

DEEP-WATER REEFS OFF THE SOUTHEASTERN U.S.: RECENT DISCOVERIES AND RESEARCH

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SOME OF THE MOST SPECTACULAR CORALS found off the southeastern U.S. were discovered as recently as the 1970s in an unexpected place—the deep waters along the edge of the continental shelf. These banks of *Oculina* corals extend for 167 km along the eastern Florida shelf. Unfortunately, even as they were being discovered by scientists, the *Oculina* banks had already been damaged by trawl-fishing activity. Parts of the reef have been protected since 1984, and the protected area was expanded in 2000, but the story of the *Oculina* banks' discovery and their damage by fishing activity is all too typical of the deep-water coral ecosystems that live and die, almost entirely unknown to the average person, in the deep waters off of some of the most populated and well-explored coastlines in the world.

Deep-water coral ecosystems provide important habitat for numerous fishes and invertebrates and are similar in function to shallow reefs. Various types of deep-water reefs occur within the U.S. Exclusive Economic Zone (EEZ) along the southeastern U.S. These include a range of high-relief habitats on the continental shelf from North Carolina to Florida and the Gulf of Mexico. The predominant corals on these reefs are the azooxanthellate, colonial scleractinian hard corals, such as *Lophelia pertusa* and *Oculina varicosa*, plus various species of hydrocorals (family Stylasteridae), black corals (order Antipatharia), bamboo corals (family Isididae), and sea fans (order Gorgonacea). Only a small percentage of deep-water reefs have been mapped or have had their biological resources characterized.

Recent research¹ has provided new discoveries of deep-reef ecosystems off the southeastern U.S. Unfortunately, deep reefs worldwide are being impacted by destructive fishing methods, such as trawling, which destroys the delicate corals. The *Oculina* reefs off Florida were the first deep-water reefs in the world to be designated as a Marine Protected Area (MPA) in order to protect them from destructive fishing gear. Habitat damage from trawling has already occurred on the *Oculina* reefs and also on *Lophelia* reefs in the northeast Atlantic. The resource potential of the deep-water coral ecosystems is unknown in terms of potential fisheries and novel compounds that may be developed as pharmaceutical drugs (see Maxwell, this issue, for more). We are currently developing priority mapping sites within this region, and the resulting data may provide potential targets for new deep-water MPAs.

WHAT IS A DEEP-WATER REEF?

Deep-water coral habitats occur at depths of 70 to greater than 1000 m and are sometimes defined as coral banks, bioherms, lithoherms, or reefs (Rogers, 1999). In general, deep-water coral banks occur below the effects of waves (generally below

100 m), and the corals lack symbiotic algae (zooxanthellae). A bioherm is a deep-water coral reef that over centuries has formed a mound of unconsolidated sediment and coral debris and is capped with thickets of coral, such as *Oculina* and *Lophelia* (Reed, 2002 a,b). Lithoherms are defined as high-relief, lithified carbonate mounds, rather than unconsolidated sediment mounds and also may be covered with thickets of live coral. Deep-water coral reefs are usually found in regions of fairly strong currents or zones of upwelling where the coral structures capture suspended sediment and build up mounds to heights of a few meters to more than 50 m.

DEEP-WATER REEF CORALS



Deep-water coral reef regions off southeastern U.S.A. and Gulf of Mexico. a) North Carolina *Lophelia* Reefs, b) Stetson *Lophelia* Reefs, c) Savannah Lithoherms, d) East Florida *Lophelia* Pinnacles, e) Miami Terrace, f) Poutalès Terrace, g) Southwest Florida *Lophelia* Lithoherms, and h) North-Central Gulf of Mexico *Lophelia* reefs.



Conger eel (*Conger oceanicus*) within a *Lophelia* coral thicket off of North Carolina, 384 m. Note galatheid crabs (*Eumunida picta*), sea urchins, and anemones on the coral.

Two species of deep-water corals dominate the deep reefs off the southeastern U.S.: *Oculina* and *Lophelia*. The deep-water *Oculina* coral reefs form an extensive reef system at depths of 70 to 100 m and exclusively occur off central eastern Florida (Reed, 2002b). These reefs are comprised of numerous pinnacles and ridges, 3 to 35 m in height. Each pinnacle is a bank of unconsolidated sediment and coral debris that is capped on the slopes and crest with living and dead colonies of *Oculina varicosa*, the ivory tree coral.²

Lophelia pertusa is another deep-water coral and is similar in morphology to *Oculina*, forming massive, bushy colonies, 1-2 m in height. It ranges in the western Atlantic from Nova Scotia to Brazil and the Gulf of Mexico, and also occurs in the eastern Atlantic, Mediterranean, Indian, and eastern Pacific Oceans at depths of 60 to 2170 m. It is the major constituent of deep reefs off the eastern U.S., primarily from North Carolina to south Florida and also in the Gulf of Mexico at depths of 370-900 m. In some areas the coral forms bioherms that appear to be unconsolidated rubble and sediment, and other sites appear as lithoherms with coral thickets growing on rocky mounds.³

RECENT RESEARCH

Recent research expeditions have compiled new information on the status, distribution, habitat, and biodiversity of deep-reef ecosystems. Expeditions by the authors and collaborators between 2000 and 2004 explored various deep-water reef sites off the southeastern U.S. and Gulf of Mexico. These were among the first human occupied submersible and remotely operated vehicle (ROV) dives to document the habitat and benthic biodiversity of these relatively unknown deep-water reefs. Ross (2004) and colleagues surveyed three *Lophelia* reefs off North Carolina as well as several from North Carolina to Cape Canaveral, Florida, and initiated studies on the associated fishes and invertebrates. Reed (2004) mapped nearly 300 mounds or pinnacles with heights of 15 to more than 150 m off the east coast of Florida and described their benthic invertebrate and fish communities. Many of these features at

depths of 700 to 800 m were verified as reefs from dives with the *Johnson-Sea-Link* (JSL) submersible. In 2002, multi-beam bathymetric maps were also made of the *Oculina* reefs and were integrated into a Geographic Information System (GIS) with submersible and ROV imagery and observations (visit www.uncw.edu/oculina).

DEEP REEF HABITATS

We have identified at least eight regions of deep-water reef ecosystems from North Carolina to Florida and eastern Gulf of Mexico.

North Carolina *Lophelia* Reefs: These are some of the best developed *Lophelia* bioherms discovered in the western Atlantic and represent the northernmost coral banks in the eastern U.S. (Ross, 2004). Three reef complexes explored to date are 50 to 80 m in height and occur at depths of 370 to 450 m on the western edge of the Blake Plateau. Because these banks appear to be the northern terminus for a significant zoogeographic region, they may be unique in biotic resources and they appear different from much of the coral habitat to the south. These mounds appear to be formed by successive coral growth, collapse, and sediment entrapment. Their tops and sides are mostly covered by dense thickets of living (white) *Lophelia pertusa* and they are surrounded by coral rubble zones. Preliminary analyses suggest that the fish community on these deep reefs is composed of many species that do not (or rarely) occur off of the reefs. Many fish species thought to be rare and/or outside their reported ranges have been found on these reefs.

Stetson Reefs: Hundreds of pinnacles occur along the eastern Blake Plateau off South Carolina, including a 152-m tall pinnacle where recent submersible dives discovered live bushes of *Lophelia* coral, sponges, gorgonians, and black coral (Reed, 2004). This area is about 120 nautical miles southeast of Charleston, South Carolina, at depths of 640-869 m. Over



Living *Lophelia pertusa* bushes off of North Carolina with associated invertebrates, 413 meters.



Oculina varicosa bioherm with large male scamp grouper (*Mycteroperca phenax*), 80 meters.

200 coral mounds may occur in this 6174 km² area that was first described from echo soundings and bottom dredges (Stetson et al., 1962). *Lophelia pertusa* and *Enallopsammia profunda* are the dominant scleractinian coral species and they are concentrated on top of the mounds.

Savannah Lithoherms: Numerous lithoherms occur at depths of 490 to 550 m along the western Blake Plateau, about 90 nautical miles east of Savannah, Georgia (Sedberry, 2001; Reed, 2004). These are 30 to 60 m tall mounds that are covered with fine sediment, dead coral fragments, and thickets of corals, sponges, and gorgonians.

East Florida *Lophelia* Pinnacles: Recent echosounder transects by Reed (2004) along a 222 km stretch off eastern Florida (depth 700 to 800 m) mapped nearly 300 coral bioherms and lithoherms, 15 to 152 m in height. The northern sites off Jacksonville and southern Georgia appear to be primarily lithoherms, which are rocky pinnacles capped with coral debris and live coral thickets (Paull et al., 2000), whereas the features from south of St. Augustine to Jupiter appear to be predominately *Lophelia* mud mounds that are capped with dense, one meter tall thickets of *Lophelia* coral with varying amounts of coral rubble (Reed, 2004).

Miami Terrace and Poutalès Terrace: Miocene-age (about 10 million years old) terraces off southeastern Florida and the Florida reef tract provide high-relief, rocky habitats for rich communities of benthic invertebrates and fish (Reed et al., in press). Along the eastern edge of the Miami Terrace, at a depth of 365 m, a 90 m tall steep rock ridge is capped with *Lophelia* coral, stylasterid hydrocoral, bamboo coral, black coral, and various sponges and octocorals. At the base of the terrace, in the axis of the Straits of Florida, *Lophelia* reefs may occur, but what little is known is primarily from dredge records (Cairns, 1979).

The Poutalès Terrace parallels the Florida Keys for 213 km and provides extensive, high-relief, hard-bottom habitat, covering 3,429 km² at depths of 200 to 450 m. The Tennessee and

Alligator Humps are among dozens of bioherms that lie in a region called "The Humps" by local fishers, about 14 nautical miles south of the Florida Keys. The peaks of some of these mounds are covered with thick layers of stylasterid corals, along with dense and diverse communities of sponges, octocorals, and fish (Reed et al., in press). In addition, numerous sinkholes occur along the outer edge of the Terrace; the bottoms of these sinkholes are 600 m deep and up to 600 m in diameter, making them some of the largest sinkholes in the world.

Gulf of Mexico *Lophelia* Reefs: Three regions are known in the eastern and northern Gulf of Mexico that have fairly extensive areas of *Lophelia* reefs. The southwest Florida Lithoherm Site occurs on the southwestern Florida shelf slope and consists of dozens, or possibly hundreds, of 5 to 15 m tall lithoherms at depths of 500 m. The lithoherms appear to be piles of limestone rock, some of which are capped with thickets of live and dead *Lophelia* coral. In 2003, SEABEAM bathymetric maps and ROV dives were made for the first time to describe this region (Reed, 2004). In addition, in the northern Gulf of Mexico, off Mississippi and Alabama, fairly extensive *Lophelia* thickets grow on upper flanks and peaks of Viosca Knoll, a deep-water salt dome (Schroeder, 2002), and also in an area known as Green Canyon off Louisiana (Sulak and Ross, unpublished data).

DEEP-WATER REEF COMMUNITIES

No detailed compilation of the benthic fauna has been made at any *Lophelia* reef sites in the western Atlantic. The primary sources of knowledge come from historical dredge and trawl surveys. However, recent use of submersibles and ROVs has allowed for direct observations and some collections of the benthic invertebrate and fish communities. A total of 146 species of benthic invertebrates have been identified from six deep-water reef sites off the southeastern U.S. (Reed, 2004; Reed et al., in press). The dominant benthic species include 70 Porifera (sponges) and 58 Cnidaria (corals and anemones). The Poutalès Terrace bioherms are different from the other sites and generally lack *Lophelia* coral but are dominated by stylasterid hydrocorals and have thick deposits of live and dead stylasters on their peaks. A striking difference between the *Oculina* and *Lophelia* reefs is that larger sessile invertebrates such as massive sponges and gorgonians are common on the *Lophelia* reefs (mostly south of North Carolina) but are not common on the deep-water *Oculina* reefs. The coral itself is a dominant component providing habitat on both the *Oculina* and *Lophelia* reefs. The percentage of live coral coverage is generally low on the majority of *Lophelia* and *Oculina* reefs in this region (1 to 10 percent); however, some areas may have nearly 100 percent live cover (such as the North Carolina and Viosca Knoll sites), and, for reasons unknown, some areas may have extensive areas of 100 percent dead coral rubble.

In total, at least 67 fish species have been identified from these deep-water reef sites (Reed, 2004; Ross, 2004; Reed et al., in press). These include 30 species from the Poutalès Terrace sites, 20 from Miami Terrace, 12 from the East



Lophelia pertusa coral and *Echinomuricea atlantica* octocoral on Miami Terrace Escarpment, 284 meters.

Florida *Lophelia* Pinnacles, and 10 each from the Savannah Lithoherms and Stetson *Lophelia* Reefs. Species that are common to most deep-reef sites include the blackbelly rose fish (*Helicolenus dactylopterus*), morid cod (*Laemonema melanurum*), red bream (*Beryx decadactylus*), roughy (*Hoplostethus occidentalis*), conger eel (*Conger oceanicus*), and wreckfish (*Polypriion americanus*). Although the deep-water *Oculina* reefs appear to be more species rich (73 species total), these reefs are shallower (50 to 100 m) than the *Lophelia* reefs, and the *Oculina* fish list also includes cryptic species collected by lockout diving from the Johnson-Sea-Link submersibles. Additional sampling of the deeper *Lophelia* reefs may significantly add to this faunal list.

WHY PROTECT DEEP-WATER REEFS?

Deep-water coral reefs are irreplaceable resources that are ecologically diverse and vulnerable to physical destruction. Bottom-trawl fishing, oil and gas production, cable laying, mining, or coral harvest could negatively impact these reefs. Protection is needed since damage from bottom trawling is a global threat. The National Oceanic and Atmospheric Administration's (NOAA's) 2001 Islands in the Stream Expedition demonstrated extensive damage from apparent shrimp trawling on the *Oculina* reefs. After trawlers were banned from the *Oculina* MPA, there was concern that trawlers might move to deeper habitats in search of valuable fisheries, such as royal red shrimp or benthic finfish. Removal by fisheries of apex predators such as groupers, snappers, sharks, and other ecologically important species may have severe long-term repercussions. Many deep-water fishes are very long lived and can not sustain long-term fishing pressure.

FUTURE OF DEEP-WATER REEFS

Compared to their shallow-water counterparts, deep reefs are relatively unknown. NOAA Fisheries and the Fishery

Management Councils are developing reports on the state of knowledge for deep-reef ecosystems. The deep-water *Oculina* reefs were the first deep-water reefs in the world to be designated as a MPA. Meanwhile the need to protect other deep-water reefs has gained worldwide attention. Norway enacted its first MPA to protect deep-water *Lophelia* coral reefs. In Canadian waters, the Northern Coral Forest Marine Protected Area has been proposed for deep-water, soft-coral habitats off Nova Scotia. As a result of our recent research, the South Atlantic Fishery Management Council is proposing six deep-water coral areas from North Carolina to South Florida as Habitat Areas of Particular Concern (HAPC). Also, a Deep Sea Coral Protection Act has been drafted and is being considered for federal legislation (see Frame and Gillelan, this issue, for more).

Education is needed for the public, the fishing community, resource managers, and legislators so they have a better understanding of the value and vulnerability of these reefs. Deep-water reefs are barely accessible to scientists; however, only by bringing knowledge of them to the public through videos, photos, and education will we gain understanding for the need to protect these unseen resources.

JOHN K. REED, Senior Scientist at Harbor Branch Oceanographic Institution (HBOI), has studied deep-water *Oculina* and *Lophelia* reefs since 1976 and has 50 publications on deep reefs. His research helped establish the *Oculina* Marine Protected Area (MPA). He has been Chief Scientist on 60 worldwide expeditions for biomedical research with HBOI's Johnson-Sea-Link submersibles.

STEVE W. ROSS, Research Faculty at the University of North Carolina at Wilmington (currently on assignment to the U.S. Geological Survey), has studied fishes and ecosystem ecology in the southeastern U.S., mostly North Carolina, for over 25 years. His research has spanned riverine, estuarine, continental shelf, and slope habitats. He has conducted numerous research cruises, many using submersibles and has been studying deep coral areas since the early 1990s.

FOOTNOTES

1. Funded in part by the National Oceanic and Atmospheric Administration's (NOAA's) Office of Ocean Exploration (OE), NOAA Fisheries, NOAA Undersea Research Program, NOAA Coral Reef Conservation Program, U.S. Geological Survey, and the State of Florida's Center of Excellence in Biomedical and Marine Biotechnology.
2. *Oculina* reefs were visited during NOAA's 2001 Islands in the Stream Expedition: <http://oceanexplorer.noaa.gov/explorations/islands01/log/sep5/sep5.html>.
3. *Lophelia* reefs were part of various NOAA Ocean Exploration Expeditions from 2001 through 2004: (<http://oceanexplorer.noaa.gov>).

REFERENCES

- Cairns, S. (1979). "The Deep-Water Scleractinia of the Caribbean Sea and Adjacent Waters." *Studies on the Fauna of Curacao and Other Caribbean Islands* 56: 1-341.
- Paull, C.K., A. Neumann, B. am Ende, W. Ussler, and N. Rodriguez. (2000). "Lithoherms on the Florida-Hatteras Slope." *Marine Geology* 166: 83-101.
- Reed, J.K. (2002a). "Comparison of Deep-Water Coral Reefs and Lithoherms off southeastern U.S.A." *Hydrobiologia* 471: 57-69.
- Reed, J.K. (2002b). "Deep-Water *Oculina* Coral Reefs of Florida: Biology, Impacts, and Management." *Hydrobiologia* 471: 43-55.
- Reed, J.K. (2004). *General Description of Deep-Water Coral Reefs of Florida, Georgia and South Carolina: A Summary of Current Knowledge of the Distribution, Habitat, and Associated Fauna*. A Report to the South Atlantic Fishery Management Council, NOAA, NMFS, 71 pp.
- Reed, J.K., S. Pomponi, A. Wright, D. Weaver, and C. Paull. (in press). "Deep-Water Sinkholes and Bioherms of South Florida and Portalés Terrace—Habitat and Fauna." *Bulletin of Marine Science*.
- Rogers, A. D. (1999). "The Biology of *Lophelia pertusa* (Linnaeus, 1758) and Other Deep-Water Reef-Forming Corals and Impacts from Human Activities." *International Review of Hydrobiology* 84: 315-406.
- Ross, S. (2004). *General Description of Distribution, Habitat, and Associated Fauna of Deep-Water Coral Reefs on the North Carolina Continental Slope*. Report for the South Atlantic Fishery Management Council, Charleston, SC, 14 pp.
- Schroeder, W. (2002). "Observations of *Lophelia pertusa* and the Surficial Geology at a Deep-Water Site in the Northeastern Gulf of Mexico." *Hydrobiologia* 471: 29-33.
- Sedberry, G.R., ed. (2001). *Islands in the Stream: Oceanography and Fisheries of the Charleston Bump*. American Fisheries Society Symposium 25, American Fisheries Society, Bethesda, Maryland, 240 pp.
- Stetson, T.R., D.F. Squires, and R.M. Pratt. (1962). "Coral Banks Occurring in Deep Water on the Blake Plateau." *American Museum Novitates* 2114: 1-39.

FOR MORE RESOURCES:

NOAA's Office of Ocean Exploration:
<http://oceanexplorer.noaa.gov>

NOAA's Ocean Exploration expeditions - 2001 to 2005:
<http://oceanexplorer.noaa.gov/explorations/explorations.html>

University of North Carolina, Wilmington - Highlighting the Deep-Water *Oculina* Coral Reefs:
<http://www.uncw.edu/oculina/>

Oceanica Oculina website - 2001 NOAA OE/ HBOI *Oculina* Deep-Water Reef Expedition:
<http://oceanica.cofc.edu/oculina/home.htm>

HBOI's At Sea website - Nature's Pharmacy and Eyes In the Sea Missions:
<http://www.at-sea.org/missions/fathoming/preview.html>

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Did You Know?

The deep-sea coral family *Isididae*, found to depths of 1,000 meters, may someday be used as a basis for new bone grafting material.

Coral has been used as jewelry since antiquity; it may have been a source of currency for trade by Paleolithic humans. Today, coral used for jewelry is known as precious coral, and this includes black, red, pink, and gold corals.