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Cold-water corals

Ancient life in the deep, dark sea

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The most common deep-sea coral in the world is named Lophelia pertusa. *It's also the dominant deep-sea coral off the U.S. southern Atlantic seaboard.*
PHOTO/WADE SPEES

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MOTHER SHIP.
The support ship R/V Seward Johnson *awaits the return of the Johnson-Sea-Link four-man submersible from a dive to study deep-sea corals in October 2005.*
PHOTO/ART HOWARD

Cold-water corals

Ancient life in the deep, dark sea

by John H. Tibbetts

Scientists once believed that nearly all corals in the ocean grow in sultry, shallow, sun-drenched waters of the tropics.

Not any longer. To their astonishment, scientists during the past 15 years have discovered deep-sea reefs (also called cold-water reefs) in refrigerator temperatures in the most unexpected places—in inky water off Antarctica, in the Arctic Circle off Northern Europe, and in the Bering Sea. Unfortunately, many biologically rich deep-sea corals are being destroyed at an alarming rate, primarily by trawling—that is, by towing heavy fishing nets along the bottom—before the corals can be studied and conserved.

Explorers have also discovered a spectacular array of deep-sea corals from North Carolina to east Florida beneath swift Gulf Stream currents. Cold-water corals grow on this region's continental slope where the seafloor descends rapidly from the continental shelf to the abyss. Off South Carolina, corals grow on the slope about 80 to 90 miles from the coast. Most of these coral banks seem to be relatively untouched by human impacts.

"We knew there were some scattered locations that had some significant amounts of corals in small areas," says Steve Ross, a marine scientist at the University of North Carolina-Wilmington whose research team has taken 65 submersible (small submarine) trips since 2000 to the region's deep sea hundreds of meters below the surface. Submersibles offer a close-up view of the sea bottom. "But we had no idea of how many there were or how much territory they covered."

The most common cold-water coral around the world responsible for reef building is named *Lophelia pertusa*, which forms elegant snow-white trees, bushes, and dense thickets on the seafloor.

Lophelia is the dominant cold-water coral off the U.S. southern Atlantic seaboard, found in depths of 360 to 1,000 meters. Generations of *Lophelia* corals have built numerous ancient mounds rising 10 to 150 meters from the sea bottom. Coral mounds are made up of dead-coral skeletons, sediments, and burrowing sponges and other sea animals. Living corals grow like rough skin across the mounds' surfaces, similar to vegetation on terrestrial hills.

Sonar-based maps show many features on the sea bottom that could be coral mounds. There are likely thousands of these mounds off the U.S. southern Atlantic seaboard, scientists say. Some mounds are probably hundreds of thousands of years old, providing habitat for sponges, crustaceans (crabs, lobsters), echinoderms (starfish, sea urchins, brittle stars, feather stars), and countless fishes.

Ross has been surprised by an abundance of corals during his voyages to the sea bottom, and he expects to see many more when he visits the deep sea in the future. "We see conditions that should support corals," he says, "and we feel there are many more coral areas yet to explore."

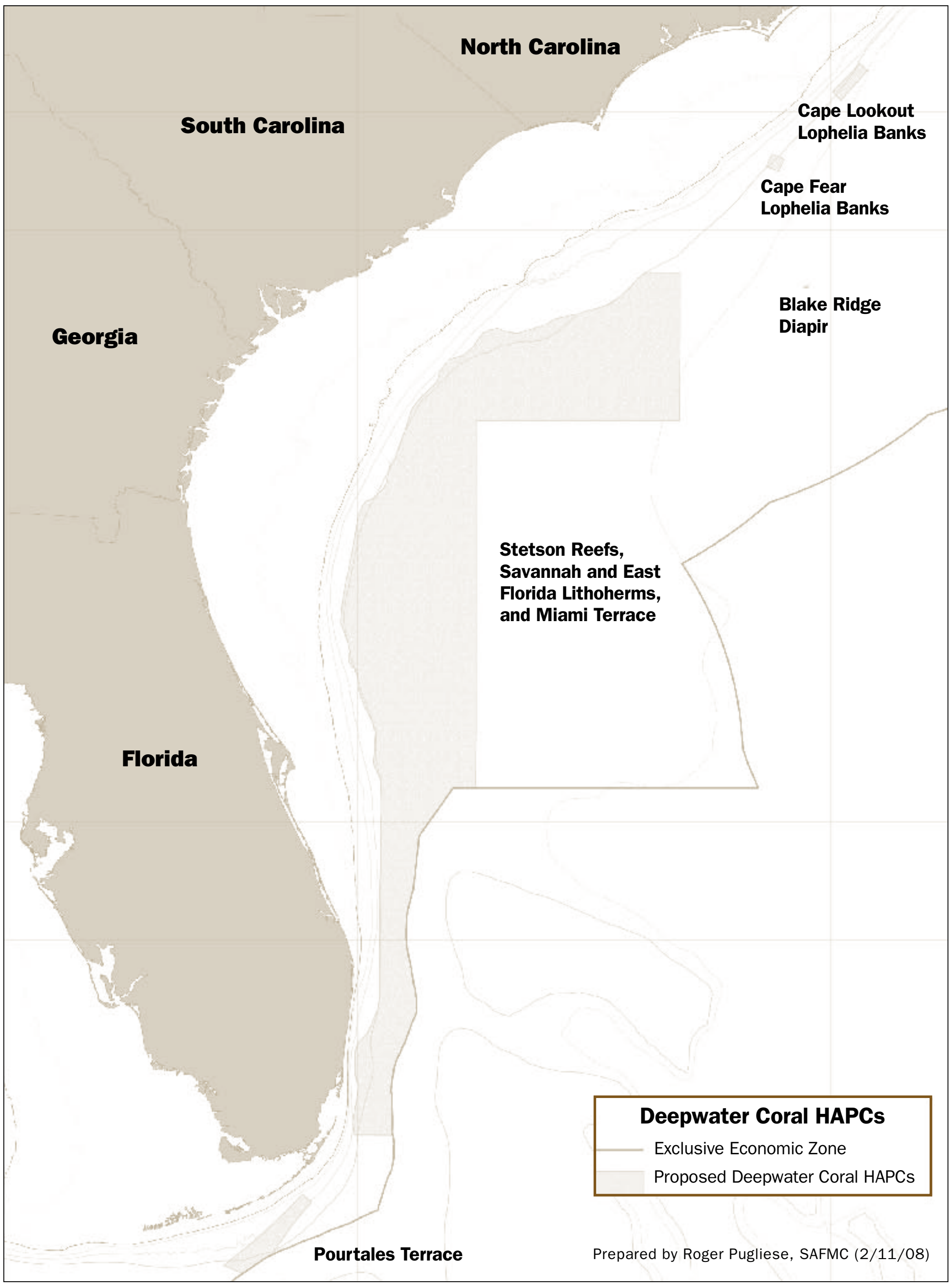
"This could be a world-class ecosystem," says Doug Rader, chair of the Habitat and Environmental Protection Advisory Panel at the South Atlantic Fishery Management Council, which manages fisheries resources in the region's federal waters. "It could very well be the densest and largest deep-coral ecosystem in the world. And it's right in our backyard."

Now, scientists, fishermen, environmentalists, and fishery managers are collaborating on a plan to protect cold-water reefs because these areas are important fish habitat.

The Council has proposed five Habitat Areas of Particular Concern (HAPCs) to conserve 25,000 square miles of deep-sea bottom. By 2010, the Council aims to have the tools in place to manage the region's cold-water corals, says Rader, who is also chief ocean scientist at the Environmental Defense Fund, a national nonprofit organization with a regional office in Raleigh, North Carolina.

What is an HAPC? In all but name, it's a "marine-protected area"—an ocean habitat determined to be essential to the health and long-term survival of fisheries, including spawning, nursery, and feeding sites. HAPCs are locations where certain activities—such as bottom trawling—may be banned to protect particularly sensitive habitats or species assemblages such as corals and associated organisms.

The region's cold-water reefs need to be preserved, scientists say, because many similar reefs around the



To manage the region's deep-sea corals from North Carolina to east Florida, the South Atlantic Fishery Management Council has proposed five Habitat Areas of Particular Concern.

world have been severely damaged or destroyed. Cold-water corals are particularly sensitive to breakage or disturbance.

With the aid of radiocarbon-dating techniques, scientists have estimated the age of one coral colony off the U.S. southern Atlantic coast at 2,000 years. A cold-water reef in Norway's waters is likely more than 8,000 years. Imagine: it's probably older than human civilization.

"The growth rate of deep-sea corals is remarkably slow," says Robert Steneck, a marine ecologist at the University of Maine. "We're talking about very diminutive coral trees that are centuries in age. They grow very slowly, they are very fragile, and they are very important."

Deep-sea reefs grow so slowly in fact that they would need hundreds to thousands of years to recover from damage but might not recover at all. The larger coral mounds would require far longer, if they were to come back.

Threats to deep-sea corals worldwide include oil and gas exploration and production, cable and pipeline placement, precious-coral mining, ocean acidification, and waste dumping.

The greatest danger, however, is trawling. Many fish species prefer complex habitats—places to hide or lay eggs, find abundant food sources, take shelter from strong currents—and deep-sea reefs often fit the bill.

Hunting for bottom fisheries, industrial trawlers have razed cold-water reefs in some parts of the world. Heavy "doors" hold a trawl net open and keep it on the bottom. Often these doors are connected to the net by wire "leg lines" that can slice through delicate deep-sea coral colonies and mounds. Dragging doors on the seafloor can also batter a coral reef. In many cases, the nets are equipped with heavy metal and rubber rollers, which hold the net close to the seabed and allow it to roll over hard rock. These rollers crush delicate corals. Some fishermen acknowledge that trawling resembles bulldozing the seafloor.

(Trawlers that catch brown or white shrimp in southeastern U.S. waters fish exclusively in shallow areas on muddy or sandy bottoms and don't affect deep-sea resources.)

A March 2008 report by the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program states, "Disturbances to deep-sea coral communities from bottom-tending fishing gear, especially bottom trawl gear, are the best documented and pose the most widespread threat."

This is a global problem, according to a 2004 report by the United Nations Environment Programme. The report points out that "many of the most spectacular examples of [deep-sea coral] discovered so far could be gone in less than a generation . . . if we do not act quickly." Deep-sea fisheries, moreover, have crashed after intense exploitation because most deep-sea species cannot sustain heavy, long-term fishing pressure.

In the 1990s, the Norwegian Institute of Marine Research estimated that probably between 30 and 50 percent of cold-water reefs in Norwegian waters had been partially or totally damaged by bottom trawls.

The deep-sea coral complex from North Carolina to east Florida is especially rich in fish diversity, and scientists are concerned that it could eventually attract harvesting pressure from deep-sea trawlers.

Some deep-sea fishes in the region have small populations and exotic names: deepbody boarfish and roughtongue bass. Others, though, have commercial potential, says Rader. Hagfish, barrelfish, blackbelly rosefish, and red sea bream have been exploited in other oceans, and are not currently managed by the South Atlantic Fishery Management Council.

Blackbelly rosefish is very abundant around these deep reefs. "We've caught quite a few that way in a research trawl," says Ross of the University of North Carolina-Wilmington. "If fisheries got in without proper management and caught all those they could, then it would not only probably damage habitat but also

REFUGE. ***Fishes in the deep-sea coral complex from North Carolina to east Florida include red sea bream (top), wreckfish (middle), and blackbelly rosefish. Only the wreckfish fishery is currently managed. Scientists are worried that new deep-sea fisheries could get established without proper management and could damage corals.***
PHOTOS/GEORGE SEDBERRY, S.W. ROSS, ET AL.

hurt the fish population."

Today, there is a very small, tightly regulated wreckfish (*Polyprion americanus*) fishery that operates around *Lophelia* corals and deep rocky reefs off the South Carolina and Georgia coasts. Wreckfish is a deep-sea grouper-like fish. That fishery would continue under the proposed HAPC.

Just one tiny, traditional fishery—golden crab—could be affected economically by the proposed HAPCs, according to the Council. There are only seven golden-crab fishermen in the region, all of them Florida-based.

Randy Manchester, who harvests golden crab out of Ft. Lauderdale, Florida, in a 50-foot former lobster boat, deploys wire traps 300 to 400 meters to the sea bottom just outside of a proposed HAPC boundary. He avoids deepwater structures such as coral pinnacles (high-relief coral mounds) because they could snag his traps. "We spend three to four hours in extensive echo-sounding of the bottom," he says. "We don't want to lose $5,000 worth of gear."

CONSERVATOR. ***To avoid harming deep-sea corals, golden-crab fishermen such as Randy Manchester are designing new fishing-gear zones in collaboration with the South Atlantic Fishery Management Council.*** **PHOTO/WADE SPEES**

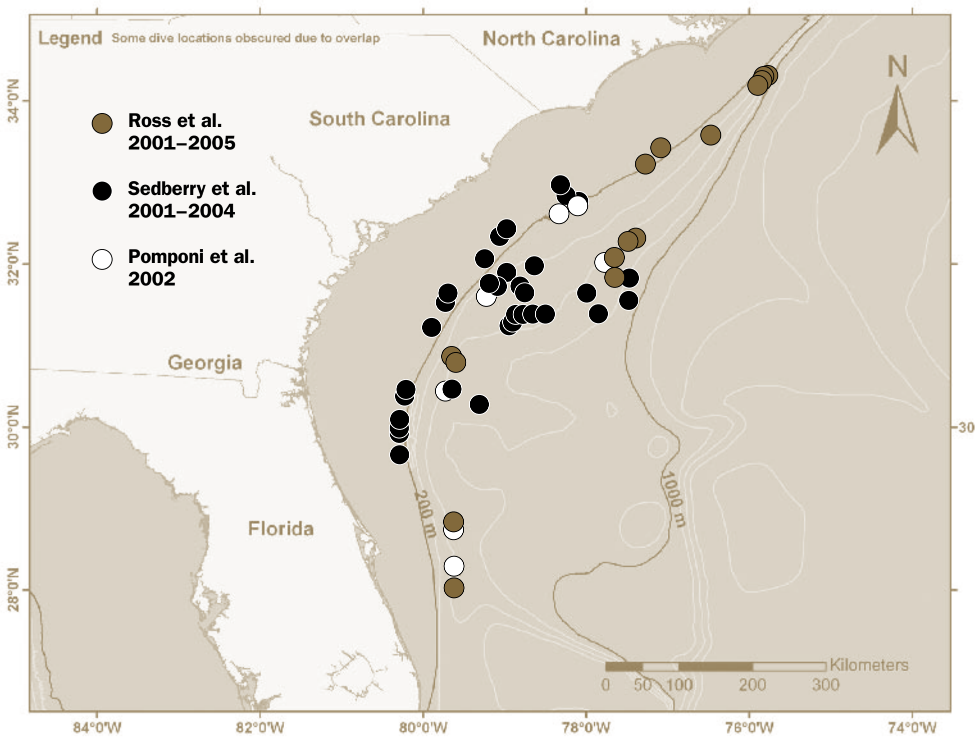
Now, the Council is collaborating with golden-crab fishermen to design allowable gear zones so they can continue fishing in their traditional areas in two of the proposed HAPCs while staying away from coral mounds and pinnacles. The Council and the golden-crab fishermen have a long record of cooperation and trust, says Kim Iverson, the Council's public information officer. "They are very green-thinking fishermen," says Rader.

A potential problem is "deep-drop" recreational fishing on the Atlantic and Gulf coasts. A growing number of recreational anglers are using sturdy lines, powerful gear—including electric reels—and 30-pound lead weights to catch deep-sea species such as snowy grouper, tilefish, and blackbelly rosefish. This is particularly an issue in southeastern Florida where fishermen have easier access to deep water because it's much closer to shore. Deep-drop fishing is rapidly gaining popularity among offshore recreational fishermen, says Iverson.

"To be blunt about it, many of those deep-drop fisheries aren't even managed," says Rader. "Many of the species involved aren't in a fishery management plan. There are bag limits and size limits for some other species but not for certain deepwater species" such as blackbelly rosefish. "Sooner or later the Council is going to have to come to terms with the unmanaged species. Fishing mortality of bottom fish is growing by leaps and bounds."

Despite future potential threats to deep-sea corals and fisheries, *Lophelia* cold-water corals from North Carolina to east Florida surveyed to date appear to be in good condition, scientists say. And the region's deep-sea fishing industry is so small that fishery managers see a chance to protect a giant stretch of ocean.

"We don't have a lot of fishing pressure on these corals now, so it's a good time to put an HAPC into place," says Andrew Shepard, director of the NOAA Undersea Research Center at the University of North Carolina-Wilmington. "There's not a lot of



These study sites have provided a wealth of data about deep-sea coral ecosystems off the U.S. southern Atlantic seaboard. **MAP/SOUTHEASTERN UNITED STATES DEEP-SEA CORALS INITIATIVE**

INTO THE DEEP. *Explorers have discovered a remarkable array of deep-sea corals from North Carolina to east Florida. Shown here is a 2001 launching of the Johnson-Sea-Link four-man submersible, which gathered coral samples and other data from the dark, cold sea bottom off the U.S. southern Atlantic seaboard.*
PHOTO/GEORGE SEDBERRY

UNDERWATER INVESTIGATIONS. *A view from inside the Johnson-Sea-Link submersible near the top of a deep-sea coral mound off Cape Fear, North Carolina, in October 2005. Scientists examined thickets of the cold-water coral* Lophelia pertusa *at a depth of about 370 meters.* PHOTO/ART HOWARD

political opposition to protecting the region's deep-sea corals because we don't have the economics against us."

THE INKY ABYSS

In 1758, Carl Linnaeus, the Swedish taxonomist, was the first naturalist to classify and name the cold-water coral *Lophelia pertusa* after fishermen had inadvertently captured it with nets and hooks in Scandinavian fjords.

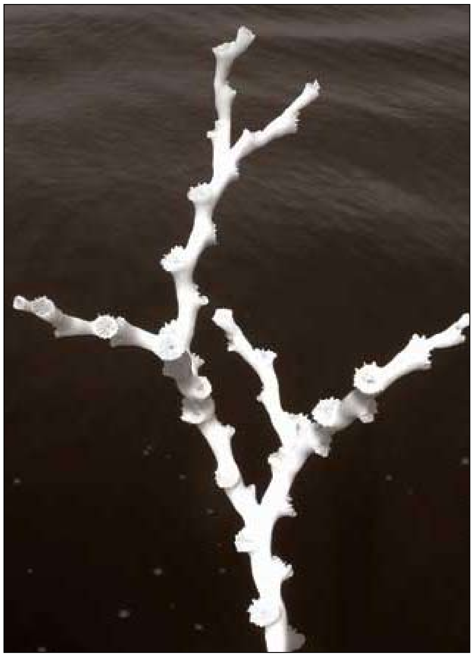
By the early nineteenth century, British fishermen were operating steam trawlers with power winches to pull up the catch. With this technology, fishermen could fish in somewhat deeper water and also accidentally grab corals. The scientist Louis Agassiz brought up cold-water coral specimens by dredging off the U.S. Southeast in 1880.

Still, it was relatively rare for hooks and trawls to grab cold-water corals. Fishing and research technologies of the time could reach only moderate depths, and scientists believed that cold-water corals were geographically limited and few in number. It seemed very unlikely—even impossible—that vast coral reefs around the world could survive in conditions of unending darkness, intense pressure, and refrigerator chill.

But in the mid-1990s improved technologies—acoustic surveys, Remotely Operated Vehicles (ROVs), and manned submersible craft—allowed scientists to study stretches of the world's deeper regions. Still, powerful currents, rough terrain, intense pressure, extreme darkness, and high costs of ship time and deep-sea technologies have continued to make deep-sea exploration difficult.

Scientists have mapped deep-sea corals in the Gulf of Mexico and Mediterranean, along continental slopes on both sides of the Pacific and Atlantic, and on hundreds of undersea mountains called seamounts in the open ocean. Seamounts often peak 300 meters beneath the ocean surface.

Today, most of the nation's cold-water corals remain hidden in an



DELICATE HABITAT. ***There are likely thousands of deep-sea coral mounds from North Carolina to east Florida. Across the surface of the mounds, the coral*** **Lophelia pertusa** ***forms dense bushes and thickets on the seafloor but also elegant, solitary trees like this one (top).*** **Cnidarian** ***coral colonies (bottom) also formed this tree-like structure.***
PHOTOS/S.W. ROSS, ET AL., LESLIE R. SAUTTER

unexplored world. Less than 10 percent of the sea bottom of the entire U.S. Exclusive Economic Zone—three miles to 200 miles from shore—has been mapped with low-resolution tools, which provide a general typography of the bottom, says Kimberly Puglise, science director of NOAA's Office of Ocean Exploration and Research.

Less than five percent of potential deep-sea coral habitat from North Carolina to eastern Florida has been mapped with high-resolution technologies, which provide detailed images of seafloor resources such as corals and rocks. To study and manage cold-water corals, NOAA would need further high-resolution images of the deep-sea floor.

"We just don't know enough about where most deep-sea corals are" in U.S. marine waters, says Puglise. "That makes it difficult to manage their use." NOAA is working on a strategic plan for deep-sea corals and sponges that would address both further research and management. It will be available for public comment in 2009. The South Atlantic Fishery Management Council has already convened experts to write a research plan for deep-sea corals of the region.

Federal budgets for deep-sea explorations nationwide have essentially been reduced since the late-1990s, limiting scientists' opportunities to explore more of the nation's deep-sea bottom and to provide the "best available science" required for fishery management as mandated by federal law, says Steneck.

U.S. funding of deep-sea explorations has been "at pittance scale compared to those of shallow-water corals," says Rader. "We are badly in need of documentation of what's down there. Still, it's amazing what scientists have been able to do on a shoestring in the Southeast."

Explorations of Southeast's deep-sea corals have generated both public excitement and concern over the fate of these unusual resources.

Students map the seafloor

Most of the sea bottom off the South Carolina coast remains a mystery to scientists and fishery managers because so little of it has been mapped with up-to-date tools. There are too few people with specialized training in high-tech mapping technologies and too few research vessels.

"It's amazing how far behind we are in mapping the seafloor," says Leslie Sautter, a geologist at the College of Charleston and director of Project Oceanica.

In October 2008, Sautter led 14 undergraduates on a scientific cruise to study the contours of the ocean bottom along the edge of the continental shelf about 60 miles off the South Carolina coast, among other undersea locations. This is Sautter's third such cruise offered in as many years to more than 30 undergraduate students.

The students met the National Oceanic and Atmospheric Administration (NOAA) ship *Nancy Foster* in Key West, Fla., and traveled to a stretch of the continental-shelf edge named "Doc's Rocks" in honor of "Doc" Sautter. The NOAA Coastal Services Center, based in North Charleston, organized the ship time.

Scientists know that some sections of this rocky feature are crucial breeding grounds for fisheries, including groupers and snappers. Many segments are under investigation as potential marine-protected areas, some of which have been mapped.

But fishery and sanctuary managers could use additional maps and data from the continental-shelf edge to establish more precise harvesting rules on some species or to create more focused marine-protected areas.

On board the *Nancy Foster*, the students sent "a huge broom-like swath of sonar beams" to the ocean bottom, says Sautter. The students used specialized software to process sonar data and create three-dimensional maps of the seafloor.

With partial support from the S.C. Sea Grant Consortium, Sautter's students had received an intensive three-day training in seafloor-mapping software developed by CARIS, Inc., a Canadian company.

Since graduating, several of her past students were hired by industry as specialists in seafloor-mapping technologies, while others are using this mapping tool in graduate studies. A couple of alums have come back and trained new students at the college, says Sautter.

In May 2008, South Carolina Gov. Mark Sanford wrote a letter to the White House asking the federal government to designate the deep-sea coral region off the southern Atlantic seaboard as a marine national monument. Monument status would provide comprehensive government protection for the corals of the region. More than 120 scientists also petitioned the president to consider protecting it as a national monument.

In 2006, conservationists praised President George W. Bush for naming a nearly 140,000-square-mile marine reserve in the Northwestern Hawaiian Islands as a national monument.

But when gasoline prices rose during the summer of 2008, there were calls for additional offshore oil and gas exploration in U.S. waters. A federal moratorium had prohibited drilling for fossil fuels along most of the U.S. coastline, including the southern Atlantic seaboard, until 2012. But the moratorium was recently withdrawn.

The deep-sea coral banks of the U.S. southern Atlantic coast did not make the White House final list of areas to be nominated for monument status. Instead, three sites in the Pacific Ocean have been designated.

Rader says that the South Atlantic Fishery Management Council's proposed HAPCs could provide nearly as much protection as a monument designation while also allowing some fishing to continue. "Once the Council acts," he says, "the biggest challenge will be finding the resources needed for enforcement, outreach and education, and research and monitoring of these world treasures."

RICH COMPLEXITY

Two generations ago, virtually all deep-sea fishes were inaccessible, living in ad hoc refuges. Deep-sea fish were too far under water to catch, and the open ocean was distant and dangerous.

Starting in the 1960s, however, fishing vessels got larger and safer in the open ocean, and fishing practices became more sophisticated. Nations including the United States, Russia, most European countries, and Japan subsidized their fishing industries through low- or no-interest loans and payments.

Boat captains increasingly used depth recorders, sonar, global-positioning systems, larger nets, and other tools that allowed them to catch more fish.

At first, most boat captains intensified their efforts in relatively shallow waters of the continental shelves where fish populations gathered to feed or breed. But after decades of increasing harvesting pressure, fishermen were taking in smaller and smaller catches. So, in the late 1980s, trawlers began chasing fisheries along the deeper shelf margins, on seamounts, and the continental slopes down to 1,500 meters in depth.

> **ROBERT STENECK**
>
> *"Fisheries in shallow zones have largely been stripped in most places, so the fishing industry has had a tendency to move into deeper and deeper water."*

"Fisheries in shallow zones have largely been stripped in most places, so the fishing industry has had a tendency to move into deeper and deeper water," says Steneck of the University of Maine.

Around the globe, more than 23,000 fishing vessels of more than 100 tons and millions of smaller ones are trawling the ocean bottom for fish and shrimp, spooling out lines and hooks for tuna and other big predators, and deploying other gear in the search for seafood in distant and deep waters.

"Fishermen want to go where there's no competition," says George Sedberry, superintendent of the Gray's Reef National Marine Sanctuary. Previously he studied deep-sea fisheries and corals for the S.C. Department of Natural Resources. "For hundreds of years, fishermen have gone farther and farther afield, searching for new stocks and new species to catch."

Before 1980, for example, a deep-sea wreckfish fishery off South Carolina didn't exist. But, by 1989, there were 90 fishing boats, using hook-and-line to harvest the then-unregulated fishery, and catches were unsustainable, says Sedberry. The South Atlantic Fishery Management Council, concerned that the wreckfish population could collapse, collaborated with fishermen to establish an innovative "individual transferable quota" system. That is, a strictly limited number of fishermen are allowed to catch wreckfish.

Moreover, the Council has limited the type of fishing gear that can be used, the fishery's total allowable catch, and closed it during spawning season. "This is an example of a management success story," says Sedberry. "It's a small, sustainable fishery."

Indeed, most deep-sea fisheries need tighter management schemes than shallow-water ones.

In shallow waters, many fish species mature and reproduce relatively early in life. When shelf fisheries are over-harvested and if their habitats aren't damaged, some species can bounce back under tighter regulatory schemes. That's why some fisheries in nearshore ecosystems—striped bass, for instance—have been resilient once fishing pressure has been scaled back.

By contrast, deep-sea species are often long living and late maturing. Organisms on the sea bottom rely on food particles drifting down from the surface or, in some cases, from localized upwelling currents. Most deep-sea fish—like deep-sea corals—grow very slowly, which makes them vulnerable to over-harvesting and population busts. Wreckfish, according to one estimate, can live as long as 75 years.

Deep-sea fish stocks can be abruptly fished out. Stocks of the orange roughy, a deep-sea species, were depleted by 75 percent within 20 years of when New Zealand began fishing for them.

The global fish trade has expanded explosively in recent decades because of rising demand and improved technologies. Flash freezers have allowed fishermen and seafood packers to preserve catches that can be shipped on refrigerated airplanes and trucks around the world.

For instance, a 100-year-old Patagonian toothfish caught near New Zealand can be flash-frozen and sold a few days later as Chilean sea bass to a Seattle or New York restaurant.

But a deep-sea harvest can be a one-time thing if fishermen are allowed to use trawls that damage coral habitat. "You can probably fill your hold on a trip or two," says Steneck, "but at great cost to the ecological community down there. It's very hard to sustain a fishery that way."

OASES IN THE DEEP SEA

What makes a region rich in deep-water corals? Two things: rockier bottoms and faster currents.

Most of the ocean floor is covered by thick sediment. But powerful currents, including the Gulf Stream, sweep away most of the fine-grained, muddy sediments along stretches of the continental slope from east Florida to North Carolina, exposing sections or fragments of rocky walls, ridges, pinnacles, terraces, and other hard-bottom places.

To establish a permanent home, a free-floating coral larva attaches itself to a rocky surface or a shell. Then it begins extracting calcium carbonate from seawater to build a chalky, protective skeleton shaped like a cup.

Coral polyps—animals related to sea anemones and jellyfish—grow alone or in colonies. To create a colony, polyps cement their skeletons together until they create a dense bush-like formation. Over a decade or two, additional polyps expand the formation into thickets that spread across the seafloor.

Corals reveal climate record

Deep-sea corals could offer a living history of the ocean, providing insights into how the sea could respond to future climate change.

To learn about the Earth's past temperatures, scientists have studied tree rings, which reflect climate conditions of each growing season. Scientists have also studied glaciers, which accumulate a new layer of ice with each year's snowfall.

Researchers can plug these data into computer models to reveal how the Earth's air temperature has risen or fallen—at times very rapidly—over the past 100,000 years.

A weakness of computer models is that they can't predict how climate change could be manifested in deep-ocean circulation. That's because scientists lack significant information about changes in the deep ocean in past climates.

Scientists have found clues preserved in sediment cores that accumulate in sequential layers on the seafloor. The problem is that organisms burrowing into sediments can mix sea-bottom layers, disrupting the chronology.

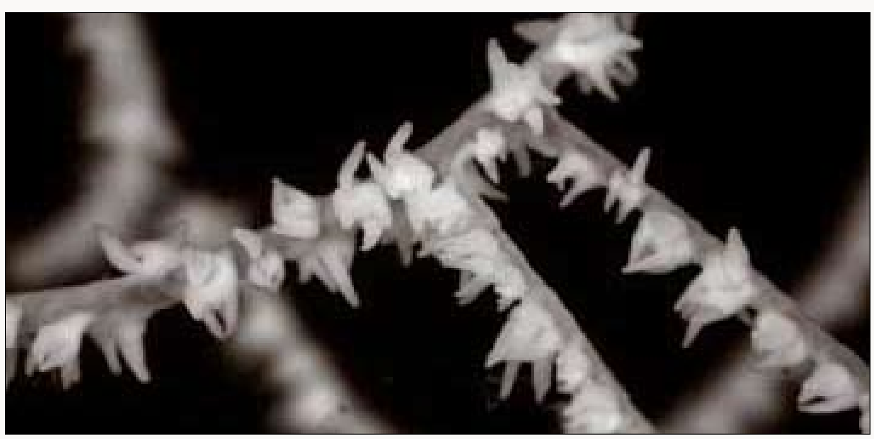
So scientists have looked to the carbonate skeletons of corals. In the deep sea, corals can live for hundreds, even thousands, of years, adding seasonal or annual layers in their hard carbonate shells.

"Many species, especially the black corals, have rings like those of trees," says Steve Ross, a marine scientist at the University of North Carolina-Wilmington. "You can not only date the rings, but you can get a lot of chemical information out of those rings so you can reconstruct a history of the ocean. You can get information on temperature, climate, and food resources from that record going back hundreds to thousands of years. It may be even more valuable than ice-cores because of the variety of more detailed information."

Deep-sea corals could also provide crucial insights into ocean acidification. The ocean is becoming more acidic as it absorbs additional carbon dioxide from the atmosphere. The 2007 report by the Intergovernmental Panel on Climate Change notes that deep-sea corals, including those off the U.S. southern Atlantic seaboard, are among four of the ocean's most threatened ecosystems because of their sensitivity to acidification.

Increased acidity reduces the saturation levels of calcium carbonate in seawater, inhibiting a coral's capacity to build a protective shell. Over time, corals weaken in acidic waters and die.

There are many dead *Lophelia pertusa* corals on the deep-sea bottom from North Carolina to Florida. Have they died from natural causes? Is the extent of dead corals in this region unusual in comparison to other regions that have extensive *Lophelia* banks? Further explorations could help scientists understand the life cycles of deep-sea corals and their susceptibility to acidification.



Polyps of black coral (*Leiopathes *sp.). This species has rings like those of trees. PHOTO/SOUTHEASTERN REGIONAL TAXONOMIC CENTER, S.C. DEPARTMENT OF NATURAL RESOURCES

COUNTERPOINT. ***Marilyn Solorzano, who owns two deep-sea trawlers in Florida, argues that today's commercial fishing vessels aren't damaging cold-water corals. But scientists say that trawling damage to some ancient reefs continues.***
PHOTO/WADE SPEES

A colony can establish itself on a small rock and start to grow bigger and bigger. Another coral might start growing on a nearby rock, and where corals touch each other they can grow together.

Some cold-water corals are evolutionary cousins of tropical corals, but they have evolved in different ways.

In the tropics, corals depend on a symbiotic, beneficial relationship with algae called zooxanthellae, which live in healthy coral tissue. The zooxanthellae capture sunlight to photosynthesize, providing nutrients to their hosts, the coral animals. Tropical coral, then, live in shallow, clear waters that allow sunlight penetration and life-giving photosynthesis to occur.

By contrast, deep-sea corals flourish in absolute darkness. With tiny tentacles, they catch microscopic live plankton and organic matter that float down from the upper layers of the ocean.

The living and dead *Lophelia* coral system can capture and accumulate sediments carried by deep-sea currents. Sediments fill in voids in the carbonate structure, which over time can develop into a substantial coral mound where sponges, snails, and other burrowing creatures take up residence.

It can take thousands of years for deep-sea resources to build a large, three-dimensional mound that provides protective habitat, food, and breeding sites for a variety of species.

Off the U.S. southern Atlantic seaboard, coral mounds have created biological oases in an otherwise desert-like deep sea. This complex of coral mounds could be connected to an equally large complex dominated by *Lophelia* on the other side of the Atlantic Ocean stretching from northwestern Europe to West Africa.

The Trans-Atlantic Coral Ecosystem Study (TRACES) is a developing international initiative to study the cold-water coral ecosystems of the North Atlantic. Involving scientists from the United States, Canada, and the European Union, TRACES seeks to examine differences, similarities, and potential interconnections among these far-flung cold-water coral systems.

THE OBJECT LESSON

Scientists calling for action to protect *Lophelia* corals point to the object lesson of the east-central Florida *Oculina varicosa* coral ecosystem.

By the early 1980s, trawlers and scallop dredgers were razing sections of Florida *Oculina* Banks, a 90-mile strip of shelf-edge reefs. The *Oculina* Banks get their name from the slow-growing ivory-tree coral, which forms huge thickets and valuable habitat on the sea bottom. Florida's *Oculina* Banks are found on the continental-shelf edge in shallower waters than the *Lophelia* corals, which are located seaward along the continental slope.

In 1984, the South Atlantic Fishery Management Council established a 92-square-mile *Oculina* HAPC at the southern end of the bank. The HAPC was designed to protect corals from damage caused by bottom-tending fishing gear, including bottom trawls, bottom longlines, dredges, and fish traps. The Council later prohibited anchoring and trawling for rock shrimp, and it required the use of vessel-monitoring systems (VMS) on rock shrimp vessels. A VMS, which uses Global Positioning System technology, automatically reports a vessel's position and speed.

Yet most of the *Oculina* reefs were not included in the original 1984 HAPC, so a decade later the Council expanded habitat protection to include most of the corals in the northern part of the bank. The *Oculina* HAPC now encompasses 300 square miles.

In 1994, the original 92-square-mile HAPC was declared the *Oculina* Experimental Closed Area, closed to all bottom-fishing, in an effort to bring back snapper-grouper populations, which had crashed, and to study the ecosystem. The Council recently extended the snapper-grouper closure indefinitely.

Trawlers were banned from most of Florida's *Oculina* reefs, but some haven't stayed away. Some rock-shrimp trawlers have been successfully prosecuted for poaching in the *Oculina* Banks since the closure.

Even today, poachers continue to illegally "mow down" *Oculina* coral reefs in protected areas, says Andrew Shepard of NOAA's Undersea Research Center at the University of North Carolina-Wilmington. "They drag things such as metal bars over the coral, so later they can get their nets through there" to catch rock shrimp without tearing the nets.

Marilyn Solorzano, who owns a seafood dock and two deep-sea trawlers in Jacksonville, Fla., says that reef destruction must have occurred several decades ago, perhaps as early as the World War II era—before government restrictions came into effect.

Royal red shrimp are deep-sea crustaceans found along the continental slope from eastern Florida to Cape Hatteras, though a commercial fishery exists only in Florida. Solorzano's boats fish for royal red shrimp in deeper water than the *Oculina* reefs but in shallower water than *Lophelia* reefs.

"We have such good technology now," which allows fishermen to know where corals are located, Solorzano says. "It's far too costly to trawl across a coral reef and allow nets to get all torn up. You'd be an idiot to trawl on the *Oculina* or other corals. We wouldn't have any equipment left if we did that."

Shepard, however, says that trawling damage is still occurring. The number of poachers on the *Oculina* Bank is probably small, but it only takes one trawler to level an ancient deep-sea reef. "Trawlers did damage in the 1980s, but they're still doing it now. We've seen the marks from recent damage. There's plenty of evidence."

It's hard to underestimate the difficulty of catching poachers in hundreds of square miles of protected ocean habitat, Shepard says.

Spotter planes and helicopters survey the area and, if they see poaching, alert U.S. Coast Guard vessels, but it's difficult for law enforcement to arrive in time to catch anyone. Also, most poaching on the *Oculina* Banks probably occurs at night.

"The key to enforcement is using VMS to track boat movements," Shepard says. NOAA Fisheries keeps track of data from VMS, which are required on all rock-shrimp trawlers in the region. "There have been prosecutions based on VMS data," says Shepard. "But we also need the general public to report these things. Some of the prosecutions have been through anonymous tips."

"Impacts to the *Oculina* Banks appear to be continuing," says Myra Brouwer, a Council fishery scientist. "Enforcement is a huge issue on the *Oculina* Banks, though it's a relatively small area" at roughly 300 square miles. "There's not a lot more we can do to enforce" existing rules on the *Oculina* Banks.

Now, scientists and fishery managers are worried that trawlers could also start poaching among *Lophelia* reefs in search of deep-sea shrimp.

The five proposed *Lophelia* HAPCs cover 25,000 square miles. That's a lot of ocean. Everyone agrees that fishing restrictions along the continental slope can't be effectively enforced without widespread public support, says Brouwer. That's why the Council has collaborated with fishermen, conservationists, boaters, and other maritime interests during a long, exhaustive process to establish the five HAPCs. "You must have public buy-in," Brouwer says, "because to some extent you must have self-regulation."

The public needs to understand what's at stake in the region's deep-sea coral reefs, says Shepard. "We don't want trawlers to get to *Lophelia* banks and knock them down the way that *Oculina* got knocked down. We don't want to allow trawlers to start out there, because that's a sure-fire way to eliminate corals."

Reading and Web sites

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South Atlantic Fishery Management Council
www.safmc.net

NEWS & NOTES

Scientists working to understand water-quality anomaly

In 2004, anglers were startled by unusually large catches of flounder in the waters off the Myrtle Beach area, which oceanographers call Long Bay, in the northern coastal ocean of South Carolina. The problem with this flounder "jubilee" was that low-oxygen levels in the water had created a "dead zone" that drove fish toward the shoreline. What caused this low-oxygen—or hypoxic—event in the first place?

"The 2004 hypoxia event was a surprise," says Denise Sanger, assistant director for research and planning with the S.C. Sea Grant Consortium. "We had not seen this kind of oceanographic dead zone in South Carolina before."

In a series of research projects sponsored by the Consortium, S.C. Department of Health and Environmental Control-Office of Ocean and Coastal Resource Management, and S.C. Department of Natural Resources, scientists are studying physical, biological, chemical, and geological coastal-ocean processes in Long Bay.

South Carolina resource managers and scientists, including Sanger, have assembled a Long Bay Working Group to collaborate on research efforts and understand the causes of the hypoxic event.

It seems that a series of oceanographic conditions in Long Bay (oscillatory wind stress, upwelling, and hot summer weather) in 2004 stratified the water column near the coast, causing the flounder jubilee. Cold water along the ocean bottom was not mixing with warmer surface water, reducing oxygen levels. These conditions, plus the contribution of nutrients in stormwater runoff and groundwater discharge, apparently led to low-oxygen events in Long Bay.

Richard Viso (right) of Coastal Carolina University and a student pump up groundwater from a beachfront area, measuring parameters such as dissolved oxygen and nutrients. This information will help researchers understand whether groundwater discharges into the northern coastal ocean of South Carolina contribute to water-quality issues.
PHOTO/S.C. SEA GRANT CONSORTIUM

"We have learned a great deal about the Long Bay system," says Sanger. "In recent years, we have not observed another long-term hypoxic event like the one in 2004. But periodically we are seeing additional low dissolved-oxygen conditions in this environment, and that's unusual. The levels observed are similar to low dissolved-oxygen that we observe in the naturally stressful, small estuarine headwater creeks. Now we're finding these conditions in Long Bay just beyond the surf zone, despite strong currents and waves."

The goal of the S.C. Sea Grant Consortium research effort is to develop tools for future use in forecasting hypoxic events in Long Bay. The research results will be of interest to coastal and fishery managers and local communities.

Consortium researcher George Voulgaris of the University of South Carolina (USC) has developed a high-resolution numerical circulation model for Long Bay. The model is being used to identify the physical scenarios under which low-oxygen events can occur.

In a related study, Eric Koepfler and his colleagues at Coastal Carolina University (CCU) and USC are evaluating the potential and relative roles of marine and terrestrial factors that can affect oxygen levels in Long Bay.

The two studies could provide insights into threshold conditions of future hypoxic events. And they would help identify relative significance of oceanic conditions and human-made sources of nutrients. This information has been identified as critically important by the state's coastal-zone management program, which funded the first years of these studies.

Moreover, Richard Viso of CCU is conducting research to identify groundwater seep locations along the shelf waters of Long Bay. The information will enable researchers to conduct fieldwork to quantify submarine groundwater discharge, and the contribution of that discharge to water-quality issues, a valuable component to understanding the nutrient fluxes and pollutant transport.

These research projects have fostered additional efforts, including research by Viso to evaluate the contribution of groundwater discharge to water-quality issues and two pilot studies using autonomous underwater

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vehicles (AUVs) to validate and expand the findings of Voulgaris and Koepfler.

In addition, the S.C. Department of Natural Resources has funded a study by Susan Libes of CCU to monitor the surface and bottom dissolved-oxygen levels, among other parameters, at Apache Pier on the Grand Strand. This information is providing continuous measurements of the conditions in the area, which researchers have not had in the past.

Whetstone receives award

In October 2008, Jack Whetstone, marine aquaculture specialist with the S.C. Sea Grant Extension Program, received the Conservation Educator of the Year award from the Georgetown Soil and Water Conservation District for his dedicated leadership in natural resource education.

Jack Whetstone
PHOTO/S.C. SEA GRANT CONSORTIUM

Project brings earth science to minority students

Relatively few minority students graduate from college with marine-science degrees and even fewer pursue employment in marine-science careers. Part of the problem is that minority students often aren't aware of career possibilities in marine sciences and other geosciences.

To help increase diversity in these fields, Elizabeth Vernon, marine-education specialist with the S.C. Sea Grant Consortium and the Center for Ocean Sciences Education Excellence–Southeast (COSEE-SE), is participating in a student mentoring initiative funded by the National Science Foundation.

Felton Laboratory School students on board the *E/V Discovery* examine a fish brought up by a trawl net. PHOTO/S.C. SEA GRANT CONSORTIUM

"Enhancing Diversity in the Geosciences: Mentoring and Research Modeling for Middle School and University Students" provides marine-science training for S.C. State University (SCSU) students who are majoring in a science field and who, in turn, mentor middle-school students at the Felton Laboratory School located on the SCSU campus.

Vernon assisted in the coordination of the field experiences for mentors and mentees at the S.C. Department of Natural Resources (SCDNR) and the National Oceanic and Atmospheric Administration's Hollings Marine Laboratory, where they studied oyster habitats, water quality, and estuarine ecosystems.

"This project gives SCSU students exposure to marine science and perhaps they might pursue an interest in it," says Vernon. "The SCSU students already on the science track also serve as models for students from the same background. We hope they'll inspire the younger students."

Institutions involved in the project include COSEE-SE, the Hollings Marine Laboratory, SCSU, Felton Laboratory School, SCDNR, and the Orangeburg National Fish Hatchery.

Wallet card promotes local seafood

A handy new wallet card, "Seafood by the Seasons," describes the seafood species landed in South Carolina and the seasons in which each species is available in the marketplace.

The card is the result of a partnership among the South Carolina Aquarium's Sustainable Seafood Initiative, the S.C. Sea Grant Extension Program, and the S.C. Seafood Alliance.

The purpose of the card is to help promote and support the purchase and consumption of locally harvested seafood, help consumers understand the seasonality of harvested seafood, provide a brief statement about the sustainability of each species, and highlight the Gold and Platinum restaurant partners in the Sustainable Seafood Initiative. The Gold and Platinum restaurants have scored among the highest on a comprehensive sustainability assessment.

The cards are available at the South Carolina Aquarium and the Consortium offices and can also be downloaded at www.scseagrant.org/Products.

EBBS & FLOWS

Coastal GeoTools

Myrtle Beach, South Carolina
March 2-5, 2009

Coastal GeoTools is the conference series that focuses on the technical information needs of the nation's coastal programs.

The theme for 2009 is "Building the Digital Coast," a new initiative that provides easy access to organized and relevant data, tools, and technical training.

The opening plenary session will be hosted by the Digital Coast Partners and will provide their perspective on the importance of geospatial technologies to their constituents.

For more information, visit www.csc.noaa.gov/geotools.

International Marine Conservation Conference: Making Marine Science Matter

Washington, D.C.
May 19-24, 2009

The goal of this conference is to put conservation science into practice through public and media outreach and the development of science-based deliverables that will be used to drive policy change and implementation.

Major themes include marine protected areas, fisheries and aquaculture, global climate change; the land-sea interface; ecosystem-based management; and poverty and globalization.

For more information, visit www2.cedarcrest.edu/imcc/index.html.

National Conference on Ecosystem Restoration

Los Angeles, California
July 20-24, 2009

This conference brings together scientists and engineers, policy makers, planners, and partners who are actively involved in all aspects of ecosystem restoration and provides an interactive forum to share their experiences and research results.

Conference participants will also have the opportunity to learn about both large-scale and local ecosystem restoration efforts and what their colleagues have learned, what factors contributed to success, and how barriers were overcome.

For more information, visit http://conference.ifas.ufl.edu/NCER2009.

Subscriptions are free upon request by contacting: Annette.Dunmeyer@scseagrant.org

ATTENTION SCHOOL TEACHERS! The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for both middle- and high-school students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available on-line at www.scseagrant.org/education.

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