STUDY TITLE: Deepwater Program: Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral

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BACKGROUND: Interest in deepwater corals has increased rapidly in the last decade as more coral systems are discovered and their importance in providing habitat for a diverse community, including commercially important fisheries species, is realized. With the increasing influence of human activity in deep waters, including energy resource development, an understanding of the biology and distribution of these corals has become vital to their protection. The

most common and well-studied deepwater coral is *Lophelia pertusa*. This study of *L. pertusa* coral communities represents a logical step for deepwater investigations in the Gulf of Mexico.

OBJECTIVES: The objectives of the study were threefold: (1) to select study sites on the northern Gulf of Mexico continental slope consisting of hard bottom areas with non-chemosynthetic biological communities, particularly areas with dense assemblages of the coral *L. pertusa*; (2) to design and implement submersible survey and sampling techniques to characterize the biological communities on these deepwater hard bottom areas; and (3) to investigate and describe environmental conditions that are correlated with the observed distribution and development of these communities.

DESCRIPTION: Ten hard bottom sites on the northern Gulf of Mexico continental slope were visited during the study using a submersible, the *Johnson-Sea-Link*. Three alpha (primary) sites were designated for intensive study and three beta (secondary) sites were selected for more limited characterization. A grant from the National Oceanic and Atmospheric Administration Ocean Exploration program allowed three additional sites to be visited. Water depths ranged from 310 to 686 m.

Study elements included the following:

Geological characterization - video and photographic observations were analyzed to develop a geological characterization of sites; sediment samples were collected and analyzed for grain size; and carbonate rock samples were collected and analyzed for carbon and oxygen isotopes.

Biological characterization and studies, part I - video and photographic observations including video and still photographic transects and photomosaics were analyzed to develop a biological characterization of sites; a Bushmaster sampling device was used to collect *Lophelia* and associated fauna; selected specimens were analyzed for carbon, oxygen, and sulfur isotopes to aid in understanding the food web; and temperature probes were deployed within coral thickets at two sites.

Biological characterization and studies, part II - sediment traps were deployed to estimate sediment flux; *Lophelia* transplantation and *in-situ* staining studies were conducted in the field; and laboratory studies were conducted to investigate *Lophelia* morphology and skeletal density, reproduction, temperature and sediment tolerance, and feeding.

Water chemistry - near-bottom water samples were collected at selected sites and analyzed for total petroleum hydrocarbons. The data were intended to help determine whether active hydrocarbon seepage is occurring at the sites.

Physical oceanography - both short-term and long-term current meter arrays were deployed at two sites to yield information about the structure of the bottom boundary layer and to examine the variability of the local currents above the boundary layer. Modeling was conducted to simulate the dispersal of coral larvae.

In addition to characterizing sites, study elements were designed to test specific hypotheses about *Lophelia* distribution, growth, survival, dispersal, and relationship to environmental factors.

SIGNIFICANT CONCLUSIONS: This was the first comprehensive study of the distribution of *Lophelia pertusa*, its biology, and community ecology in the Gulf of Mexico. Results suggest that *L. pertusa* plays a significant role in the ecology of hard-bottom habitats on the upper slope. *L. pertusa* colonizes hard substrata, following the decline of seepage. Corals therefore rely on seeps as a source of hard substratum in the form of authigenic carbonate but do not incorporate significant amounts of seep productivity into their diet. *L. pertusa* appears to structure the surrounding slope community largely through the provision of habitat rather than food. *L. pertusa* creates habitat for a number of associated species, many of which show significantly higher densities near coral. A number of species have only been found in tight association with *L. pertusa* in the Gulf of Mexico. *L. pertusa* therefore plays a similar role to tubeworm aggregations, although the fauna attracted to these two types of biogenic habitat are mostly different.

STUDY RESULTS: The Viosca Knoll (VK) 826 site and nearby VK826NE supported the most-developed and extensive *L. pertusa* colonies. *L. pertusa* aggregations provided the dominant biogenic habitat for other fauna at these sites. These sites were also unique in that most of the colonies were composed of the heavily calcified ("*brachycephala*") growth form. Cnidarian diversity was low, although some large antipatharian and gorgonian colonies were interspersed with *L. pertusa*. There was some localized evidence of seepage at these sites.

Two Green Canyon (GC) sites (GC234 and GC354) had both seep communities and much less *L. pertusa* than VK826. These sites supported locally dense populations of *Callogorgia americana delta*, a large branching octocoral with associated communities of ophiuroids and galatheids. Some *Lophelia* thicket development was observed, but the colonies did not expand to form the type of habitat seen at VK826, and a large percentage of the coral colonies were dead. The main seep site at GC234, approximately 250 m to the east of the coral ridge, supported one of the most spatially extensive and active seep communities known on the upper slope, with numerous aggregations of tubeworms, mussels, gas hydrates, and both white and red bacterial mats. The seep community at GC354 may be in a later stage of development, as no mussel aggregations or gas hydrates, and relatively few tubeworm aggregations have been documented at this site.

Two Mississippi Canyon (MC) sites (MC885 and MC929), and GC184/185 had both seep communities and well developed *C. americana delta* communities, but little or no living *L. pertusa*. MC885 was mostly soft sediment interspersed with large holes (burrows or slumps) and locally dense areas of *C. americana delta* on exposed hard substratum. The MC929 site was mostly soft sediment with shell fragments, partially exposed hard grounds, and low-relief outcrops with large *C. americana delta* and/or small *L. pertusa* colonies, as well as mussel beds and small brine pools. At GC184/185 (the well known "Bush Hill" seep site), there were a few small colonies of mostly dead *L. pertusa* on the ridge on the western edge of the active seep area, and several small colonies attached to a metal mooring buoy. Large colonies of *C. americana delta* occurred on carbonate outcrops on the north and northwest edges of the active seep area. One other MC site (MC709) provided no *Lophelia* data, as only soft-bottom substrates were observed.

Two sites (VK862 and VK862S) were much shallower (310 to 335 m) and warmer (~11.5ºC) than the other study sites, and supported a very different fauna from the other sites. The *L. pertusa* thickets present were composed of mainly live coral. The highest cnidarian diversity and abundance was observed here. The substratum was covered with dense patches of small white anemones, and large colonies of antipatharians and bamboo coral provided structure for other animals. Some of the large carbonate boulders supported *Lophelia* colonies; however, these were isolated and did not form coalescing thickets. There was also no seep fauna identified at VK862 or VK862S, and dense stands of *C. americana delta* were also absent.

In addition to the photographic observations, Bushmaster collections provided detailed information about community composition. At least 68 species of invertebrates were closely associated with *L. pertusa* aggregations in the Gulf of Mexico. Matrix correlation analyses indicate that on the scale of an individual carbonate outcrop or *L. pertusa* thicket (tens of square meters), the depth of collection followed by the proportion of live and dead coral were the most significant factors correlated with the composition of the associated communities. The other important factors controlling the similarity of coral communities were the relative complexity of the coral framework and the location of collection. Communities associated with *L. pertusa* were generally more similar within sites than they were among sites. While *L. pertusa* communities were easily distinguished from tubeworm-associated communities, there consistently was overlap in species composition.

Factors potentially affecting the distribution and development of *Lophelia* communities include water depth, substratum availability, hydrocarbon seepage, sedimentation rate, water temperature, current regime, and food availability. This study addressed some of these environmental factors through observations and field and laboratory experiments. Bathymetric limits to distribution in the Gulf of Mexico are most likely related to confounding variables such as temperature, current speed, sedimentation, and other factors. In this study, the sites visited ranged in depth from 310 to

686 m. Temperature tolerance experiments suggest that the shallowest site (VK862) may be near the upper temperature threshold for *Lophelia*.

Lophelia requires hard substrata for attachment. Below depths of 300 m in the Gulf of Mexico, the surficial sediment regime is dominated by fine-grained pelagic and hemipelagic material. However, on the upper slope, authigenic carbonate is produced as a by-product of coupled methane oxidation and sulfate reduction by microbial consortia. This seafloor lithification is a regular component of hydrocarbon seep sites and provides a substratum for establishment of coral and other hard-bottom communities. Isotope analysis of rock samples from several study sites confirms that the hard substrata consist of authigenic carbonate produced as a result of hydrocarbon seepage.

Whether the distribution of *L. pertusa* in the Gulf of Mexico is linked to local hydrocarbon seepage is a key question for ecology and management. Results of this study indicate that, although the carbonate substratum at *Lophelia* sites is seep-derived, the corals derive little or no nutrition from seep productivity. Apparently, *L. pertusa* prefers areas where seepage has almost completely subsided prior to settlement. *L. pertusa* thickets may represent the end point of seep community succession.

STUDY PRODUCTS: Continental Shelf Associates, Inc. 2007. Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2007-044. 169 pp. + app.