US Geological Survey Deepwater Program: *Lophelia* II: Continuing Ecological Research on Deep-Sea Corals and Deep Reef Habitats in the Gulf of Mexico

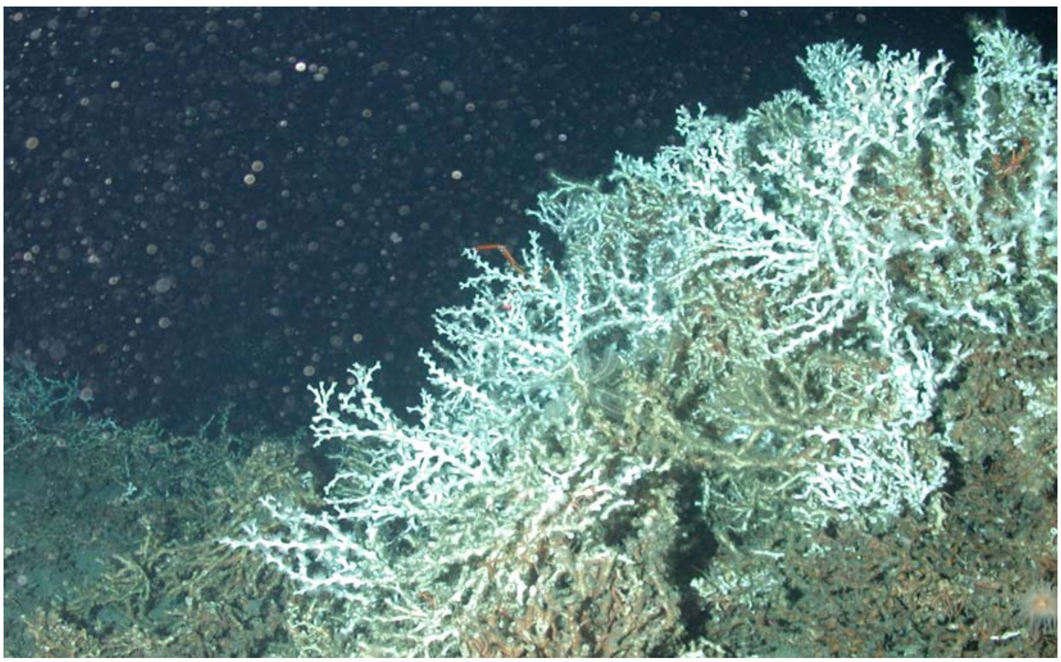
Four Year (1 April 2008 – 30 September 2011) Study Plan Proposal

For study components

Part I. Physical oceanography, ecology, and overall cruise support

Part II. Trophodynamics

Part V. Benthic Ecology



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INTRODUCTION

Our ongoing studies (2000-present) exploring southeastern US (SEUS) and Gulf of Mexico (GOM) continental slope coral ecosystems are based on the observation that these poorly documented habitats are ecologically important and productive. There is increasing evidence that deep-water (aphotic) corals are important fish habitat (Costello et al. 2005; Ross and Quattrini 2007; Sulak et al. in press), a repository of data on ocean climate and productivity (Adkins et al. 1998; Williams et al. 2006), and are hotspots of increased biodiversity, including undescribed species (e.g., Fernholm and Quattrini in press). This is underscored by the growing literature and management concern directed toward these ecosystems (Roberts et al. 2006). Deep-coral habitats are more abundant than previously known (Freiwald et al. 2002; Ross and Nizinski 2007), yet our knowledge of these systems is inadequate to address questions necessary to understand and conserve these vulnerable habitats (Rogers 1999; Koslow et al. 2000; Fossa et al. 2002). The SEUS and GOM may have the most extensive deep-coral areas in the US (Hain and Corcoran 2004). It appears that deep-coral habitat occurs abundantly on the SEUS slope (Stetson et al. 1962; Paull et al. 2000; Reed 2002; Popenoe and Manheim 2001), but may be more scattered in the GOM (Brooke and Schroeder 2007); however, these large regions are poorly explored, even considering recent expeditions. Like seamounts (Rogers 1994), these unique habitats have escaped detailed examination in the SEUS and GOM because of their great depths, rugged bottom topography, and extreme currents (i.e., Gulf Stream, Loop Current) that overlay these habitats, and the lack of substantial fisheries in these depths. Most studies on deep-coral banks require expensive unconventional sampling techniques (e.g., manned submersibles, ROVs).

While the SEUS slope harbors many (> 100) species of corals, few corals create extensive, complex reef structures. *Lophelia pertusa*, the major hermatypic coral in the deep sea (documented to > 2100 m), is a cosmopolitan species (Rogers 1999). It is the dominant hard coral occurring at depths > 300 m throughout the SEUS and GOM (Reed and Ross 2005). Biological and ecological data for *L. pertusa*, in particular, and the fauna associated with the deep-coral banks in this region are limited (see reviews in Ross and Nizinski 2007 and Brooke and Schroeder 2007), but are becoming more prevalent. For example, some fishes appear to have an obligate association with the deep-coral or deep-reef habitats (Ross and Quattrini 2007; Sulak et al. in press), but this may not be the case for fishes in other areas (Auster 2005; Costello et al. 2005) or for this region's invertebrate fauna. Additionally, ages and growth rates of live corals and ages of coral mounds or dead coral stands are poorly known in this area. The genetic structure of *Lophelia* in the northeastern Atlantic has been examined (Le Goff-Vitry et al. 2004 a, b), but western Atlantic population and community genetics studies are just beginning.

Our research priorities of locating, describing, and mapping deep corals and conducting basic biological studies in these habitats are aligned with global priorities for deep-sea corals (Roberts and Hirshfield 2003; Puglise et al. 2005). We have concentrated our work around *L. pertusa* areas because of its abundance, wide distribution, and structure forming abilities, but our objectives are applicable to other hard substrate habitats including mixed corals and sponges, as well as artificial substrates (wrecks, oil platforms). This four-year project will build upon our previous work, which is to date the most comprehensive survey of deepwater coral habitats in the SEUS region. Our previous deep-reef work in the Atlantic SEUS will complement and provide excellent comparative data to this GOM effort. Our research plan involves using several advanced tools (ROV/submersible, multibeam sonar, benthic landers), requiring at least one cruise per year. We will undertake new initiatives and will continue and expand ongoing research topics in order to increase our knowledge of these habitats as well as address major gaps in our studies of deep reefs. As an integrated regional exploration of deep-reef physical structure and ecology, this interconnected, multidisciplinary approach should advance our understanding of critical deep-sea habitats. Using standardized methods throughout this large region will allow comparisons among complex habitats over great depth and latitudinal ranges.

The study components described below represent three parts of a six part U.S. Geological Survey (USGS) study in collaboration with the competitive procurement titled "Continued Investigation of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral." These studies will be integrated and will rely on each other to address continuity and diversity of deep-sea reef habitats.

Part I. Physical oceanography and ecology of the habitat

This study component will use sophisticated benthic landers provided by outside collaborators to gather intensive data on physical and biological aspects of deep coral habitats. We suspect that water depth, water temperature, substrate type, currents, and food availability play important roles in the ecology of these systems, but there are limited data on variability of these and other parameters. Our understanding of deep-water ecosystem function is restricted both temporally and spatially due to the short time research vessels can remain on station or the even shorter time that submersibles can survey the seafloor. Long-term benthic landers or hard-wired seafloor observatories permit measurements to be made through time, allowing behavioral (Roberts et al. 2005) and seasonal (Duineveld et al. 2005) investigations. When equipped appropriately, benthic landers can measure biological and physical processes and rates, including benthic community respiration, erosive characteristics of sediment and sediment geochemistry (Tengberg et al. 1995; Black et al. 2001) at the seafloor.

Cold-water coral ecosystems are a challenging environment for work with benthic landers because the habitats are structurally complex and often swept by fast currents. The Royal Netherlands Institute for Sea Research (NIOZ) and the Scottish Association for Marine Science (SAMS), cooperators in this proposal, have developed proven lander technology which has been deployed on northeastern Atlantic deep-sea coral sites (280-824 m) for periods up to a year. These landers have recorded the activity of benthic megafauna, hydrographic regimes and provided a first estimate of sediment resuspension on cold-water coral reefs (Roberts et al. 2005; Mienis et al. 2007). The NIOZ landers are autonomous and carry dual acoustic releases and enough buoyancy to float to the surface.

NIOZ has agreed to provide two fully instrumented benthic landers as part of a trans-Atlantic cooperation. The landers will record benthic activity unobtrusively using a combination of time-lapse video and still photography. Time-lapse photography of the deep-sea floor provides unparalleled information on the flux of materials and activity of benthic organisms (Lampitt 1985; Priede and Bagley 2000). Current meters, optical sensors and sediment traps will provide data on near-bed particle flux and basic water chemistry and physics. The landers will gather five to six months (perhaps more) of temporally high intensity environmental information from a deep-sea coral site to complement submersible/ROV surveys. Related to all study components, better physical data, especially on long and short-term variability, are needed. These will be the most extensive long-term data of these types collected around such habitats in US waters.

Additionally, we will test a small monitoring package being developed in cooperation with Dr. J.M. Roberts (SAMS) which includes cameras and other sensors to be deployed on the seafloor by submersible or ROV. This micro-lander will record benthic activity unobtrusively using a combination of time-lapse video with infra-red illumination and still photography. The micro-lander will gather temporal environmental information from several sites to complement ROV (or submersible) surveys, allowing deployments to be precisely targeted to the habitat of interest.

Deep-water ecosystems are in perpetual darkness, and the behavior of many deep-water organisms is altered by light. Megafaunal density estimates obtained from lander-based observations differ from those from submersible/ROV, probably due to either attraction or avoidance of mobile megafauna to the submersible (Roberts et al. 2005). Lander observations made using infra-red illumination will provide accurate temporal data on the density and behavior of reef megafauna. Eunicid polychaetes are widespread symbionts of *L. pertusa* and aquarium observations suggest an important reef-aggregating role (Roberts 2005). This and other aspects of deep-water reef 'natural history' have not been recorded in the field. The ability to accurately place the micro-lander will allow these field observations to be made for the first time.

Objectives

The overall goals of this study component are to describe short term (hours-days) and longer term (weeks-months) variability of benthic physical oceanographic parameters on deep-coral habitats and provide a platform for instruments for use in various biological/ecological studies. Specific objectives include:

1) Describe water column and benthic currents around a deep-coral habitat, using ADCP technology
2) Describe variability in basic benthic water chemistry,
3) Collect data on particle flux and food value of particle rain,
4) Conduct long-term observations of habitat and fauna,
5) Examine invertebrate settlement and microbial recruitment via settling plate experiments.

Part II. Trophodynamics

This study component addresses energy flow (trophodynamics) around deep coral/hardground ecosystems. This component is also supported by Part I (see above), and analyses will be conducted through multiple collaborators (UNCW, NOAA Fisheries, USGS, NIOZ).

Ocean waters and many of the inhabitants regularly move across perceived boundaries, and systems are much more connected than previously reported (Knight et al. 2005). Without understanding the degree of connectivity, it is difficult to accurately determine or interpret the impacts of natural or human events. Previously, input of energy to the deep-sea floor was thought to be passive from the top down. It is also likely that active vertical movements of animals provide a substantial, regular flow of energy through the water column to the bottom (Kinzer 1977; Genin 2004; Gartner et al. in press). Such movements may be diel, ontogenetic, or both and move resources in both directions, variously impacting a large section of the water column, including bottom and surface habitats. During past submersible observations (coupled with depth discrete sampling) off the SEUS we have noted large concentrations of mesopelagic fauna on the bottom near deep-water (360-700 m) coral (*L. pertusa*) banks (Gartner et al. in press). We have also observed mesopelagic fauna acting as both predator on and prey to benthic organisms. Whether this activity is sporadic, limited to a few species, or whether various animals depend on such interactions are unknown. We hypothesize that the migrating mesopelagic fauna is a major conduit of energy through the water column in these areas. However, open ocean ecological coupling (expressed by food web inter-connection among benthic and water column nekton) is poorly studied. Alternatively, water column, and benthic communities are ecologically/trophically separate (aside from the basic pervasiveness of phytoplankton or *Sargassum* based production). Horizontal trophic pathways among benthic habitats on and around reef areas will also be investigated with the same objective of determining the degrees of interaction, interdependency, and connectivity.

This component will define benthic faunal connectivity in terms of trophic linkages around deep-sea coral or hardground/reef ecosystems and will identify important food resources and their sources, feeding periodicity, and how various habitats are linked. In addition to traditional diet analyses of collected specimens, we will use carbon and nitrogen (and perhaps sulfur) stable isotope ratios of dominant organisms from the deep-coral area samples to establish trophic signatures that will help define trophic relationships (Thomas and Cahoon 1993; Kwak and Zedler 1997; MacAvoy et al. 2001). From these data we can answer important questions about the broad impacts to a particular habitat or group of organisms from human or natural events. Not only will the feeding relationships of the associated fauna be addressed with this sampling regime, but considerable amounts of additional data can be gleaned from the specimens collected. These include, data on species-habitat associations, distributions, abundances, sizes, and reproductive states. This study component is closely tied to results collected in the physical study component (Part I) but is also well connected with the genetics (derivation of foods has implications for dispersal), microbiology (role of microbes in trophodynamics), and benthic ecology components.

Trophic data collected during the Lophelia I effort provided a good starting point, but were not sufficient to characterize benthic trophodynamics. In general, very little information is available on the food sources for deep-sea corals (Guinotte et al. 2006) and their inhabitants. We will examine benthic food webs in the coral habitat and, for comparison, nearby non-reef habitat, which includes the adjacent water column. This component will share samples and analysis efforts with the related trophic study component described by Demopoulos. Since filter feeders (corals, anemones, sponges, brisingid seastars) are a dominant component of these reefs and they are physically part of the habitat, we will emphasize collecting data on their food sources and feeding dynamics. We will also target smaller benthic organisms (meio- and macrofauna), benthic zooplankton, and a broad spectrum of megafaunal organisms that compose reef and non reef communities (see related study components). We will identify important primary food sources for the coral associates using stable isotopes and multi-source mixing models. For example, Lophelia I results suggested that at VK 826 there may be substantial incorporation of terrestrial-derived organic carbon, indicated by the light ^{13}C data, for some animals (in particular the suspension feeding, sedentary sponges and anemones). Thus, organic carbon sources and supply to spatially separated reefs may differ throughout the GOM.

Objectives

The overall study goals are to describe the benthic trophic web, construct an energy flow model, and evaluate impacts from potential changes in food supply on and around deep-coral habitats in several GOM locations (in cooperation with the USGS study component by Demopoulos). Specific objectives include:

1) Determine basic feeding patterns of major faunal groups using deep-reef and near-by habitats,
2) Determine food sources for deep-reef communities,
3) Assess adequacy of the food supply to major faunal groups,
4) Assess the impact of seeps on deep-coral trophodynamics,
5) Develop a carbon budget for selected deep-coral systems,
6) Determine impact of habitat or micro-habitat characteristics on trophic patterns,
7) Determine extent of trophic isolation.

Part V. Benthic ecology

This study component will focus on the identification, biodiversity, ecology, and community structure of the invertebrate and vertebrate fauna associated with deep-reef habitats at various study sites in the GOM. This work is fundamental to all other aspects of this research initiative and will complement and expand previous studies of the fauna found on and around deep-coral communities from the upper slope. The data collected during this component, in combination with our extensive SEUS data set, will provide the information necessary to compare local (among sites), regional (SEUS vs GOM), and habitat-specific (*L. pertusa* vs other hardgrounds vs non-reef) patterns in species diversity, biodiversity with depth and latitude, biogeography and community structure of the associated invertebrate (mega-, macro- and meio-) and vertebrate fauna.

Deep-water coral and hardground systems are important habitats for both vertebrates and invertebrates, and are hotspots of increased biodiversity. Our knowledge of species diversity and habitat associations continues to increase, yet systematics, ecology, and species distributions of even the most conspicuous faunal groups remain largely unknown. Fishes and crustaceans are of particular interest to decision-makers because of their large size and fishery potential. But, our knowledge of these groups is still limited regarding their abundance, micro-habitat affinities, and importance in structuring these biotic communities. Deep-coral fish communities have been described off the SEUS north of Cape Canaveral (Ross and Quattrini 2007; in review), and an initial description for two central GOM locations is available (Sulak et al. in press). Studies of *L. pertusa* and the invertebrate megafauna associated with these habitats are underway off the SEUS and on the upper Louisiana slope; however, the invertebrate communities are still poorly known throughout the proposed study region and fish communities are poorly documented from several areas within the region (e.g., Florida Straits, West Florida slope, Gulf Penn wreck). Associated small macrofauna (< 1 mm) and meiofauna have yet to be examined and identified (see USGS study component by Demopoulos).

Proper identification is critical to assessing the distinctiveness of the fauna and estimating biodiversity. Therefore, this study component will be closely coordinated with and support all other components of this research program. Many deep-sea invertebrate species are underrepresented in museum collections, and available specimens are often old and fragile with vague locality information. Thus, museum collections provide limited insight into natural color patterns, intraspecific variation and habitat associations. Targeted collections made with a submersible or ROV, therefore, are invaluable to our basic understanding of these species. Also, the potential for discovery of species new to science at the GOM deep coral sites is extremely high. To date, at least three new species of decapod crustaceans have been identified from samples taken at GOM *Lophelia* sites. Additionally, two new species of fishes were recently discovered at *Lophelia* sites off the SEUS (McCosker and Ross, 2007; Fernholm and Quattrini, in press) and several other invertebrate species (e.g., decapod crustaceans, hydroids, sea stars) from this region may prove to be new also.

Habitat association data and basic biology are lacking in the GOM from all areas. In particular, no study has addressed the interconnectedness and relationships between meio-, macro-, and megafauna. Understanding the linkages between the invertebrate and vertebrate assemblages and coral habitats will provide data necessary for assessment of Habitat Areas of Particular Concern and Essential Fish Habitat designations. Many of the objectives in this study component are closely related to the genetics, microbial, and trophodynamics components; all study components will share samples.

Besides benthic sampling, sampling throughout the water column will be conducted. On past research cruises, we made limited efforts to determine the community structure of the mesopelagic environment directly over the coral mounds. If coral banks concentrate resources like seamounts, we predict that larval and midwater organisms will be most dense in areas directly above the *Lophelia* banks compared to adjacent non-reef areas. We propose to sample the water column over and away from the GOM coral mounds. Mid-water samples will allow us to determine whether the larval pool reflects the adult species composition found on the coral mounds, and if so, this will provide baseline data on recruitment dynamics of fishes at these banks and substantial amounts of material for future genetic studies (see USGS study component by Morrison).

<u>Objectives</u>

The overall study goal is to gain improved understanding of deep-reef habitat usage and associations through descriptions of deep-reef and off-reef (nearby) fauna and related ecosystem characteristics. Specific objectives include:

1) Identify the megafauna observed on and around the study sites and assess habitat usage,
2) Assess levels of endemism at deep-reef habitats,
3) Examine patterns of species diversity and geographic distribution of the invertebrate and fish fauna between sites and make comparisons with similar habitats in other locations,
4) Assess community structure and basic ecology of the invertebrate and fish fauna.

STUDY AREAS

Deep-water (≥ 300 m) corals and hardgrounds occur along the slope of the Gulf of Mexico, but deep-coral habitats appear to be more scattered and exhibit smaller structures than those off the SEUS (Schroeder et al. 2005; Brooke and Schroeder 2007). As reported elsewhere, the dominant structure-forming coral in the deep Gulf of Mexico is *Lophelia pertusa,* but many other anthozan species contribute to the deep-reef ecosystems (Brooke and Schroeder 2007). It is unclear whether deep-water corals in the GOM form mounds as they do in other places, or instead take advantage of a variety of hard substrates (e.g., authigenic carbonates, shipwrecks, limestone outcrops) (Brooke and Schroeder 2007). Upper to middle slope depths in the GOM are influenced by the Loop Current which provides strong currents over coral habitats. Although deep-coral habitat is continuing to be documented in the GOM, studies on the biology and ecology of these systems are generally lacking.

All target study sites for this project are on the continental slope (> 300 m) in the north-central to western Gulf of Mexico (Fig. 1). Some sites (e.g., Vioska Knoll 826, Vioska Knoll 862, Green Canyon, Gulf Penn wreck) were visited during previous studies funded by MMS and USGS (Church et al. 2007; CSA International Inc. 2007; Schroeder 2007; Cordes et al. in press; Sulak et al. in press). The West Florida slope site (Fig. 1) was first described by Newton et al. (1987) from sampling with dredge and seismic profiles and was also briefly visited with ROV by Reed et al. (2006) who provided a preliminary description of benthic habitats and biota. The West Florida slope site encompasses hundreds of lithoherms and a rocky escarpment in an area about 20 km long in depths around 500 m (Reed et al. 2006). *Lophelia pertusa* (mostly dead) was common at this site. This area is large, poorly explored and represents an important comparative site for this study. The Vioska Knoll 826 site (430-520 m, Fig. 1) contains the most extensive deep coral communities known in the GOM to date (Brooke and Schroeder 2007) and is probably the best studied site. This site and the neighboring VK 862 will be used for intensive studies involving repetitive visits during the project.

GENERAL METHODS

We plan to use a total of 24 days of ship/ROV operations in late summer or fall of 2008 (exact schedule pending) and at least 12-14 days of ship/ROV (or submersible) operations in summer or fall in each year of 2009 and 2010. This period is compatible with our past cruises. Objectives outlined above will be addressed in each of the three field years. The final (4th) project year will be dedicated to data analyses, report writing and preparation of peer-reviewed publications. We will allocate most of our efforts in 300-900 m within and around our previous general sample areas in the north-central Gulf of Mexico, but will also explore and survey new sites (Fig. 1) to help put these studies into a broader regional perspective. Twenty-four hr sampling will occur for the duration that a study area is occupied. Ports of operation and ships are currently being investigated and scheduled. In 2008 the NOAA ship *Nancy Foster* will be used for all or most cruise legs.

The ship based ADCP current profiler will be run throughout the cruise to collect water column current speeds and directions. The ship's CTD will be deployed over the coral mounds and off-reef areas where samples are taken to obtain temperature, salinity, and dissolved oxygen profiles of the water column associated with those samples.

<u>Multibeam Mapping</u>

Using the R/V *Nancy Foster* multibeam system in 2008, we (as well as the MMS contractors) will survey areas of known and potential deep coral concentrations ranging from off southwestern Florida through the north-central GOM in 300-1000 m depths (Fig. 1). Mapping will proceed at a speed of about 6 kn, using the Simrad EM 1002 multibeam sonar. Mapping will be conducted in the area when other gear is not in the water. This system provides a dense overlapping coverage of depth and backscatter (strength of each received beam). CTD casts will be made at appropriate intervals to measure the sound velocity profile as well as basic water quality. We will process the bathymetry data and produce two- and three-dimensional maps at regular intervals. Near-final products (bathymetry, backscatter, and sun illuminated images) that meet hydrographic mapping standards can be generated soon after a survey is completed. These digital data products (gridded data, contour lines and bathymetric images) will be imported into a GIS system. Using the georeferenced bathymetric (X, Y, Z) and backscatter (grayscale) data, we will construct a variety of detailed maps of each coral bank area in a GIS format (ARC GIS 9.2).

Operationally, depth data are gridded at an appropriate interval to create a digital terrain map (DTM) that can be contoured at various intervals. A sun-illuminated (shaded-relief) image of the DTM provides a remarkable view of the sea bed, and small bathymetric features difficult to resolve on contoured bathymetry are readily visible (e.g., Gardner et al. 1998; Lundblad et al. 2004). Areas with higher backscatter often include coarser materials (rocks, sand and shell). Areas with lower backscatter (lighter tones) represent soft substrates. The combined bathymetry and backscatter data are also useful for identifying anthropogenic features such as debris and gear drag marks.

We will identify the likelihood of coral concentrations (by analysis of bathymetry and backscatter data) from multibeam data, testing the systems' accuracy at identifying corals versus other bottom attributes. Maps will be referenced to our (and other) previous sampling sites and associated benthic habitat data. The ground truth data along submersible/ROV tracks will yield habitat classifications (e.g., relief, soft substrate, rock, coral type and amount) coupled with differential GPS coordinates acquired at a minimum rate of once every 30 seconds. These location specific habitats will be compared to the georeferenced multibeam data. From this we expect to determine whether we can generate predictable, accurate classifications of bottom type from the multibeam signals.

<u>ROV (or submersible) Sampling</u>

Benthic sampling with ROV or submersible relates to every study component. Four to five submersible/ROV cruises are planned during the first three years of the study to sample deep-sea reef habitats from the central GOM through the West Florida Slope (300-800 m). Two or three sites (e.g., VK 826, Gulf Penn or similar, W. FL slope) will be selected for focused research, and most of the trophic data would be collected from these intensive study sites. In general, the ROV will operate during the day for a 12-hour period every day that we occupy a study site. Currently we plan to use the ROV *Proteus* in 2008 (Fig. 2). This Max Rover class ROV is operated by the NOAA Undersea Research Center at Univ. of Connecticut (NURC-UCONN). The ROV will be provided as part of a partnership with NURC-UCONN and NURC-Univ. of North Carolina at Wilmington, and will come with a four-person crew. When the ROV (or submersible) is not in operation, other sampling methods will be employed to meet a variety of objectives (see other sections).

Although we must be flexible, most dives will follow a similar pattern, emphasizing video transects or stationary video, specimen/habitat photography, and collection of specimens for specific study components. On the bottom, after targeted collecting and/or photography, the video camera will be moved to pre-determined pan/tilt positions, and the vehicle will run video transects generally following Ross and Quattrini (2007). Methods may be modified in heavy currents, coral/rock areas or if camera angles cannot be maintained. We will execute replicate transects in many reef habitat types (various reliefs and amounts of coral/rock, reef valleys, ledge edges) as well as transects over adjacent non-reef habitat (guided by the multibeam mapping). Numbers of replicates and exact lengths of transects are dependent on sea and equipment conditions, but our goal is to conduct as many standardized replicates as possible. Periodically during the dive when the vehicle is stationary, we will also conduct "point counts" by recording identity and counts of all fishes and megainvertebrates within the visual hemisphere in front of the camera for a duration of 3 min. During each transect and at each stationary station, general habitat metrics to be recorded include percent of coral rubble, percent of living coral, percent soft substrate, percent other substrate (e.g., rocky pavement), slope inclination, and depth. Statistical analyses using methods similar to Ross and Quattrini (2007) will be used to correlate habitat parameters and fauna. Photography will be conducted throughout the dives (not just during transects). Scientists monitoring the dives will have audio recorders to record observations throughout the dives.

Specimen and Data Treatment:

Most biological data (identifications, numbers, sizes, etc.) will be taken after the cruise. Many species will be photographed on board before preservation to add to our photo archive of all species collected. These voucher/photo specimens will be preserved separately and eventually deposited in regional and/or national museums.

Specimens will be treated in several ways to meet present and future objectives. For isotope studies, white muscle tissue samples will be removed from the dominant fauna collected; samples will be frozen or dried onboard the ship. For genetic studies (described in USGS study component by Morrison), additional tissue samples from dominant benthic fauna and all live corals will be taken and preserved in 95% ethanol. Later, DNA will be extracted and amplified, and DNA fragments will be subjected to capillary electrophoresis. Additional tissue samples will be taken and processed from these coral-associated mobile fauna and used for microbial ecology studies (described in USGS study component by Kellogg). Onboard the ship, otoliths will be removed from dominant fish and stored post-cruise for future microchemistry (see USGS study component by Demopoulos) and aging. After removal of the tissue samples, all benthic fishes will be preserved onboard in 10% formalin seawater solution and benthic invertebrates will be preserved in 70% ethanol. At the lab, all benthic fishes and invertebrates will be identified, measured, and weighed. Stomachs will be dissected from the dominant fauna and the contents will be identified, counted, and % volume will be calculated.

Part I Methods: Physical oceanography and ecology of the habitat

The two NIOZ benthic landers (Fig. 3) will be deployed for 5-6 months (or longer) at one of the intensive study sites selected for focused research (probably VK 826). Landers would be deployed during one of the 2008 cruises and retrieved later in a separate short cruise. Each benthic lander supplied by NIOZ consists of a robust metal frame with twin acoustic releases, supporting two video camera systems, sediment trap (12 cup for twice monthly samples), and sensors (ADCP current meters, CTD), all depth rated to 3000 m (Fig. 3). The camera is controlled by computer and will record time-lapse color video onto a hard drive throughout the deployment. To this system we will add a passive acoustic monitor and settling plate experiments. Cameras will record time-lapse video (full color) onto a hard drive during the deployment. Both landers will be deployed the first day in the same general area (one on top of a mound and one at the base). We plan to use multibeam sonar maps to guide these deployments. Protocols for this operation will follow those developed by NIOZ for coral mounds, and the operation may require 4-6 hr to lower the landers onto target sites and acoustically release them.

Analysis of lander data will be shared between NIOZ, SAMS, and the USGS team. Stable isotope (^{15}N, ^{13}C) analysis will be performed on the sediment trap samples as per Duineveld et al. (2004). Plankton collected in the traps will be identified and counted.

Part II Methods: Trophodynamics

Most of the trophic data would be collected from one or two study sites that will be intensively studied. Representative specimens from numerous functional groups, from as many reef and near-reef habitats as possible, will be collected (see below). Post-cruise, tissue samples will be dried and then analyzed for stable isotopic ratios (C, N, S). Traditional diet analysis (where appropriate), stable isotope (Fry 2006), and elemental analysis (Demopoulos et al., in review) would be accomplished for collected organisms, and the influence of habitat and ocean physics will be incorporated. Stomach contents analysis (methods modified from Ross and Moser 1995) will be a major activity (in the lab on shore). The benthic landers (see Part I) will provide particle flux data at one site (probably VK 826) through the programmed collection of monthly sediment trap samples. Sediment trap samples will be analyzed for stable isotopes to yield data on the value and types of foods being delivered to the reefs (see Duineveld 2004; Lavaleye et al. in press) over a 4-6 month period. Isotope analysis of benthic sediments and substrata, accompanying the benthic ecology components (see Part V), will provide similar data for benthic food sources (see USGS study component by Demopoulos).

Part V Methods: Benthic Ecology

Using existing and proposed habitat maps and physical oceanographic data, we will plan quantitative, standardized, replicate sampling for benthic fish and invertebrate communities on and around deep-coral habitats to describe species composition, species habitat associations, behaviors, and interactions. Much of these data will be collected via video and photographic techniques (see ROV methods above), supplemented with faunal collections. Colonization substrates will be placed on the benthic landers (see Part I) to examine short-term (months) colonization of sessile invertebrates. The landers will also collect time-lapse video and programmed still photography (coordinated with CTD and bottom current data) to address a variety of issues from suspended particle variability to animal movements. Traditional community analysis (mostly using PRIMER software) and elemental fingerprinting techniques (see Demopoulos study component) will be used to describe the community ecology and habitat residency.

A 2 x 2-m Tucker Trawl (TT) with 1.59-mm mesh will be used for midwater sampling. This gear will be deployed over the deep reefs at night. Coral bank tows will be alternated with tows over off-reef, sand habitat. The TT will be fitted with a single net and a 0.5 m plankton net (505 µm mesh) will be inserted inside to collect smaller fauna that may pass through the larger mesh of the outside net. The outside net will be deployed in a closed position. Upon reaching target sampling depth, a weighted messenger will trigger the net to open. The net will then be towed at the discrete target depth for 30 min at a 2 kn (3.7 km/hr) ground speed. After 30 min, a second messenger will trigger the net to close, and the net will be retrieved. A SBE 39 Sea-bird data logger will be attached to the TT to measure temperature and depth of the sample.

Aside from ROV techniques, benthic sampling efforts will use benthic otter trawls, traps, and box cores. Otter trawls (4.9 m head rope, 38.1 mm mesh) will be towed for 30 min at ~2 knot (3.7 km/hr) ground speed. Tows will be made in off-reef areas and as near to coral mounds as possible, ensuring that trawls are not towed directly on the mounds where live corals are most abundant. Trawl areas will be chosen so that tows are completed on all sides and between coral mounds. Box cores will also be deployed on the tops and bases of *Lophelia* mounds to obtain quantitative samples of infauna and benthic species. Baited deep-sea traps will be set on reefs at times using either the ROV or surface deployments with acoustic releases. Soak times should range from a few hours to as much as 12 hours.

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OVERALL DELIVERABLES/PRODUCTS:

A brief (two page) annual report will be delivered electronically on 1 December of each year, beginning in 2008. This report will include a cruise report (as an appendix) from the current year's cruises as well as updates on accomplishments, progress, and problems. The cruise plans prepared by the chief scientist in advance of the research cruises will also be submitted prior to each cruise. A final report will be delivered by 30 September 2011 in a format to be determined at a later date. This report will include a summary of results from all UNCW study components and recommendations for future work. Manuscripts, peer-reviewed publications, graduate student thesis/dissertation, etc., will be included as chapters or sections of annual/final reports as appropriate. MMS will be provided review copies of all written reports, publications, and PowerPoint presentations (if requested).

Throughout the project oral presentations will be presented at a variety of venues. Oral presentations will be given at national and international conferences, workshops and symposia, such as the Fourth International Symposium on Deep-Sea Corals (Dec 2008), ASLO Ocean Sciences meeting, Annual meeting of the American Fisheries Society, Annual meeting of the American Society of Ichthyologists and Herpetologists, Annual meeting of the Crustacean Society, and at MMS Information Transfer Meetings (if requested).

Factsheets and other educational materials will be prepared that target scientists, managers and the public. In preparing such material the guidelines for "Fundamental Science Practices" will be considered. These products will often be in collaboration with other Lophelia II team members.

Peer reviewed publications will be the highest priority for final products. The lead scientist (SWR) will prepare an initial list of all planned publications from all USGS study components, including proposed authors, author responsibilities, target journals, and target dates. This list will be updated and revised as needed. Team scientists will use this list to help guide their activities, and it will be used to judge group productivity. A variety of peer reviewed papers are envisioned from the study components described here and would be submitted to such journals as Deep-Sea Research, Bulletin of Marine Science, Marine Ecology, Marine Ecology Progress Series, Journal of Crustacean Biology, Fishery Bulletin, and Oecologia.

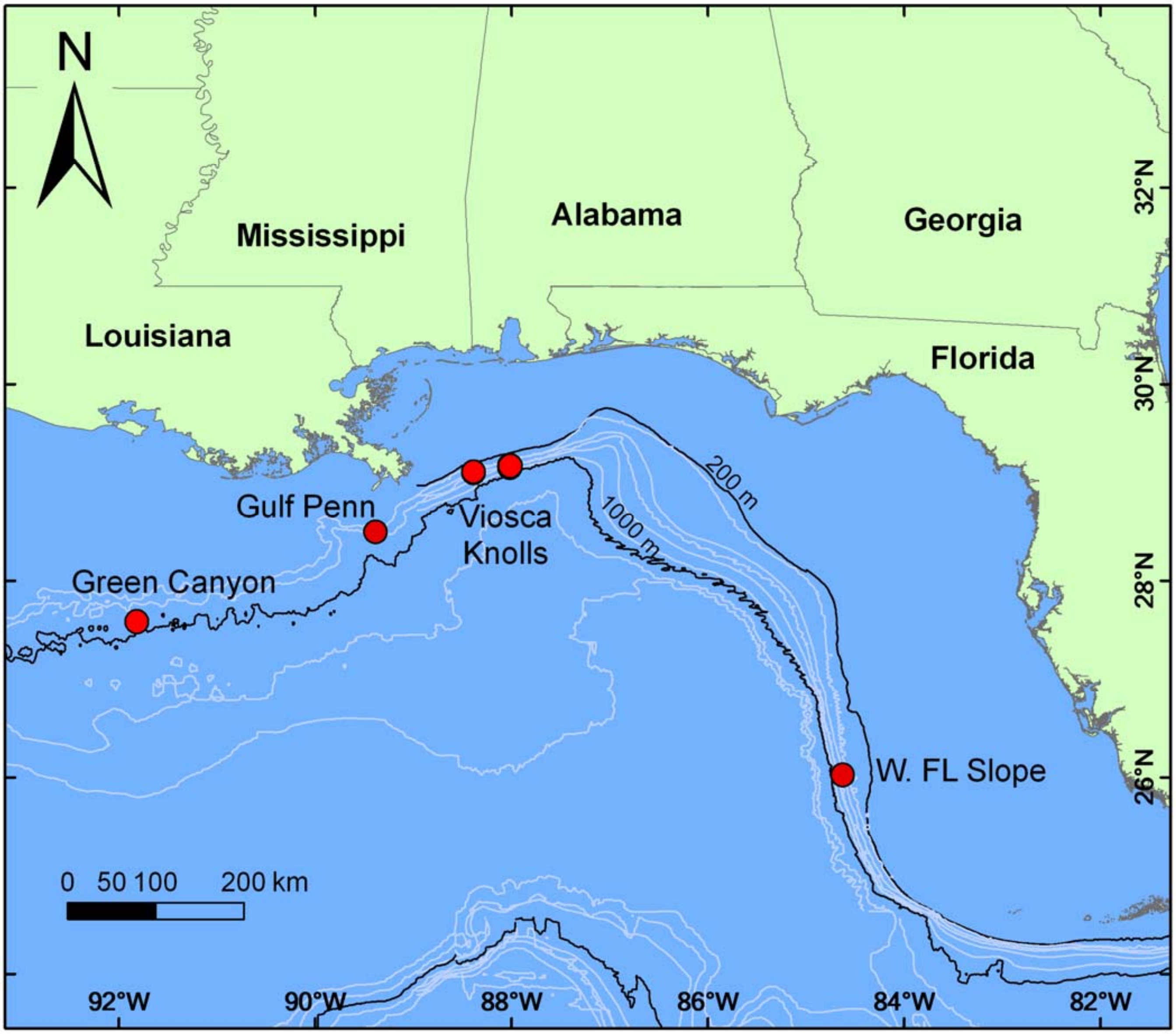

Figure 1. Map of the north-central to eastern Gulf of Mexico illustrating deep-sea coral study sites (red dots).

Figure 2. We propose to use this Max Rover class ROV operated by the NOAA Undersea Research Center at Univ. of Connecticut for 2008 field work in the Gulf of Mexico. This vehicle is currently being rebuilt and tested.

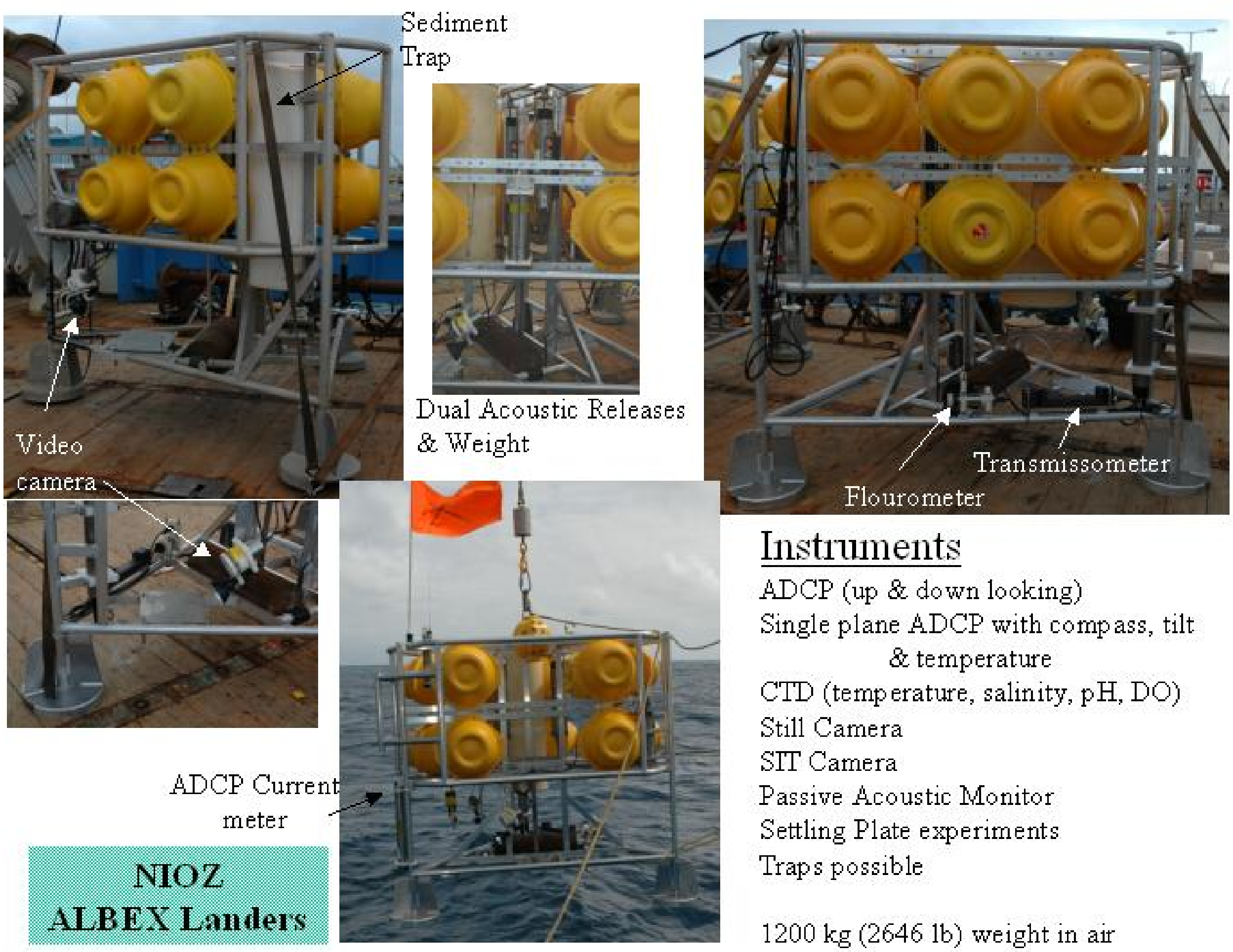

Figure 3. In cooperation with scientists at the Royal Netherlands Institute for Sea Research (NIOZ), we plan to deploy two benthic landers at a Gulf of Mexico deep-sea coral site for at least 5-6 months.