-18). In addition to its value for population genetic samples of these soft coral species, comparison of water chemistry between these two sites could be quite informative.

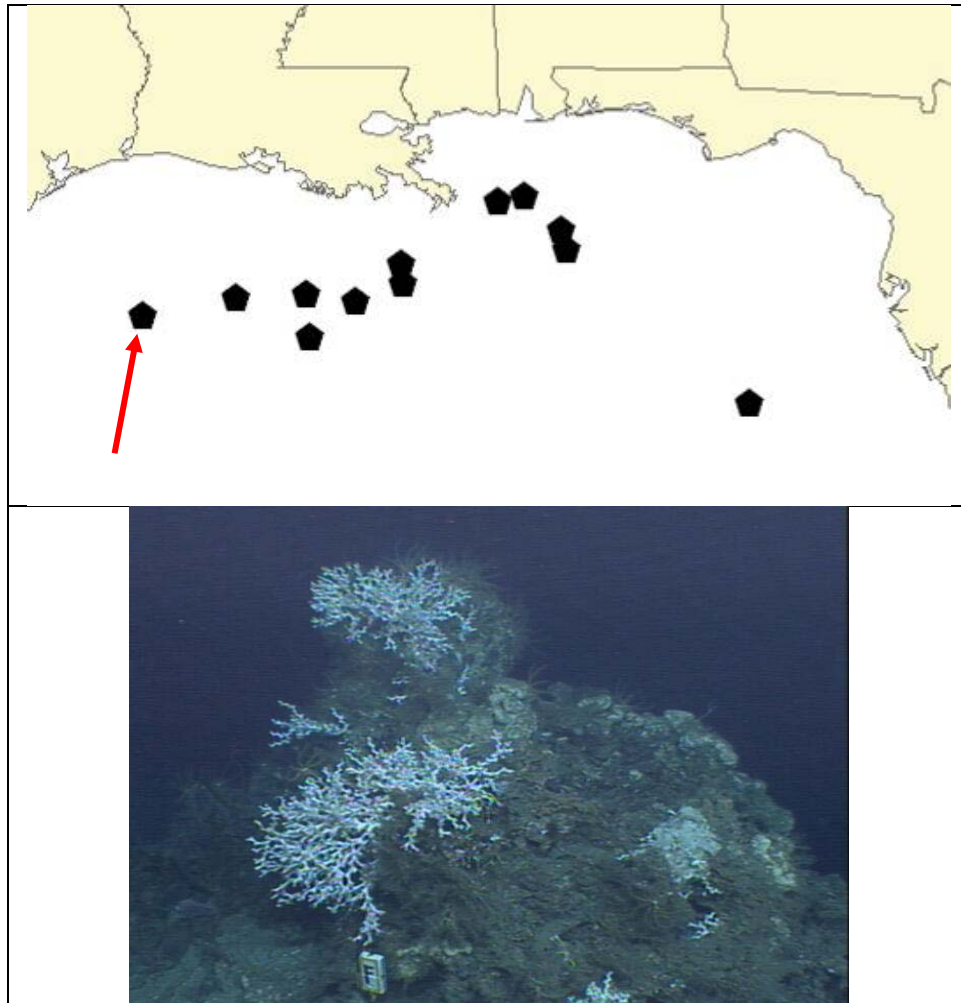


Figure 5-17. Garden Banks (GB) 535.

Characteristics:

- Deepest and furthest west abundant *Lophelia*
- No *Callogorgia* or *Leiopathes*: Why?
- More area to explore

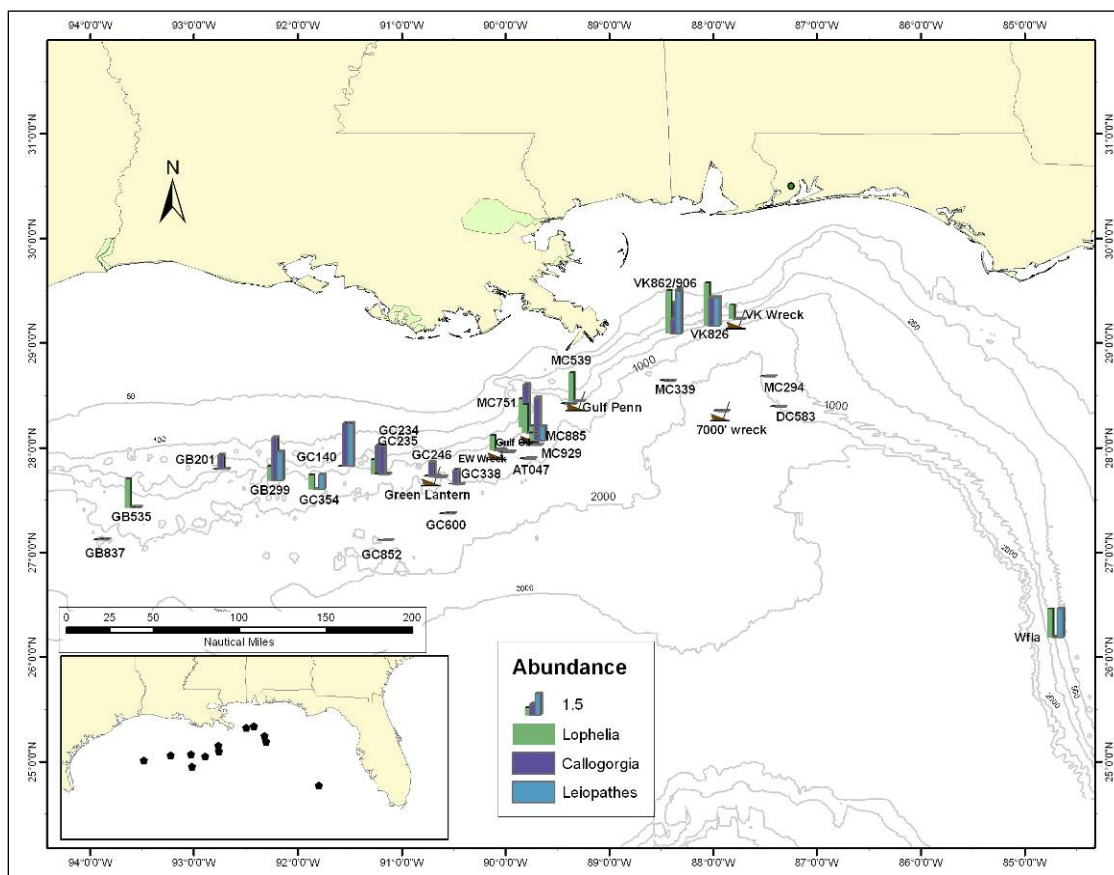


Figure 5-18. Species abundance.

In summary, we have occupied and sampled sites over a wide depth and geographic range and they are spaced appropriately for an efficient and productive field effort in the fall of 2010. However, we will also need to seriously consider additional exploration in two depth ranges not well covered up to this point. The deepest known occurrence of both *Leiopathes* and *Lophelia* in the GoM is currently 627m. However, we have done very little exploration at depths between 627m and 850m, and we will consider additional sites in this range both to document the depth range of these species and because we may find additional abundant *Madrepora* occurrence in this range. We have also done relatively little additional exploration for corals at depths below 1,000m, and we will also consider additional exploration at logistically favorable sites at these greater depths to better understand the occurrence, density, and biodiversity of colonial cnidarians at these depths.

5.2 SITE CHARACTERIZATION OVERVIEW: MAPS, TEMP, PH, OXYGEN

CTD data was collected on the R/V *Nancy Foster* cruise in September-October 2008 and the *Ronald H. Brown/Jason II* cruise in August–September 2009. The CTD from the *Brooks McCall/Sentry* cruise did not yield any usable, realistic data—it was not working properly. Despite the overall success of the *Jason II* cruise, there were some issues with the agreement between the pH and DO probes on the CTD and some of our (and collaborators) previous data. We are currently working on a solution to this. Furthermore, no data was collected from the CTD on the *Jason II* cruise at sites West Florida Slope (J2-453) and GB535 (J2-460) due to technical issues with the CTD (Figure 5-19).

5.2.1 Multibeam and Physical Oceanography

Multibeam data: 22 sites

- Nancy Foster: 15 sites
 - plus W. Florida slope (USGS and S. Ross lab processing))
- *SENTRY*: 4 sites
- *Ronald H. Brown*: 5 sites
- *Jason II* SM2K: VK906 (Roberts' Reef)

CTD data: 15 total sites

- SeaView: 6 sites
- *Jason II*: 13 dives, 11 sites
- *Ronald H. Brown*: 3 casts
- Seward Johnson: 11 casts, 5 sites
 - plus 2 on subsequent cruise

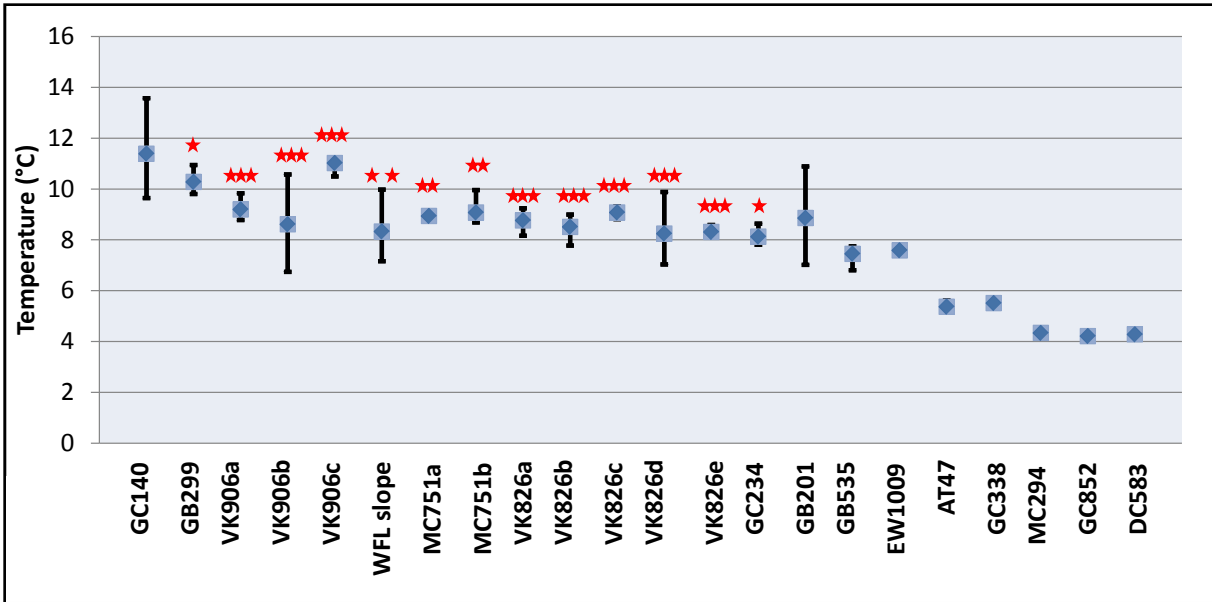


Figure 5-19. Temperature values for *Lophelia* in the GoM.

5.2.2 Aragonite Saturation States

We took water samples to measure the total alkalinity and aragonite saturation state at nine sites in 2009. Seven of these sites were undersaturated with aragonite. Despite low saturation states, scleractinian corals (including *Lophelia pertusa*) are present at these sites. Saturation states ranged from 0.75 (at GB535) to 1.50 (at VK906). At VK906, the water sample that yielded the high saturation state ($\Omega_{\text{arag}} = 1.50$) came from Roberts' Reef, the first cold-water coral carbonate mound found in the northern GoM. Subsequent water samples at Roberts' Reef showed that this high saturation state is not ubiquitous over the Reef.

To couple the saturation state data, we measured skeletal density of live and dead *Lophelia pertusa* skeletons collected from coral pots at GB535, MC751, VK826, and VK906. Skeletal densities ranged from 2.05 g/cc (at MC751) to 2.89 g/cc (at VK906). The density of pure aragonite is 2.93 g/cc. One-way ANOVA showed that live skeletons from VK906 were significantly different ($p < 0.05$) from live and dead skeletons at MC751 and GB535.

5.2.3 Live Lophelia Experiments

Lophelia pertusa tolerance and preference experiments

- approximately 30 colonies (~8 polyps/colony) available for experiments
- experienced ≤ 40 percent mortality from transport, initial transfer to aquaria, and
- mechanical failures

The maintenance aquarium is fully installed at the Cordes lab (Figure 5-20). The setup includes a 120-gallon glass aquarium, 50-gallon sump (biological and mechanical filtration), and a back-up chiller to control temperature during cold-room malfunctions. There are approximately 30 live *Lophelia* colonies (>5 polyps) in the maintenance aquaria. The experimental aquaria (6) are installed in a separate cold-room. These are 20 gallon tanks

equipped with individual filtration and pH controls. The live coral experiments are set to begin in March 2010 following genotyping of the live coral samples. We will perform temperature tolerance experiments first.

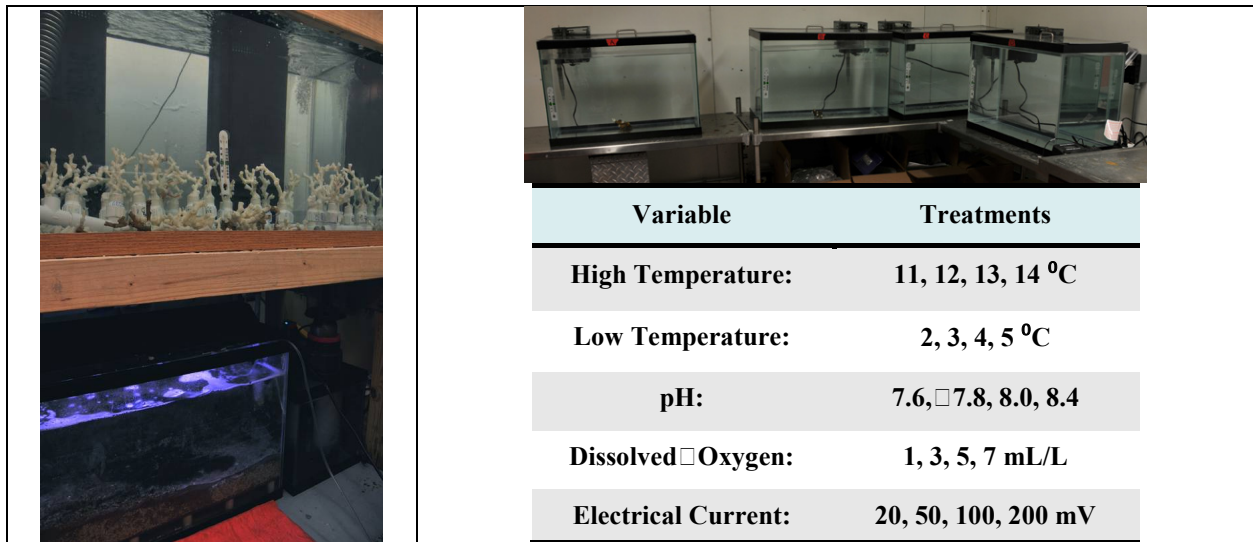


Figure 5-20. Garden Banks (GB) 535. Live *Lophelia* experiments.

6 ANIMAL DISTRIBUTIONS AT BASIN SCALE

6.1 *LOPHELIA* AND ASSOCIATE POPULATION GENETICS

Effective protection of deep reefs requires knowledge of the directions and distances that the mobile juvenile stage of corals (larvae) travel. However, larval movement (dispersal) can be influenced by various factors, including:

- Physical factors, such as topography and currents, which can promote or restrict dispersal
- Biological factors, such as larval duration and behavior. Generally, longer time spent by larvae in the water column is thought to translate to higher dispersal.
- Little is known about any of these factors in the deep sea.

It is very difficult to directly measure larval dispersal. Indirect estimates of larval dispersal (or reef connectivity) can be obtained through comparisons of genetic profiles. Since dispersal homogenizes genetic signatures between reefs, highly connected reefs should be similar and isolated reefs will have unique genetic signatures

The 2009 field season was highly successful in terms of sample collection for each of four genetics study components. The majority of collections were taken during two at-sea missions: the *Ronald H. Brown/Jason II* cruise with Chuck Fisher and Erik Cordes as chief scientists, followed by the USGS R/V *Seward Johnson*/JSL cruise with Steve Ross as chief scientist.

Sampling for *Lophelia* population genetics and reef connectivity was highly successful during the 2009 field season, with a total of 176 *Lophelia* samples from natural deep reef areas (Table 6-1, Figure 6-1). At the Viosca Knoll sites, the majority of new samples originated from areas of these Knolls that hadn't been sampled previously. Given this additional sampling, we have adequate sampling to examine fine-scale spatial genetic structuring at each of the main sites (VK826 and VK862/906). These analyses will allow for more detailed estimates of both clonality and fine-scale relatedness among individuals. Several new *Lophelia* sites were visited during the 2009 season, allowing for broader sampling coverage of the GoM. Key new sites were the West Florida Slope in the southeastern quadrant of the GoM and GB-535 in the western GoM. The addition of numerous *Lophelia* samples from MC751 makes this the best sampled natural site centrally located in the GoM. This site is located near the *Gulfoil* wreck, which is a high sampling priority in the upcoming field season given extensive *Lophelia* coverage. *Lophelia* samples from the *Gulfoil* wreck will allow for comparisons to be made between wreck sites, such as the *Gulfpenn* and Ewing Bank wrecks. Four *Lophelia* samples from each of two oil rigs, the Pompano and Virgo rigs, were obtained by TDI-Brooks. These samples are very interesting given the proximity of the rigs to our best sampled Viosca Knoll sites. From the *Lophelia* I project, a total of 104 samples have been analyzed from the GoM. With the addition of samples from the 2009 field season, we have nearly tripled our genetics sample size of *Lophelia* from the GoM, with 302 samples in total (Table 6-1). Our improved sampling of *Lophelia* throughout the GoM will allow more accurate estimates of gene flow both within the basin as well as between the GoM and northwestern Atlantic Ocean. During the upcoming field season, additional *Lophelia* samples from the following natural sites would even sampling: GB535; GB299; MC751; and the West Florida slope. Additional *Lophelia* samples from oil rigs

will be necessary before robust estimates of gene flow between natural and artificial *Lophelia* reefs can be made.

Table 6-1.

Collection Summary

Site	Lat	Long	Depth (m)	Jason II Cruise	Loph.	Jason II Cruise	JSL cruise	TDI-BI	<i>Lophelia</i> l
VK862	29.10713	88.38459	317		x	0	2		17
GB299	27.68562	92.22344	355	x	x	0	0		0
VK906	29.08513	88.38475	380	x	xxx	33	22		0
Wfla	26.184105	84.70741	425	x	xx	9	21		0
MC751	28.19113	89.80375	450	x	xx	12	9		0
VK826	29.16112	88.01688	457	x	xxx	32	23		74
GC234	27.74695	91.22447	500		x	0	0		5
GC354	27.60053	91.82379	515		x	0	0		2
GB535	27.42574	93.58819	530	x	xx	13	0		0
MC885	28.06465	89.69509	627		x	0	0		0
VK Wreck			612		x	0	0		0
EW wreck			621		x	3	0		0
<i>Gulfpenn</i>			554		xx	11	0		6
GULFOIL			600		xx	0	0		0
Pompano								4	
Virgo								4	
Total						113	77	8	104
Grand Total									302

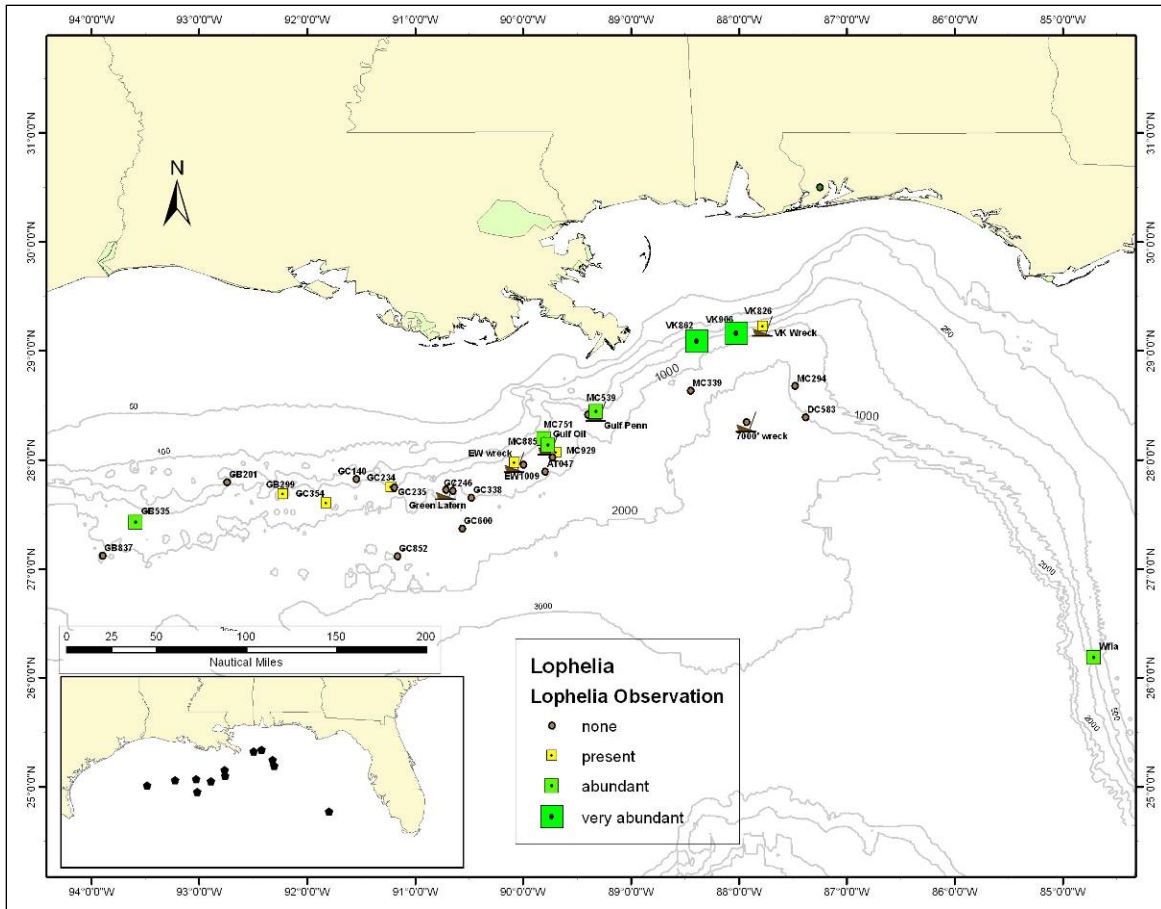


Figure 6-1. *Lophelia* II sampling: natural reefs.

Progress was made in sampling *Lophelia*-associated invertebrates for community genetics during the 2009 field season. Sixty *Eumunida picta* squat lobsters were collected from four sites in the GoM (Table 6-2). Twenty-four *Echinus* urchin and fifteen *Eunice* polychaete samples, were collected from the West Florida Slope and Viosca Knoll. Additional samples of each of these species from the southern and western GoM would be useful during the 2010 field season (Figure 6-2).

Table 6-2.

Community Genetics Collection

						Total	Total
	WFL	VK826	VK906	MC751	GB535	Gulf	W Atlantic
<i>Eumunida picta</i>	10	14	25	10	1	60	80
<i>Echinus tyloides</i>	2	14	8	0	0	24	53
<i>Eunice</i> sp.	5	8	2	0	0	15	55
Total						99	188

The scleractinian coral *Madrepora oculata* is not common in the GoM, but has been observed at four sites during several projects. Generally, *M. oculata* observations in the GoM do not overlap with sites at which *Lophelia* or *Lophelia* associates were sampled. On the *Jason II* cruise, *M. oculata* samples were collected from AT047 (one sample) and GC852 (two samples). During previous projects, an additional six *M. oculata* samples were collected (three from *Lophelia* I at MC885 and three from Chemo III at MC462 and GC852). DNA sequences and microsatellites will be generated from GoM *M. oculata* samples for comparison with 44 samples from the North Atlantic Ocean. During the *Jason II* cruise, a scleractinian coral thought to be *M. oculata* was collected at GB299. Upon further examination, the initial field identification does not appear to be correct. This sample, along with several other solitary corals collected during the 2009 field season, await identification by Dr. Stephen Cairns at the Smithsonian Institution.



Figure 6-2. Mobile fauna associated with *Lophelia*.

Numerous galatheid crab samples were also collected during the 2009 field season. These samples will be discussed in a report by Martha Nizinski. DNA extractions of tissue samples are underway and DNA sequences will be generated for phylogenetic and phylogeographic analyses.

6.2 ANTIPATHARIAN AND *CALLOGORGIA* SPP POPULATION GENETICS

6.2.1 Octocoral Collections

Octocorals were collected for genetic analyses from 16 sites during the 2008 and 2009 field seasons (Figure 6-3). The 2008 (20 Sep–2 Oct 2008) cruise with the ROV *Seaview* yielded 14 specimens representing ca. four species collected from three authigenic carbonate sites. During the 2009 cruise (19 Aug–12 Sep 2009) with the ROV *Jason II*, 118 octocoral specimens representing ca. 28 species were collected from 11 authigenic carbonate sites. Five specimens were collected from two shipwreck (*Green Lantern*, *Gulfenn*) sites, adding one extra species to the total list. During the cruise (15–24 Sep 2009) with the USGS personnel and the *HOV JSL*, an additional 37 specimens were collected from five sites. These collections yielded ca. eight additional octocoral species. In total, 174 octocoral specimens representing ca. 37 species were collected during the 2008–2009 field season.

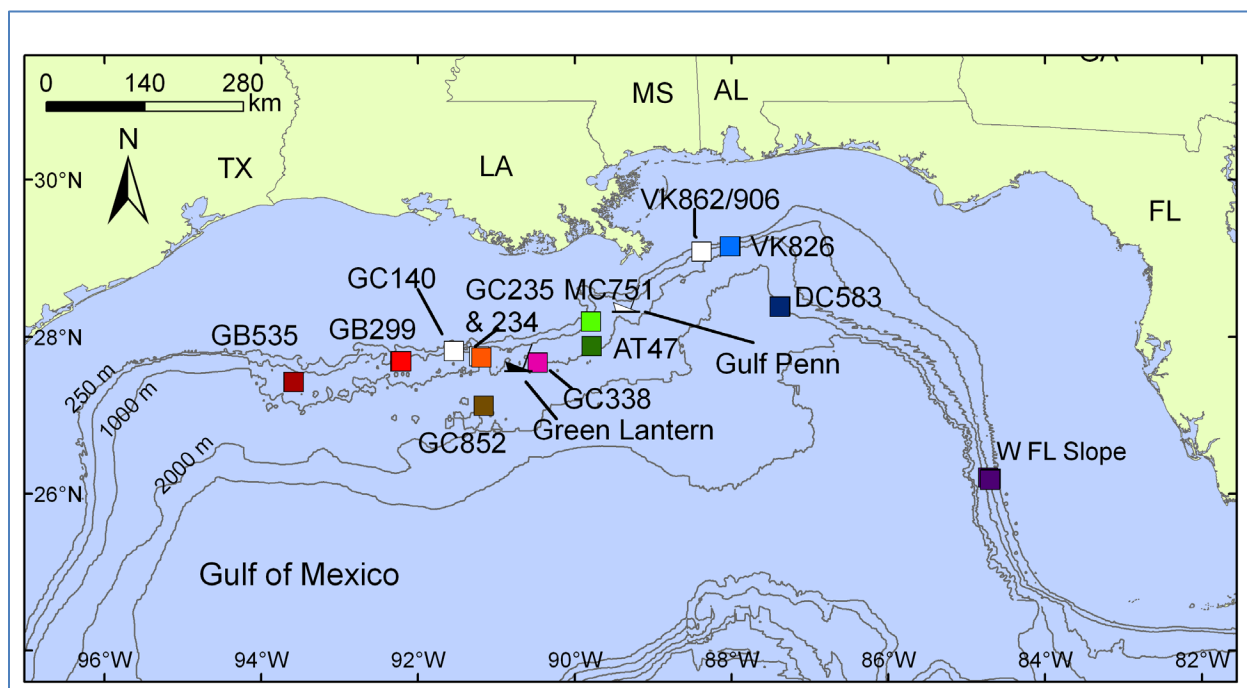


Figure 6-3. Octocoral collections 2008-2009.

We prioritized *Callogorgia* collections in 2008 and 2009, to obtain sufficient samples for population-level genetic analyses. Forty-four percent of our octocoral collections were *Callogorgia*. Seventy-six specimens were collected from 10 sites, with collections ranging from 1-22 individuals per site. Although this is an adequate number of specimens to begin genetic analyses, more individuals (~ 30) are needed per site for appropriate population-level analyses.

The diversity and abundance of octocorals varied across sites in the GoM, with the shipwrecks depauperate of octocorals (Table 6-3). Octocorals, particularly *Callogorgia*, were abundant at MC751. We collected the highest number of specimens at this site, with 22 *Callogorgia* specimens out of a total of 35. *Callogorgia* was also abundant at GB299 and VK826, where we collected 15 and 17 specimens, respectively. *Callogorgia* also dominated the octocoral assemblage observed at the shallowest site visited, GC140. However, we were only

able to collect 4 specimens with the ROV *Seaview*. In contrast to the northern GoM, *Callogorgia* was absent from the West Florida Slope, but the octocoral assemblage appeared diverse at this site. We collected 22 specimens representing at least 12 species at the West Florida Slope.

Table 6-3.

Octocoral Diversity and Abundance

Site	Lat	Long	Depth (m)	Callogorgia	Seaview Cruise	J II Cruise	JSL Cruise	Other Octo-corals	Seaview Cruise	J II Cruise	JSL Cruise
GC140	27.82024	91.54463	259	xxx	4	0	0	x	7	0	0
VK862	29.10713	88.38459	317	xx	0	0	4	x	0	0	0
GB299	27.68562	92.22344	355	xxx	0	15	0	xx	0	6	0
VK906	29.08513	88.38475	380	x	0	1	0	x	1	1	3
Wfla	26.184105	84.70741	425					xx	0	10	12
MC751	28.19113	89.80375	450	xxx	0	14	8	xx	0	5	8
VK826	29.16112	88.01688	457	xx	0	15	2	x	0	6	0
GC234	27.74695	91.22447	500	xx	1	0	0	x	1	0	0
GC354	27.60053	91.82379	515					x	0	0	0
GC235	27.74278	91.19191	530	xx	0	7	0	x	0	0	0
GB535	27.42574	93.58819	530					x	0	8	0
MC885	28.06465	89.69509	627	xxx	0	0	0	x	0	0	0
AT047	27.88999	89.79425	835					x	0	3	0
GC338	27.64876	90.47948	939	x	0	4	0	x	0	3	0
GC852	27.11175	91.16488	1,410					xx	0	11	0
DC583	28.387143	87.38143	2,440					xx	0	9	0
VK Wreck			612								
EW wreck			621								
<i>Gulfpenn</i>			554					x	0	1	0
<i>Gulfoil</i>			600								
<i>Green Lantern</i>			915	x	0	1	0	x	0	3	0
Pompano											
Virgo											
Total					5	57	14		9	66	23
Grand Total							76				98

J II = *JASON II*

6.2.2 Preliminary Phylogenetic Analyses

The 5-foot end of the mitochondrial *msh* gene was analyzed for 55 specimens to date. DNA was extracted following Phenol/ Chloroform/ IAA protocols. PCR was carried out in 25µl reactions with: 2.5µl template, 1mM dNTPs, 1µM of each primer (ND4-2599F, Mut-3458R), 2.5mM MgCl₂, 1X BSA, 1X TE, and 1.2 unit EconoTaq polymerase. The following temperature profile was employed: an initial denaturing step of 94° C (5 min), followed by 32 cycles of 94° C (45 sec), 50° C (45 sec), 72° C (1 min), and then a final elongation step of 72° C (10 min).

Approximately 850 bp sequences were obtained (Genewiz, Sanger Sequencing). Sequences were then edited in BioEdit and aligned using ClustalX. The most similar *msh* sequences were downloaded from GenBank using BLAST and included in the alignment. Bayesian analyses (MrBayes v 3.1.2) were performed on four sets of octocoral sequences: 1) sub-order Holaxonia, 2) sub-orders Calcaxonia-Scleraxonia, 3) family Paramuriceidae, and 4) *Callogorgia* clade. Outgroups for each clade were included in analyses. For each Bayesian analysis, we chose the GTR model with gamma-distributed rate variation across sites and a proportion of invariable sites. 1X10⁶ generations were employed followed by a burnin of 2,000. Consensus trees were constructed in FigTree.

Phylogenetic analyses of 55 specimens yielded 10 calcaxonia taxa followed by eight holaxonia and one scleraxonia. Higher genetic diversity was apparent among the deep (> 800 m) sites and the West Florida Slope. The octocoral assemblage at the West Florida Slope appears to differ from the octocoral assemblages at the other sites in the GoM. It is possible that the Loop Current serves as a biogeographic barrier between the eastern and northern GoM.

Bayesian analysis of the Paramuriceidae revealed seven species. *Paramuricea* cf. *multispina* and ?*Acanthogorgia* spp. were restricted to sites < 600 m (MC751, GB299, VK826, GB535). Either morphospecies or cryptic species are evident within the *Paramuricea* clade; additional analyses are warranted (Figure 6-4).

6.2.3 Future Work

We will continue to sequence the 5-foot end of the mitochondrial *msh* gene for the remaining specimens collected in 2009 and 2008. In addition, we will sequence the mitochondrial *ND2* gene region. Nuclear molecular markers will be explored and included as needed in phylogenetic analyses. In addition, population-level analyses of *Callogorgia* will begin this year. We will develop appropriate molecular markers for *Callogorgia* that can resolve patterns of genetic differentiation within and among sites. Finally, (in cooperation with Peter Etnoyer) we will begin morphological examination of 2008–2009 octocoral specimens.

6.3 GENETICS STUDIES OF DEEP CORALS AND ASSOCIATED COMMUNITIES

Corals were collected on three cruises in 2008 and 2009. Limited collections were made on the 2008 cruise with the Seaview systems ROV, while the 2009 field season was highly successful in terms of sample collection for each of the four genetics study components (Table 6-4). The majority of collections were taken during two at-sea missions: the TDI-Brooks R/V *Ronald H. Brown/Jason II* cruise with Chuck Fisher and Erik Cordes as chief scientists, followed by the USGS R/V *Seward Johnson/JSI* cruise with Steve Ross as chief scientist.

6.3.1 Antipatharians

A total of 83 Antipatharians were sampled in 2009, including 73 *Leiopathes* samples. *Leiopathes* was found from 259m–627m but was less abundant >500m. The Viosca Knoll sites yielded the most samples including several color morphs ranging from red, bright red, orange and white to salmon. The existence of this wide variety of color morphs might indicate the presence of several, as yet undescribed species of *Leiopathes* in the GoM. Before population genetic analysis is conducted, this question must be resolved. We are thus testing recently developed mitochondrial DNA sequence markers to aid in distinguishing species. Once the species question has been resolved, population genetic studies can proceed. For population genetic analysis to be successful, an estimated 30 individuals per population are needed. We have near adequate sample sizes of the red and the white color morph from Viosca Knoll for this purpose. Our main question is whether *Leiopathes* colonies from throughout the Gulf represent one interbreeding population or if significant population structure is observed. To detect population structure, we are developing highly polymorphic microsatellite markers. Preliminary results indicate that the *Leiopathes* genome has a high abundance of microsatellite loci of greater lengths than observed in scleractinian corals. Sequence lengths ranged from ca. 71–564 bp (basepairs) and 30% of searched sequences had microsatellites. The average length of the microsatellite loci was 299 bp. We are thus confident that we will be able to develop adequate markers for the population genetic study. During the upcoming field season, additional *Leiopathes* samples from the following natural sites would bring us to the required 30 samples per population: GB299 and GC140/234 in biogeographic region III, VK862/906 and VK826 in biogeographic region II; and the West Florida slope in biogeographic region I. Biogeographic region designation follows Cairns and Opresko (1993).

Table 6-4.

Diversity and Abundance of Octocorals

Site	Lat	Long	Depth	Jason II Cruise	Loph.	Jason II Cruise	JSL Cruise	TDI	Lophelia I	Callag.	Seaview Cruise	Jason II Cruise	JSL Cruise	Other Octos.	Seaview Cruise	Jason Cruise	JSL Cruise	Galatheids	JasonII Cruise	JSL Cruise
GC140	27.82024	91.54463	259							xxx	4	0	0	x	7	0	0			
VK862	29.10713	88.38459	317		x	0	2		17	xx	0	0	4	x	0	0	0			
GB299	27.68562	92.22344	355	x	x	0	0		0	xxx	0	15	0	xx	0	6	0			
VK906	29.08513	88.38475	380	x	xxx	33	22		0	x	0	1	0	x	1	1	3	xxx	3	24
Wfla	26.18411	84.70741	425	x	xx	9	21		0					xx	0	10	12	xxx	1	11
MC751	28.19113	89.80375	450	x	xx	12	9		0	xxx	0	14	8	xx	0	5	8	xxx	5	16
VK826	29.16112	88.01688	457	x	xxx	32	23		74	xx	0	15	2	x	0	6	0	xxx	4	30
GC234	27.74695	91.22447	500		x	0	0		5	xx	1	0	0	x	1	0	0			
GC354	27.60053	91.82379	515		x	0	0		2					x	0	0	0			
GC235	27.74278	91.19191	530	x						xx	0	7	0	x	0	0	0			
GB535	27.42574	93.58819	530	x	xx	13	0		0					x	0	8	0	x	6	
MC885	28.06465	89.69509	627		x	0	0		0	xxx	0	0	0	x	0	0	0			
AT047	27.88999	89.79425	835	x										x	0	3	0	x	1	
GC338	27.64876	90.47948	939	x						x	0	4	0	x	0	3	0	x	1	
GC852	27.11175	91.16488	1410	x										xx	0	11	0	x	3	
DC583	28.38714	87.38143	2440	x										xx	0	9	0			
VK Wreck			612		x	0	0		0											
EW wreck			621		x	3	0		0									x	6	
Gulfpenn			554		xx	11	0		6					x	0	1	0	x	2	
Gulfoil			600		xx	0	0		0											
Green Lantern			915							x	0	1	0	x	0	3	0			
Pompano								4												
Virgo								4												
Total						113	77	8	104		5	57	14		9	66	23			
Grand Total									302				76				98			

6.3.2 *Lophelia*

Sampling for *Lophelia* population genetics and reef connectivity was highly successful during the 2009 field season, with a total of 176 *Lophelia* samples from natural deep reef areas. At the Viosca Knoll sites, the majority of new samples originated from areas of these knolls that hadn't been sampled previously. Given this additional sampling, we have adequate sampling to examine fine-scale spatial genetic structuring at each of the main sites (VK826 and VK862/906). These analyses will allow for more detailed estimates of both clonality and fine-scale relatedness among individuals. Several new *Lophelia* sites were visited during the 2009 season, allowing for broader sampling coverage of the GoM. Key new sites were the West Florida Slope in the southeastern quadrant of the GoM and GB535 in the western GoM. The addition of numerous *Lophelia* samples from MC751 makes this the best sampled natural site centrally located in the Gulf. This site is located near the *Gulfoil* wreck, which is a high sampling priority in the upcoming field season given extensive *Lophelia* coverage. *Lophelia* samples from the *Gulfoil* wreck will allow for comparisons to be made between wreck sites, such as the *Gulfpenn* and Ewing Bank wrecks. Four *Lophelia* samples from each of two oil rigs, the Pompano and Virgo rigs, were obtained by TDI-Brooks. These samples are very interesting given the proximity of the rigs to our best sampled Viosca Knoll sites. From the *Lophelia* I project, a total of 104 samples have been analyzed from the GoM. With the addition of samples from the 2009 field season, we have nearly tripled our genetics sample size of *Lophelia* from the GoM, with 302 samples in total. Our improved sampling of *Lophelia* throughout the GoM will allow more accurate estimates of gene flow both within the basin as well as between the GoM and northwestern Atlantic Ocean. During the upcoming field season, additional *Lophelia* samples from the following natural sites would even sampling: GB535; GB299; MC751; and the West Florida slope. Additional *Lophelia* samples from oil rigs will be necessary before robust estimates of gene flow between natural and artificial *Lophelia* reefs can be made.

6.4 GALATHEID AND OTHER DISTRIBUTION AND PHYLOGENETICS

USGS supports BOEM interests in deep-sea coral research efforts by funding a separate but integrated research group to conduct complimentary scientific sampling and work in cooperation and collaboration with the TDI Brooks team of *Lophelia* II investigators. A main component within the USGS group is the study of taxonomy, ecology, and phylogenetics of megafaunal invertebrates associated with both deep-sea coral and surrounding habitats. Accurate identification of species is fundamental and critical to all aspects of the *Lophelia* II project. Through extensive sampling during the 2008 and 2009 field seasons (Steve W. Ross, chief scientist), both on and adjacent to the coral habitats as well as off-reef habitats, we continue to add to our knowledge of the diversity and species composition of mega-invertebrates that utilize these habitats. The species accumulation curve is still ascending and has not reached an asymptote. Most collections continue to add species to the list of species that utilize these habitats. For example, in 2009, 15 species of galatheid crabs were sampled on or adjacent to corals. Many of these species had not been collected previously. This is due in part to increased sampling efforts, use of new sampling methods (push cores, box cores, suction sampling at base of corals) and sampling new locations. At least four species new to science have been discovered. These include three new species of galatheid crabs and one new species of alpheid shrimp. More new species are expected in various phyla as identifications to the lowest taxonomic level possible continue.

Sampling methodologies differed between the two sampling years. In 2008, the majority of collections were made away from deep coral habitats using various nets and trawls. These collections, taken from 45 stations (30 bottom, 13 mid-water, and two surface stations), yielded 1873 specimens which represent seven phyla and 55 families. To date, 85 percent of individuals are identified to family and 60 percent are identified at least to genus. Additionally, 105 DNA tissue samples and 351 isotope samples were collected from this material. In 2009, collections of organisms on or adjacent to the coral habitat were made using the *Johnson Sea Link*. These collections, taken from 47 stations (21 bottom, 17 mid-water, 9 surface stations), yielded 647 specimens which represent eight phyla and 45 families. To date, 90 percent of this material is identified to family, 85 percent at least to genus. Additionally, 267 DNA tissue samples and 175 isotope samples were collected from this material.

Overall, species diversity was higher in collections taken on or adjacent to coral habitats, but the number of individuals collected per species was lower. In contrast, collections made in off-reef habitats were less diverse, but consisted of larger numbers of individuals for each species collected. In both sampling years crustaceans were the dominant taxon collected both on and off the coral habitat. Crustaceans represented 66 percent and 45 percent of all individuals collected in 2008 and 2009, respectively.

An additional 23 samples were collected during the 2009 TDI-Brooks R/V *Ronald H. Brown* cruise (Chuck Fisher and Erik Cordes, chief scientists) for inclusion in this portion of the study. These samples consisted of 12 species of galatheid crabs. Chirostylids (five species) were well represented in these collections. Of particular interest are two specimens of *Uroptychus* and two specimens of *Gastroptychus*. Members of these genera are poorly represented in samples previously collected on and adjacent to the coral habitats. Six species of *Munidopsis* (nine specimens) and one species of *Munida* (three specimens) were represented in the galatheid collections also. Additionally, sea urchins (*Echinus tyloides*), a lithodid crab (*Paralomis cubensis*) and eunicid polychaetes were included in these collections. These samples were a valuable addition to the USGS collections, increasing the diversity of galatheids sampled during the 2009 field season to approximately 20 species. DNA tissue samples were taken from each individual collected.

Material collected continues to be processed and identified to the lowest taxonomic level possible. We continue to refine our knowledge of species abundances, geographic and bathymetric distributions. It appears that species thought to be rare may be more common than once thought based on observed differences between our data, published reports and material housed in museum collections. Two new records for the GoM have been identified. Additionally, data gleaned from these samples will be used in a variety of taxonomic and ecological investigations. Genetic sequences provided by Cheryl Morrison will be used in phylogenetic and phylogeographic studies.

6.4.1 Objectives

- Provide accurate taxonomic identifications of associated megafaunal invertebrate assemblages observed on and around deep-sea coral habitats
- Assess levels of endemism at deep coral habitats
- Examine patterns of species diversity and geographic distribution of the mega-invertebrate fauna between sites; comparisons with similar habitats in other locations

- Assess community structure, basic ecology and population dynamics of the invertebrate fauna
- Examine phylogenetic and phylogeographic relationships of these species assemblages

6.4.2 Taxonomy

Accurate identifications are fundamental and critical to all aspects of this research program. The following is a summary of taxonomic progress.

- 2008: 7 Phyla; 55 Families; 1,873 species
 - 80% identified to Family; 60% to Genus
 - 45 stations: 30 bottom; 13 mid; 2 surface
- 2009: 8 Phyla; 45 Families; 647 species
 - 90% identified to Family; 85% to Genus
 - 47 stations: 21 bottom; 17 mid; 9 surface
- Species new to science identified
 - At least four new decapod crustaceans
 - More expected from various phyla
 - Endemic species minimal
- Patterns of diversity
- Species accumulation curve still ascending
- Increased sampling, new sampling methods, new sampling locations

6.4.3 Abundance and Distribution

- Large sample sizes provide data necessary to assess relative abundances and population dynamics of some species
- Species thought to be rare may actually be more common than once thought
- New records for the GoM
- Refining distributions for some species
- Geographic range
- Bathymetric range

6.4.4 Galatheid phylogeny

- Related groups of species occupy similar depths
- Closest relatives for some in Eastern Pacific

- Possible sister species
- Opportunities to examine rates of speciation
- Regional perspectives

6.4.5 Shrimps

- Relationships among mid-water shrimps
- Relationships between mid-water and benthic shrimps
- Comparisons between chemo and coral habitats

6.4.6 Echinoderms

- Phylogeography of *Novodinia antillensis*
- Phylogeny of goniasterid starfishes

6.4.7 Future Directions

Taxonomic and ecological investigations continue

- Provide identifications; complete species descriptions
- Gathering abundance/distribution/biodiversity data
- Habitat use; community structure
- Coral versus non-coral habitat megainvertebrate assemblages
- Collaborative work with other aspects of USGS science plan (microbes, trophodynamics, residency, community genetics)
- Phylogenetic analyses of additional groups of organisms
- Comparative phylogeography
- Comparisons between SEUS and GoM associated faunal assemblages

7 CORAL AND COMMUNITY ECOLOGY

7.1 WITHIN-SITE SCALE CORAL/COMMUNITY DISTRIBUTION

Due to the exploratory component of this study, one first-order goal was as comprehensive a description of the species diversity and habitat characteristics present at each site visited as possible. Because we used very effective and efficient imagery and physical collection devices (Figure 7-1), we have developed an inventory of species present that is considerably more comprehensive than would be possible otherwise with the dive time available.

7.1.1 Goals

- Verify and document known or suspected deep-coral sites
- Inventory relative proportions of habitat and fauna
- Rank differences among sites to identify similar/dissimilar sites
- Identify causes of differences
- Assign confidence intervals to findings

Figure 7-2 through Figure 7-5 present a variety of sites visited during the cruises and products produced.



Figure 7-1. The AUV SENTRY.

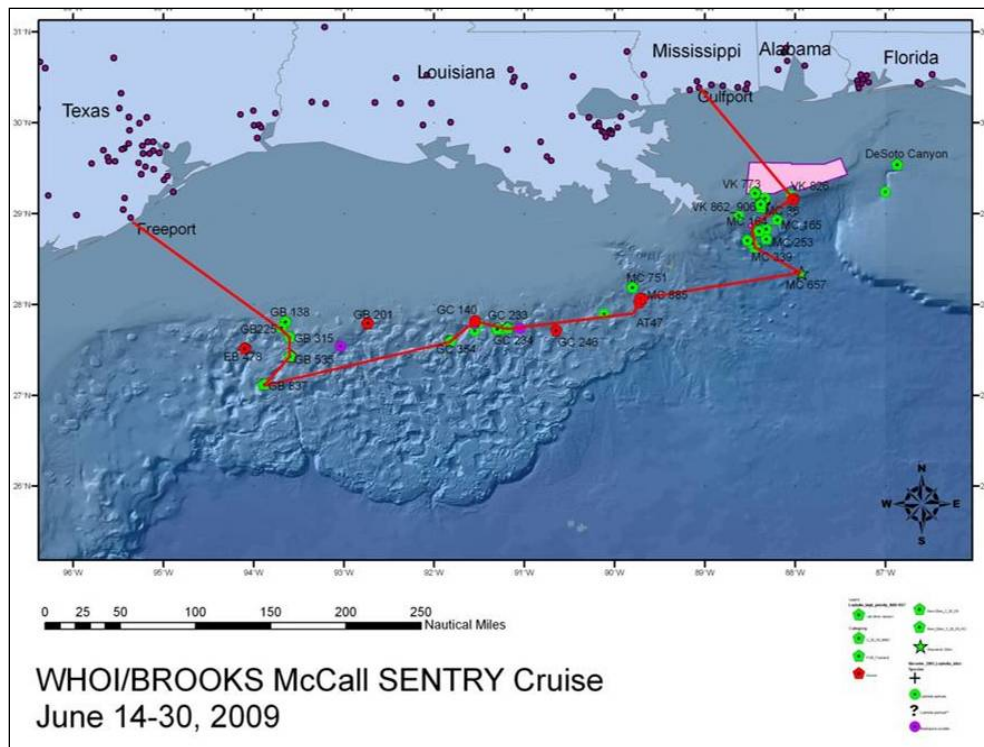


Figure 7-2. The RV *Brooks McCall*/WHOI AUV *Sentry* cruise.

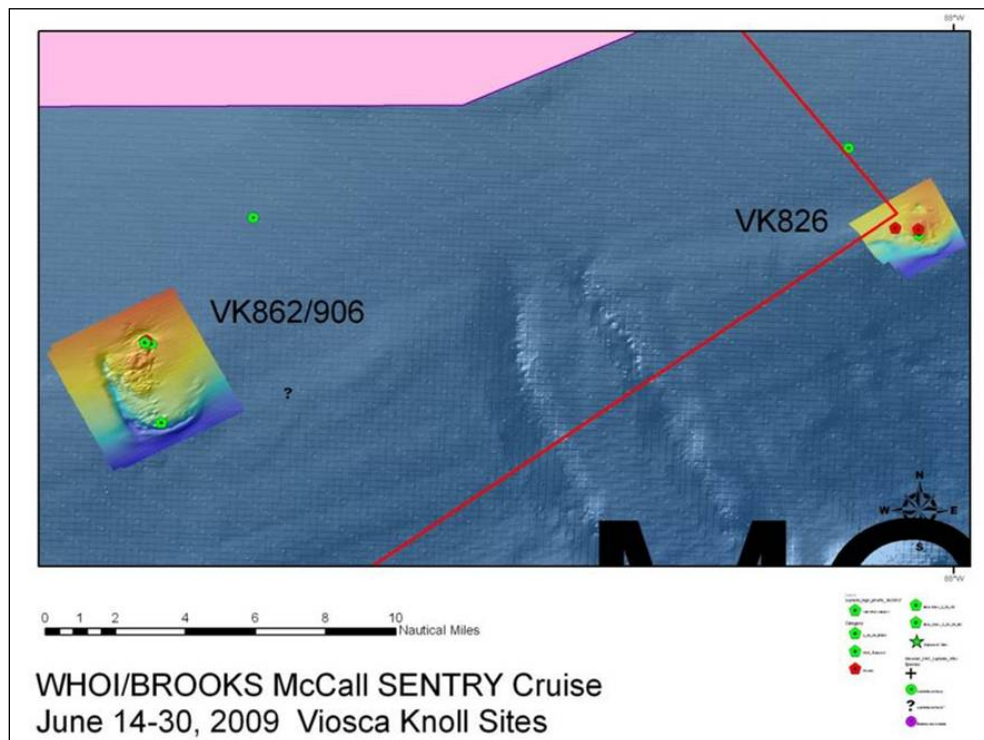


Figure 7-3. The R/V *Brooks McCall*/WHOI AUV *Sentry* cruise, Viosca Knoll.

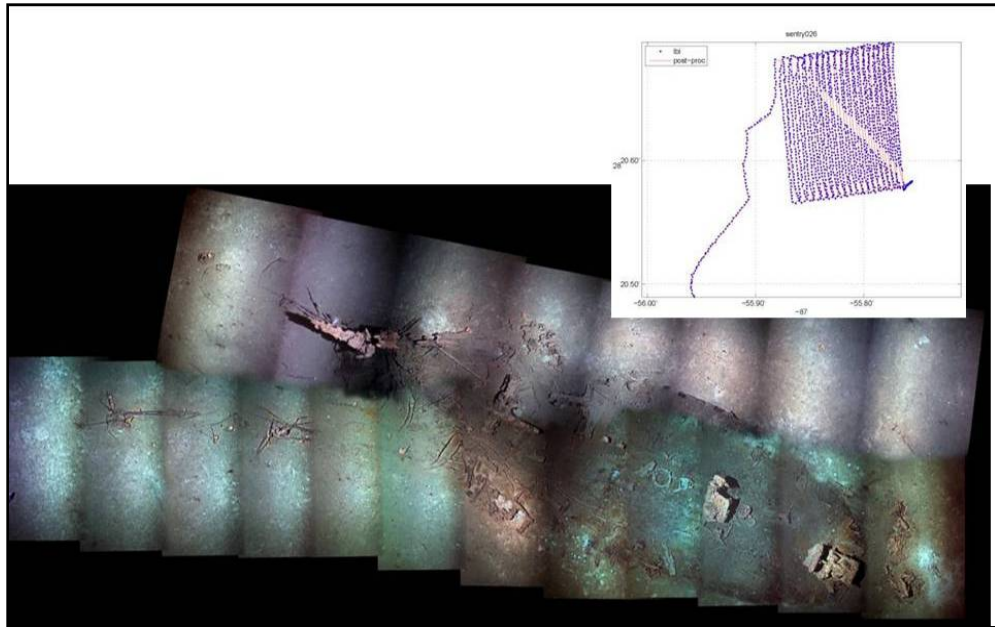


Figure 7-4. The R/V *Brooks McCall*/WHOI AUV *Sentry* cruise, 2,700m shipwreck.

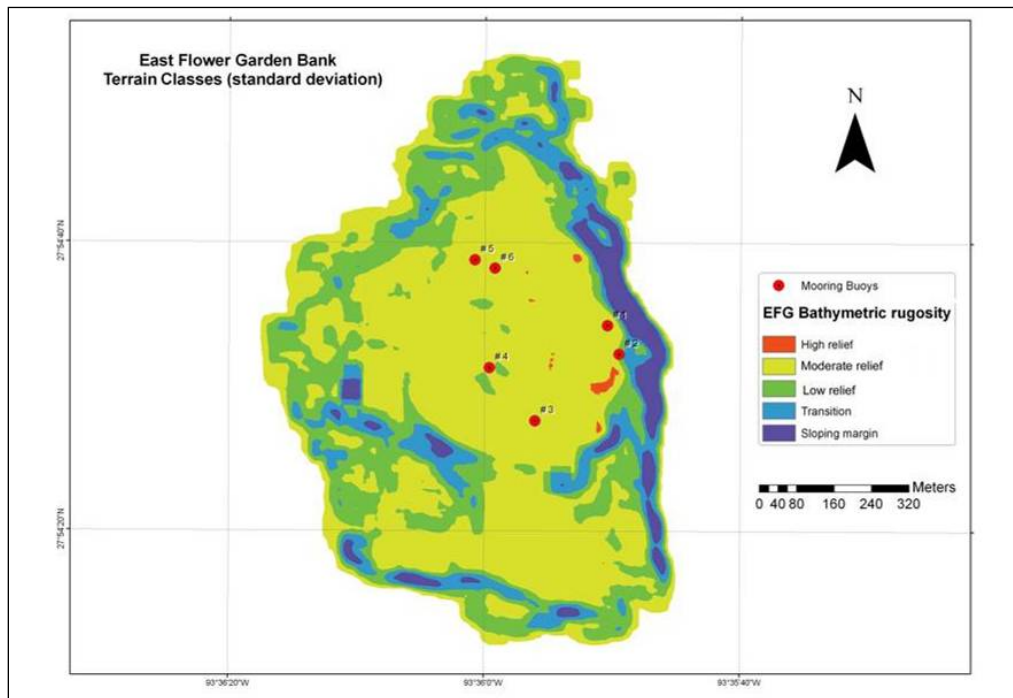


Figure 7-5. Coral habitat terrain classification.

7.2 CORAL AGGREGATION SCALE COMMUNITY ECOLOGY

On the most recent *Jason II* cruise on *Ronald H. Brown*, a total of 15 photomosaics were obtained at seven different sites. *Lophelia pertusa* colonies were imaged at GB535, MC751, VK906, and VK826. *Madrepora oculata* was imaged at AT047, and a stand of *Callogorgia* sp. gorgonians and associated community was imaged at GB299. The mosaic over the coral community at GC852 represents a time-series study as it was previously imaged in its entirety in 2007 as part of the Chemo III project. Images were also obtained for one large-scale mosaic of the corals on the *Gulfpenn* and mosaics of the other wreck sites for use by the archaeology group. There has been some progress on the assembly of these mosaics, and results from the image analysis will be forthcoming.

There have been a total of 14 coral-pot collections obtained at seven different sites. Five collections were of *L. pertusa* associated communities at five sites (West Florida slope, G535, MC751, VK906, VK826), one was from the wreck of the *Gulfpenn*, and one was of the *M. oculata* associated community from AT047. Thus far, 51 taxa have been identified from these collections. The vast majority of these identifications are to higher taxonomic levels, and we are in the process of sending off representative specimens to the taxonomic collaborators for further identification. The most common groups in the collections are primarily suspension feeders including hydroids, polychaetes, sponges, and anemones. Other common groups in the community collections include predatory polychaetes, shrimp, amphipods, and galatheid crabs. Many of these taxa were subsampled for stable isotope studies. A total of 193 samples of 49 different taxa (including coral species and other collections) were obtained and are being processed in the lab at Penn State for further analysis.

7.3 MEIOFAUNA AND TROPHODYNAMICS

Our study of trophic interactions in the communities uses a combination of tissue stable C, N, and S isotope determinations and the quantitative data for each species present.

7.3.1 Background

- 3D substrate with matrix of interstitial spaces providing habitat, more complex than a sediment flat
- Sheltered cavities within colonies provide pockets for sediments to accumulate
- Branching coral supplies substrate for encrusting organisms (Figure 7-6)
- Discrete communities reside within coral relative to adjacent habitats

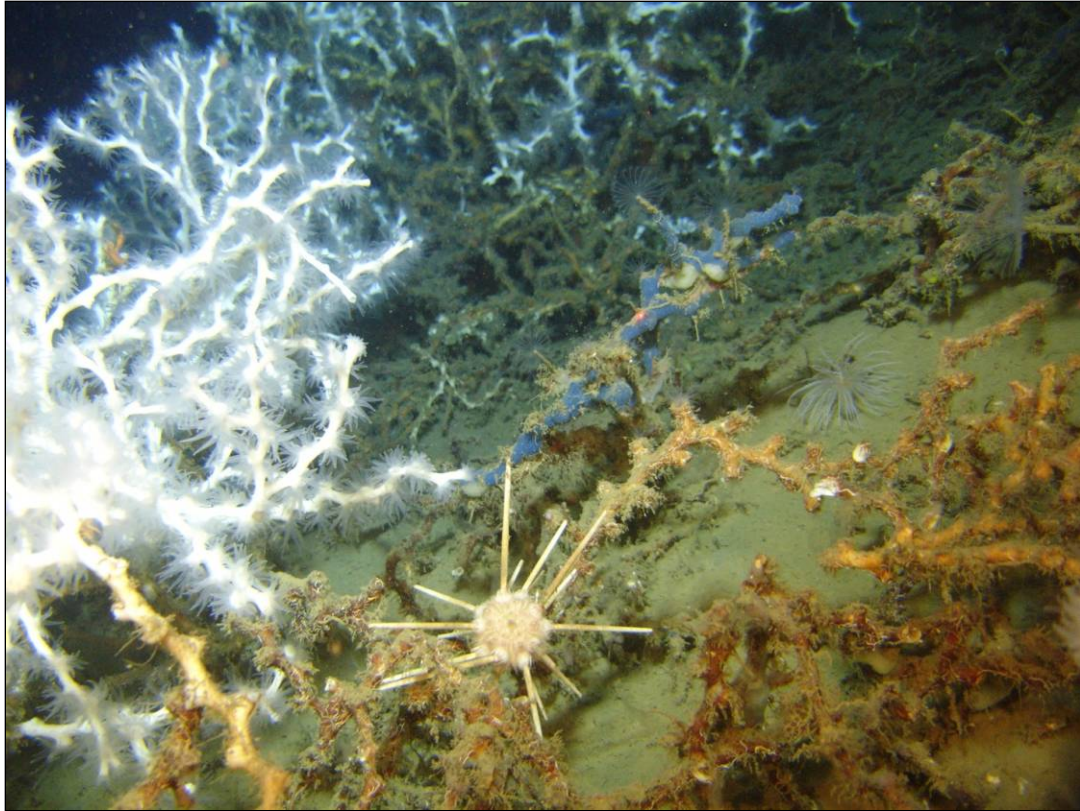


Figure 7-6. Branching coral substrate.

- Most work has focused on larger macrofauna and megafauna (e.g., Fossa and Mortensen 1998; Cordes et al. 2008)
- Very little is known regarding the smaller, meiofauna (Figure 7-7) associated with deep-sea corals (Jensen and Frederiksen 1992)
- Deep-sea corals enhance habitat complexity and promote nematode biodiversity
- Depth-dependent pattern in meiofaunal abundance in deep GoM associated with steep gradient in chlorophyll a abundance (food availability)

Ecological Importance of Infauna

- Alter sediment chemistry
- Breakdown organic matter
- Transfer nutrients
- Link primary producers to higher consumers



Figure 7-7. Meiofauna associated with deep-sea corals.

7.3.2 Progress

- Sample collection sites:
 - GoM and SEUS Atlantic
- Community collections:
 - Push Cores: 33cm² x 10 cm deep
 - Coral/Mussel pots: < 1 mm, > 45 mm fraction
- Habitats:
 - Live coral-Lophelia, Madrepora, Callogorgia
 - Background sediments
 - Five Wrecks, near and far core samples
- Subset of pushcores collected for sediment characterization: organic C/N, isotopes, particle size (Figure 7-8, Figure 7-9).

- Prioritized *Lophelia* samples from VK 826 and 906/862, > 300 mm fraction
 - best representation in terms of previous work
 - greatest number of samples near and far
 - plus chemistry cores



Figure 7-8. Pushcores and sub-sampling.

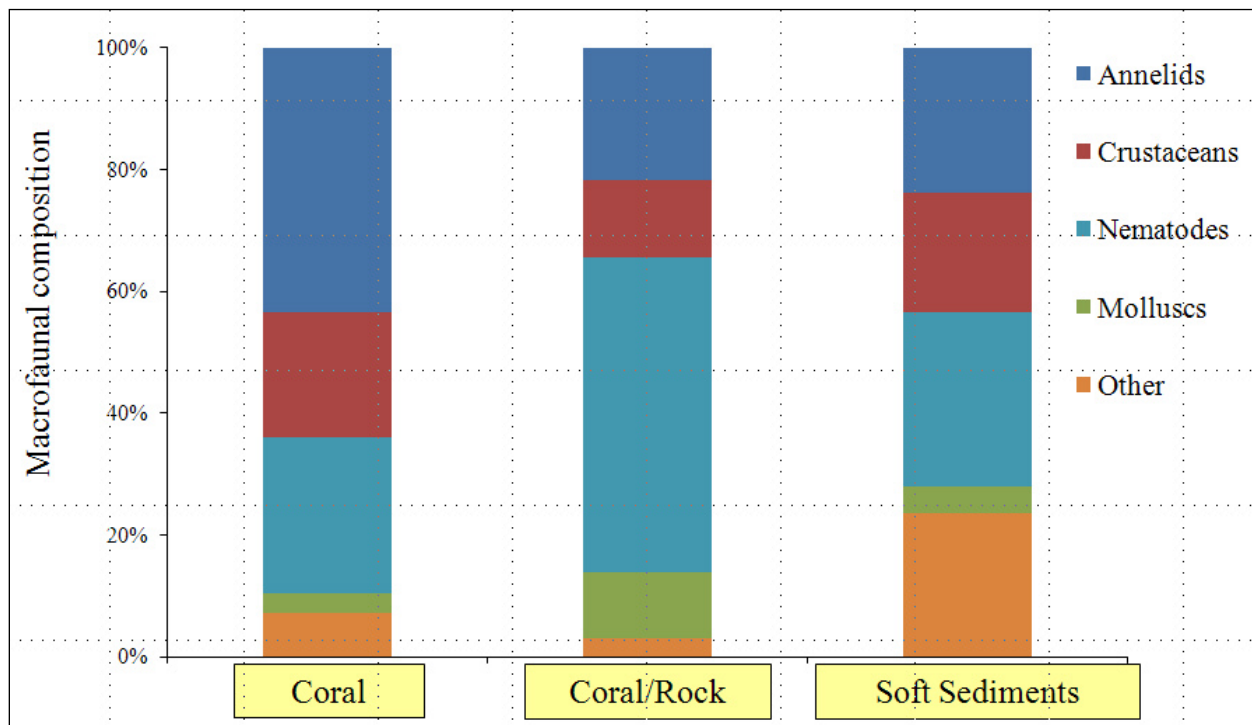


Figure 7-9. Macrofaunal composition compared with substrate.

7.3.3 Trophodynamics

- Energy flow around deep-sea coral and hardground environments
- Defining directions of energy flow within and among deep-sea and midwater ecosystems

7.3.4 Stable Isotope Review

- Stable isotopes provide information on time-integrated diets of the consumer
- Stable C isotopes estimate possible food sources (you are what you eat)
- Stable N isotopes estimate trophic level (Figure 7-10)

Work to date:

- Deep-sea corals fueled by POM, various zooplankton prey, or mixed diet
- Benthic food web reliant on phytoplanktonic production

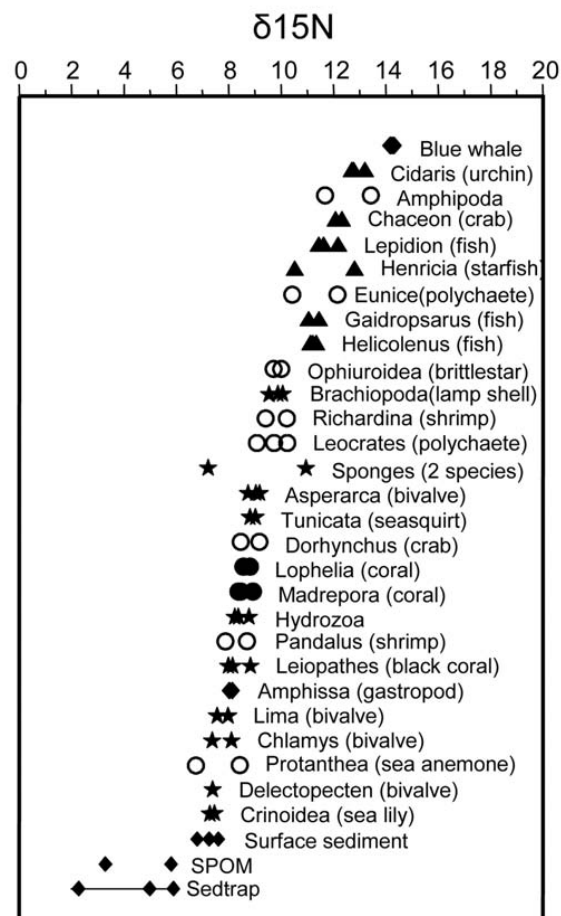


Figure 7-10. Stable N isotopes and trophic level.

7.3.5 Trophodynamics in GOM: Questions and Objectives

- To determine degree to which seep production is used by deep-sea corals and identify if this dependence increases with depth
- Broader question-what controls coral growth and development?
- To examine the food-web structure within coral communities, identify trophic relationships between individual species (Figure 7-11)

L. pertusa and associated communities show at most very little nutritional dependence upon seep production.

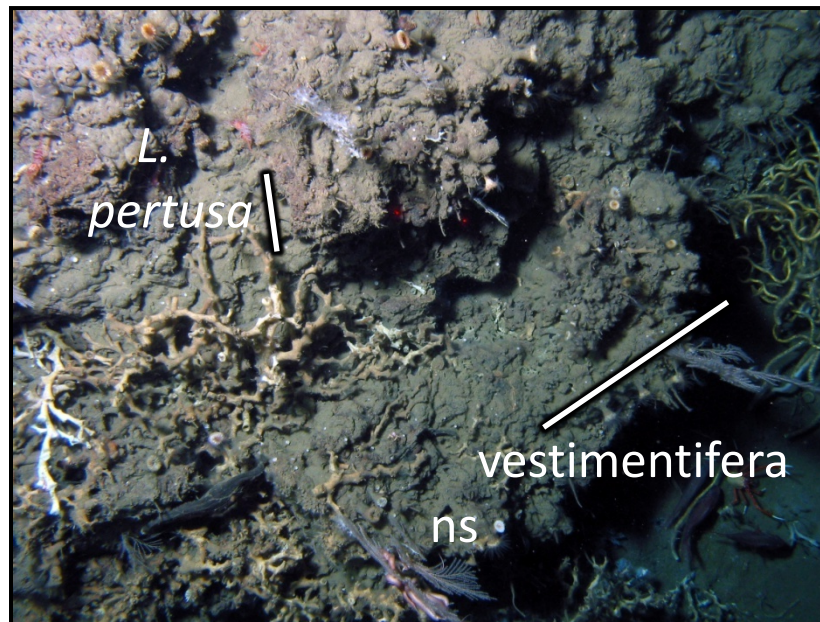


Figure 7-11. *Lophelia pertusa* and vestimentiferans.

7.4 CORAL GROWTH, REPRODUCTION AND LARVAL ECOLOGY

Very little is known about the reproductive ecology of deep sea species in general. The most well-studied deep sea corals are the structure-forming scleractinians: all are gonochoristic broadcast spawning species with seasonal reproductive cycles. Octocorals have a variety of reproductive strategies, with tendency towards brooding in gorgonians. There is no published literature on gorgonians or antipatharians from the deep GoM and factors driving reproductive cycles in deep sea corals have not yet been determined. Limited information is currently available on environmental variation in the deep sea.

7.4.1 Objectives

We will provide comprehensive information on the reproductive biology of dominant habitat forming corals in the deep GoM and coordinate results with other study components

- Complete description of the gametogenic cycle of *L. pertusa* (Figures 7-12 and 7-13)
- Describe embryology and larval biology of *L. pertusa* in the GoM
- Describe reproductive strategy and timing of gametogenesis in other dominant anthozoans (*Leiopathes* spp., *Keratoisis* spp., *Callogorgia a. delta*)
- Correlate variation in environmental factors with timing of gametogenesis in *L. pertusa* (and other taxa if data are sufficient)
- Correlate quantity of food supply to the benthos with reproductive output and energy content of *L. pertusa* in different locations (and other taxa if possible)

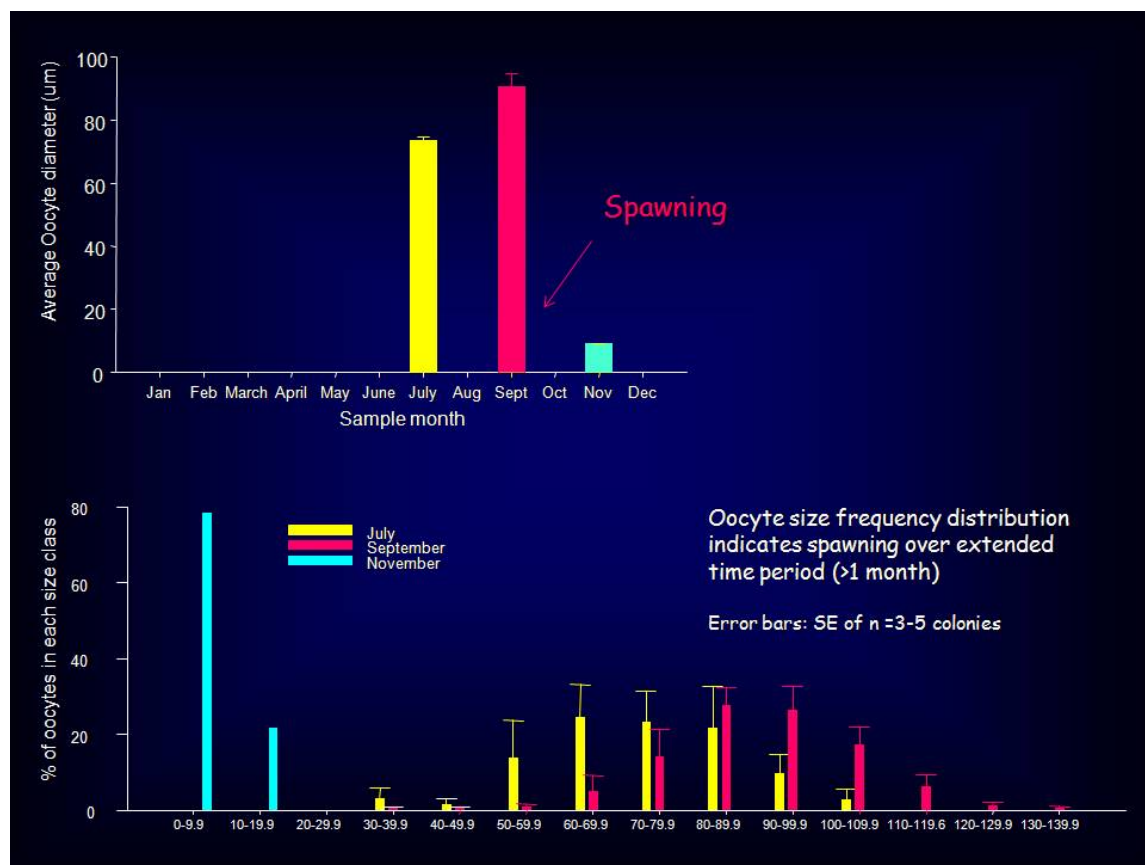


Figure 7-12. *Lophelia pertusa* reproduction in the GoM.

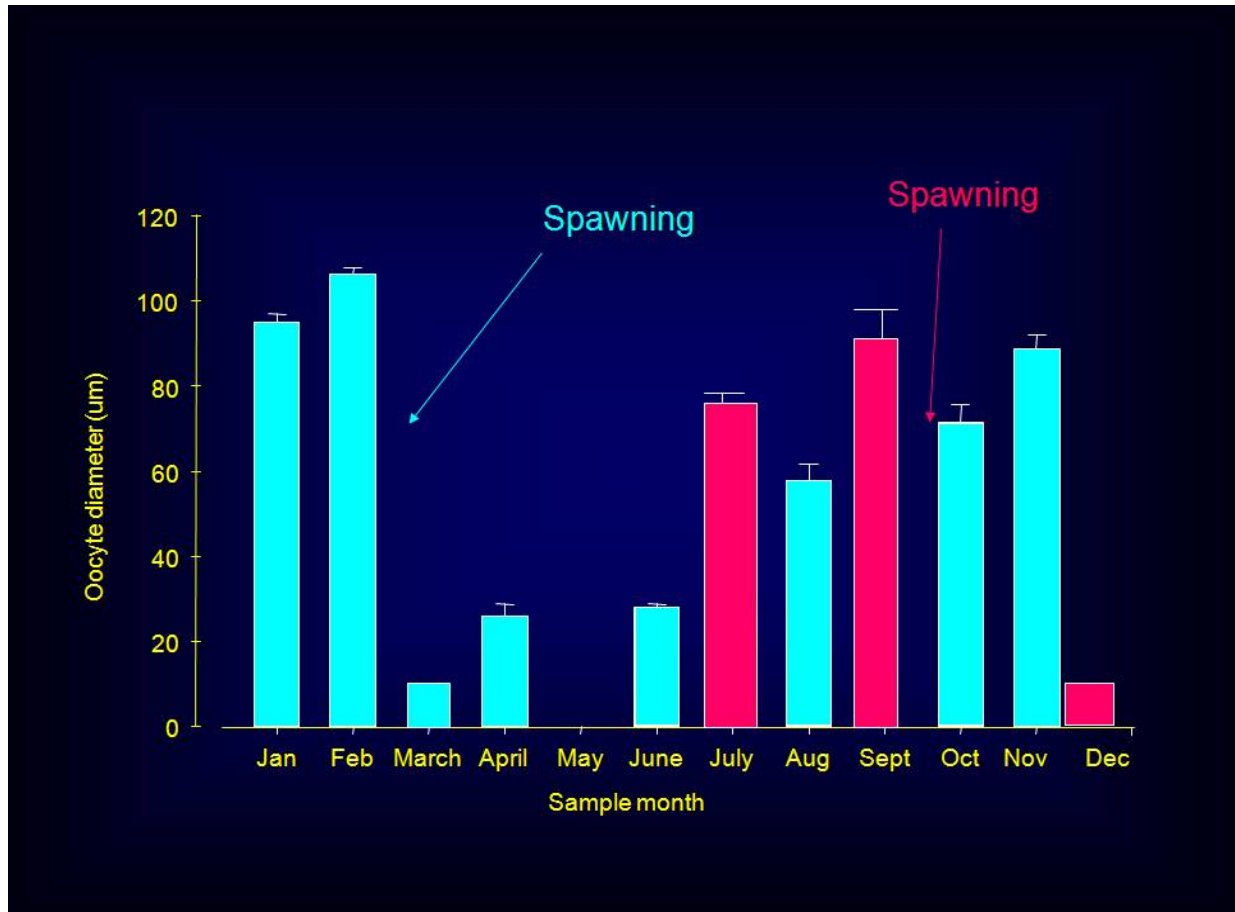


Figure 7-13. Comparison of the gametogenic cycles of *L. pertusa* from Trondheim Fjord and GoM.

7.4.2 Summary

- In the GoM, *L. pertusa* has early oocytes in November and was observed spawning in early October.
- Reproductive cycles of *L. pertusa* from the Trondheim Fjord begins in early January and terminates with spawning approximately one year later in late February.
- Spawning has been observed in *L. pertusa* from both eastern and western Atlantic ecosystems.
- Embryogenesis took approximately 24 hours and larvae were long-lived in the laboratory (> 2 weeks). Timing may vary by region.

8 ASSOCIATED STUDIES

8.1 CORAL COMMUNITY MICROBIOLOGY

Microbes are now recognized to be an important part of the total biology of shallow-water corals. In the same way that human health is affected by the approximately quadrillion bacteria hosted by each person, coral health and biology also involve maintaining a normal microbiota. The goal of this study is to characterize the bacterial associates of *Lophelia pertusa*. The coral holobiont (metaorganism) is composed of the coral animal plus its associated microbiota, which includes bacteria, archaea, and fungi. The main umbrella questions to be answered in a coral microbial ecology study such as this are: (1) what microbes are present in the coral-associated community and (2) what functional or biogeochemical roles are the microbes involved in, as both related to the complex interactions between the symbionts and their host. The objectives of this study, under those umbrella questions, are as follows:

- identify and characterize the microbial communities associated with *Lophelia* at multiple sites in the GoM
- study temporal changes in *Lophelia*-associated microbial communities (Viosca Knoll sites);
- determine if *Lophelia*-associated mobile fauna are acting as vectors (not necessarily disease vectors, but simply as a mechanism to connect deep reefs); and
- identify and characterize the microbial communities associated with other deep-sea coral species in conjunction with the population genetics task.

Key achievements to date include the design and construction of several versions of specialized sampling containers for the proper collection of deep-sea coral samples for microbiology. Important features of these containers are that they have multiple compartments so that samples do not contaminate each other, o-ring seals to prevent contamination from the water column during ascent, and, most critically, they must be insulated to prevent thermal shock. Two groups of *Lophelia*-specific bacterial symbionts have been identified; one group includes novel mycoplasmas and the other novel sulfide-oxidizers. Dramatic difference in coral-associated bacterial communities between two geographic sites <50 km apart (Viosca Knoll 906 versus 826) suggests physiological differences in the corals, which may be evidence of heat stress at the shallower site.

Plans for the final field year of *Lophelia* II activities include the following:

- attempt to culture the *Lophelia*-specific bacteria (mycoplasmas and sulfide-oxidizers) for further characterization while continuing to culture other bacteria on a variety of low-nutrient media;
- compare bacterial communities from *Lophelia* at multiple sites in the GoM to each other and to samples from the southeastern U.S. to fully characterize the variability on this side of the Atlantic (and overlay that with coral genetics);

- determine if mobile fauna (fish, crabs, snails) are transporting bacteria among *Lophelia* reefs;
- look at temporal changes in *Lophelia*-associated bacteria (can site-differences still be detected between VK826 and VK862?); and
- 454 sequencing of the *Lophelia* metagenome (bacterial functional genes, archaea, fungi, viruses).

These plans effectively link this microbiology component to other components of the U.S.G.S. study, including fish and invertebrate taxonomy (via vector analysis) and population genetics (by comparing patterns of microbial community variability to connectivity patterns of the coral host). Future work will be considered that may also complement benthic ecology and coral reproduction efforts.

8.2 PALEOECOLOGY OF CORALS

Deep-sea corals can be spectacularly long-lived, which makes them critical contributors to our efforts to understand the past.

- Slow grow rates (7–8 $\mu\text{m}/\text{year}$) indicate a high vulnerability to harvesting (Figure 8-1).
- Reproducibility between solution and laser ablation ICP-MS yields promising results for this rapid analytical technique of in situ elements at the micron level.

Preliminary results of redox-sensitive elements suggest wide scale sensitivity to low-oxygen levels in the GoM.

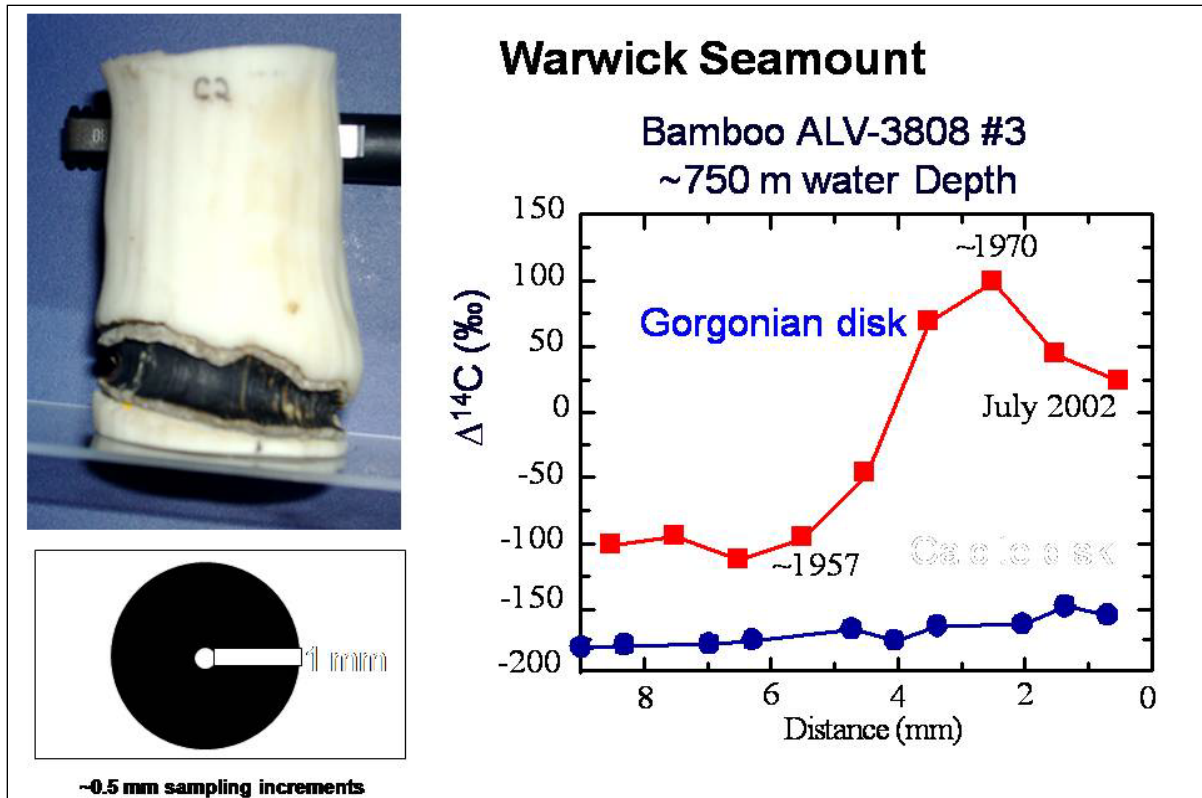


Figure 8-1. Corresponding linear “growth rate” is ~120μm/year. Sample is ~75 years old.

8.3 LANDERS AND OTHER LONG-TERM DEPLOYMENTS

Ships and other vehicles (ROV, HOV) can occupy a study area for only a relatively short time. Landers are multidisciplinary, multi-instrument tools for collecting data more relevant to deep-sea communities.

- Provide long-term, high-intensity physical and biological data not otherwise available.
- Two Dutch landers deployed at Viosca Knoll 826 (GoM) - October 2008.
 - Five-day test deployments
 - One-year deployments, retrieved September 2009 (data being analyzed)
- Landers moved to NC coral mound (December 2009).

8.3.1 ALBEX and BOBO Landers

The ALBEX (Figure 8-2) and BOBO (Figure 8-3) bottom landers have the following specifications:

- CTD
- Fluorometer & turbidity

- Programmed sediment traps-12 bottles per sediment trap, sampling roughly at monthly intervals. Contents analyzed for: stable isotopes of C & N, organic C & N, mass flux, carbonate content, grain size & components, biota captured
- Video & still photos
- ADCP & Doppler current meters
- Acoustic monitor
- Settling plate

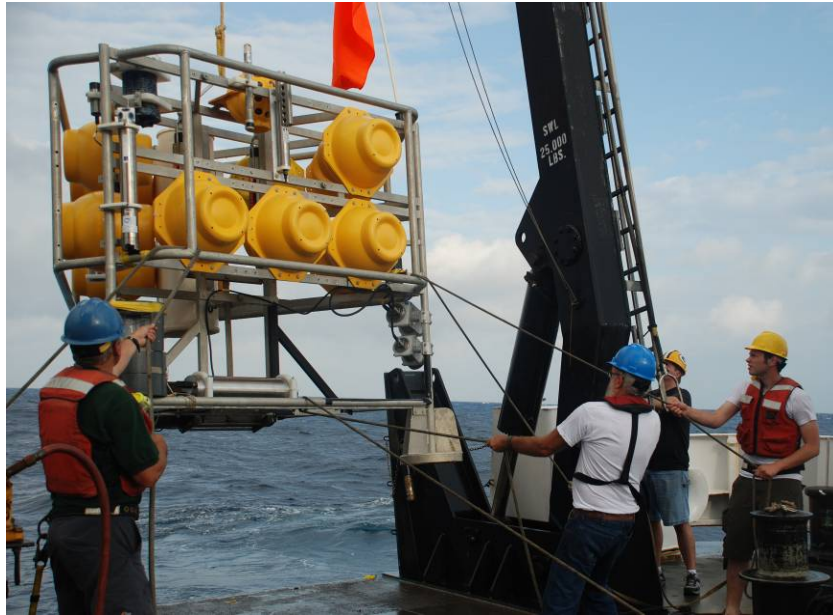


Figure 8-2. ALBEX lander.

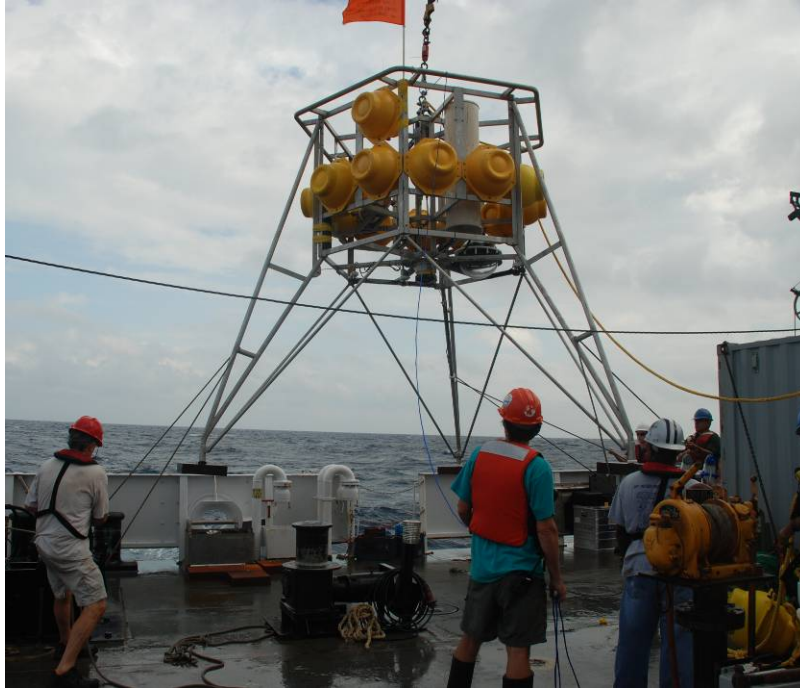


Figure 8-3. BOBO lander.

8.3.2 Stationary Digital Still Camera

Objectives:

- Quantify encounters with mobile fauna
- Observe species interactions (e.g., predation or grazing on corals)
- Record bottom-water temperature time-series (potential for thermal stress to *Lophelia*)
- Potentially observe episodic events (e.g., hurricane, LCR, etc.)

The Nikon 990 with 250-watt sec strobe takes a 2048x1536 pixel image every three hours. A Hobo thermistor/logger inside camera housing records temperature every 30 min. VK906 is approximately 550m deep (Figure 8-5).

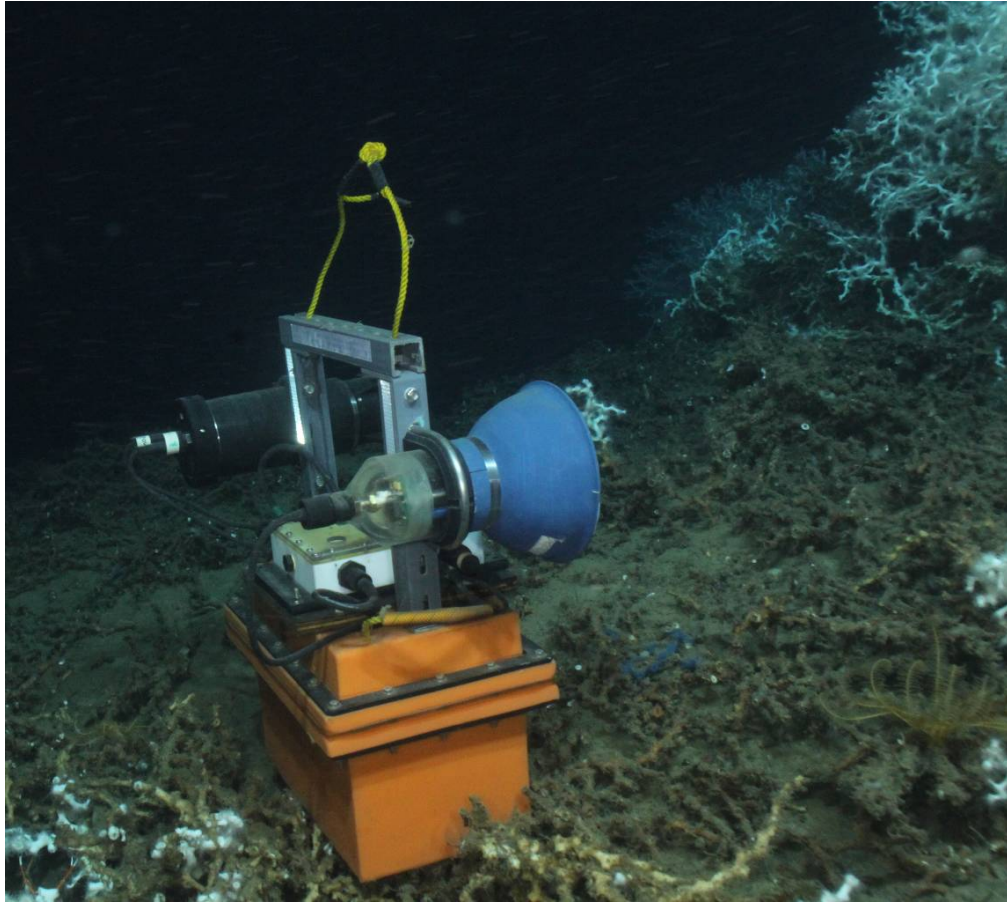


Figure 8-4. Digital still camera.

8.3.3 Stationary Moorings

The two types of stationary moorings that were employed are referred to by overall height: the 102-m mooring (Figure 8-6) and the 9-m mooring (Figure 8-7).

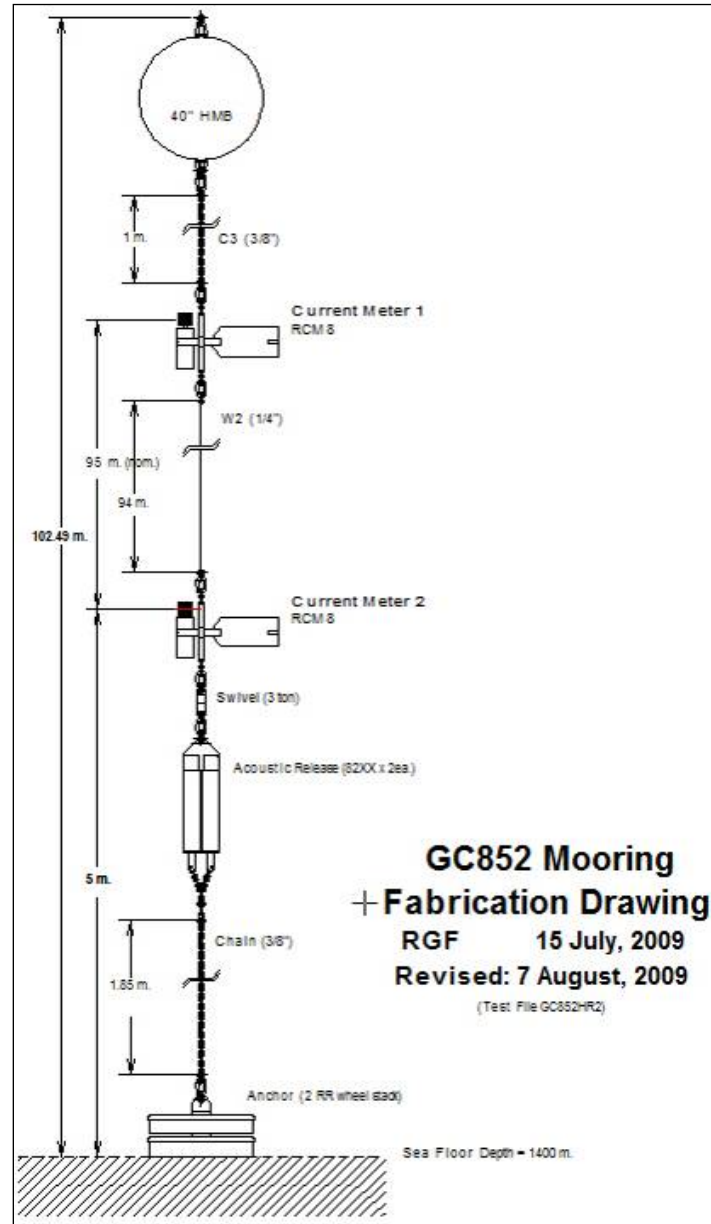


Figure 8-6. 102-m tall mooring with 2 RCM-8 current meters.

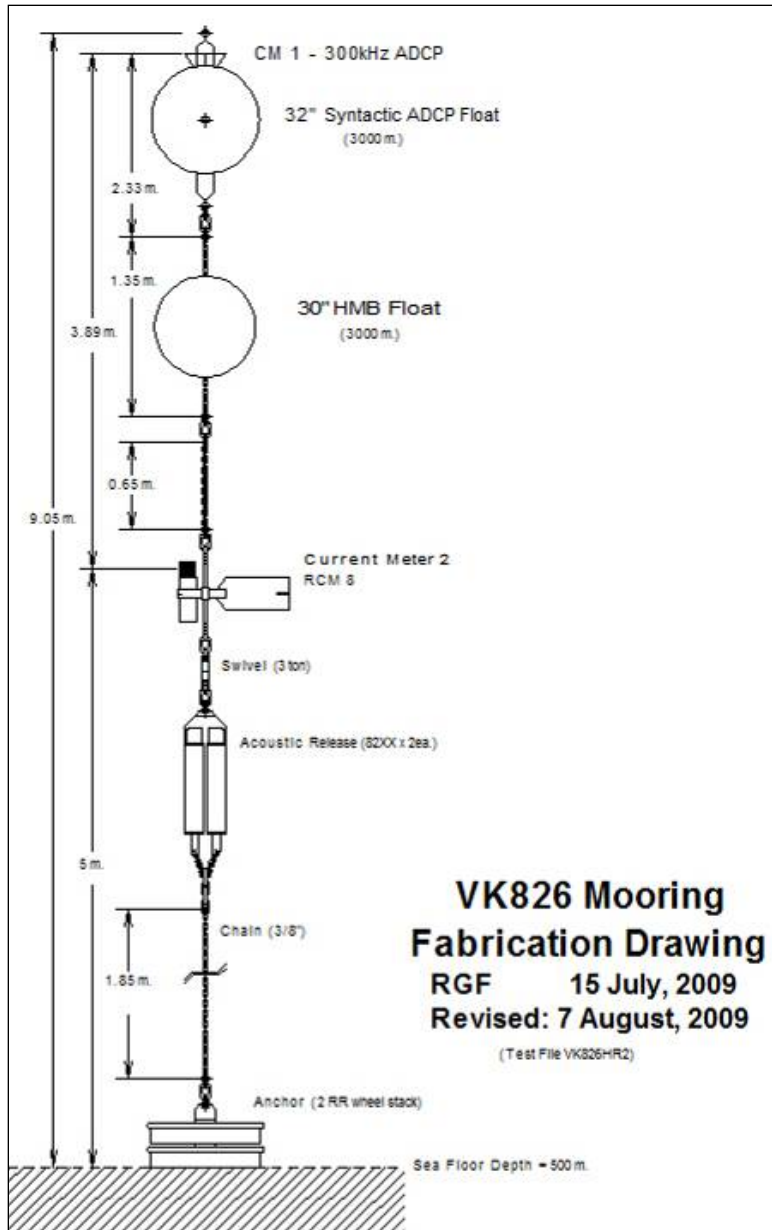


Figure 8-7. 9-m tall mooring with ADCP at top and RCM-8 below.

8.3.4 Time Series Analysis of Particulate Organic Input & Larvae

Two PARFLUX Mk 78H-21 time series sediment traps (Figure 8-8) on 60-m moorings were deployed from the ship to collect two sets of 21 discrete samples for one year and were moved into final positions using an ROV. One trap each was deployed at VK826 and MC751 (coral/chemo sites).

Sediment trap top surface is 5 m above the seabed. The recording thermistor is mounted below the trap and a current meter is 15 m above the sediment trap, to record current velocities across trap's upper surface without "shadowing" of particle fluxes.

Each preservative (DMSO)-filled 250-ml sample cup will be analyzed for mineralogical, geochemical, microbial, and larval content (includes molecular investigations).

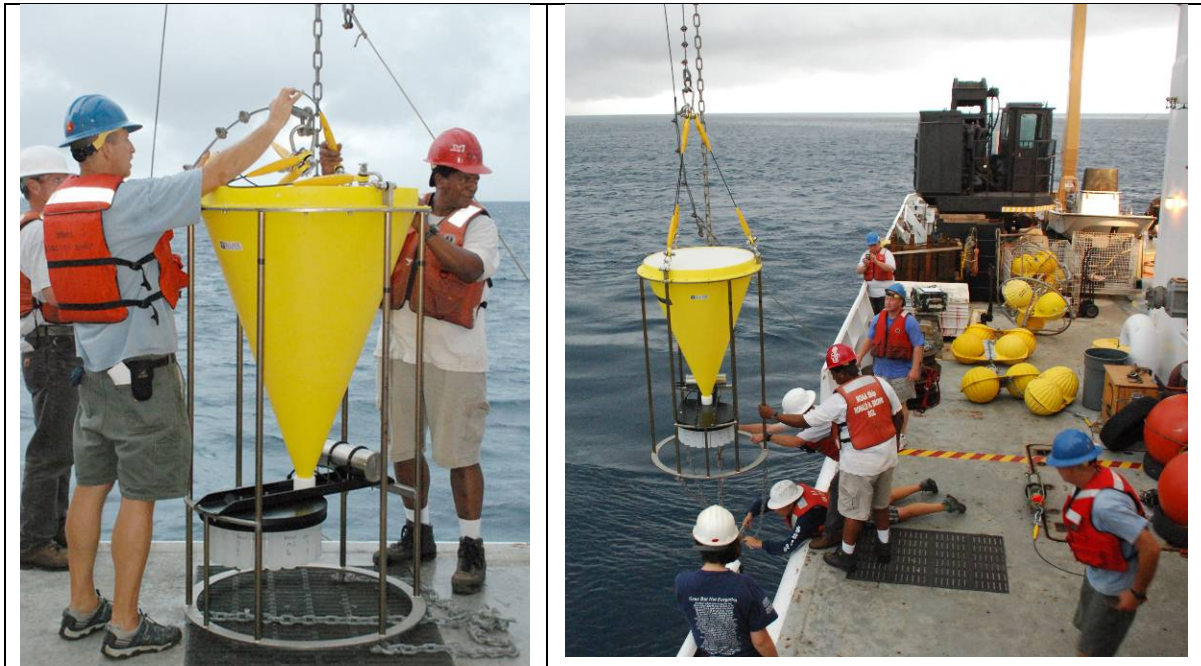


Figure 8-8. PARAFLEX sediment traps.

The following deployments were made:

- VK826
 - Two benthic landers
 - Mooring
 - Sediment trap
- VK906
 - Still camera
- GC852
 - Mooring
- MC751
 - Sediment trap

8.4 EDUCATION AND OUTREACH: SUMMARY OF ACTIVITIES, PLANS, DISCUSSION

8.4.1 Lophelia II Outreach Summary

The project has several strands of outreach:

- NOAA Ocean Explorer Signature Cruises
 - <http://oceanexplorer.noaa.gov/explorations/08Lophelia/welcome.html>
 - <http://oceanexplorer.noaa.gov/explorations/09Lophelia/welcome.html>
- Deep Wrecks and the Past Foundation education efforts
 - <http://www.pastfoundation.org/DeepWrecks/>
- K-12 curriculum/unit on deep-sea coral ecology
- USGS *DISCOVRE* Project
 - <http://fl.biology.usgs.gov/DISCOVRE/>
- Video production and Google Ocean

The *Lophelia* II project has been featured as a NOAA OER Signature Cruise twice (in June 2008 and August 2009). Background essays on earlier reconnaissance efforts, coral population connectivity, archaeology, and potential impacts from climate change are featured, along with mission overviews and summaries. Log entries on the second cruise were chosen to feature the multiple aspects of the research including:

- *Jason II* Operations
- Deep Water Corals Basics (Cheryl Morrison)
- First-Hand Observation (Santiago Herrera)
- Deep-Water Coral Associations (Tim Shank)
- Managing the Reefs, Rigs, & Wrecks (Bill Shedd)
- Meiofauna associated with Deep-Water Corals (Amanda Demopoulos)
- Careers Onboard a Research Vessel (Lt. Nicole Manning)
- Diversity of Octocorals (Peter Etnoyer)
- Photomosaics – Worth a Thousand Words (Liz Podowski)
- Connecting Corals and Chemistry (Jay Lunden)
- Larval/sediment traps and current meter deployments (Chris German)
- An Eye in the Water – Imaging the Deep Sea (Ian MacDonald)
- Shipwrecks (Sheli Smith)
- 18 videos and over 100 images were also posted

The archeology team and the Past Foundation worked with several Ohio schools to incorporate archeological research from *Lophelia* II into high school ROV design classes. Participating schools were provided materials on ROV technology and archeological sampling, and then followed the research through the NOAA Ocean Explorer website. School teams were challenged to develop low-cost ROV mechanical arms as their design project.

The project team is developing a new Deep-Water Coral Unit. The problem-based unit features six lessons on deep-water coral ecology and is designed around a challenge scenario. The scenario mimics the real-life challenge of managing and developing oil/gas resources with minimal impact on coral ecosystems. The series of lessons (e.g., on *Lophelia* biology, coral skeletons and climate change, deep-water currents and movement of food and larvae, and coral community trophic relationships) provide the background necessary for students to address the challenge. Potential datasets and related resources needed for each lesson have been identified. A summer 2010 teacher workshop featuring the unit and research project has been proposed, with classroom testing in the fall 2010.

A parallel website featuring *Lophelia* II research is provided through the USGS DISCOVER project. The site features project summaries, cruise logs, blogs, factsheets, and articles, and cross-links with the NOAA Ocean Explorer website, and the www.Lophelia.org site.

A Google Ocean tour of six *Lophelia* II sites has been created by Peter Etnoyer. The tour features a good representation of GoM study sites and is accompanied by text and external links where appropriate. Because the sites are incorporated into Google Ocean, the tour is automatically available to anyone viewing Google Ocean.

8.5 VIDEO PRODUCTION

8.5.1 Video Production Summary

A massive amount of video was collected aboard *Lophelia* II 2009. In total, 1,200 hours of were collected and archived. The ROV *Jason II* is equipped with four video cameras, and each recorded more than 300 hours of compressed video (mpeg format) on DVD media. A total of 24 hours of broadcast quality “Best of” video was collected on DVCam tape media from the three-chip camera on *Jason II*. Additional broadcast quality footage of ship operations (three hours) was recorded to Mini-DV tape format using a Sony three-chip camera shooting standard definition.

The “Best of” video was edited into two different output products: 1) moderate resolution (360 x 240) videos in .mov format (240 minutes) showing highlights from all sites, suitable for public lectures and presentations and 2) broadcast resolution (720 x 480) highlight videos (16 minutes) from 10 select sites, suitable for broadcast media. The 10 selected sites were: West Florida Shelf, DeSoto Canyon, Viosca Knoll 826, Viosca Knoll 906, Mississippi Canyon 751, Green Canyon 852, and Garden Banks 535, the *Gulfpenn* wreck, a 7,000-ft wreck, and the *Green Lantern* wreck. Durations range from 1–3 minutes depending on the site. Videos include title cards, rights-free music, and logos from NOAA and BOEM. The broadcast quality highlights are ultimately intended for a 20-minute documentary about the *Lophelia* II project, but the short format also helps to accomplish interim tasks, such as public outreach and education. Currently, 10 videos are uploaded to YouTube with text and metadata approved by project Principal Investigators. The clips are popular online. The average *Lophelia* II video was viewed 4,300 times since March 2010. Videos from VK826 and VK906 were each viewed more than 6,400 times.

The YouTube format has also proven useful in other ways. For example, clips were previewed online by Dan Rather's news team for a June 22, 2010, broadcast on HDNet featuring Dr. Erik Cordes. The production quality and popularity of the highlight videos also gained an invitation for the collection to appear in Google Earth's new Ocean layer. A Google Earth tour has been rendered from these highlights, complete with text, metadata, and web links relevant to our research (Figure 8-9). (The tour can be downloaded from: <http://db.tt/IwvW2d>.) The *Lophelia* II tour in Google Earth is a narrative progression (with a beginning, middle, and end) that tells the story of *Lophelia* II using approved text with the best available footage (see Table 8-1 for text and links). So, in a way, the tour functions as a storyboard for our final 20-minute documentary. The final documentary will include new elements, like voice-over narration, interviews, and other footage to help explicate our story, but the Google Earth tour provides a preliminary working structure.

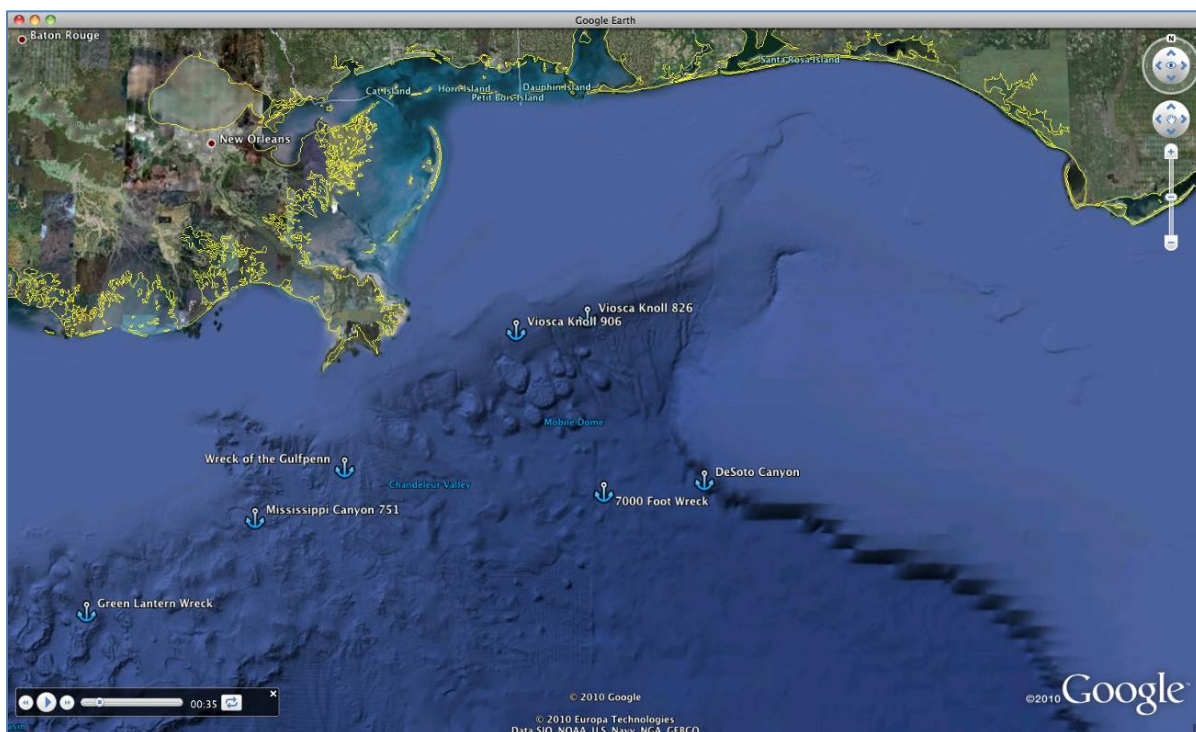


Figure 8-9. Video tour on Google Earth.

Additional venues may become available for the videos in the near future. There is potential for the highlights to appear in the Smithsonian Hall of the Oceans as part of an “ocean kiosk.” Another potential venue is the popular NOAA Ocean Explorer Channel at YouTube. These venues would require a Federal “stamp of approval” but the result would make *Lophelia* II video widely available for perpetuity, for public viewing and download to computers and smartphones around the world.

Table 8-1.

Lophelia II Tour in Google Earth

Location	Lat	Lon	Depth	RunT	Description
West Florida Slope	26.20467	-84.7225	459	1:47	Submerged ridges near 500 meters depth on the West Florida slope were the first targets for the <i>Lophelia</i> II: Reefs, Rigs, and Wrecks 2009 Expedition. Many animals were seen, including the deep-sea coral <i>Lophelia pertusa</i> , our flagship species (white with zig-zag branches). Fish included a shark, silver dollar, sea robin, and an Atlantic roughy. Small <i>Lophelia</i> colonies grew on the twig-like skeletal axis of a black coral. <i>Jason II</i> collected <i>Lophelia</i> , and a yellow sea fan with a brittle star attached.
					http://www.youtube.com/watch?v=aa9yoUZYQp8
DeSoto Canyon 583	28.38602	-87.3873	2455	1:49	Scientists peer through the lens of <i>Jason II</i> at 2,500 meters (8,200 ft) depth near DeSoto Canyon. Submarine canyons are steep-sided features that cut through the continental slope. At this site, an exposed rock bed juts from the abyssal plain, providing substrate for bamboo and black corals, a chemosynthetic mussel community, and a deep-sea octopus. This was the deepest dive of <i>Lophelia</i> II 2009 expedition.
					http://www.youtube.com/watch?v=r2Q-a-nNoTI
Viosca Knoll (VK) 826	29.15636	-88.01608	496	1:24	A school of alfonsino fish swims over Viosca Knoll 826 (VK826), a natural deep reef, and an example of the kind of habitat scientists will study aboard the <i>Lophelia</i> II expeditions. VK826 refers to a BOEMRE leasing system for oil and gas. BOEMRE sponsored researchers aboard <i>Lophelia</i> II will compare the biota of natural reefs to biota on artificial reefs, like oil rigs and shipwrecks. Ocean chemistry is measured using a rosette of Niskin bottles and a Conductivity-Temperature-Depth (CTD) deployed over the side of the boat.
					http://www.youtube.com/watch?v=J6dAS1ScmbA
Gulfpenn Wreck	28.44	-89.32	561	1:05	The USS <i>Gulfpenn</i> was transporting 90,000 barrels of gasoline when it was torpedoed by German submarine U-506 on May 13, 1942. Twenty-five crewmembers survived the attack, but thirteen died. The ship now lies at 550 m in the Gulf of Mexico, encrusted by an amazing community of <i>Lophelia pertusa</i> coral, fish, and invertebrates.
					http://www.youtube.com/watch?v=8Ir6uJfvYwQ
Mississippi Canyon (MC) 751	28.19072	-89.79861	455	2:52	The Mississippi River continues below the sea surface in the Gulf of Mexico to 4000 m depth as a submarine canyon called the Mississippi Canyon. Nutrients from the river support abundant deep-sea coral communities. <i>Callogorgia</i> and <i>Lophelia</i> corals settle and grow on carbonate outcrops, feeding on suspended matter. Brittlestars, squat lobsters, and urchins occur on most colonies. Active methane seeps are in the immediate vicinity. The “infaunal” community is observed using sediment push-cores.
					http://www.youtube.com/watch?v=CyMSvvhx_r0A
7,000-ft Wreck	28.33	-87.93	2256	1:14	A 7,000-ft wreck is the deepest known shipwreck in the Gulf of Mexico. The original name is unknown, but archaeologists suspect the wooden-hulled vessel was a two-masted schooner. The bow and ships wheel are encrusted with rusticles and other signs of life. A date inscribed on the compass recovered from the wreck indicates the ship sank after June 1, 1875. The ship's wheel is prominent on the wreck.

Table 8-1.

Lophelia II tour in Google Earth (continued)

Location	Lat	Lon	Depth	RunT	Description
					http://www.youtube.com/watch?v=5kYOIBCbeVk
Viosca Knoll 906	29.09839	-88.40345	300	1:15	Viosca Knoll 906 is home to a <i>Leiopathes</i> black coral community. The number “906” identifies the oil and gas lease block that encompasses area. Black corals can be incredibly long lived. Living colonies are white, salmon, or orange. Only the skeleton is black. The branches are habitat for fishes and crustaceans. Barrelfish were one type of commercial fish that was present in the area. Geneticists aboard <i>Lophelia</i> II will decode the black coral DNA to determine whether we see one species or many.
					http://www.youtube.com/watch?v=U6lqiLHT7nU
Garden Banks (GB) 535	27.42292	-93.59727	600	1:30	The westernmost aggregation of <i>Lophelia pertusa</i> coral in the North Atlantic was discovered in an oil and gas lease block called Garden Banks 535 during <i>Lophelia</i> II 2009 Expedition. <i>Lophelia</i> colonies occurred on large carbonate outcrops near 500 m depth. Many squat lobsters and fishes were seen in and around the coral colonies, including slimeheads, tinselfish, and a chain catshark.
					http://www.youtube.com/watch?v=85YtHgRAV3I
Green Lantern Wreck	27.71667	-90.71667	915	1:13	C&C Technologies, Inc. found the <i>Green Lantern</i> wreck during a deep-tow survey in 1996, and their archeologists investigated in 2004. The wreck is an unidentified copper-clad sailing vessel that measures approximately 20 meters in length. The wreck is named for one of the ships lanterns found lying just outside the stern. The lantern caught the attention of the archeologists. It was embossed with the word Estribor, Spanish for “starboard.” Just like modern ships, historic vessels ran a green light on the starboard side and a red lantern on the port side.
					http://www.youtube.com/watch?v=6BermqpuVis
Green Canyon (GC) 852				3:08	Green Canyon is a submerged ridge at 1410 meters (4625 feet) depth in the Gulf of Mexico with high diversity of deep-sea corals. The ridge was explored by the science party of the <i>Lophelia</i> II 2009 Expedition in August, 2009 using the <i>Jason II</i> ROV. The research was part of an ongoing initiative by Bureau of Ocean Energy Management, Regulation and Enforcement (now BOEM) and National Oceanic Atmospheric Administration to understand deep-sea habitat in the Gulf. The project now provides important baseline information to the Natural Resource Damage Assessment resulting from the <i>Deepwater Horizon</i> oil spill.
					http://www.youtube.com/watch?v=1Liif6f5cd2M
Attribution:					Videos by Aquanautix. Music is by Kevin MacLeod, www.incompetech.com . <i>Lophelia</i> II 2009: Reefs, Rigs, and Wrecks Expedition was sponsored by the Minerals Management Service (later BOEMRE, now BOEM) and National Oceanic and Atmospheric Administration (NOAA).
Total				15:57	Description

9 ARCHAEOLOGY

9.1 INTRODUCTION

The historic shipwreck component of the *Lophelia* II study is planned around a four-year timeline and will detail investigations of six historic shipwrecks. Years one through three of the project will be dedicated to fieldwork, historical research, data collection and data analysis. The fourth year will involve additional research, data analysis and reporting.

The shipwreck component is an important continuation of the MMS 2004 Deep Wrecks I Study. It will expand our knowledge base of how shipwrecks function as artificial reefs and allow scientists to compare findings and test hypotheses put forth in the first study findings. The inclusion of wooden hull shipwrecks in this study will provide new information on deepwater reef processes because these wrecks represent long-standing areas of hard substrate in a mostly barren seafloor environment. These studies and others like them will help researchers understand the processes and importance of deepwater shipwrecks as artificial reef environments.

Archaeologically, the documentation, identification, and analysis of additional deepwater shipwreck sites will increase our understanding of deepwater wreck site formation processes, wreck corrosion rates, and the role of the GoM shipping in both regional and global maritime history. The study of these deepwater wrecks will assist BOEM in refining the avoidance criteria predictive model developed during the Deep Wrecks I Project by increasing the sample size of the studied shipwrecks and including non-steel wreck sites into the equation. Refinement of this predictive model will allow government agencies, such as BOEM and other archaeological researchers to accurately assess the potential limits of wreck sites, establish adequate avoidance areas around them, and develop comprehensive research designs.

Archaeological objectives:

- To record each vessel through detailed imagery to establish its type, date of construction, and positive identification if possible.
- To establish nationality, ownership (past and present), use history, cause of loss, mission and cargo at time of loss through fieldwork and historical research.
- To determine the extent and condition of the artifact assemblage on each vessel and the presence of diagnostic artifacts.
- To determine potential eligibility to the National Register of Historic Places through archival research and the analysis of imagery and to prepare a National Register nomination form for potentially eligible vessels.
- To assess impacts of biofouling communities to these shipwrecks to determine the stability of these sites and rate of deterioration.

9.2 FIELD OPERATIONS-ARCHAEOLOGY

9.2.1 Summary: Season I (2008)

The shipwreck leg of the 2008 *Lophelia* II field season ran from September 5 to 17, 2008. This was the first part of a planned two-part cruise season. Operations were carried out from the

NOAA Research Vessel *Nancy Foster* using a Saab-SeaEye Falcon DR ROV. The main objective of this leg was reconnaissance of eight shipwreck sites to assess their archaeological and biological potential for inclusion in the project. The planned sites for the reconnaissance include the Ewing Bank Wreck site, the *Gulfpenn* site, the tentatively-identified *Gulfoil* site, the *Green Lantern* Wreck site, the tentatively identified *Holly Ann Vieser* site, the Oval Shape site, the Steel Hull site, and the Viosca Knoll Wreck site. Planned objectives at these sites included photo mosaics, visual surveys of artifact scatters, detailed imaging of coral colonies, reexamining a microbial experiment placed at *Gulfpenn* in 2004 and setting microbiology experiments at two additional wreck sites.

Technical problems with the ROV and research vessel, severe weather (Hurricane Ike), and resulting adverse bottom conditions limited bottom time to 13 hours total for wreck site investigations and allowed investigations of only four of the eight planned wreck sites. Data was collected at three sites: Ewing Bank, *Gulfoil*, and *Gulfpenn*. The Ewing Bank Wreck site was confirmed to be an historic shipwreck that appears to date to the nineteenth century. More *Lophelia* was discovered growing at the site than on any other wooden wreck currently known in the GoM. A brief dive confirmed the identity of *Gulfoil* and revealed substantial coral colonies at the site. Preliminary examinations suggest the *Lophelia* coverage at *Gulfoil* may be more abundant than the colonies previously documented at *Gulfpenn*. The dive on *Gulfpenn* identified the stern section of the tanker, reexamined the microbial experiment placed on the site in 2004 and placed a temperature logger on the bow. Overall, only 10 to 15 percent of the cruise's planned objectives were met.

9.2.2 Summary: Season II (2009)

9.2.1.1 C & C AUV Survey (June 2009)

Shipwreck investigations for the 2009 field season used both AUV and ROV systems. Two of the AUV surveys supplemented the planned 2009 field investigations. They were carried out by C & C Technologies, Inc. (C & C) as part of internal AUV testing programs. The first survey was in May 2009 at the *Gulfoil* shipwreck site. It was carried out as part of a test program comparing the AUV's dynamically focused and 410-kHz side scan sonar systems. During this survey, *C-Surveyor III*TM ran eight transects over the GULFOIL at 75-m line spacing to image the site and associated debris fields.

In June 2009, the second survey was carried out over the Ewing Bank Wreck as part of an internal testing program for a new AUV underwater photographic system. Launched from the support vessel M/V *Miss Ginger*, *C-Surveyor III*TM ran five camera transects covering the site at 5m lines spacing, collecting 64 images over the wreck site and surrounding area. On completion of the survey, the data was returned to the C & C Offices where the images were analyzed and mosaics produced. The *C-Surveyor III*TM camera survey gave the scientists the first complete imagery of the Ewing Bank Wreck. Scientists used the mosaic created from this survey to plan the work for the September 2009 ROV investigations.

9.2.1.2 WHOI Sentry AUV Survey (June 2009)

The third AUV survey was scheduled as part of the 2009 field season. It was carried out between June 17 and July 1, 2009. The main objective of this survey was the investigation of suspected hard ground and potential coral sites, but investigations at the 7,000-ft Wreck site was also undertaken. Field investigations utilized the Woods Hole Oceanographic Institute's

(WHOI) *Sentry* AUV system. The system was deployed from the TDI Brooks vessel R/V *Brooks McCall*. The AUV *Sentry* conducted the first visual survey of a site known as the 7,000-ft Wreck on June 28, 2009. *Sentry* flew a survey grid of 40 lines centered over the wreck site. Each line was approximately 200 m long. Lines were spaced at 5-m intervals and flown at a 5-m altitude. A total of 5,160 photographic images and multibeam data were collected at and around the 7,000-ft Wreck site.

9.2.1.3 WHOI Jason II ROV Survey (September 2009)

The shipwreck leg of the 2009 *Lophelia* II field operations ran from September 4 to 12, 2009. This was the second leg of a two-part cruise season. Operations were carried out from the NOAA Research Vessel *Ronald H. Brown* using WHOI's *Jason II* ROV. The main objective of this leg was the detailed archaeological and biological investigations of five shipwreck sites. Site investigations (detailed below) were carried out at the Viosca Knoll (VK) Wreck site (Figure 9-1), Ewing Bank (EW) Wreck site, the 7,000-ft Wreck site, the *Green Lantern* Wreck site, and the *Gulfpenn* Wreck site. During the investigations, *Jason II* was used to document the sites with video and digital still imagery and recover limit material remains for diagnostic purposes.

9.3 METHODOLOGIES

9.3.1 ROV Investigation Methods

9.3.1.1 Reconnaissance Transects

After the ROV was deployed, the first task undertaken was a reconnaissance survey of the main wreckage. The reconnaissance allowed the science team to assess the current conditions of the wreck site and aided them in determining where to collect samples and place the microbial experiments. For the reconnaissance survey, the ROV slowly moved down each side of the hull (outboard of the gunwale) to inspect the outer hull (where applicable) and the material on the seafloor near, but outside of the hull. Then the ROV moved inboard to view the inner hull and contents (at some sites it was necessary to only make one pass along the side). Time was also spent thoroughly inspecting the bow and stern areas.

9.3.1.2 Biology Transects

Biology transects documented the sea life near and away from the wreck site. The survey consists of two sets of predetermined survey lines consisting of three parallel transects, 50 m long, and spaced 10 m apart (line spacing will depend on conditions at each site). One set ran over the long axis of the wreck at an altitude that allows good visual documentation of the wreck. The second set was run in the same pattern 100 m away from the wreck.

Core samples were taken near the wreck site and away (100 m) from the wreck. The cores were taken in pairs for collection consistency and to expedite this task.

Microbial platforms were placed by the ROV at each site. These are long-term experiments to analyze the microbial activity and rate of hull deterioration at each site.

9.3.1.3 Mosaic Transects

The mosaic transects were comprised of a series of closely spaced parallel ROV lines. They were designed to allow *Jason II*'s downward looking digital still camera to capture overlapping

images of the wreck site. A mosaic of these images was produced to form a single image encompassing the entire wreck site.

9.3.1.4 Close-Up Transects

Close-up inspections of biological and archaeological areas of interest followed the photo mosaic operation. The close inspections included detailed photography and documentation of specific corals or other areas of biological interest (i.e., rusticle formations, etc.), and specific areas of archaeological interest (i.e., specific artifacts or areas of hull construction, etc.). The archaeologists and biologists conducted these operations in conjunction with each other or split the time depending on the varying interests at each site.

9.3.2 Artifact Recovery

Limited diagnostic artifacts were recovered at each site upon instructions of the principal archaeologist and in consultation with the BOEM archaeologist. The materials recovered from the wreck sites for identification and dating purposes included copper sheathing, wood, ceramics, and shipboard equipment.

9.4 CONSERVATION METHODS

9.4.1 Field Conservation

The recovered artifacts were placed in plastic containers filled with seawater, and kept submerged in an environment similar to the one in which they had rested since the wrecking event. Some field photos were taken, but, with the movement of the ship, most details were blurry. All current photos were taken in the lab. Any of the objects that may have been light sensitive, such as the paper in the compass, were kept covered as much as possible to reduce damage. Artifacts were protected with foam mattress padding during transport from the ship to the University of West Florida Conservation Laboratory.

9.4.2 Laboratory Conservation

For every artifact, the first step of the conservation process was to photograph and document the artifact. The next step was the removal of chlorides from the artifact. An object immersed in salt water absorbs salt chlorides from the water. If the chlorides are still in the artifact as it dries, serious damage can occur. Chlorides are removed by soaking artifacts in successive tap water baths until the chlorides have been lowered to below 100 parts per million. Once the chlorides have been removed, the conservation process, which is dictated by artifact type, can proceed.

9.5 SHIPWRECK SITES

9.5.1 Viosca Knoll (VK) Wreck (Site 15303)

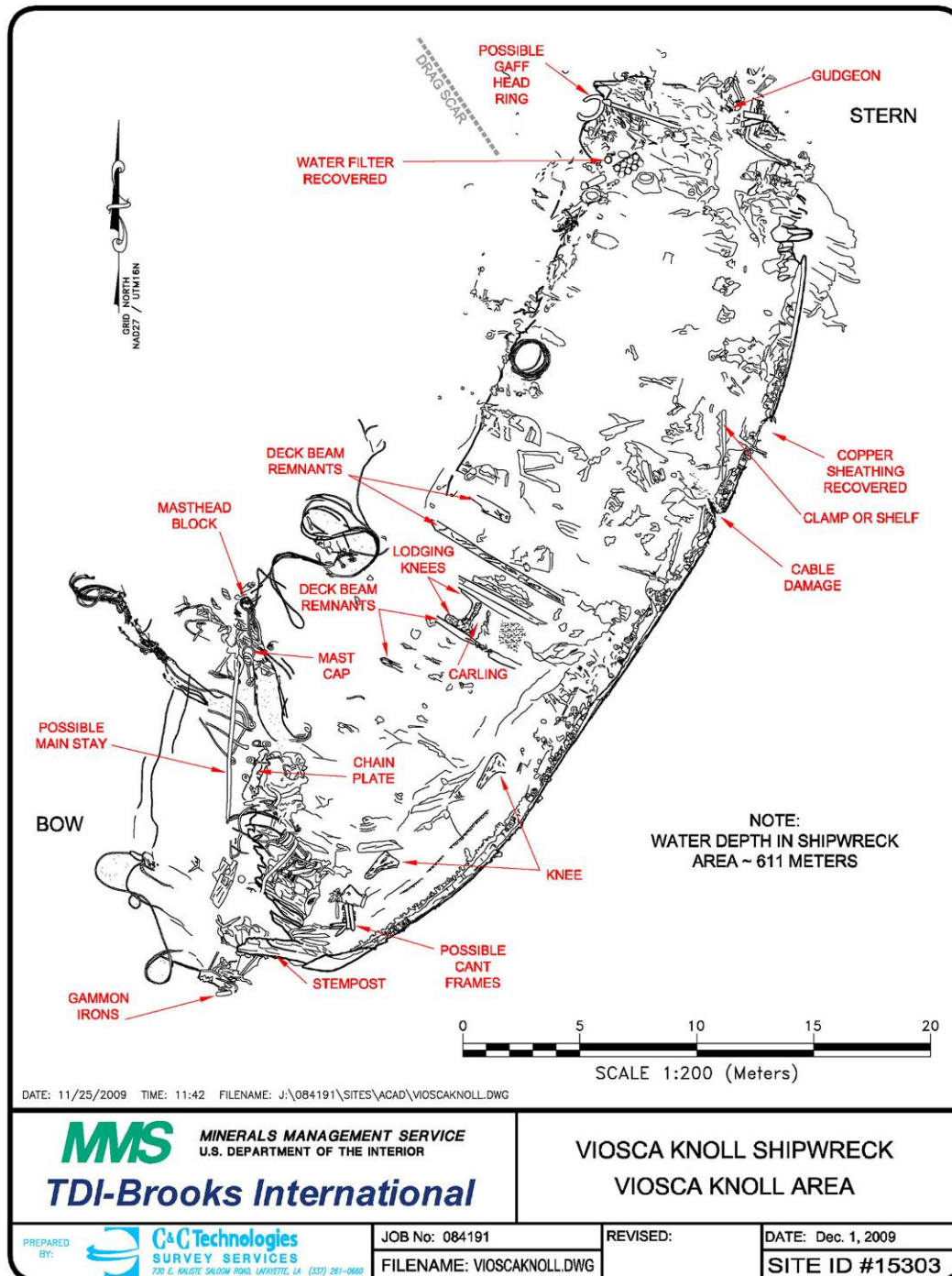


Figure 9-1. Site map of the Viosca Knoll (VK) Wreck site.

9.5.1.1 Overview and History

This wreck, referred to as the Viosca Knoll Wreck (VK Wreck), measures 43 m long and approximately 36 m at beam. It is listing to starboard and has more than 2 m of relief. The wreck was discovered during a deep-tow survey in 2003 (Church 2003). A detailed AUV survey was conducted by C & C in May 2004. C & C conducted an ROV investigation of the site in July 2006 as part of an MMS study (Church and Warren 2008). The wreck is a copper-clad sailing vessel that appears to date from the nineteenth century. Small colonies of *Lophelia* are growing on several locations on the hull and outlying debris (Church and Warren 2008). This wreck is historically significant and potentially eligible for the National Register of Historic Places.

9.5.1.2 Previous Investigations

The MMS (later BOEMRE, now BOEM) sponsored investigations at the VK Wreck in July 2006. The site was visually inspected with a Remotely Operated Vehicle (ROV) under the direction of C & C Technologies (C & C) marine archaeologist Robert Church and MMS marine archaeologists Jack Irion and David Ball. The findings of the ROV investigation suggested the wreck was possibly an early nineteenth-century brig.

9.5.1.3 Season I Cruise (2008)

No investigations were undertaken at the VK Wreck Site in 2008.

9.5.1.4 Season II Cruise (2009)

Archaeological investigations of the VK Wreck took place on September 5 and 6, 2009. *Jason II* entered the water at 23:07 on September 5 and began the 611-m descent, arriving at the wreck site at 01:19. The reconnaissance survey began shortly after arrival on site. Beginning at the port bow, the port side of the wreck was imaged as *Jason II* moved towards the stern. Scientists examined the hull structure, view construction attributes, observe coral growths and identify potential targets for recovery (Figure 9-2). Sheathing fastener patterns were documented and it was noted that the copper sheathing showed evidence of considerable patching and repairs. Near the port stern in an area where the copper had deteriorated a 7- to 10-cm thick section of outer planking was exposed (Figure 9-3). At the wreck's stern area, a dense debris zone occurs, including fragments of the disarticulated stern, sternpost, and artifacts associated with shipboard life. From the debris field, the reconnaissance work continued as *Jason II* moved up the starboard side imaging remnants of rigging and mast hardware. From the starboard investigations *Jason II* moved inboard documenting the wreck's interior before completing the reconnaissance survey.

With the reconnaissance completed, scientists used *Jason II* to mosaic the wreck site. The mosaic survey consisted of 19 transect lines spaced 1 m apart and run from the port side to the starboard side. For the mosaic transects, *Jason II* was flown at an altitude of 6 m. Following the completion of the mosaic survey, a series of soft sediment core samples were taken from areas adjacent to and away from the wreck site and the short and long term microbiological experiments were deployed. With these tasks accomplished, scientists next examined selected areas of the wreck in detail, including the ship's stove (Figure 9-4) located 77 m away from the main wreckage.

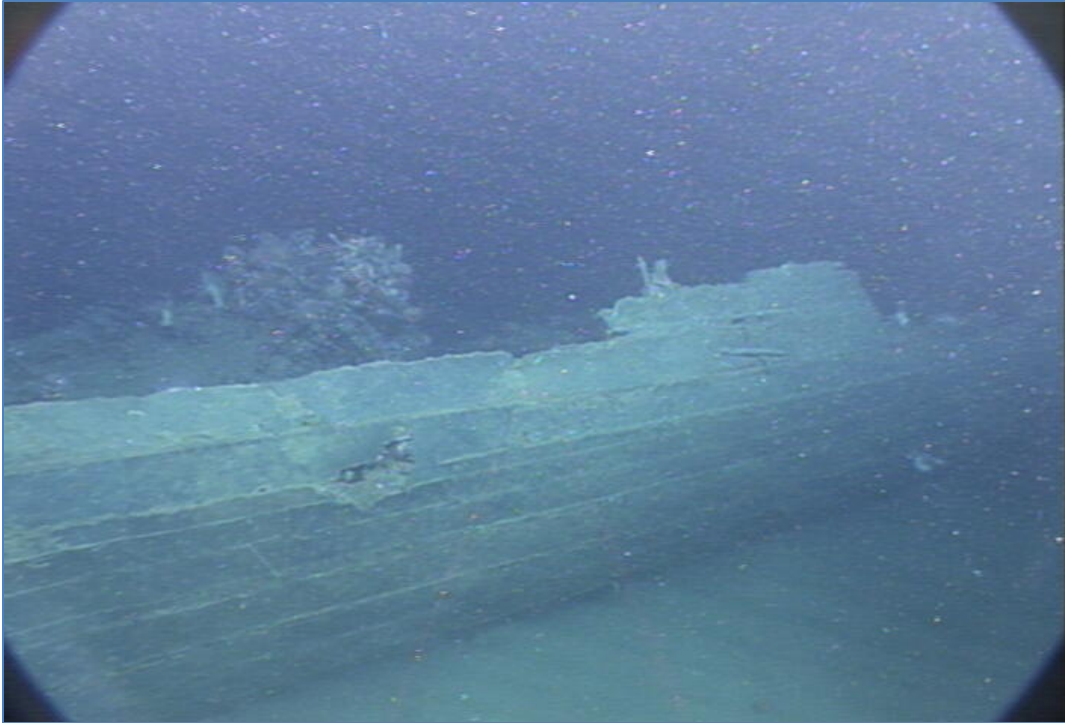


Figure 9-2. Copper sheathing on the Viosca Knoll (VK) Wreck's port side hull.

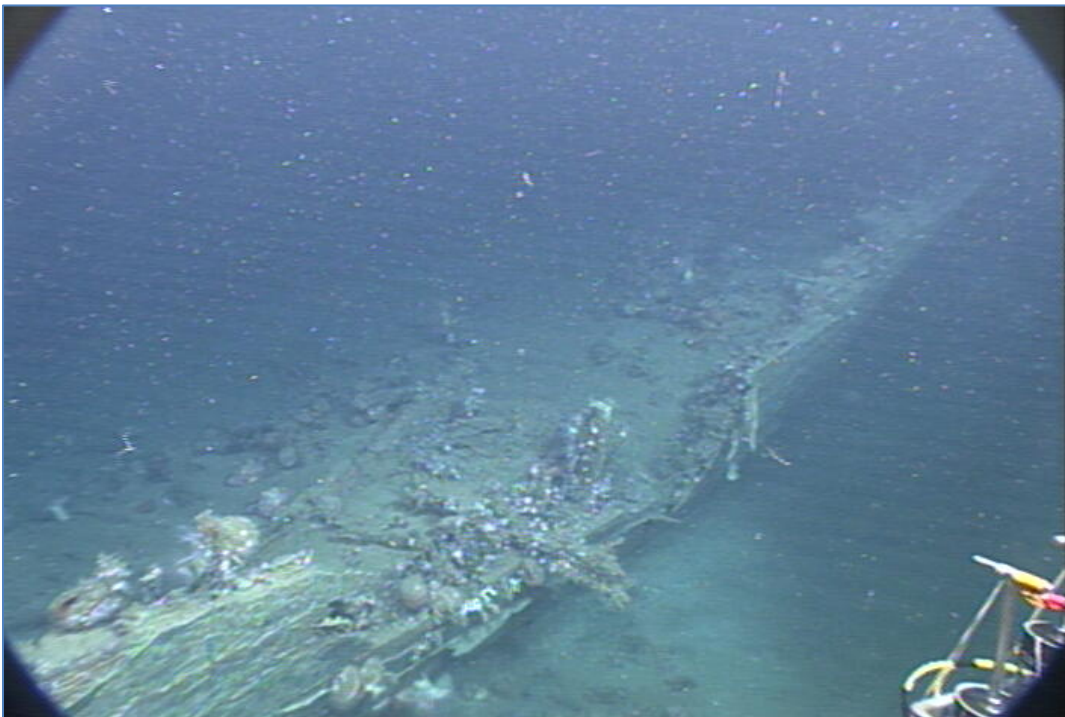


Figure 9-3. Damaged area on the VK Wreck's port stern area.

Before researchers left the wreck site, the short-term biological experiment and select artifacts were retrieved. The recovered artifacts included a sample of the copper sheathing from the port side and a stoneware ceramic jar from the starboard stern (Figure 9-5). At 11:47 on September 6, *Jason II* completed investigations on the VK Wreck site and returned to the surface.



Figure 9-4. An image of the VK Wreck's ship stove.

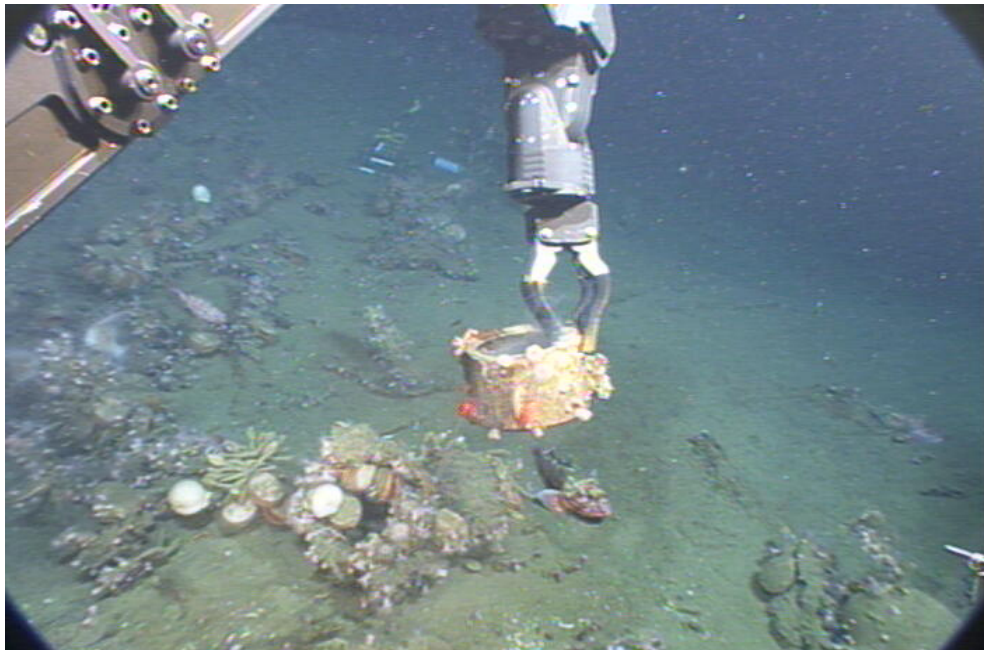


Figure 9-5. *Jason II* recovering a stoneware container from the VK Wreck.

9.5.1.5 Analysis

Analysis of the VK Wreck is proceeding. Detailed reviews of the *Jason II* video and still imagery have begun and a site mosaic is being produced. Historical research is in progress on all aspects of the wreck. Emphasis is on locating information on the stoneware water filter and copper sheathing recovered from the wreck in hopes that it will help to not only date, but potentially assist in the identification of the VK Wreck.

9.5.1.6 Conservation

Conservation of the materials recovered from the VK Wreck is on schedule. A brief summary of the conservation status of each artifact is provided below.

Artifact: MMS09.15303.C.001 Salt Glazed Stoneware Water Filter

The first step in conserving the water filter (Figure 9-6 and Figure 9-7) was to remove all of the sediment that had accumulated within. Half of the sediment was removed and saved as a sample for later testing if needed; the other half was screened through a set of three copper stacking screens; the largest size was 2 mm, the middle 1 mm, and the smallest 0.5 mm. The screened sediment was examined under a microscope, where it was determined that the makeup of the sediment consisted of small pebbles of various size, shape, and color. Also contained in the mix are small fragments of wood and marine life. The filter is still desalinating in tap water, as porous objects absorb more chlorides, and in turn, it takes longer to remove those chlorides. It will likely be a few more months before the artifact is ready for conservation.



Figure 9-6. Stoneware water filter recovered from VK Wreck (top view).



Figure 9-7. Decoration and writing on stoneware water filter from the VK Wreck.

Artifact: MMS09.15303.M.002 Copper Sheathing

This piece of copper sheathing has just finished the desalination process, and is ready for conservation. Like the other pieces of sheathing, it will be mechanically cleaned with a wire brush with bristles gentle enough not to scratch the copper.

9.5.2 7,000-ft Wreck (Site 15373)

9.5.2.1 Overview and History

This site (Figure 9-8) was first identified from a 1986 deep-tow survey but was not reported as a shipwreck discovery until the data was re-analyzed in 2005 when the Mississippi Canyon Lease Area was declared a high probability area for historic shipwrecks. The target was described as an “elongated, apparently solid, oval sonar contact 27 m in length and 11 m in width.” In October 2006, an AUV survey was conducted over the site with *C-Surveyor I*TM. The survey data imaged what appeared to be a sailing vessel with a bowsprit and an elliptical stern. The subbottom profiler image suggests that a large portion of the hull is buried. There is a hard acoustic return in the middle of the hull, which could be cargo or ballast. This wreck is considered a historic wooden sailing vessel. No positive identification was possible based solely on the remote sensing records (Warren 2006).

9.5.2.2 Previous Investigations

No previous ROV investigations have been undertaken at this site. A survey in July 2009 using WHOI’s *Sentry* AUV provided the first camera images of this site and confirmed that it was a historic shipwreck.

9.5.2.3 Season I Cruise (2008)

This site was not visited during the 2008 Field Season.

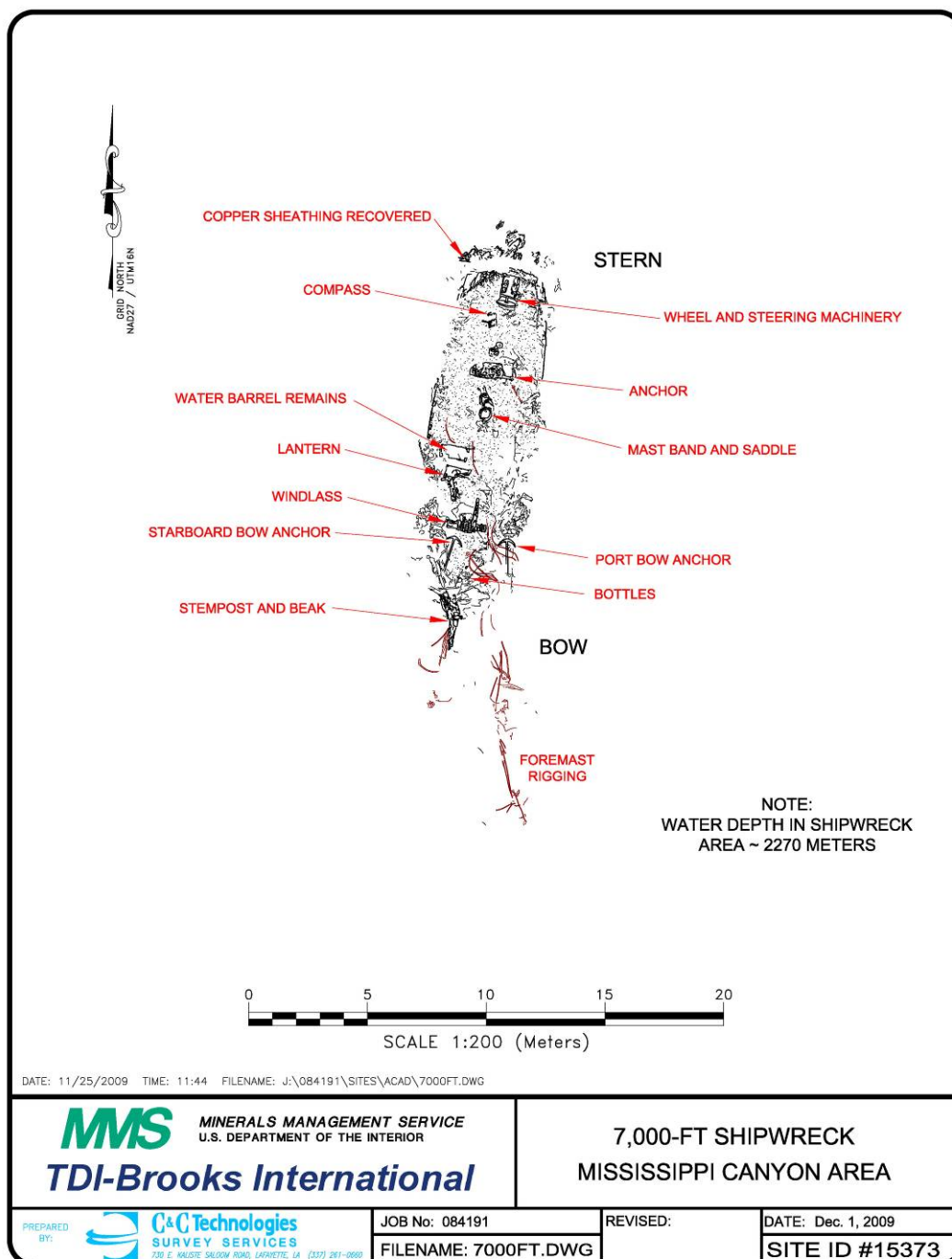


Figure 9-8. Site map of the 7,000-ft Wreck Site.

9.5.2.4 Season II Cruise (2009)

Archaeological investigations of the 7,000-ft Wreck took place on September 6 and 7, 2009. *Jason II* entered the water at 19:56 on September 6, and began the 2,270 m descent, arriving at the wreck site at 21:14. As at the VK wreck, the investigations commenced with a reconnaissance of the site. Beginning at 21:30 scientists used *Jason II* to image the beak remnants (Figure 9-9), then proceeded aft along the starboard side towards the stern. As *Jason II* moved down the vessel's starboard side, various debris and artifacts were noted including, wood and metal fragments, two anchors, and the ship's upside down windlass (Figure 9-10). Continuing aft near amidships, the team imaged part of the ship's water tank, main mast remnants, decking, and another anchor. Nearing the stern, the ship's compass was observed near a hatchway. Further back of the hatchway, the remains of the ship's patent steering gear rise up from the wreckage (Figure 9-11). At the stern, the vessel's rudder was observed entangled with steering cables. After imaging the stern, *Jason II* was flown up the port side towards the bow, then down the interior of the vessel, imaging these sections of the wreck site. The research team completed the reconnaissance at approximately 22:36 and began the mosaic survey.

The wreck mosaic survey at the 7,000-ft Wreck was comprised of 12 lines at 1-m line spacing run at 6 m altitude. The research team finished mosaicing the wreck at 00:19 on September 7, 2009. At 00:22 the collection of push core samples, rusticle retrieval, and deployment of microbial experiments commenced. These operations were completed by 03:29 when close up examinations and photography of wreck details began (Figure 9-12). At 09:07 artifact retrieval began with recovery of the navigational compass (Figure 9-13). Next, the short-term microbial experiment was retrieved. Finally, a sample of hull sheathing was collected at the stern before *Jason II* ascended to the surface at 10:56 on September 7.

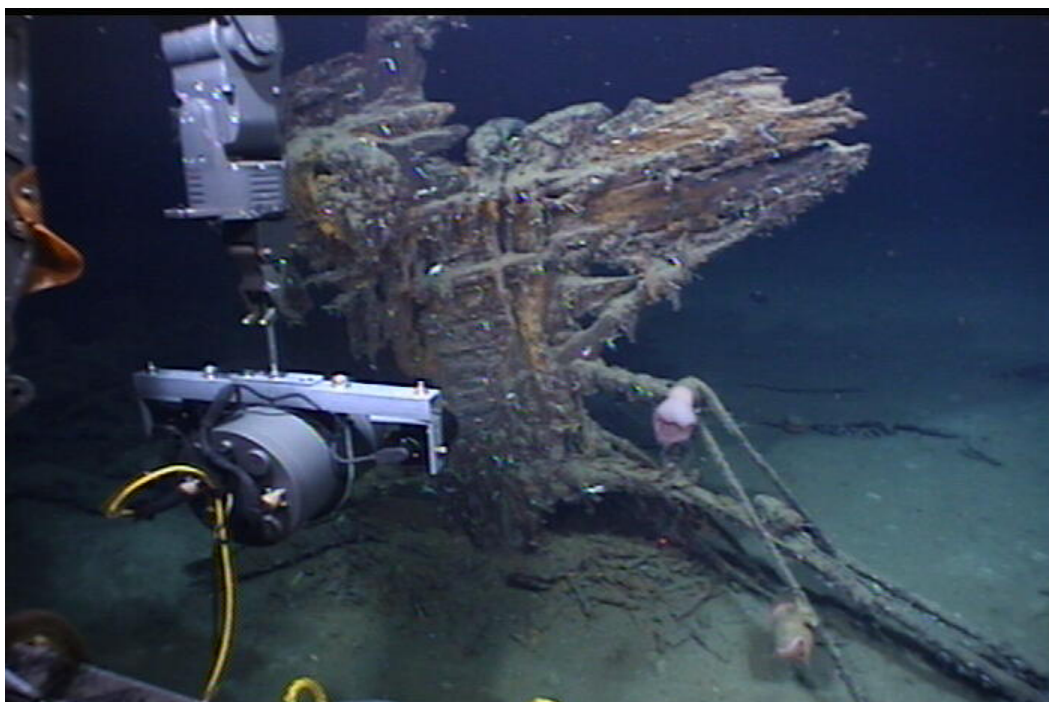


Figure 9-9. The beak remains on the 7,000-ft Wreck.



Figure 9-10. The windlass and anchors visible on the 7,000-ft Wreck.



Figure 9-11. The intact steering mechanism on the 7,000-ft Wreck.

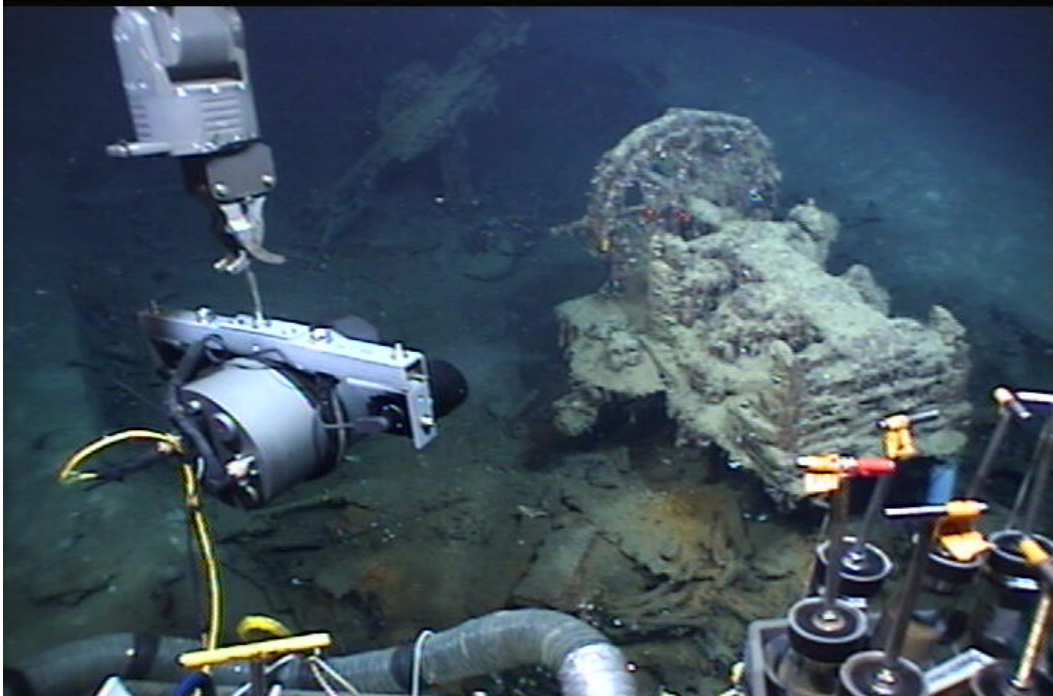


Figure 9-12. Using the high-resolution digital camera to document the 7,000-ft Wreck.



Figure 9-13. Navigational compass being recovered from the 7,000-ft Wreck.

9.5.2.5 Analysis

Analysis of the 7,000-ft Wreck is ongoing. Detailed reviews of the *Jason II* video and still imagery have begun and a site mosaic is being produced. Historical research is being carried out on all aspects of the wreck. Emphasis is on locating information about the navigational compass

recovered from the wreck in hopes that it will help to not only date, but potentially assist in the identification of, the 7,000-ft Wreck.

9.5.2.6 Conservation

Conservation of the materials recovered from the 7,000-ft Wreck is on schedule. A brief summary of the conservation status of each artifact is provided below.

Artifact: MMS09.15373.CO.001 Compass

The compass (Figure 9-14) is a complex artifact, with moving parts and a composite structure. It was also filled with oil, which must be removed before conservation can begin. The oil has also made desalination difficult, which means the process will be greatly extended. It will be a few more months before conservation on the compass will begin.



Figure 9-14. Navigational compass recovered from the 7,000-ft Wreck (top view).

Artifact: MMS09.15373.M.002 Copper Sheathing with Tacks

This piece of copper sheathing (Figure 9-15) is almost finished with the desalination process, and will be ready for mechanical cleaning in the next few weeks. Since there is wood still attached to the sheathing, the wood will need to be conserved first to prevent deterioration as it dries.



Figure 9-15. Copper sheathing sample from the 7,000-ft Wreck.

Artifact: MMS09.15373.M.003 Wood Sample with Copper Sheathing

Originally intended as a wood sample (Figure 9-16) from the wreck, this artifact contains no wood, and is only sheathing. This artifact is still in the desalination process, and will likely be ready for conservation in the next few weeks. This artifact is very fragile, and will have to be gently cleaned with a wire brush so as not to scratch or damage the material.



Figure 9-16. Wood and copper sheathing fragments from the 7,000-ft Wreck.

9.5.3 Ewing Bank (EW) Wreck (Site 15401)

9.5.3.1 Overview and History

The Ewing Bank (EW) Wreck (Figure 9-17) was discovered during a 2006 oil and gas AUV survey with the *C-Surveyor I*TM. The acoustic signature suggested this was an historic shipwreck site. The wreck was estimated to be roughly 45 m long and 12 m wide, based on geophysical data. Processed multibeam imagery over the wreck showed an oval ship-like feature surrounding a central depression. Data indicated the wreck site is resting on a south trending slope with an average gradient of 1°. Maximum seafloor relief occurs at the south end of the site where the remains are approximately 2 to 2.4 m above the ambient seafloor. The wreck appears to be leaning to the west at a maximum angle of 7° at the southern end. The multibeam data corroborated the findings of the side scan sonar. The outer materials shown in the acoustic imagery were thought to represent substantial portions of a wooden hull. The inner materials, shown as a hard return on the side scan sonar, and as a depression on the multibeam, were considered to be the vessel's cargo or ballast. As with the side scan sonar data, the multibeam resolution was not high enough to determine which ends represent the vessel's bow and stern (Warren 2006).

9.5.3.2 Previous Investigations

A high-frequency AUV survey, flown over the site in 2007, provided evidence suggesting the site was a historic shipwreck.

9.5.3.3 Season I Cruise (2008)

The R/V *Nancy Foster* arrived at the site of the EW Wreck at 20:18 on September 6, 2008. The ROV was in the water about thirty minutes later at 20:50. A short dive was planned to check out the ROV systems and get a first look at the wreck to aid in planning the next day's dives. The ROV was on the seafloor at 21:30. The ROV arrived at the wreck site approximately an hour and fifteen minutes later. Forty-five minutes were spent exploring the wreck site during this dive. The ROV reached the surface at 23:05, but was not recovered and on the deck of the R/V *Nancy Foster* until nearly 23:50.

Second day of investigations on the EW Wreck began with the launch of the ROV at 09:30 on September 7, 2008. The ROV descended to the bottom from 09:30 to 10:11. Once on the bottom, the ROV left the cage and nine minutes later was on the wreck site. From 10:20 until 12:16, the science team conducted a reconnaissance of the wreck site. At 12:16, however, problems with the 3-chip camera system forced the suspension of the dive and the ROV ascended to the surface for repairs. The ROV was back on the deck of the R/V *Nancy Foster* at 13:07. Between 1308 and 1714, the ROV crew retooled the ROV camera system, replacing the 3-chip camera with the SeaEye low-light camera. During the retooling, the digital still camera was damaged and removed from the ROV system. Because of the length of time necessary to install the replacement camera, the next dive was without a digital still camera. By 17:55 all repairs were completed and the ROV was back on site, from 19:11 to 19:30, the R/V *Nancy Foster* was repositioned to insure that the ROV cage was in position for biological assessment and collection. At 19:39, the cage was set down on the seafloor on the east side of the wreck and preparations were made to collect biological samples.

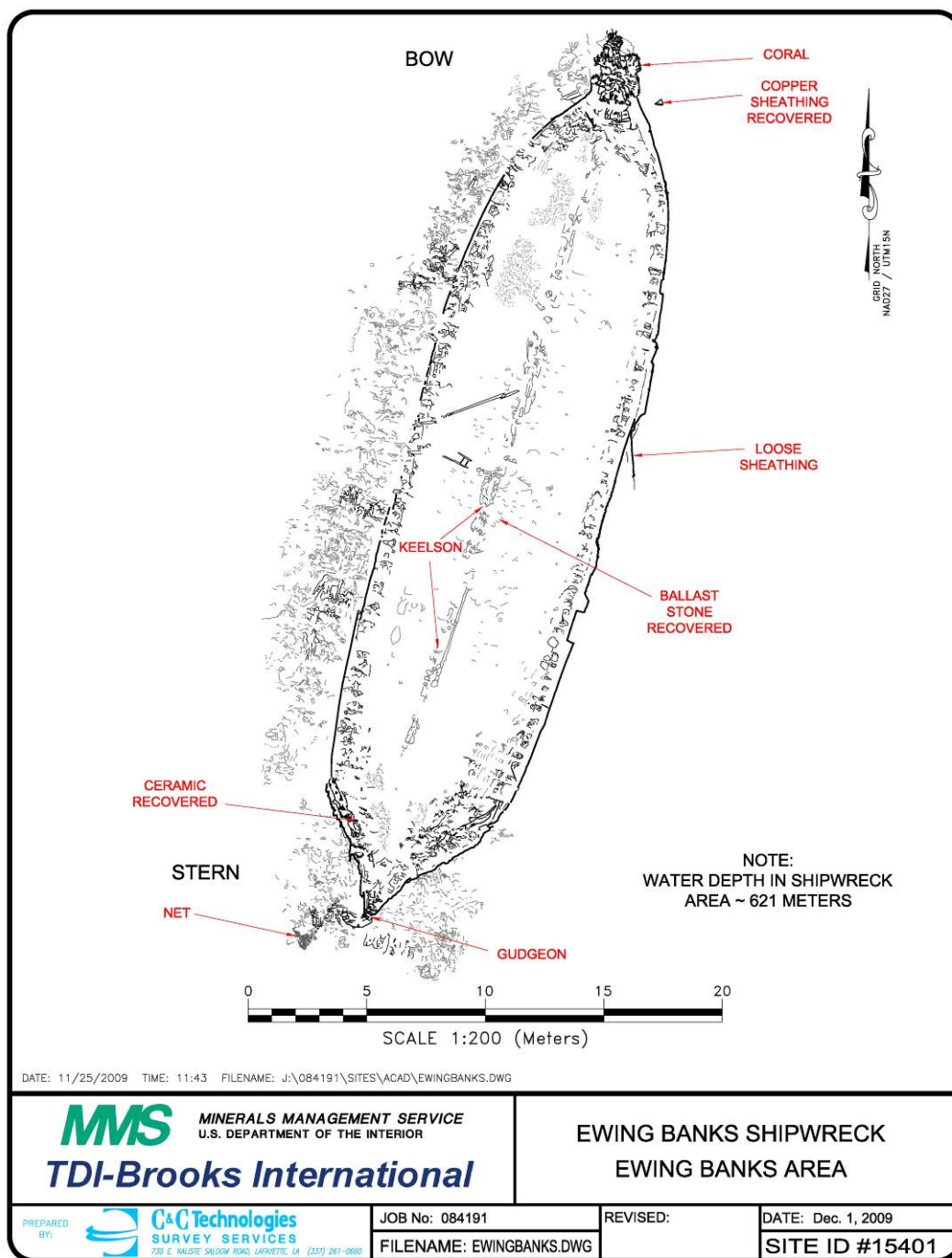


Figure 9-17. Site map of the Ewing Bank (EW) Wreck Site.

Coral colonies on the bow were imaged with scale. A ball on a T-handle was used for scale. The ROV was equipped with parallel lasers, but it is difficult to scale branching coral with the lasers. Then the operation moved to a small coral colony along the aft starboard side of the wreck for collection. It was discovered that the ROV could not reach the colony from the current location of the ROV cage (the tether was approximately one foot too short). The cage was

moved 20feet closer to the wreck site and the collection attempt proceeded. An attempt was made to collect a small sample of the coral, but the entire colony fell to the seafloor upon contact. The colony had apparently not been well anchored to the side of the hull (the colony was growing along the copper sheathing and was likely attached to a small fastener rather than to the copper). The colony fell in a precarious location below the side of the hull. Numerous attempts were made to collect a sample of the coral, resulting in a small wood sample being collected, before coral collection was suspended and the team turned to sediment core collection.

The ROV also experienced problems collecting the core samples. From 19:50 to 22:20, several attempts were made to retrieve the core tubs from the core holsters, but due to a strong cross current, the ROV was able to successfully retrieve only one core tub and collect a sample. Operations were discontinued at 2220. The ROV was back on the surface at 23:19 and successfully transferred onto the deck of the ship by 23:20.

9.5.3.4 Season II Cruise (2009)

The 2009 archaeological investigations of the EW Wreck took place on September 7 and 8, 2009. *Jason II* entered the water at 23:56 on September 7 and began the 622-m descent, arriving at the wreck site at 00:28 on September 8, 2009. At 00:56 the reconnaissance survey started at the stern of the wreck (Figure 9-18) and moved up the starboard side of the wreck towards the bow. Along the starboard side, the science team observed construction aspects of the wreck, as well as corals, vertebrates, and invertebrates (Figure 9-19). Moving amidships, several sections of damaged hull sheathing clearly showed sheathing fastener patterns (Figure 9-20). At the bow the team photographed the *Lophelia* colony on the stem post. The stem post extends approximately 2.4 m up from the seafloor and is home to the largest growth of *Lophelia* on the wreck (Figure 9-21). After imaging the bow, the survey was continued aft down the vessel's port side. Investigations revealed stratified hull and framing remnants along this side of the ship. Just forward of the stern, the team located the remnants of a shelf containing several ceramic vessels. At 02:08, *Jason II* was moved inboard of the stern to document the wrecks interior. By 02:20, the science team finished the reconnaissance and began the mosaic survey.

Since the EW Wreck had been previously imaged using an AUV mounted camera system, only six combined biological and mosaic lines were surveyed over the wreck. These lines were flown at roughly 5.5 to 6.5 m altitude. The research team completed the mosaic survey at 03:50. Between 03:57 and 06:19 researchers collected nine cores and deployed the long and short-term microbial experiments. At 06:29 close up inspection and photography of wreck details was started. Because of the limited artifacts scheduled for recovery at this site, the team retrieved materials concurrently with the detailed inspections. Between 06:29 and 11:03, the crew took detailed images of wreck features and recovered four artifacts for study, including a sample of netting, a ballast stone, hull sheathing, and a part of a ceramic container (Figure 9-22). The short-term microbiological experiment was also recovered during this period. Following the artifact recovery, rusticle and additional biological samples were collected before ending survey operations and returning to the surface at 12:08.



Figure 9-18. The EW Wreck sternpost showing the pintle and gudgeon remnants.

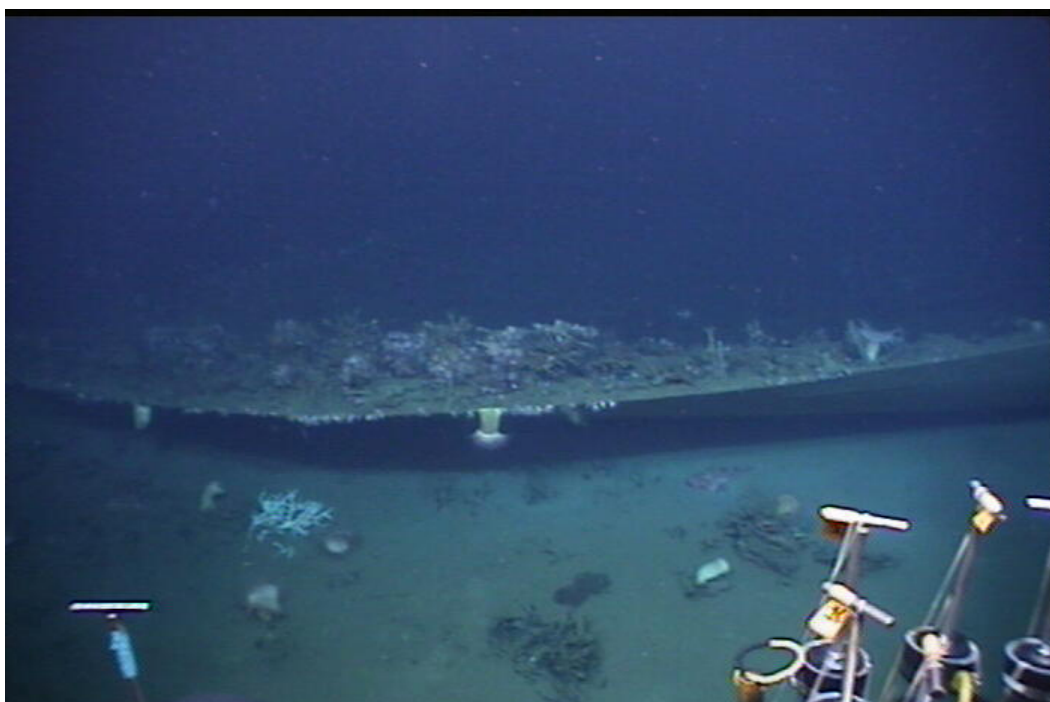


Figure 9-19. The starboard hull of the EW Wreck.



Figure 9-20. Damaged sheathing and fastener patterns on the EW Wreck's starboard side.

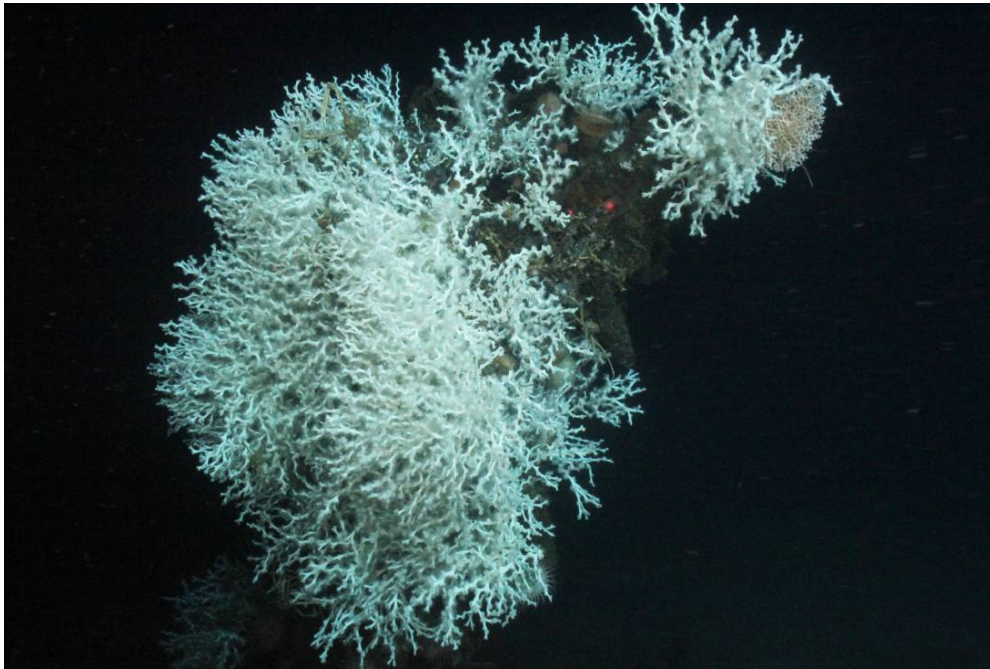


Figure 9-21. View of the *Lophelia* colony growing on the EW Wreck's stem post.



Figure 9-22. *Jason II* recovering an ironstone vessel from the EW Wreck.

9.5.3.5 Analysis

Analysis of the EW Wreck video and imagery is in its early stages and a site mosaic has been produced. Historical research on the wreck is in progress. Emphasis is on locating information related to the ceramic vessel and sheathing fragment recovered from the wreck in hopes that it will help to not only date but also potentially assist in the identification of the EW Wreck.

9.5.3.6 Conservation

Conservation of the materials recovered from the EW Wreck is on schedule. A brief summary of the conservation status of each artifact is provided below.

Artifact: MMS09.15401.C.001 Ceramic Vessel

After desalinating, the ceramic (Figure 9-23 and Figure 9-24) was first cleaned with a three percent solution of hydrogen peroxide and a soft toothbrush to remove the organic stains on the surface. Next, the artifact was cleaned with a five percent solution of oxalic acid to facilitate the removal of metallic stains that were on the surface. Once the ceramic was clean of stains, it was rinsed thoroughly to ensure any acid residue was removed. After being washed, the ceramic was allowed to air dry, and conservation of the artifact was complete. Post-conservation photographs and measurements were taken.



Figure 9-23. Ironstone vessel from the EW Wreck before conservation.



Figure 9-24. Ironstone vessel from the EW Wreck after conservation.

Artifact: MMS09.15401.M.002 Copper sheathing with tacks, wood, and felt attached

Due to the wood on the sheathing (Figure 9-25), the artifact is still undergoing desalination. After desalination, much care will be taken to preserve all of the elements of this artifact, especially the felt that is still attached.



Figure 9-25. Copper sheathing and fastener sample from the EW Wreck.

Artifact: MMS09.15401.I.003 Ballast

This ballast (Figure 9-26) was not sent to the University of West Florida lab to undergo conservation, but was sent to the Geology Department at Louisiana State University for analysis and sourcing. The ballast stone is currently at the C & C offices in Lafayette, Louisiana, awaiting further analysis.

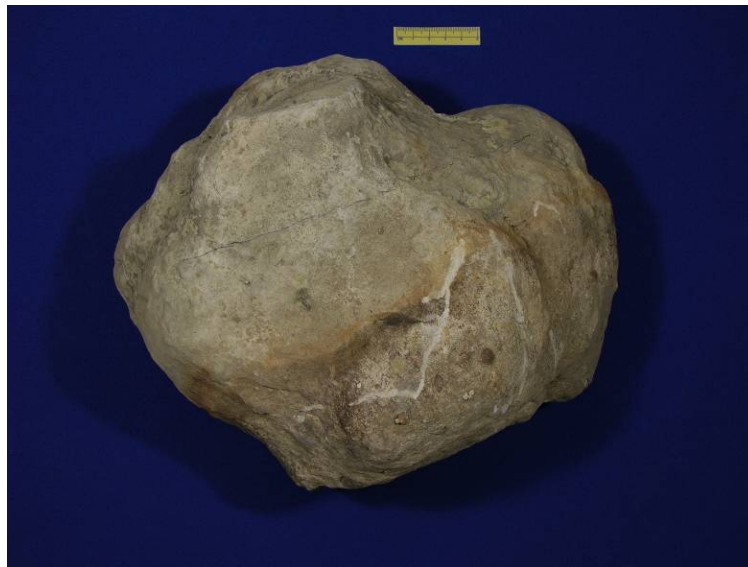


Figure 9-26. Ballast stone from the EW Wreck.

Artifact: MMS09.15401.O.004 Net Sample

This artifact (Figure 9-27) was photographed and later inspected under the microscope. It was constructed from synthetic-based fibers (i.e. nylon or polypropylene) and is considered intrusive to the wreck site. A miscommunication between the field PI and the conservator led to the net sample being inadvertently discarded.



Figure 9-27. Net sample from the EW Wreck.

9.6 GREEN LANTERN WRECK (SITE 337)

9.6.1 Overview and History

The vessel known as the *Green Lantern* Wreck (Figure 9-28) is an unidentified shipwreck dating to the mid-nineteenth century. The vessel was found during a deep-tow survey by C & C Technologies in June 1996 and resurveyed with the *C-Surveyor I* AUV in August 2004 (Church and Samuel 2004). An ROV investigation revealed that the wreck was a copper-clad sailing vessel measuring approximately 20 m in length. An area of debris, including chain, cable, and small remains, extends out from the bow section. The word *estribor*, Spanish for “starboard,” is embossed on one of the ship’s lanterns, indicating the vessel may be of Spanish or Latin American origin (Church 2004 and Horrell 2006). There is considerable biological growth associated with the wreck. Because of the vessel’s age and state of preservation, it is considered historically significant and potentially eligible for the National Register of Historic Places.

9.6.2 Previous Investigations

9.6.2.1 2004

A 2004 ROV survey was undertaken at this site as part of a BOEMRE oil and gas permit requirement to determine if the site represented a historic shipwreck. Fugro-Chance and Oceaneering conducted the ROV investigation using a Millennium VI ROV on board *Ocean Service*. C & C Marine Archaeologist Robert A. Church oversaw the investigation. The shipwreck site covers a 36.6 m x 11 m area and has approximately 1.5 m of relief. The vessel is oriented near north to south, with the bow pointing south-southeast. The ROV investigation revealed that the wreck is a sailing vessel measuring approximately 19.8 m in length. The vessel is sheathed with a greenish-tented metal, which is either copper or possibly Muntz metal. It is not possible to determine sheathing type without laboratory analysis. Large round copper bolts were used to fasten the main structural frame components of the vessel and many large copper spikes are visible across the wreck site. Smaller square nails with round heads were used to fasten the sheathing to the hull of the vessel.

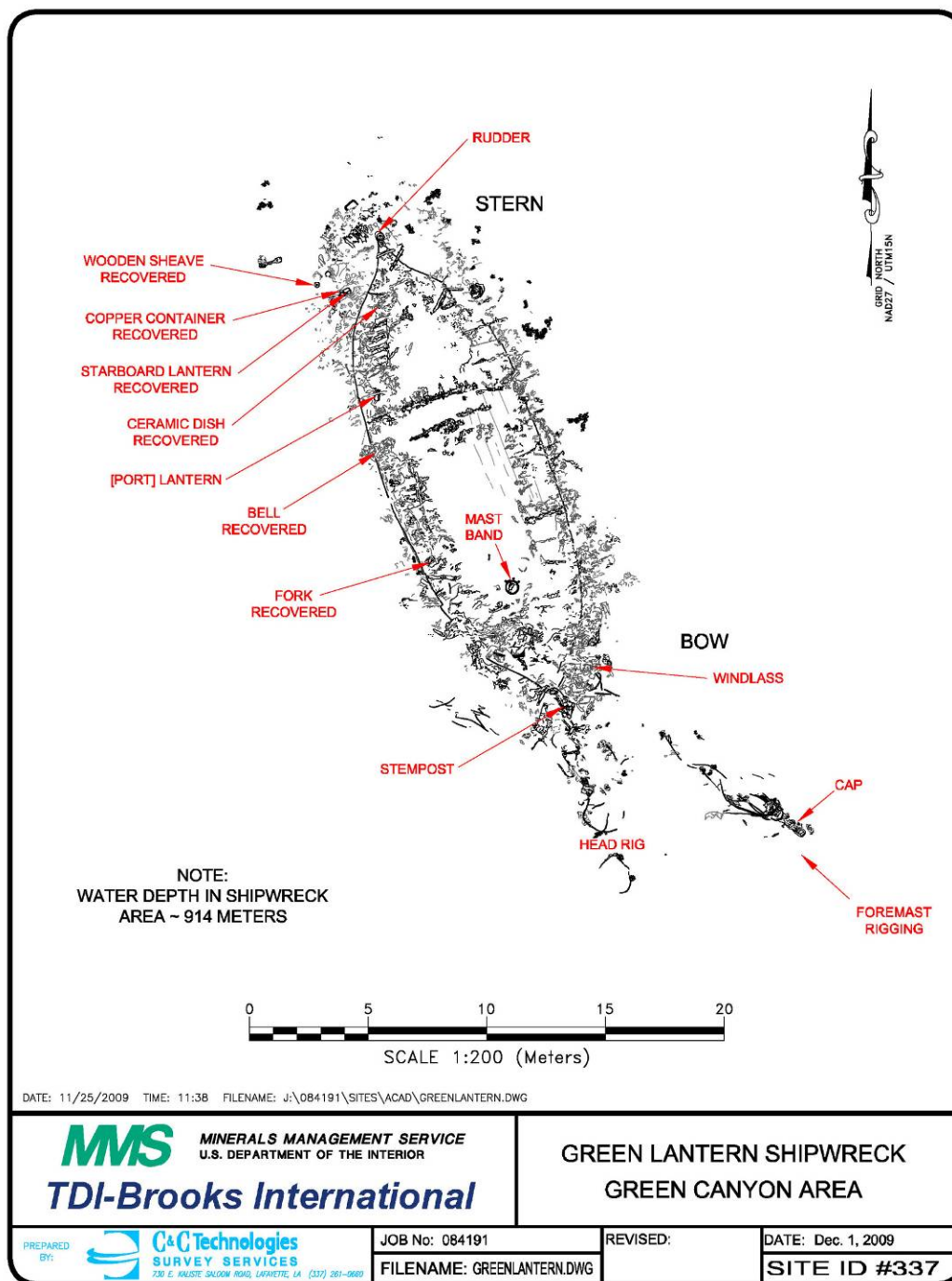


Figure 9-28. Site map of the *Green Lantern* Wreck site.

9.6.2.2 2007

In 2007 another investigation of the *Green Lantern* Wreck was undertaken under MMS guidance. This survey verified the findings of the 2004 investigations and identified several components of the wreck, including a second navigation lantern and the ship's bell. No materials were recovered as part of this investigation.

9.6.3 Season I Cruise (2008)

The R/V *Nancy Foster* arrived on the site at 02:22 on September 16, 2008 and the ROV was on by 05:02. As a result of poor visibility and strong currents hampering operations, the wreck site was not reached until nearly an hour later. At 05:50, the wreck was imaged on the scanning sonar. The ROV was slowly maneuvered to the stern facing into the current. The pilot found the ROV extremely difficult to control in the current without setting the ROV down on the seafloor. Each time the ROV pilot attempted to fly up to the wreck, he lost control of the vehicle in the current. At 06:59 the dive was aborted because of unsafe conditions and the decision was made to cease operations at the *Green Lantern* Wreck and move to a different location. By 08:20 the ROV was on deck and the R/V *Nancy Foster* was transiting to the next location.

9.6.4 Season II Cruise (2009)

Archaeological investigations of the *Green Lantern* Wreck during the Season II Cruise took place on September 8 and 9, 2009. *Jason II* entered the water at 20:00 on September 8 and began the 914 m descent, arriving at the wreck site at 20:48. At 21:00 the reconnaissance survey commenced at the stern. The sternpost and rudder remains (Figure 9-29) were imaged before documenting remains along the vessels starboard side. Near the starboard stern a concentration of debris was observed. Within this debris was a large navigational lantern as well as rigging and hull remains (Figure 9-30). Continuing up the wreck's starboard side, the *Jason II* science crew imaged various biological species and ship-related materials (Figure 9-31). At 21:48 *Jason II* arrived at the bow and documentation began on the forward hull. A key feature of the bow is the extant stem post with intact load level markings (Figure 9-32). By 21:53, imaging of the bow was completed and the *Jason II* crew continued the reconnaissance survey down the port side of the wreck. Along the port side, scientists noted a portion of hull ceiling planking, mast and spar rigging, and various personal artifacts. Following completion of the portside and centerline examinations, the reconnaissance survey was ended at 22:25.

At 22:36, *Jason II* was positioned at the bow to fly mosaic lines over the *Green Lantern* Wreck. The mosaic survey consisted of 14 lines flown at 5-m altitude and spaced 1 m apart. Mosaic lines over the wreck were finished at 01:37 on September 9. Following the mosaic survey, photo transects, push core collection, and deployment of microbiological experiments were undertaken until 04:56. Following the biological transects, at 06:29 close-up inspection and photography of the wreck were undertaken until approximately 10:48. Shortly thereafter, the short-term microbiological experiment was retrieved and artifact collection started. Six artifacts, the most from any site, were recovered from the *Green Lantern* Wreck, including an eating fork, rigging sheave, ceramic plate, the ship's bell, one of the ship's lanterns (Figure 9-33), and a sealed box initially thought to be a lantern cap. Once all the artifacts were secured in *Jason II*'s storage bins, the vehicle moved away from the wreck site and began its ascent to the surface at 15:36.



Figure 9-29. The sternpost on the *Green Lantern* Wreck.



Figure 9-30. Debris field off starboard stern of the *Green Lantern* Wreck.



Figure 9-31. Crab, coral, and hull remains on the *Green Lantern Wreck*.



Figure 9-32. Stem post and bow remains at the *Green Lantern Wreck*.



Figure 9-33. *Jason II* recovering a navigation lantern from the *Green Lantern* Wreck.

9.6.4.1 Analysis

Analysis of the *Green Lantern* Wreck has started. Detailed reviews of the *Jason II* video and still imagery are ongoing and a site mosaic is being produced. Historical research on the wreck is in progress. Emphasis is on locating information related to the ceramic vessels, navigational lantern, and wooden sheave fragment recovered from the wreck in hopes that it will help to not only date, but potentially assist in the identification of the *Green Lantern* Wreck.

9.6.4.2 Conservation

Conservation of the materials recovered from the *Green Lantern* Wreck is on schedule. A brief summary of the conservation status of each artifact is provided below.

Artifact: MMS09.373.CO.001 Lantern

The lens of the lantern (Figure 9-34) was manufactured as two sections that fit together in the lantern side by side. One of the sections, which had fallen out of the lantern during recovery, was broken into two pieces. The other half of the lens was still secured in the lantern during recovery, but was also broken into two pieces. During conservation, the two pieces of the lens still in the lantern were carefully removed, as they were unlikely to stay in the lantern. The lenses were gently scrubbed with a soft toothbrush, which removed much of the buildup that had accumulated. They were then cleaned with a five percent oxalic acid solution to remove the metallic stains, then washed repeatedly to remove any acid residue, and left to air-dry. After the lens pieces were completely dry, the broken pieces were reconstructed using Locktite Instamix Epoxy. Rubbings of the two halves of the lens were taken to document the patent marks and allow photographs to be taken.

The glass from the door of the lantern was discovered inside the lantern among the mud and various lantern fragments. Around the small rectangle of glass was a copper frame. The glass was cleaned with five percent oxalic acid solution to remove the metallic stains from the surface. The copper frame was mechanically cleaned with a wire brush. The frame was soaked in a one percent solution of benzotriazole (BTA) and water in order to prevent further corrosion. Once the BTA was dry, the frame was sprayed with Krylon to seal and protect it.

The lantern itself is being stabilized in a passive treatment of five percent sodium sesquicarbonate. The sodium sesquicarbonate will prevent further deterioration of the metal frame due to alkaline pH and remove copper chloride ions, until the lantern is ready for conservation.



Figure 9-34. Lantern recovered from the *Green Lantern Wreck* site.

Artifact: MMS09.373.M.002 Metal Fork

The fork (Figure 9-35) was partially cleaned with a wire brush to remove the corrosion and encrustation. On the back of the fork an engraving can be made out [SIM... GEORGE H. ROGERS]. The fork is currently being stabilized in a five percent solution of sodium sesquicarbonate until the rest of the encrustation can be removed.



Figure 9-35. Fork recovered from the *Green Lantern* Wreck site.

Artifact: MMS09.373.M.003 Copper Container

The copper container (Figure 9-36 and Figure 9-37) is still undergoing the desalination process. Before any conservation treatment was started, x-rays were taken to determine the container's contents. Radiography revealed that the round container is most likely empty of original contents and filled with sediments.



Figure 9-36. Copper container from the *Green Lantern* Wreck site.

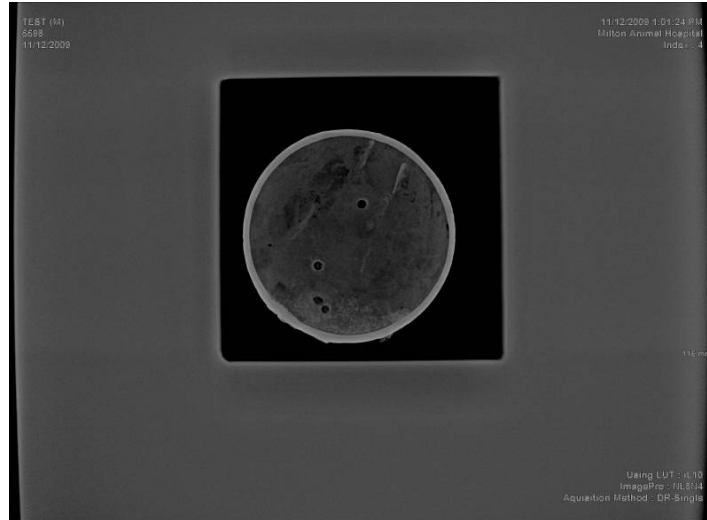


Figure 9-37. X-Ray of copper container from the *Green Lantern* Wreck site.

Artifact: MMS09.373.W.004 Wood Sheave

The sheave (Figure 9-38) is still undergoing the desalination process because it still contains a high percentage of chlorides. Once the chlorides have been removed, the sheave will be conserved.



Figure 9-38. Wooden sheave recovered from the *Green Lantern* Wreck site.

Artifact: MMS09.373.M.005 Bell

After desalination, the bell (Figure 9-39) was placed in electrolysis in five percent sodium carbonate for about a week. After electrolysis, the bell was cleaned with a fiberglass brush to help scrub and polish the metal. The bell was then polished with baking soda, and is ready for a sealant to be applied to protect the metal.



Figure 9-39. Ship's bell from the *Green Lantern* Wreck site.

Artifact: MMS09.373.C.006 Ceramic Plate

After desalination, the ceramic (Figure 9-40 and Figure 9-41) plate was cleaned with a 31 percent hydrochloric acid solution to remove the thick encrustation that had developed on its surface. After cleaning, the plate was rinsed in multiple fresh water baths to remove any acid residue. The plate was then set out to air dry and then was photographed, completing the conservation process.



Figure 9-40. Ceramic plate from the *Green Lantern Wreck* before conservation.



Figure 9-41. Ceramic plate from the *Green Lantern Wreck* after conservation.

9.7 TANKER *GULFPENN* WRECK (SITE 15265)

9.7.1 Overview and History

Gulfpenn was built in 1921 as an 8,862-ton tanker (Figure 9-42). On May 13, 2003, she left Port Arthur, Texas, loaded with ninety thousand barrels of fuel oil. At mid-afternoon the same day, the tanker was struck in the engine room by a torpedo from U-506. Twenty-five of the crew survived the attack but thirteen perished (Berman 1971; and Wiggins 1995).

The vessel was located in 1994 and was investigated in 2004 as part of the Deep Wrecks I Study (Church et al. 2007). This site has extensive *Lophelia* coverage as well as deep reef fish and various other invertebrates. As part of the previous MMS study, Droycon Bioconcepts test coupons were left at the site to assess deterioration rates (Church et al. 2007). This wreck is considered historically significant and a National Register Nomination was prepared for this site as part of the Deep Wrecks I Study.

9.7.2 Previous Investigations

The *Gulfpenn* shipwreck site was investigated in 2004 as part of the Deep Wrecks I Project. Investigations at the site were carried out using a Triton XL11 ROV from August 4 to 5 and August 11–13, 2004 operated from the M/V HOS *Dominator*. As part of this project, the main hull and the surrounding area were investigated in detail. The examinations found the bow and forward sections of the main hull relatively intact, but with extensive deterioration of the superstructure. The aft section of the vessel was severely damaged and the stern had detached from the main hull. The missing stern section was found approximately 27 meters northwest of the bow. Debris fields surround the main hull structure, with the largest extending out nearly 161 meters northwest of the primary hull remains. The investigation concluded that the damage noted on *Gulfpenn* was consistent with the historic accounts and surmised that following the torpedo attack the stern tore away from the main hull.

The 2004 investigations also determined the site is in a moderate state of preservation. It is speculated that the aft section is deteriorating at a higher rate than the rest of the vessel as a result of the damage sustained at the time of wrecking.

9.7.3 Season I Cruise (2008)

Archaeological investigations at *Gulfpenn* were undertaken on September 8, 2008 from the R/V *Nancy Foster*. At 10:41, the ROV was put in the water to check the trim after the camera changes (The macro-camera was added to the ROV to replace the WesTech SDS3030). Unfortunately, during the trim check the ROV was pulled under *Nancy Foster* and the tether fouled between the ship's rudder and port Z-drive. At 11:05, the cage was launched in an effort to pull the ROV down and unfoul the tether, which was successful and at 11:10, the tether cable was pulled free. The ROV was safely on the deck of *Nancy Foster* at 12:20. The ROV was back in the water at 13:15. Between 13:15 and 13:58, the ROV descended to the *Gulfpenn* site. After a forty-three minute descent, the ROV was on the bottom. Progress across the seafloor was slow, because of strong current and poor visibility. At 14:39, the team began ROV investigations of the suspected stern section. They observed what appears to be the vessel's rear flagpole, still standing after more than a half century on the seafloor. At 15:00, the ROV was moved to the cage for a brief inspection. At 15:05, the ROV headed to the wreck's main section. The ROV maneuvered to inspect the abundant coral colonies on the bow. Significant amounts of coral, which had broken off and fallen from the hull above, were observed on the seafloor. From

15:20 to 16:00, the team inspected *Gulfpenn*'s leeward (port) side where working conditions were more favorable. At the forward edge of the aft deckhouse, a large *Lophelia* colony, once attached to the lifeboat davit, was found in pieces scattered across the ship's hull and a the surrounding seafloor.

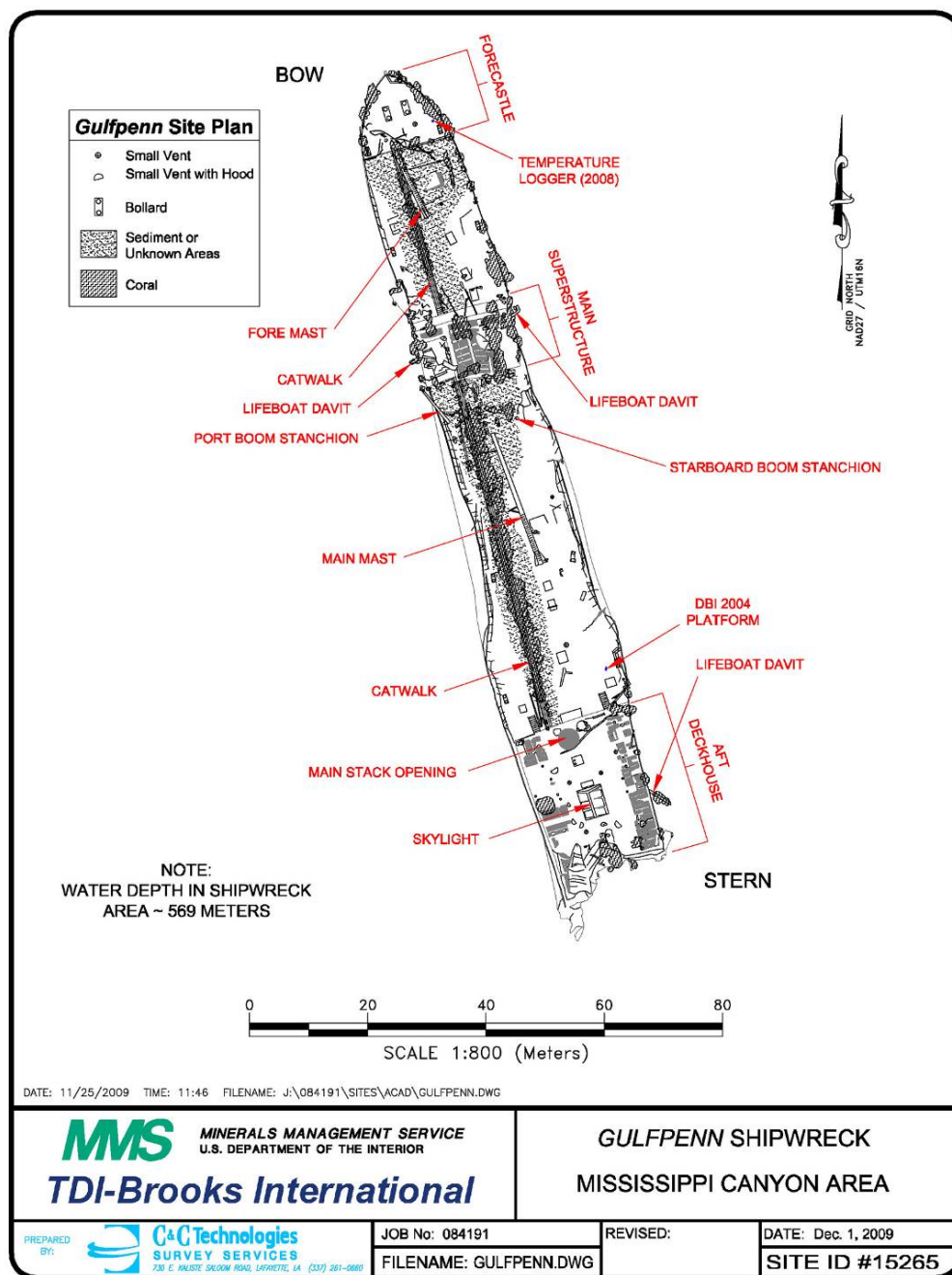


Figure 9-42. Site map of the *Gulfpenn* Wreck site.

Following the port side investigations, the ROV moved to the starboard side to inspect a microbial platform placed in 2004, but strong currents hampered ROV operations. Between 17:57 and 18:03 a temperature logger was placed on the starboard bow. At 18:05, the main LED

light on the ROV malfunctioned and the vehicle was recovered without collecting biological samples.

During the ROV recovery, the tether was fouled in the port Z-drive and severed. The damaged tether forced the termination of further investigations on *Gulfpenn*.

9.7.4 Season II Cruise (2009)

The 2009 investigation of *Gulfpenn* took place on September 10, 2009. This investigation focused on documenting the *Lophelia* colonies and biologic activity on the wreck, so archaeological investigations were limited. (For a complete description of the 2009 investigations at *Gulfpenn*, please refer to the biological section of this report.) The limited archaeological investigations at the site focused on the superstructure near the middle of the wreck and on the previously placed microbiological platform. *Jason II* was used to image areas of the bridge and take pictures of the engine order telegraph that was used to communicate between the bridge and the engine room. Near the aft deckhouse, the microbial experiment deployed in 2004 was relocated. It had fallen over on its side, so the team picked it up with *Jason II* and stood it against one of the structures on the deck. An additional long-term microbiological experiment was set on *Gulfpenn*'s port bow along with a short-term experiment. The short-term experiment was unfortunately not recovered at the end of the dive. At 11:37, the investigations on *Gulfpenn* were finished and *Jason II* returned to the surface.

9.7.5 Analysis

Gulfpenn was documented during the Deep Wrecks I project, so only limited analysis of the site is being conducted to better document the stern section, continue the deterioration rate analysis and expand the history of the vessel.

9.7.6 Conservation

No artifacts were recovered from the *Gulfpenn* site.

9.8 TANKER GULFOIL WRECK (SITE 430)

9.8.1 Overview and History

Gulfoil was a 5,188-ton tanker built in 1912 (Figure 9-43). On May 16, 1942, she left Port Arthur, Texas with a cargo of petroleum headed for New York City. At 10:41 the same night a torpedo struck the tanker amidships on the starboard side. Minutes later a second torpedo hit the engine room. The ship began listing hard to starboard and went down fast, taking 21 of the crew with her (Wiggins 1995; Burch 1942; Browning 1996).

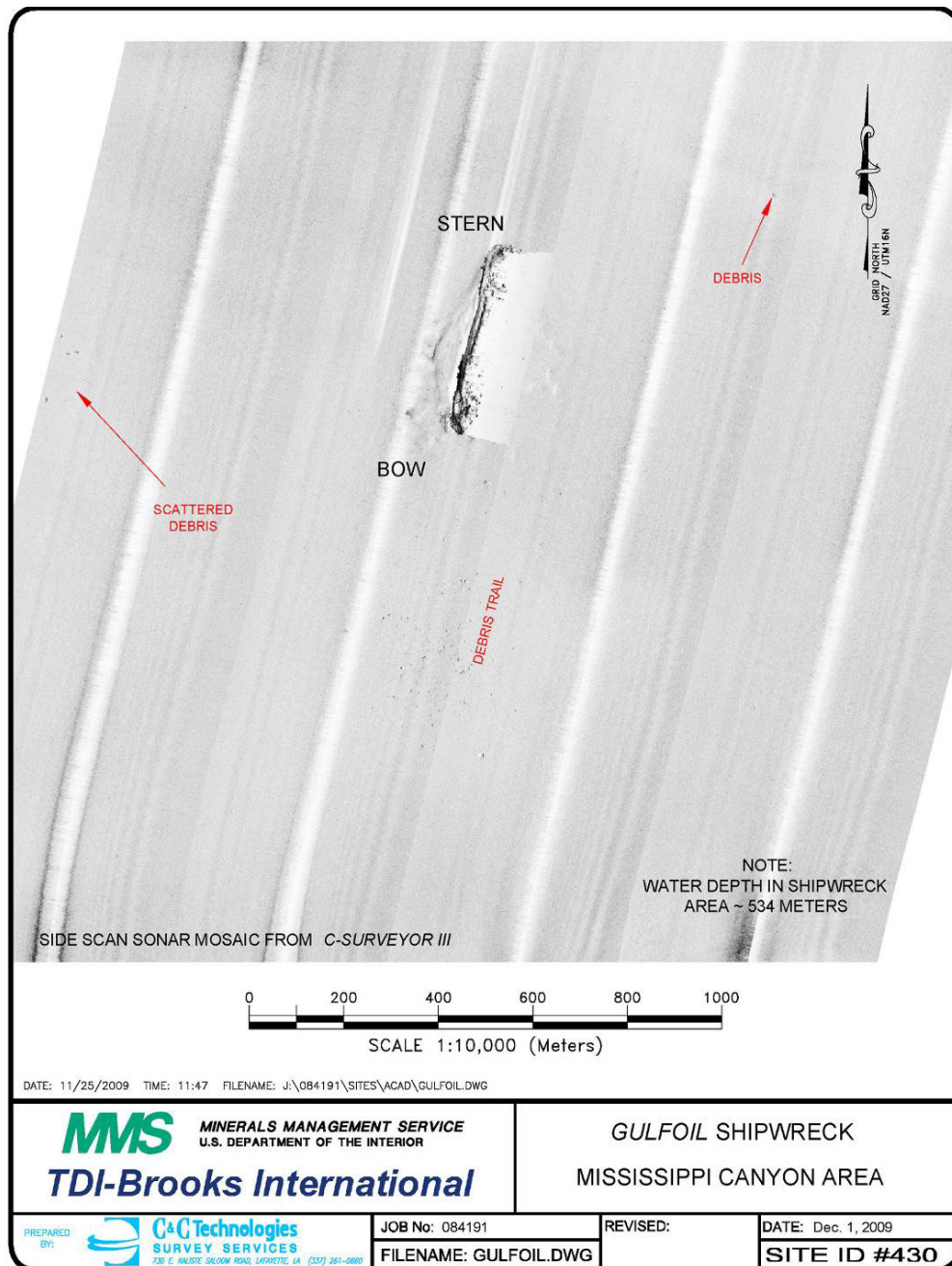


Figure 9-43. Site map of the *Gulfoil* Wreck site.

C & C researched *Gulfoil* in anticipation of visiting the site during the 2004 Deep Wrecks I Study. Before field investigations began, however, the wreck thought to be *Gulfoil* was determined to be a modern wreck and was not included in the study. Another vessel thought to be *Gulfoil* was located during a deep-tow survey conducted after Hurricane Katrina in 2005. The vessel has a length of 116 m and beam of 15.5 m. This shipwreck was visually inspected and so was not confirmed as *Gulfoil*. The wreck is located on the western slope of the Mississippi Canyon, opposite and 150 m deeper than *Gulfpenn*, which is located on the eastern slope of the Canyon. The wreck site will likely be of great interest biologically as well as historically.

9.8.2 Previous Investigations

No ROV investigations were carried out at the suspected *Gulfoil* site before the 2008 fieldwork.

9.8.3 Season I Cruise (2008)

Investigations were carried out on the suspected *Gulfoil* site on September 15, 2005, from the R/V *Nancy Foster*. The ROV was in the water at 08:25 and nearing bottom at 09:10, when one of *Nancy Foster's* generators broke down, sending the vessel adrift. At 09:50, the vessel regained her propulsion, but the ship had drifted off the wreck site. *Nancy Foster* was back on location by 10:38, and at 10:55 the ROV was on the bottom. Strong subsurface currents and low visibility, a result of Hurricane Ike, hampered operations and resulted in the loss of the microbial experiment intend to be placed on the wreck site. The ROV reached the wreck at 11:23 and began the reconnaissance survey. From 11:23 to 12:30, the ROV, although hampered by currents and low visibility, successfully surveyed a portion of the starboard side of the wreck site. The team found the wreck covered with *Lophelia* colonies and was able to positively identify the wreck as *Gulfoil* from the name on the bow. Although time constraints and the site conditions did not allow a detailed, systematic survey, approximately 150 feet of the starboard side of the hull was inspected (deck level from the bow to just past the superstructure) before the ROV was recovered between 13:40 and 14:40.

9.8.4 Season II Cruise (2009)

No investigations were carried out at the site during the 2009 field season cruise.

9.8.5 Analysis

Analysis of *Gulfoil* is underway using the limited imagery collected during the 2008 field season and a recent AUV testing survey over the site. The analysis is focusing on the orientation and distribution of the wreck and artifact scatters to ascertain where the wreck falls within the site avoidance predictive model developed during the Deep Wrecks I Project.

9.8.6 Conservation

No artifacts were recovered from the *Gulfoil* site.

9.9 CONCLUSIONS

Despite a tenuous beginning plagued by weather problems and equipment failures, the established 2008 and 2009 milestones for the *Lophelia II* Shipwreck Component have been achieved. Six shipwrecks were investigated for the first time or revisited during the 2008 and 2009 field seasons. These investigations have led to the positive identification of one vessel (*Gulfoil*) and have garnered new intriguing information on the four wooden wrecks that are part of this study. Preliminary assessments from the field data suggest the wooden wrecks are of later dates than originally expected both in construction and sinking. Additionally, the artifacts recovered from the wooden wreck sites have the potential to help identify and further refine the chronology and understanding of these wrecks. Whether the preliminary assessments hold up to further scrutiny remains to be seen as continuing research begins to tell each wreck's story.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.