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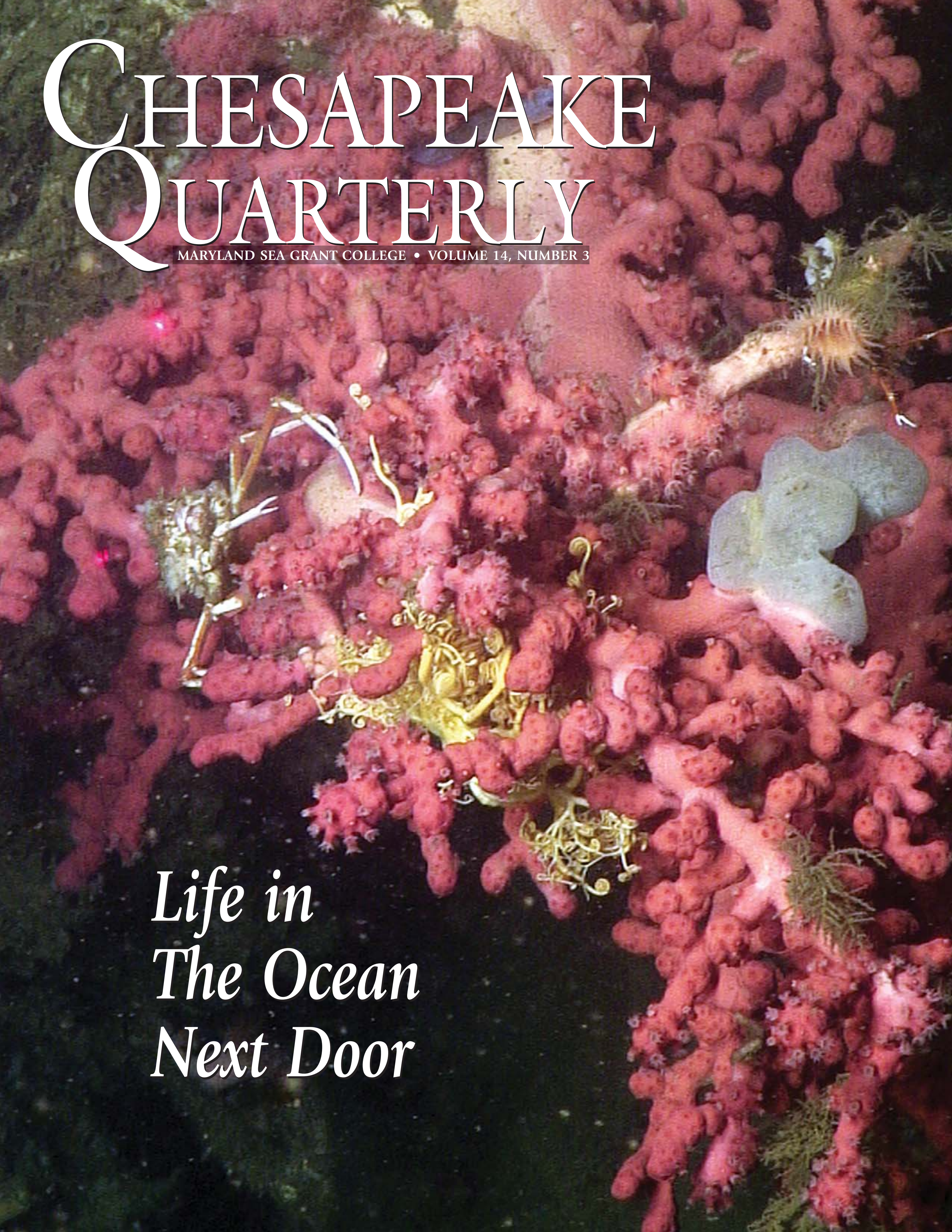

Life in The Ocean Next Door

contents

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Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed. The magazine is produced and funded by the Maryland Sea Grant College.

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Cover photo: *Did you know that Maryland's coastal ocean is home to colorful corals, like this bubblegum coral? They live in deep, dark submarine canyons more than 50 miles off the coast.* ***Page 3:*** *Canyons attract large game fish like marlin, and each summer the fish attract charter boats and fishing tournaments, like the White Marlin Open shown in this photo. This map shows the nearshore coastal zone off the Mid-Atlantic. The outer edge of the continental shelf lies in an area approximately 50 fathoms (300 feet) deep. The federal government controls an "exclusive economic zone" (EEZ) that extends farther out, to around 200 nautical miles from the coastline.* PHOTOGRAPHS, NOAA OFFICE ON OCEAN EXPLORATION AND RESEARCH (COVER) AND WHITE MARLIN OPEN (P. 3); MAP (P. 3), NOAA

Protecting the Resources

We stroll across the beach at Ocean City, Maryland, dip our toes in the surf, and look out to sea. As tides and seasons pass one after another, the ocean seems endless and timeless.

But 18,000 years ago, if we had been alive and standing at the ocean's edge, we would have stood in a different location, miles east of Ocean City, at the bottom of what is today the Atlantic Ocean. Over long periods of time, the coastline has moved and changed. In that long-ago era, the coastline lay farther east because the sea's level was 400 feet lower than today. A period of global cooling had locked up the earth's water in glaciers.

With the sea level lower, the area that is now a continental shelf was then dry land. Archeological evidence indicates that paleo-Indians once inhabited this coastal plain. There was no Chesapeake Bay then, only a river valley through which flowed what is now the Susquehanna River, stretching across this plain eastward to the ancient coastline. Starting around 15,000 years ago, the earth warmed, the glaciers melted, the sea rose, and the coastal plain flooded. Over several thousand years, the valley filled, creating the Chesapeake Bay. Rising waters moved the ocean-facing coastline westward, where it eventually reached its current location.

Even though people can no longer walk across this plain, Marylanders and residents of our neighboring states today retain important connections to this ocean region next door. *Chesapeake Quarterly* generally focuses on the Bay and its watershed, but in this issue, we take a broader view of the Chesapeake region and look at some of the diverse, surprising natural resources offshore — and at emerging concerns about how best to conserve them.

One of these resources is Norfolk Canyon, a giant submerged valley that lies about 60 miles east of the mouth of the Chesapeake Bay. This underwater chasm developed from the ancient channel of the Susquehanna River. This river channel also carved the Bay, so you can think of the canyon as an offshore echo of our great estuary. In recent years, scientists have used new technologies to explore both Norfolk Canyon and Baltimore Canyon, its neighbor to the north off Ocean City, Maryland. Research expeditions brought back a trove of data and images about the biologically rich communities there. Living in these canyons, for example, are brightly colored, temperate-water, deep-sea corals like the one pictured on the cover of this magazine (see The Grand Canyons off Our Coast, p 4). But the scientists also saw plenty of plastic bags and other garbage, a reminder that these remote deep-water habitats are linked to the people living on and near the coast.

Plastic garbage is one of many present-day and future human impacts in the ocean portion of Maryland's coastal heritage that warrant our attention. The coastal zone supports a variety of important economic activities, some of which could harm the environment and some of which conflict with each other.

- **Oil and gas development.** The federal government is moving to allow companies to conduct exploratory drilling for oil and gas on the outer continental shelf from Virginia to Georgia starting in 2017. This prospect has raised concerns that oil spills from these operations to the south could affect Maryland's coastal waters.

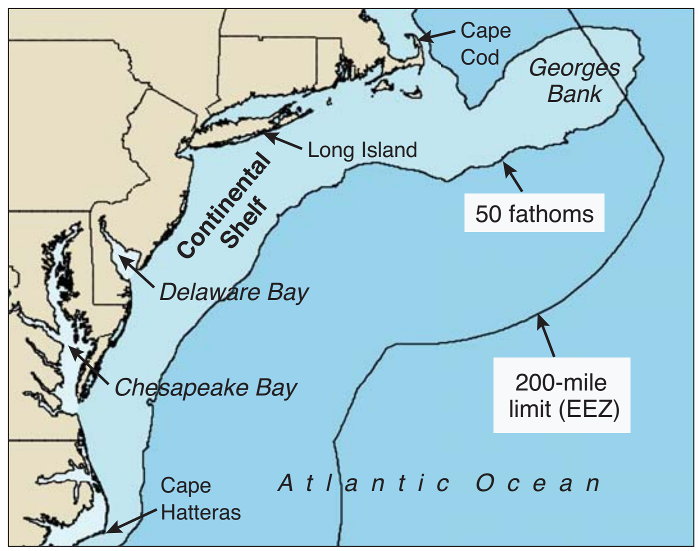
- **Wind energy.** In December 2014 federal regulators issued leases for the development of offshore wind turbines in waters 10 nautical miles east of Ocean City, Maryland. With turbine towers sitting atop pilings sunk into the ocean floor, will the noise from survey work and construction drive away or harm game fish? Will it affect the migrations and behavior of marine mammals such as dolphins and endangered right whales? Federal agencies are evaluating these risks, and University of Maryland researchers are

# of Our Mid-Atlantic Coastal Ocean

gathering information that could help answer these questions (see Whale Watching, Beneath the Waves, p. 15). In addition, Defense Department officials have voiced worries that offshore wind and oil energy facilities will interfere with naval exercises and training off the Mid-Atlantic coast.

- **Commercial and recreational fishing.** Fishing is an important business in the Mid-Atlantic, so potential conflicts in the coastal zone could affect harvests, earnings, and jobs. In 2012, commercial landings in the Mid-Atlantic totaled $488 million. In Maryland alone, the recreational fishing industry reported that $637 million in sales helped support 5,683 jobs.
- **Climate change.** Trends in ocean conditions are already altering the habitats of commercially valuable fish. The Northeast Fisheries Science Center, part of the National Oceanic and Atmospheric Administration, has reported that warming temperatures led half of 36 Mid-Atlantic fish stocks to shift their range northward over past decades in search of cooler water. Fisheries could also be affected as ocean water grows more acidic, an effect of increasing carbon dioxide in the atmosphere. This acidity could weaken the hard skeletons that make up deep-sea corals, which provide important habitat for fish species and other creatures.
- **Shipping traffic and navigation.** The Panama Canal is currently being widened and deepened to allow access by new cargo ships that are larger and carry more freight than existing vessels do. That change is expected to increase traffic to and from East Coast ports, like Baltimore, that are retrofitting their docks and other facilities to serve these large vessels.

In recent years, government, academic, and non-profit organizations have been considering how best to manage these environmental effects and conflicts in use. Many of the management decisions will be made by federal agencies, like the Bureau of Ocean Energy Management, which have the lead role and jurisdiction in managing much of the Mid-Atlantic's coastal zone.



Now a group called the Mid-Atlantic Regional Planning Body is leading a new effort to improve planning and coordination among the many federal and state agencies and other organizations that share an interest in this coastal zone. In 2010, the Obama administration established a National Ocean Policy that called for this planning at the regional level. The planning body, formed in 2013 to create a new regional framework for this work, is scheduled to release a draft Ocean Action Plan for public comment in summer 2016 and to finalize it later in the year. The hope is that this and other efforts will help to balance uses and conservation of natural resources in our ocean zone next door.

— *Jeffrey Brainard*

***The Atlantic Ocean's deep canyons are home** to a diversity of marine life, including corals and other species that attach themselves to rocky ledges (opposite page). Here an octopus shares space with bivalves and cup corals (*Desmophyllum *spp.).*
PHOTOGRAPH, NOAA-OER/BOEM/USGS

The Grand Canyons Off Our Coast

Jeffrey Brainard

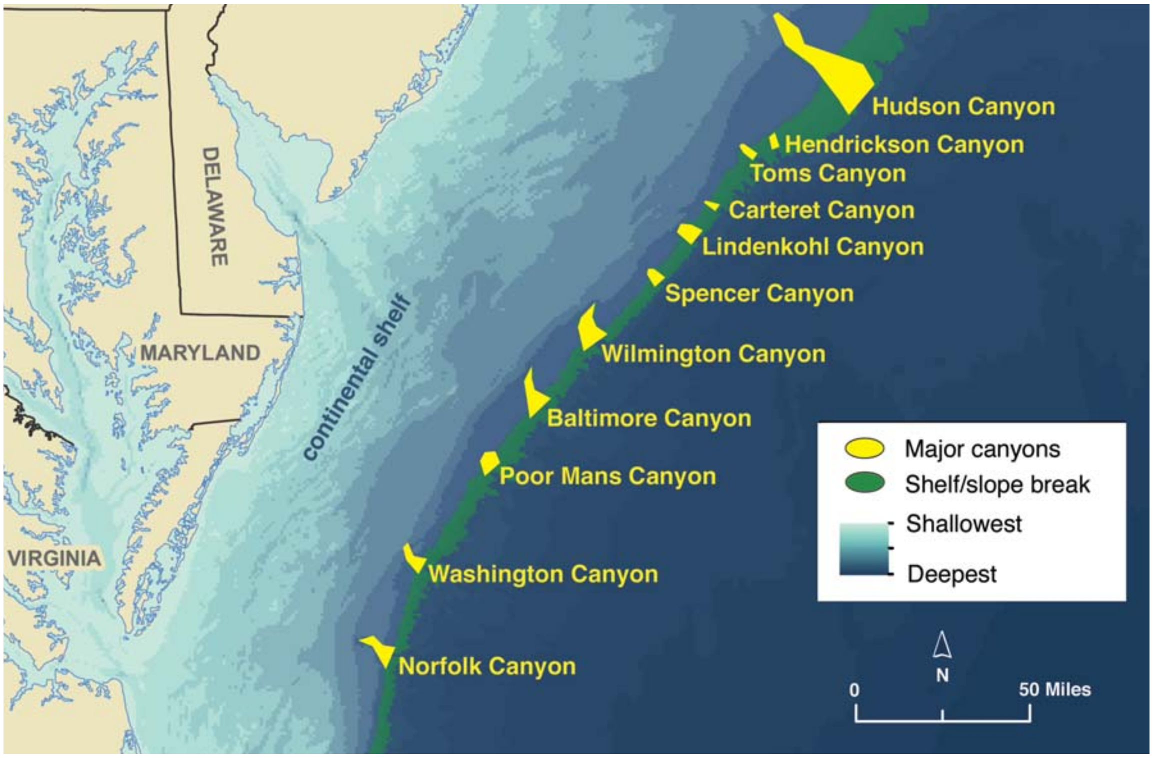
It was back in 1981 when scientists caught an early glimpse of the extraordinary sea life dwelling at the bottom of Baltimore Canyon.

Barbara Hecker was leading an offshore research expedition that year to investigate a little-studied group of deep underwater gorges off the Mid-Atlantic coastline. A benthic ecologist at the Lamont-Doherty Earth Observatory in New York state, Hecker was aboard a ship towing an underwater camera as it crossed one of these chasms, Baltimore Canyon, about 60 miles east of Ocean City, Maryland. The camera took close-up pictures of the ocean floor, and some of these pictures would take Hecker by surprise.

A diversity of coral and other surprising sea life species hide in deep gorges in the Mid-Atlantic.

The moment of surprise didn't come until the cruise had ended. The towed camera recorded images on film, and the film had to be analyzed back on shore. This was deep-water exploration in the era before modern underwater digital video cameras that send real-time images to scientists shipside at the surface. It wasn't until Hecker saw the photos that she and her colleagues made an interesting discovery — a large bed of mussels. "The sea floor was totally paved with them," she recalls.

In shallower coastal waters, the mussels would have been commonplace, but in this deeper location near the canyon's



***More than 70 large underwater canyons** stretch along the East Coast from Virginia to Canada at the edge of the continental shelf, including these off the Mid-Atlantic coast. Baltimore Canyon was created by an ancient channel of what is now the Delaware River.* MAP, COURTESY OF THE NATURE CONSERVANCY/MID-ATLANTIC REGIONAL COUNCIL ON THE OCEAN

rim, they were a big deal. Scientists knew that mussel beds can form around plumes of methane gas leaking from the sea floor. But nobody had ever discovered methane "seeps" along the Mid-Atlantic.

New findings often lead to new questions, and this discovery was no exception. What kind of ecosystem lay hidden in those deep canyons? Were there more methane seeps? Answers to questions like those would have to wait.

The wait lasted for 30 years. In 2011 a new team of scientists launched a three-year series of scientific expeditions that returned to these same offshore locations and explored some new ones as well. This time they brought along remotely operated underwater vehicles (ROVs) that could carry high-definition video cameras hundreds of feet down and use robot arms to collect samples.

On one of their voyages the researchers went looking for Hecker's mussel bed. They found it again and this time discovered many streams of bubbles rising from it. The bubbles were yet more evidence that methane fields were buried beneath the ocean floor.

It was one of many revelations that the scientists would uncover as they studied these little-known undersea canyons, launching more than 30 ROV dives and photographing the unusual corals and fishes that favor these ecosystems. Their discoveries would help to fill in gaps in information provided by Hecker 30 years earlier and inform resource management decisions aimed at protecting the canyons from human disturbance. Inevitably these glimpses of the ocean bottom left the scientists with more questions.

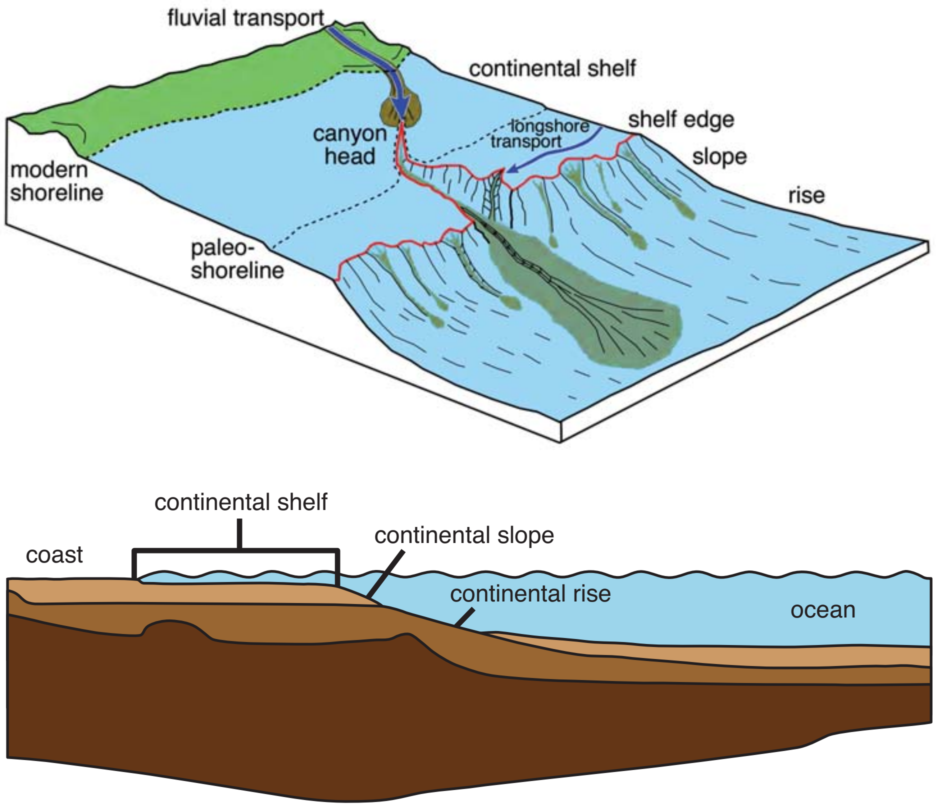
Grand Canyons

Think of a canyon, and images of the Grand Canyon or the Southwest desert may come to mind. But the earth's ocean floor also has been shaped by geological forces that have created dramatic contours and strange-looking habitats. These are remote, inaccessible, and invisible to us terrestrial residents, but the tools of science can help us to understand them.

Some of these remarkable underwater seascapes lie off the Mid-Atlantic coastline. More than 70 named deep canyons stretch like a necklace from North Carolina to Canada along the outer part of the U.S. Atlantic continental shelf. The heads of these canyons lie between 50 and 100 miles from shore. Their gorges extend miles farther out on the continental slope, the zone where the continental shelf tilts down toward the ocean abyss beyond.

Baltimore Canyon is among the largest of these canyons. Its head begins at about 300 feet below the ocean surface. The canyon extends about 25 miles seaward along the ocean bottom, deepening to hundreds of feet below its rim. Other canyons nearby have similar topography. Most of the abundant life in the canyons abides in complete darkness because sunlight dims rapidly beginning at about 600 feet below the surface.

The canyons are remnants of ancient rivers that flowed long ago across the Mid-Atlantic continental shelf when it was dry land. More than 15,000 years ago, sea levels were lower because cooler temperatures bound the planet's water in glaciers. Baltimore Canyon is located where the early Delaware River flowed across this coastal plain and emptied into the sea at what is now the continental shelf edge. A neighboring chasm, Norfolk Canyon, marks a similar terminus of the early Susquehanna River. In time, temperatures warmed, glaciers melted, and the sea covered the continental shelf. Once flooded, the ancient river valleys continued to be eroded by underwater currents. This natural excavation began hundreds of thousands of years ago, con-



***Geological forces formed** the Mid-Atlantic's deep submarine canyons over millennia. The heads of these canyons today lie near what was the paleo-shoreline, where ancient river channels once flowed into the ocean when global temperatures and sea levels were lower. Eventually temperatures warmed, sea levels rose, and the ocean reached the modern shoreline. Erosion continued to carve the flooded canyons into the edge of the continental slope.* ILLUSTRATIONS, ADAPTED FROM J. OBELCZ ET. AL., DEEP-SEA RESEARCH II 104: 106–119 (2014) (TOP); BOEM (BOTTOM)

tinued as the earth underwent successive periods of cooling and warming, and persists today.

Fishermen know about these canyons as prime locations for catching large, migratory game fish like marlin and tuna, which congregate there. Each summer Ocean City hosts tournaments, and hundreds of charter boats take out fishers eager to hook big quarry.

But the remoteness, depth, and steep walls of these underwater valleys help to explain why until recently their biology and geology were little known. The canyons stood as an exception to the rest of the East Coast's continental shelf, which has been called one of the most extensively studied and mapped portions of the earth's ocean floor. Scientists have used trawling nets to scrape up marine life and sonar equipment to map the shelf's contours. But in the canyons, researchers avoided trawling because the nets would get ripped and lost on the steep walls. Earlier versions of sonar technology had limited capability to map such rugged terrain in detail. The canyons were an unknown world.

But hardly a lifeless one, it turns out. The underwater cameras used in the recent scientific expeditions recorded clusters of brightly colored "bubblegum" coral (*Paragorgia arborea*), some ten feet high. These are among several coral species that favor ocean habitats deeper and colder than those occupied by the tropical reefs that are more easily glimpsed in the Florida Keys or the Caribbean Sea. Scientists say the Mid-Atlantic's temperate-water reefs may be as abundant, biologically diverse, and ecologically important as their tropical cousins. And the deeper corals live over a wider expanse of the oceans.

Steve Ross, a fisheries biologist at the University of North Carolina at Wilmington, was a leader of the Mid-Atlantic canyon expeditions, and he says that when he shows audiences photos of these deep-sea corals, people immediately connect with these remote places. "They say, 'Oh my god, that's beautiful, I had no idea that was out there,'" he says. "They have the same reaction they would have if I were to show them the Great Barrier Reef. They are all of a sudden a lot more interested and concerned. We tend not to appreciate things that are valuable if we can't see them."

What's Down Below

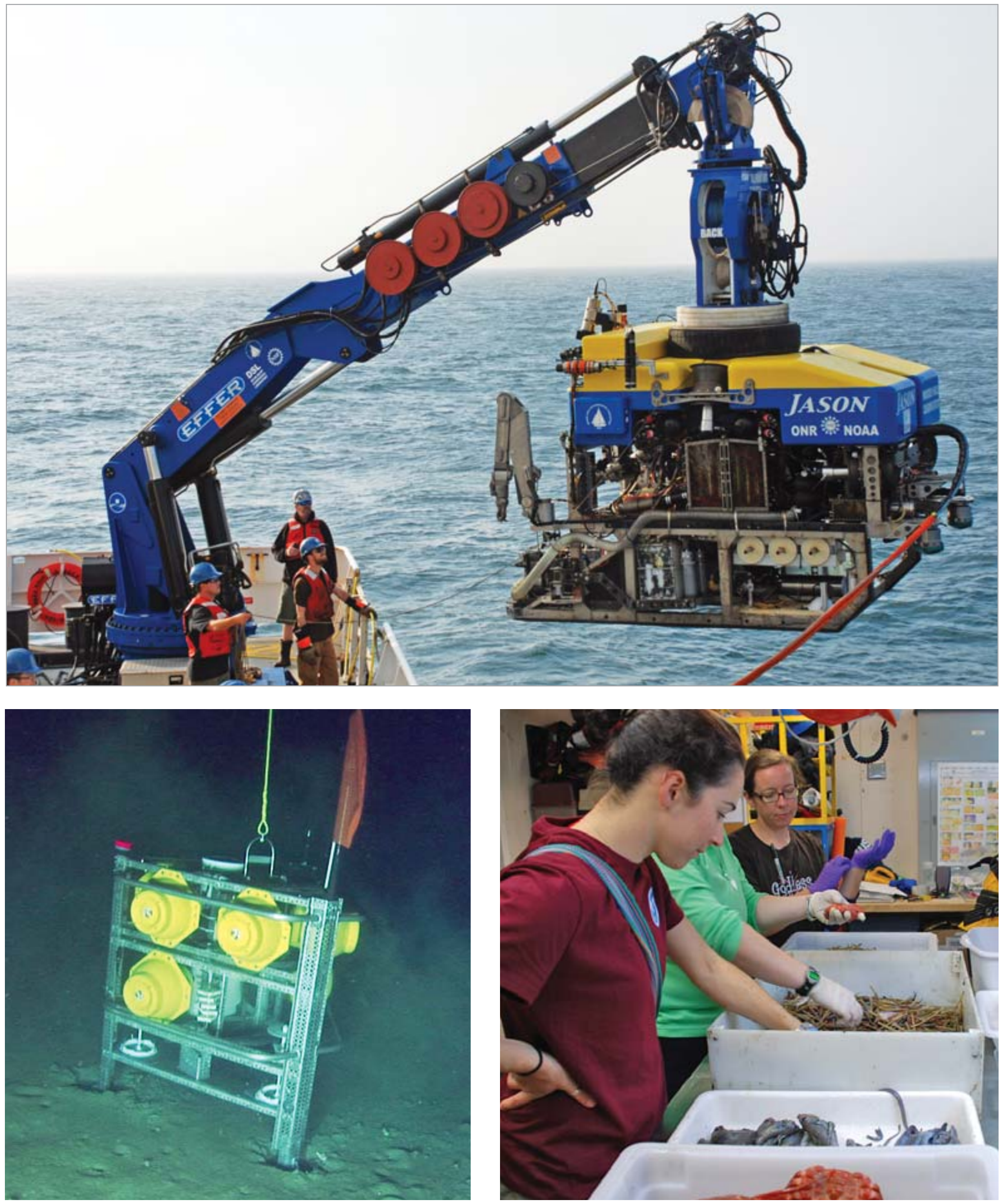
For scientists like Ross, discovering the value of habitat like the Mid-Atlantic canyons requires knowing what they contain. It's a quest that involves more than simply satisfying intellectual curiosity. The federal government has long considered allowing oil and gas exploration and drilling on the Mid-Atlantic continental shelf and slope, and scientists, environmentalists, and federal officials have wanted to know more about how the deep canyons might be affected.

In 2010 the Obama administration was poised to issue leases for exploratory drilling off Virginia. But the administration put that plan on hold after the Deepwater Horizon blowout that year leaked billions of gallons of crude oil into the Gulf of Mexico. Still, federal officials continued making plans for an eventual start of Mid-Atlantic exploration and drilling. Evidence about undersea canyons located in other parts of the world suggested that they contain hot spots of biodiversity housing many species of fish and coral. But deep-sea corals grow very slowly, making them especially vulnerable to the effects of human activities and disturbances like drilling and fishing.

So in 2010, the federal agency that regulates off-shore drilling — the Bureau of Ocean Energy Management (BOEM), part of the Interior Department — invited proposals from scientists to explore the offshore canyons and the life there. Supporting the project were two other federal agencies whose work could also be informed by this research: the National Oceanic and Atmospheric Administration (NOAA), which regulates offshore ocean fisheries, and the U.S. Geological Survey, which maps and studies the ocean floor.

An international team of scientists led by Ross and Sandra Brooke of Florida State University submitted a multidisciplinary proposal that was selected for funding. The research team included coral biologists, fishery biologists, geochemists, geologists, marine archaeologists, molecular geneticists, and physical oceanographers — an array of disciplines that reflected the complexity of the habitat they would investigate.

The scientists were eager to study how the physical features of Mid-Atlantic canyons might support deep-sea corals. One feature favorable for corals is the undersea currents that move up and down the canyons. The canyons act as funnels, carrying food and nutrients from the coast and offshore shelf down to the lower depths inhabited by deep-sea coral. These coral species filter their food from the passing water — a method of survival different from that of tropical corals, which obtain some of their energy from a symbiotic relationship with algae that can perform photosynthesis in the shallow tropical waters. But in the dark regions where deep-sea corals live, photosynthesis cannot occur.



Scientists use a variety of equipment *and methods to study the deep ocean and the abundant life it contains. The* Jason II *unmanned submersible, fitted with robotic arms to collect samples of undersea life, is prepared for launch from the NOAA ship* Ronald H. Brown *to explore Norfolk Canyon in 2013 (top). Scientists left devices called benthic landers (bottom left) at the bottom of Norfolk and Baltimore Canyons for more than a year to continually collect data on water conditions as well as samples of invertebrate larvae. Researchers used a trawl net to collect fish, crabs, and other animals; here they sort specimens by species for further study (bottom right).* PHOTOGRAPHS, NOAA-OER/BOEM/USGS

The canyon currents not only carry food for deep-sea corals, they provide a home. Along the canyon walls, currents sweep rocky ledges clear of sediment, exposing the kind of hard, rocky surface on which deep-sea corals typically prefer to attach and grow. Such habitat is rare along the sandy Mid-Atlantic continental shelf and muddy slope zone. That's why evidence of deep-sea corals had rarely been found in previous undersea surveys of the Mid-Atlantic region, Ross says.

Advances in Technology

To see what was living in these depths, the scientists proposed using marine-research tools that incorporated new technology more advanced than the towed camera and other tools used by Barbara Hecker in her research in the 1980s.

One was multi-beam sonar. This technique allows scientists to shoot multiple beams of sound waves at the ocean bottom. Receivers collect the echoes; software constructs a three-dimensional portrait of the bottom that covers a broader area than is provided by earlier types of sonar that shot a single beam straight down. Depending on the water's depth, the multi-beam method can reveal a kilometer-wide swath of the bottom topography at a high resolution, ten meters square. By going back and forth in a gridlike pattern, a research vessel can precisely map areas as large as canyons and bigger. Using this tool, Ross says, "you've got an amazing map of the bottom."

The scientists used this tool to map Baltimore and Norfolk Canyons and other ones during the project's initial research expeditions in 2011. The scientists picked Baltimore and Norfolk Canyons for further in-depth study in part because of their proximity and similarities, which would allow the scientists to compare the canyons' biology and geology.

In return trips over the next two years, the scientists used the detailed maps of the canyons' contours to decide where to lower remotely operated vehicles and other scientific instruments to collect images and samples. They wanted to study a range of topography at different depths to find out what kinds of coral and fish lived there.

The scientific team knew that, even with weeks of ROV dives planned over a two-year period, its time at sea and opportunities for collecting data were limited to spot-sampling a small portion of the canyons' vast area. Indeed, this is the challenge facing ocean research around the world — gigantic areas to study, limited finances to do it. The NOAA ships that support the missions typically cost about $35,000 a day and the ROV submersibles about $25,000 a day. "You get a lot of zeros very quickly," says Brooke, the co-leader from Florida State.

The researchers had the advantage of using one of the most-advanced ROVs, called *Jason II*, which is operated by the Woods Hole Oceanographic Institution in Massachusetts. ROVs like *Jason II* can be deployed for more hours at a time and cover a larger area than the crewed, deep-diving submersibles, like *Alvin*, that conducted many early studies of the ocean bottom. The team also used a second ROV, the *Kraken II*, owned by the University of Connecticut and named after a kind of sea monster. Like *Jason II*, it also carried video cameras and tools to collect samples.

A typical day of ROV research started in the morning — when the research team deployed the machine, lowering it to the depths on a long tether — and ended 10 to 12 hours later when they finally retrieved it. In between, scientists worked four-hour shifts, sitting in a special trailer and control room attached to the deck of the research vessel. There they guided the ROV's movements and kept their eyes glued to the live video streaming from its cameras. The days stretched closer to 18 hours straight for

During a 2012 dive, a submersible *photographed a number of species that live in the deep canyons of the Mid-Atlantic. Scientists found the distinctive white coral* Lophelia pertusa *(above top) for the first time in this geographic region. An armored sea robin (*Peristedion *spp.) uses chin appendages called barbels to feel for food (above). Bubblegum coral, or* Paragorgia arborea*, (at right) can grow in a fan structure 10 feet tall. Besides pink, other shades of this coral include white, red, and orange.* PHOTOGRAPHS, NOAA-OER/BOEM/USGS the project's lead scientists as they worked to keep the mission operations on track.

All of that screen-gazing at times made the hours and days blend into each other. But the watching and the waiting were punctuated with whoops of excitement when key discoveries were made. Like during one dive in Baltimore Canyon in 2012.

Brooke had worked eight hours straight in the ROV trailer one morning, a not-so-joyous start to her birthday. "I was freezing cold, and I was really tired, and I went to sit out on deck for ten minutes to warm up. And as soon as I got comfortable, they came charging up and said, 'You've got to get down to the van!'"

She hustled down, "and there on the screen was this massive colony of bright white *Lophelia*." This is a species of stony coral that the researchers had hoped they might find and study in these canyons. Brooke let out at a salty cry of joy that started with "Holy!"

It was the first time that scientists had observed *Lophelia pertusa* in the Mid-Atlantic between North Carolina and Cape Cod. The species is widely distributed around the world and is considered a particularly important kind of deep-sea coral because it forms reefs and structures that can provide habitat for fish and other sea creatures. *Lophelia* comes from Greek words meaning "a tuft of suns," a playful reference to the species' bulbous polyps.

The *Lophelia* seen in the two canyons was on the small side; none were more than six feet across. Still, it had taken those corals a long time to grow even that big. Based on known growth rates for this species, Brooke and her colleagues estimated that the coral had been growing, undisturbed, for perhaps as long as 400 years. (*Lophelia* reefs off Norway measure up to 75 feet high and are estimated to be more than 8,000 years old.) They soon found more colonies of the coral in Baltimore and Norfolk Canyons.

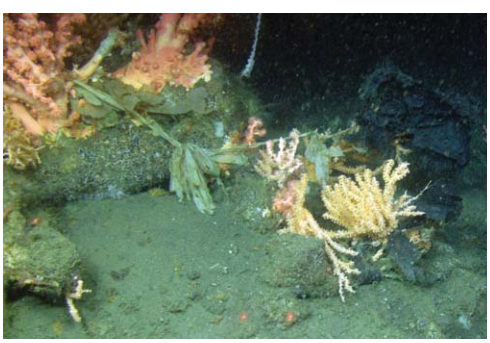
According to Brooke, simply finding out that *Lophelia* lives in a place where it wasn't previously known tells scientists a lot. "If we find these things naturally occurring in a range of habitats, it provides some insight into what their distributional range might be and what their environmental tolerances are," she says. And knowing that range is important as environmental conditions shift because of global climate change. Shift the conditions enough, and some species might not be able to survive.

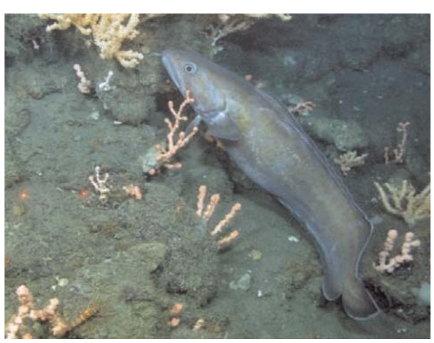
If indeed the deep canyons are among the few places in the Mid-Atlantic that *Lophelia* prefers to call home, the finding raised the question of how the coral got there. The closest known *Lophelia* populations are 340 miles to the north, off Cape Cod, and 190 miles to the south, off Cape Lookout, North Carolina. Brooke and her colleagues estimated that *Lophelia* larvae, which can live for three weeks, could have been carried that distance by a current. In the open ocean, even a sedentary species like coral can migrate far.

A Refuge for Fish?

The researchers encountered more surprises when they counted fish species in the canyons. During all of the ROV dives in Baltimore and Norfolk Canyons, scientists identified 123 fish species. Many of these have also been found elsewhere in the North Atlantic Ocean, but 12 were not known previously to live in the canyon area. Ross calls this a surprisingly high number of species given that the areas outside the canyons had been more extensively studied by earlier sampling work. "It reflects how little we knew about the canyons," he says.

One of the canyons' secrets might be that they serve as a refuge for fish species that are harvested elsewhere, Ross says. Among the novel species discovered swimming among the canyon walls and





***Underwater cameras also captured images** of plastic wrapped around coral (bottom left) and rare fish like the cusk (bottom right). During the research expeditions, scientists, including project co-leaders Steve Ross (top, second from right) and Sandra Brooke (top, far right), identified locations on a canyon map for submersible dives.* PHOTOGRAPHS, NOAA-OER/BOEM/USGS coral was cusk (*Brosme brosme*). This cod-like fish is caught commercially in the North Atlantic and is listed by NOAA's National Marine Fisheries Service as a species of concern, meaning the long-term health of the species' population may be at risk.

Another surprise was the size and extent of the mussel beds and the methane seeps (also called cold seeps) that surrounded them. After the researchers examined the mussel bed in Baltimore Canyon that Barbara Hecker had photographed, they investigated an even bigger, newly discovered seep near Norfolk Canyon. This one consisted of two mussel beds, each measuring more than a half-mile in length, and is possibly the largest cold seep yet discovered in the western North Atlantic region.

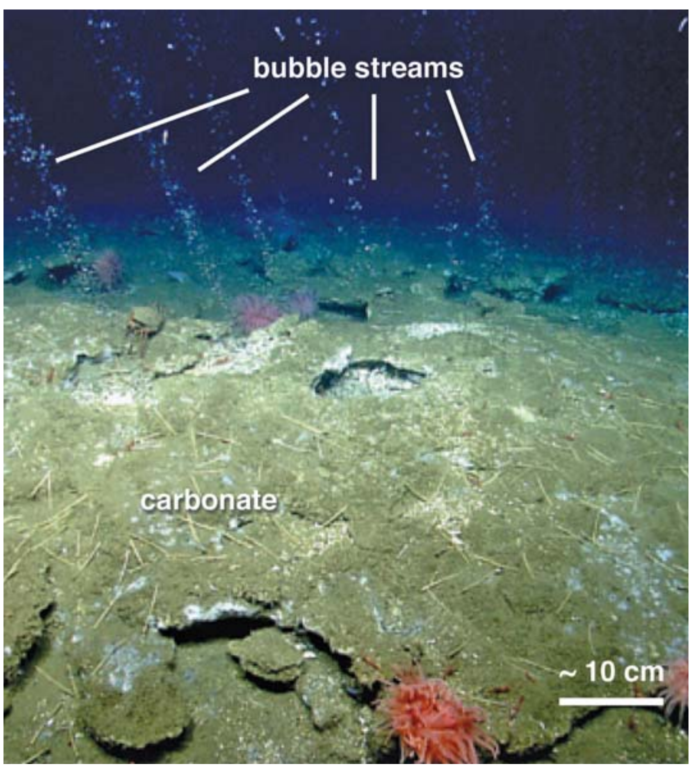
In both canyons, methane was bubbling through the sediment. On land, methane flows into our homes as flammable natural gas that sustains our heating and cooking. In this deep, dark, undersea environment, the bubbling methane supports life in a biologically unusual way. Colonies of "chemosynthetic" bacteria use methane as an energy source. Mussels living at the methane seeps contain these bacteria in their tissues and consume excess energy from the bacteria for their own metabolic needs. This energy source is far different from that of most other creatures living at these depths, where the food supply is based on photosynthetically derived morsels drifting down from shallower waters. A byproduct of the chemosynthetic bacteria's metabolism is calcium carbonate, which forms hard rocky reefs to which mussels and corals can attach.

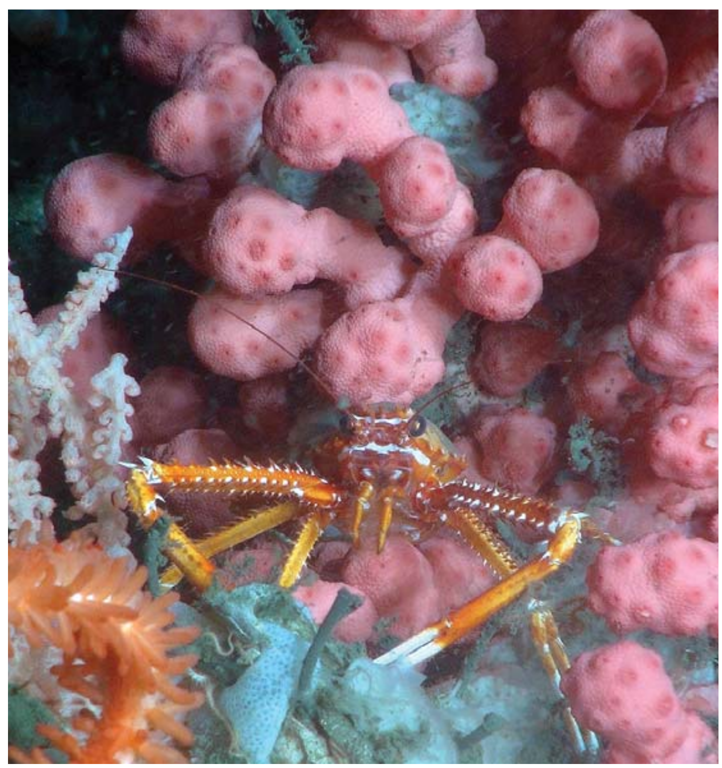
These seeps were just two instances of a large abundance that a separate team of researchers found in the Mid-Atlantic in 2014. Researchers from Mississippi State University and other institutions analyzed data from multi-beam sonar readings taken by the NOAA research ship *Okeanos Explorer*. The scientists detected 570 previously unknown gas plumes on the continental shelf between Cape Hatteras, North Carolina, and Georges Bank off New England. Many of these seeps were in or near canyons, perhaps because the canyons disrupted and cut through ancient geological layers containing methane, the scientists wrote in the journal *Nature Geoscience* in 2014. Now researchers are interested in exploring the seeps further to learn more about whether these plumes are emitting methane that enters the atmosphere, where it would act as a greenhouse gas and contribute to climate change.

Moments like seeing the mussels and seeps were why "most dives were pretty exciting," Ross says. "We were in new territory every time."

Considering Conservation

But the ROVs also captured distressing images of canyons. There was plastic garbage, lots of it, and some of it was wrapped around living coral. "Plastic grocery bags, garbage bags, plastic utensils, plates, cups, anything you could imagine," Ross says. "It could have been swept in from shore." Those images, he adds, are a





***A squat lobster rests among** a bubblegum coral, a red tree coral, and a sponge (above right). In a closeup of a bubblegum coral (opposite page) its extended polyps look like flowers. Researchers captured an image of bubbles believed to be methane gas streaming up from the ocean floor near Norfolk Canyon (above left). "Chemosynthetic" bacteria can use methane as an energy source in a process that creates carbonate, a hard substrate to which corals can attach.* PHOTOGRAPHS, NATURE GEOSCIENCE, 7: 657 (2014) (ABOVE LEFT); AND NOAA-OER/BOEM/USGS (ABOVE RIGHT AND OPPOSITE PAGE) good argument for taking additional steps — like bans on plastic shopping bags — to reduce and recycle plastics in our homes before they spread in the environment, both on shore and off.

The ROV images showed another kind of refuse: lost crab and lobster traps and fishing lines used to harvest squid and other species. Ross and Brooke have conducted similar underwater expeditions in the Gulf of Mexico and southeastern U.S., where, compared with the Mid-Atlantic, "we hadn't seen nearly the number of discarded trawls or traps, and that's pretty significant," he says. Advocates for Mid-Atlantic commercial fishermen have said they avoid fishing in the offshore canyons because they don't want to risk snagging and losing nets and other gear. But "somebody did," Ross says. "The evidence is down there."

This evidence helped persuade policy makers to take action to protect the deep-sea corals and other habitats in the canyons. NOAA scientists had been developing a computer model, called a habitat suitability model, to predict areas of coastal ocean bottom off the northeast U.S. Atlantic coast where deep-sea corals were likely to be present. The model was based on geological features such as slope, temperature, and turbidity. The Mid-Atlantic research expeditions of recent years reported data about the presence and absence of deep-sea corals that helped to confirm that the model's predictions were accurate.

In 2015, the Mid-Atlantic Fishery Management Council used the model to justify a new proposal to restrict fishing in the canyons. Fishers would be banned from using any type of ocean-bottom fishing gear such as trawls, dredges, bottom longlines, or traps in any of 15 discrete zones representing ecologically important populations of deep-sea coral. These canyon areas comprise more than 38,000 square miles, an area nearly the size of Virginia. Among all of these canyon zones, the council ranked Baltimore and Norfolk Canyons as among the most important habitats for coral. If the U.S. secretary of commerce approves the council's proposal, the 15 canyons would be one of the largest protection zones for deep-sea coral in the United States.

The proposal would exempt red-crab fishers for two years. The fishery management council said that only two such boats operate full time in the Mid-Atlantic and their impact may be small (see Red, Not Blue: The Mid-Atlantic's Other Big Crab, p. 12).

A different kind of potential impact on the canyons — the future development of oil and gas drilling — remains a topic of debate. In 2015 the federal government authorized energy exploration in waters off Virginia from 2017 to 2022. In Virginia, Governor Terry McAuliffe allowed his state's participation in the federal leasing plan. But for now there will be no drilling in Maryland — former Governor Martin O'Malley opted out of the federal plan. Even so, some Maryland elected officials and environmentalists continue to worry about the effects of any oil spill off Virginia on Mid-Atlantic canyons and on Maryland's coastal waters, including the Chesapeake Bay.

The recent canyon research expeditions may provide a fresh impetus for government resource managers to take other steps to help protect these special resources. Given that the adjacent continental shelf has been so well studied, "It's pretty astounding that we're still making new discoveries," Steve Ross says. He says the data collected in recent years will help scientists to ask new and better questions about the canyons — like why corals of the same species living in adjacent canyons show genetic differences and how these differences influence their survival. "While this was a really extensive study," he says, "we rushed through a lot of parts because of needing to cover so much territory."

Just as Ross and his colleagues were able to eventually return to the scene of Barbara Hecker's earlier discovery, he hopes that even in a tight fiscal environment for ocean research, scientists will continue visiting the canyons and trying to find more answers.

— *brainard@mdsg.umd.edu*

Red, Not Blue
The Mid-Atlantic's Other Big Crab

Scientists get a rare glimpse of a mysterious deep-sea crustacean

Daniel Strain

***A deep-sea red crab** hangs out on a bubblegum coral.* PHOTOGRAPH, NOAA OKEANOS EXPLORER PROGRAM

The weather took a downturn, and white-topped waves tossed around the *Hannah Boden*. It was September 2014, and the fishing vessel was motoring along the Atlantic coastline of Virginia, hunting for a type of crustacean called the Atlantic deep-sea red crab (*Chaceon quinquedens*). These crustaceans live in the depths of Norfolk Canyon, a submarine gorge that begins about 60 miles off the mouth of the Chesapeake Bay and extends far below the ocean's surface.

On board the boat, crustacean biologist Bradley Stevens struggled to keep his gear from scattering across the bucking deck. The scientist had hitched a ride in order to collect samples of the same crabs. He was no stranger to bad weather. Stevens had worked for more than 20 years as a fisheries biologist in Alaska where he kept an eye on populations of king crabs, monster crustaceans that live in the Bering Sea. There, he spent days out on the water, sailing on the sorts of boats made famous on *Deadliest Catch*, the reality show that depicts the rough seas and dangerous conditions that fishing crews face on the Bering Sea. But the conditions onboard the *Hannah Boden* were worse.

"We had eight-foot waves, and the wind was blowing," says Stevens, now a professor at the University of Maryland Eastern Shore in Princess Anne. "I thought to myself, 'Why am I doing this? Why did I leave Alaska to come here and do this?' "

It was a good question: the biologist is among the few scientists who study Atlantic red crabs. These crustaceans, with orangish-red shells and spindly legs, are bigger than the blue crabs (*Callinectes sapidus*) living in the Chesapeake Bay. But, as Stevens's journey on the *Hannah Boden* shows, they're also hard to get to. The crabs scuttle along the sea floor at depths of 600 feet to more than a mile below the surface. And unlike their shelled relatives in the Bay, red crabs are virtual unknowns: what they eat, how they reproduce, and what role they play in the deep sea's ecology are all unanswered questions.

Stevens is trying to gather basic data about how red crabs eke out a living in the cold ocean. He hopes this information will become useful as red crabs face a number of challenges in the future. Those challenges include warming ocean temperatures and fishing pressure from boats like the *Hannah Boden*, which procure crabmeat for a niche seafood market.

Red crabs "are so poorly studied, and that means there are lots of things we can learn," Stevens says. "Sometimes just getting your hands on them can give you new information."

Life in the Deep

You can think of these elusive animals as Maryland's other big crab. One of several related species of crustaceans that live in various deep stretches of the Atlantic, red crabs flank the edge of the continental shelf from Nova Scotia south to the Gulf of Mexico. Blue crabs are called swimming crabs because they can use their paddle-like rear legs to propel themselves through the water. But red crabs have no choice but to walk along the seafloor. Most live at greater depths than do the king crabs Stevens studied in Alaska, surviving in habitats that are "at the frontiers of our understanding" of the oceans, says Richard Wahle, a marine biologist at the University of Maine.

This sparse environment makes the Chesapeake Bay look like a spa: at these depths, there's little to no light to navigate by, and water temperatures hover around 38 degrees Fahrenheit. Sustenance can be hard to come by, too, says Wahle, who has also studied red crabs. Like other deep-sea animals, these crustaceans often depend on food that sinks down from the surface. The carcasses of dead whales, for example, serve up a nutrition bonanza that the crabs can sniff out from long distances away. "They're very tuned into their chemical environment," he says. "They can hone in on these sources of food like oases in the desert."

Scientists have made sporadic attempts to view red crabs in their natural habitat. For a study published in 2008, Wahle used a camera towed on an underwater sled to capture images of red crabs scuttling about in the deep. But such efforts are expensive and few and far between. Which is why, for Bradley Stevens, the *Okeanos Explorer* presented a new opportunity.

Stevens got help in fall 2014 from the crew of the research vessel, which is operated by the National Oceanic and Atmospheric Administration (NOAA). The *Okeanos Explorer* participated in a series of research expeditions in recent years that investigated the Atlantic's deep-sea habitats (see The Grand Canyons off Our Coast, p. 4). The *Okeanos* crew lowered a camera-equipped, remotely operated underwater vehicle, or ROV, on nine dives that probed the Atlantic's underwater gorges, including Norfolk Canyon. This robotic explorer was more maneuverable than Wahle's sled-mounted camera. The ROV could swivel and home in on objects of interest and pipe its video footage live to computers on land.

Stevens, who had moved to Maryland in 2009, saw a chance to collect valuable data on red crabs. He assigned his students to watch the mission footage in two-hour shifts as it streamed in real-time on their lab computer. Each dive started at 8 a.m. and wrapped up at around 4:30 p.m., and for those hours, Stevens and his students stayed glued to the computer screen.

As the ROV explored the underwater canyons, the students spied expanses of muddy bottom and sites where corals clung to rocky cliff faces. If the students spotted a crab, they sent a message to the *Okeanos* team, which recorded the observation in the mission's official log.

"When they were doing the dives in the Norfolk Canyon, it was super interesting because there were red crabs all the time," says Stephanie Martinez-Rivera, a graduate student in Stevens's lab who participated in the watch.

Some of the most important information that Stevens and his students collected, however, was basic data: where the red crabs lived and under what water temperatures. Such information is critical, Stevens says, because the oceans are changing. Even in the cold depths where red crabs live, water temperatures are likely to heat up in the coming decades because of climate change. That, in turn, could have consequences for red crabs. Warming waters could force the crustaceans into new habitats or shift when they time key events in their lives, such as when they reproduce.

It's a phenomenon that scientists have seen before: every summer around July, American lobsters (*Homarus americanus*) in New England stage a mass migration from their deeper water habitats toward the shore. In 2012, however, an ocean heat wave hit the East Coast, and lobsters wound up making their move three weeks earlier than normal. That year, commercial fishermen caught a record number of crustaceans. Without basic data, however, scientists would have no idea if something similar happened to red crabs.

"I'm hoping that we'll be able to set some baselines and look back on them in 20 or 30 years and say, 'Oh, these cycles have changed,' or 'the temperature environment has changed,' " Stevens says.

But warming waters aren't the only uncertainty in the red crab's future. Another comes in the form of a crab trap.

Crab Alfredo

Like the crustacean biologist, Jon Williams got his start with king crabs in Alaska. In his case, he was harvesting them from boats in the Bering Sea. Looking for work a little closer to home, the Maine native got a job in the mid-1990s working for a relatively new industry: the red crab fishery. Today, Captain Williams owns the Atlantic Red Crab Company, the sole harvester of deep-sea red crabs in North America.

His operation is a modest one: the company operates four boats, which sail throughout the year. Three of them are based in New Bedford, Massachusetts, while the fourth — the same *Hannah Boden* that carried Stevens into the fall storm — docked in Newport News,

Red Crab
Chaceon quinquedens

Brad Stevens/UMES

Geographic range: Nova Scotia to the Gulf of Mexico

Depth range: 600 feet to 5,800 feet

Key distinguishing characteristics: Relatively small carapace (up to 7 inches wide); long legs and no swimming paddles; maximum weight of about 3.75 pounds

Life span: Up to 15 years

Reproduction: Unlike most deep-sea crabs, female red crabs do not produce off-spring annually and may reproduce only once every two years

Larval dispersal: Newly hatched larvae (zoeae) likely swim to surface waters, returning to the deep sea as megalopae (juveniles)

Blue Crab
Callinectes sapidus

Iain McGaw and Carl Reiber

Geographic range: Nova Scotia to Argentina

Depth range: Maximum of about 290 feet

Key distinguishing characteristics: Wide carapace (up to 9 inches); short legs with swimming paddles on the hindmost legs; maximum weight of about one pound

Life span: Usually not longer than 3 years

Reproduction: Females mate once in their lives; they store the sperm and may produce offsprings in multiple years

Larval dispersal: Newly hatched (zoeae) in the Chesapeake Bay ride currents to the open ocean, returning to the estuary as megalopae (juveniles)

SOURCES: BLUE CRAB – NOAA, FISHERIES AND AQUACULTURE ORGANIZATION OF THE UNITED NATIONS; RED CRAB – NOAA

Virginia, in 2014 and 2015. The four boats target deep-sea habitats between New England and the Mid-Atlantic Bight, including canyons off the coast of Maryland.

Some of the gear differs, but hunting for red crabs is similar work to harvesting king crabs. Williams's crews drop lines of 150 crab traps, bigger than those used by crabbers in the Bay, down to the sea floor. When his crew pulls the traps back up, they can collect thousands of crabs in a single go. Every year, his boats bring in about three million pounds of red crabs valued at roughly $3 million. That's a small sum compared the $50 million worth of blue crabs caught annually by watermen in Maryland.

Without knowing it, you may have eaten red crab meat. During the early years of his business, Williams sold his harvest exclusively to the Red Lobster restaurant chain. "We were the crab in the Crab Alfredo," he says, at least until the chain phased out the dish in 2008 because of changing tastes. Today, Williams works with a number of different seafood wholesalers both in the United States and in Asia. One client shipped 3,000 pounds of red crabs every week by plane from New York to Asia — the animals alive and in specially cooled tanks — to satisfy a growing demand for seafood overseas.

At home, it's hard to compete with staples like blue crabs, even if red crabs, Williams says, have a sweeter-tasting meat. "To be honest, it's a tough sell," the captain says. Seafood consumers want "what they've always had."

As with all fisheries, the government has a stake in ensuring that the Atlantic Red Crab Company doesn't deplete the supply of these sweet-tasting crustaceans to unsustainable levels. In this case, a regulatory group called the New England Fishery Management Council sets a limit on how many crabs Williams can catch in a year: four million pounds of males, and no females. That's about one million more pounds of crab than Williams has caught in recent years — largely because the market won't support a bigger haul.

But what's different about the red crab harvest, Bradley Stevens says, is that it's what scientists call a "data-poor" fishery. In ideal circumstances, limits for fisheries are based on solid data: there are, for instance, so many mature crabs in a population, and they produce a certain amount of offspring in a year. That, in turn, can help to tell you how many crabs you can catch each year without depleting the stock. For red crabs, however, much of that biological information is missing. That makes the fishing quota more of "a gentleman's agreement between NOAA and the catcher-processor," Stevens says.

Based on the limited, existing data, scientists believe the fishery isn't in peril. One 2008 survey of red crabs, conducted by Richard Wahle, the marine biologist from Maine, reported that the number of red crabs in the Atlantic hadn't declined from the 1970s to the 2000s. In fact, there seemed to be more crabs around than there were before Williams started his operation.

Still, Stevens says that it's important to bring more biology to the management of the red crab fishery. To that end, he and his students are collaborating with Captain Williams to collect and study red crabs from the deep. They're asking basic questions like at what size, for example, do female and male crabs reach maturity. This sort of information not only satisfies the scientists' curiosity. It could also help fisheries managers to develop more finely-tuned regulations for the red crab harvest that could ensure the sustainability of the fishery into the future.

As for Stevens, he says he still gets those "why-am-I-doing-this?" moments.

"I'm always somewhat envious of my colleagues who work on things that are in shallow water," Stevens says. "I'm trying to study this animal that is out there in 2,000 feet of water."

Daniel Strain, formerly a science writer with Maryland Sea Grant, now lives in Denver, Colorado, where he writes occasional articles for Chesapeake Quarterly.

Whale Watching, Beneath the Waves

Jeffrey Brainard

Studying the travels of marine mammals may influence the construction of offshore wind power

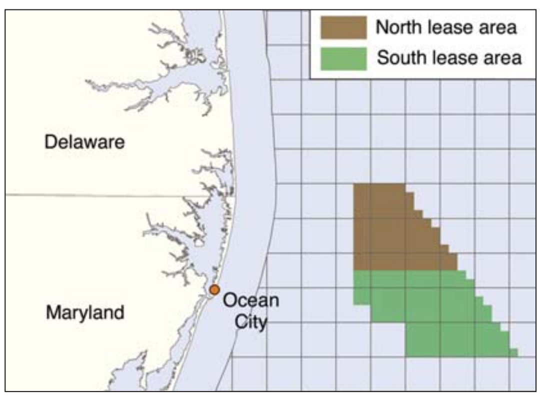
Every three months, a crew of scientists and assistants rides a boat out into the Atlantic Ocean off Ocean City to do a kind of submarine surveillance — but not the Defense Department kind.

The scientists retrieve a set of hardy, underwater microphones and data recorders from the ocean bottom and replace them with similar units. Then the researchers return to their labs at the University of Maryland Center for Environmental Science (UMCES) and Cornell University carrying reams of data about the signature sounds made in these waters by dolphins, porpoises, and the critically endangered North Atlantic right whale. By analyzing data about the animals' clicks and calls, the researchers hope to learn more about where these animals live and when they travel through these offshore waters.

This research and related new findings are expected to help answer practical and timely questions about this coastal ocean zone. Will these creatures be jeopardized by the construction of offshore wind turbines? Can steps be taken to reduce the risks?

" 'Where in the ocean are whales?' is a fairly basic question to ask," says Aaron Rice of Cornell University, one of the project scientists, "and it's kind of astonishing that in this day and age, despite the amount of attention paid to the pressures facing whales, it's still a mystery. This will be the first time in Maryland waters that we'll be able to get a complete, year-round picture."

Where the whales are and how they will be affected by wind turbine towers have become salient questions because of hopes that Maryland could become a leader in developing this renewable energy source. The federal Bureau of Ocean Energy Management (BOEM) issued leases in 2014 allowing U.S. Wind Inc. to explore building a wind farm off Maryland's coastline. The corporation plans to build up to 100 wind-turbine towers generating a total of 500 megawatts.



***Researchers are using sound** to track the highly endangered North Atlantic right whale,* Eubalaena glacialis, *shown here with a calf (top left), in Maryland's proposed wind-power lease zone (bottom left). Helen Bailey, a scientist at the University of Maryland Center for Environmental Science, prepares a C-POD device that will be left on the ocean bottom for three months to record data about clicks from dolphins and porpoises.*

PHOTOGRAPHS, NOAA/NMFS (TOP LEFT), SARAH BRZEZINSKI (TOP RIGHT); MAP, BOEM

This year U.S. Wind began exploring its 124-square-mile lease zone, located from 10 to 27 miles offshore, to identify locations for the turbines. If the project obtains financing and moves forward, it could be one of the first offshore wind farms in the United States.

The research by UMCES and Cornell is part of a set of studies in recent years that have counted a variety of animals in the coastal ocean, including birds and sea turtles, that might be affected by offshore energy projects. Research has been organized and funded by the Maryland Department of Natural Resources (DNR) and the Maryland Energy Administration (MEA) with additional funding from the U.S. Department of Energy and BOEM.

The development of offshore wind energy raises concerns because crews drive piles into the ocean bottom to install the turbine pylons. This work creates loud underwater noises that pose risks to the survival of marine mammals. The sound waves can permanently damage the hearing of whales and dolphins nearby,

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and farther away, they can interfere with communication among members of the same species. The noise can cause animals to move to avoid it. If whales take a detour from their preferred migration route, it could lengthen their journey or increase the frequency of collisions with cargo ships, says Helen Bailey of the UMCES Chesapeake Biological Laboratory, leader of the marine mammal research project.

Under the Marine Mammal Protection Act, federal agencies are required to manage these animals to maintain sustainable populations. The federal Endangered Species Act also protects the right whale and other species of baleen whales in the Northern Atlantic.

The scientists who are tracking whales and dolphins in the coastal ocean are using different but complementary scientific methods. One approach is to count individual animals through visual observations. The Virginia Aquarium, for example, has counted whales during a series of airplane flights over the wind-power lease zone, and the Biodiversity Research Institute has sent out observers on boats and planes. Using those counts, researchers can extrapolate to arrive at population estimates covering a wide area. But the counts can be made only during daylight hours and good weather.

The UMCES and Cornell groups, on the other hand, are gathering data around the clock by using the underwater microphones to pick up whale calls and dolphin clicks — telltale clues that the animals are nearby. "It's a really great technique for looking at distributions of animals over long time periods," Bailey says. In all, the data collection is planned to run for two years, through 2016. Maryland's Department of Natural Resources obtained funding for this research from BOEM, which licenses offshore wind energy projects, and the Maryland Energy Administration.

The Cornell group is using the whale calls to identify their locations and potentially track the direction these animals take as they move through the wind-power lease zone. Tracking the right whales is a priority because only about 450 are left. The UMCES researchers are recording data only about the presence or absence over time of common dolphins, bottlenose dolphins, and harbor porpoises.

Determining where dolphins and whales are located in Maryland's coastal waters is a necessary step to help reduce risks posed to these animals by the construction of offshore wind projects, Bailey says. For example, if dolphins and whales are absent from the construction zone at predictable times of the year, pile-driving might be scheduled for those times. If Maryland becomes a pioneer in developing these projects, it could show other states a way to build them without endangering the animals that live in their waters.

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Bay Sentinel Site Cooperative Gains First Coordinator

Sarah Wilkins has been named as the first-ever coordinator of the Chesapeake Bay Sentinel Site Cooperative (CBSSC). She will work to disseminate data about the Bay and to provide related tools, visualizations, and services to a variety of audiences to help them understand and prepare for the effects of changing climate conditions, including increased coastal flooding.

CBSSC is a partnership among local, state, and federal agencies as well as academic institutions, non-profit and regional organizations, and local communities. The cooperative brings together experts from scientific, resource management, and environmental stewardship groups to inform management decisions relating to flooding and rising seas.

Wilkins works for the Maryland Sea Grant Extension Program and the Maryland Department of Natural Resources; she is based in Annapolis, but will work throughout the Bay region. The position is funded through a grant from NOAA to Maryland Sea Grant, with additional support from the University of Maryland Extension and DNR's Chesapeake and Coastal Service. For more details about Wilkins and CBSSC, visit: www.mdsg.umd.edu/news/CBSSC.

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