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Megafauna community composition associated with *Lophelia pertusa* colonies in the Gulf of Mexico

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ABSTRACT

The deep-water coral *Lophelia pertusa* provides habitat for diverse communities in the Gulf of Mexico. Photomosaics and analyses within a Geographic Information System (GIS) were used as non-destructive sampling tools to examine megafauna community composition associated with *L. pertusa* colonies on authigenic carbonate outcrops in two regions of the Gulf of Mexico. Megafauna communities associated with *L. pertusa* were more similar within a region than between regions. Within regions, the amount of dead coral, number of abiotic and biotic substrata, and percentage of live *L. pertusa* influenced the diversity, composition, and structure of the coral-associated communities. Elevated diversity levels in the communities associated with *L. pertusa* structure indicate that *L. pertusa* provides a distinct, localized habitat source. Outcrops with high proportions of dead *L. pertusa* harbored more higher order consumers than outcrops with primarily live coral framework.

1. Introduction

Foundation species (sensu Dayton, 1972), such as reef-building corals and the kelp *Macrocystis pyrifera*, provide habitat, colonization opportunities, and increased local and regional habitat complexity. Different types of foundation fauna provide different forms of structure, and these distinct habitats often harbor distinct assemblages of associated organisms (Bruno and Bertness, 2001). Mixed assemblages of structuring organisms, such as those forming coral reefs, provide increased habitat heterogeneity and complexity, which affect the composition of the associated community and typically lead to higher diversity.

The deep-water coral *Lophelia pertusa* (*L. pertusa*) is a foundation species (Jonsson et al., 2004; Cordes et al., 2008) that is found throughout the world's oceans on topographic features, from depths ranging from 40 m (Freiwald and Roberts, 2005) to 2170 m (Cairns, 1979). *L. pertusa* requires a hard substrate such as carbonate rock to settle (Moore and Bullis, 1960). On the Upper Louisiana Slope of the Gulf of Mexico, authigenic carbonate is produced as an indirect byproduct of a coupled reaction between methane oxidation and sulfate reduction carried out by microbial consortia in seep sediments (Aharon and Fu, 2000; Boetius et al., 2000; Thiel et al., 2001). As a result, *L. pertusa* and other deep-water corals are frequently found near areas of active hydrocarbon seepage in the Gulf of Mexico. However, corals appear to be limited to regions where hydrocarbon concentrations are at most slightly elevated above background levels (Hovland et al., 1998; Cordes et al., 2008) and current speeds are high enough to provide sufficient prey and prevent sedimentation on coral tissues (Frederiksen et al., 1992; Mortensen et al., 2001).

L. pertusa's anastomosing branches provide a large, stable structure, and host communities consisting of both coral-dependent and habitat-generalist fauna, including many other types of corals (e.g., octocorals and other scleractinians), other cnidarians, crustaceans, fishes, and polychaete worms (Reed et al., 2006; Roberts et al., 2006; Mortensen et al., 2008). In the northeast Atlantic, extensive communities of *L. pertusa*-associated fauna have been discovered that have diversity indices as high as those found in shallow-water coral communities (Jensen and Frederiksen, 1992; Mortensen et al., 1995; Rogers, 1999). In the Atlantic and the Gulf of Mexico, these corals have been shown to provide important habitat for commercially important deep-sea fishes (Ross and Quattrini, 2007). Targeted physical sampling using a Bushmaster device to obtain standardized collections of *L. pertusa* colonies on the upper slope of the Gulf of Mexico found 64 species associated with the coral framework, of which at least three had well-identified relationships with the coral (Cordes et al., 2008).

In this study, we investigated the relationship between substrata and associated megafauna to determine which habitat characteristics influence the community composition, diversity, and structure across carbonate outcrops with *L. pertusa* present.

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We used a Geographic Information System (GIS) to analyze photomosaics created from high-resolution imagery obtained from two regions of the Gulf of Mexico. Megafauna were identified and their densities and coverage areas were quantified within each photomosaic. We expected that live and dead *L. pertusa* would host specific communities that differ from other hard-bottom and biogenic substrata.

2. Methods

2.1. Site descriptions

Photomosaics were assembled from nine locations at five sites in two regions in June 2004 and September 2005. Sites are named according to the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) lease blocks in which they occur. Each site provided at least one photomosaic location. Two of the sites were within the Viosca Knoll (VK) region of the Gulf of Mexico, on the upper DeSoto Slope between 315 and 470 m depths (Table 1). Three sites were in the Green Canyon region on the Upper Central Dome and Basin region, more than 350 km west of Viosca Knoll, at depths of 500 and 535 m (Table 1).

The four photomosaics at the Viosca Knoll lease block 826 site (VK826) were obtained from the top and flanks of a knoll that rises approximately 100 m from the seafloor (Brooke and Schroeder, 2007; Cordes et al., 2008). Extensive *L. pertusa* colonies occur over an area of 600×300 m^2, including living coral growing from a dead coral framework. Aggregations of seep-related *Lamellibrachia luymesi* and *Seepiophila jonesi* tubeworms (Polychaeta: Siboglinidae) occur occasionally near coral colonies in this area (Cordes et al., 2006). Sediment, disarticulated shells, and carbonate rubble surrounded the outcrops selected as study sites. The single photomosaic at the Viosca Knoll 862 site (VK862) is on a topographic high of exposed carbonate rock. Scattered live *L. pertusa* thickets grow on large carbonate boulders with abundant anemones, *Callogorgia americana delta*, bamboo corals (Isididae), antipatharians, and an unidentified species of hexactinellid sponge. This area lacked visible seep megafauna.

The photomosaic in the Green Canyon 354 site (GC354) was obtained over a slope that descends from 520 to 560 m. Abundant authigenic carbonate boulders occur, along with occasional *L. pertusa* colonies (between 3–5 m in diameter and 2–3 m height) that consist primarily of dead coral and intermittent live coral branches extending from the framework. As the slope descends, carbonate outcrops support smaller *L. pertusa* colonies. There are also scattered vestimentiferan tubeworms around the periphery of the many carbonate outcrops near the base of the slope (Cordes et al., 2006). The two photomosaics within the Green Canyon 234 site (GC234) were obtained along a single ridge approximately 100 m long at 500-m depth that contains colonies of *L. pertusa* with predominantly dead coral and live outer branches. Abundant *C. americana delta* gorgonians are also found on authigenic carbonate boulders in this site. A few colonies of scattered vestimentiferan tubeworms occur along the ridge. Corals and abundant chemosynthetic communities, dominated by tubeworms and mussels, occur a few hundred meters east of the ridge (MacDonald et al., 1990, 2003; Sager et al., 1999). Corals at the "Bush Hill" site in Green Canyon 185 (GC185) are located on the western edge of an active seep on an authigenic carbonate hillock approximately 40 m tall. There are several low-relief boulders colonized by *C. americana delta* and small colonies of mostly dead standing *L. pertusa*. Vestimentiferan tubeworms and bathymodiolin mussels with methanotrophic symbionts are abundant along the crest of the hill at approximately 540-m depth (MacDonald et al., 1989).

2.2. Image collection and analysis

All imagery was collected using a Canon PowerShot G2 digital camera encased in a pressure-safe housing and mounted on the side of the *Johnson-Sea-Link I* submersible perpendicular to the sea floor. Light for the images was provided by xenon arc lights. The submersible was maneuvered over haphazardly selected outcrops colonized by *L. pertusa* in a series of overlapping lines, while overlapping pictures were taken of the sea floor. The images within each line and the lines within the photomosaic overlapped one another by approximately 20%. Parallel lasers were spaced 10 cm apart and were visible in most images to provide a scale reference. The images were optimized using Photoshop CS2 autolevel, autocolor, and autocontrast settings to maximize image evenness and clarity. Optimized images were then assembled into photomosaics using a Matlab program (Pizarro and Singh, 2003) that seamlessly blends the overlapping edges of the images together to produce a composite image (Fig. 1A).

A scaling system was created for the photomosaics based on the presence of the parallel lasers in each image. The distance between the laser points in the images was measured using Photoshop CS2's measure tool for at least 10 images per photomosaic, and this distance was averaged and scaled to represent 10 cm. Photomosaics were imported into ArcGIS v 9.1 using the laser-derived scale in an undefined coordinate system. Each of the individual high-resolution images was hyperlinked to the photomosaic. The individual images have resolution sufficient to identify organisms and objects greater than 2 cm in size and were referenced to identify and digitize the fauna and abiotic substrata. Living, standing dead, and mixed live and dead *L. pertusa*, other habitat-forming corals (including bamboo corals, antipatharians, and gorgonians), carbonate rock, rubble

Table 1
Description of areas containing photomosaics. The first two letters of each area represent the region (GC = Green Canyon and VK = Viosca Knoll) and the numbers represent the BOEMRE lease block number. The species richness (number of taxa found in each of the study sites divided by the area of the outcrop in the photomosaic) included all fauna, and the Shannon diversity index (H') and Pielou's evenness index (J') were calculated for all organisms that were enumerated in the images.

Study site	Area (m^2)	Depth (m)	Latitude	Longitude	Area-weighted species richness (# m^{-2})	Shannon Diversity (H′)	Pielou's Evenness (J′)
GC185	3.3	540	27°35.90′N	91°49.60′W	2.14	0.76	0.47
GC234a	10.2	509	27°44.81′N	91°13.44′W	1.37	0.85	0.35
GC234b	11.6	507	27°44.81′N	91°13.44′W	1.21	1.79	0.75
GC354	26.5	524	27°35.89′N	91°49.60′W	0.49	1.71	0.71
VK826a	45.9	465	29°09.50′N	88°01.07′W	0.33	1.99	0.75
VK826b	11.0	464	29°09.50′N	88°01.07′W	0.91	1.73	0.79
VK826c	9.9	470	29°10.21′N	88°00.72′W	1.01	1.74	0.79
VK826d	11.4	459	29°10.21′N	88°00.72′W	0.79	1.85	0.89
VK862	26.5	313	29°05.80′N	88°23.09′W	0.57	1.09	0.41