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THERE'S NO PLACE LIKE HOME:

DEEP SEAFLOOR ECOSYSTEMS OF NEW ENGLAND AND THE MID-ATLANTIC

Margot L. Stiles, Heather Ylitalo-Ward, Prisca Faure, Michael F. Hirshfield | www.oceana.org

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[STOP DESTRUCTIVE TRAWLING]

Cover image | Yellow Enallopsammia stony coral with pink Candidella coral covered with red brittle stars, New England Seamount Chain | Mountains in the Sea Research Team, IFE, NOAA Office of Exploration

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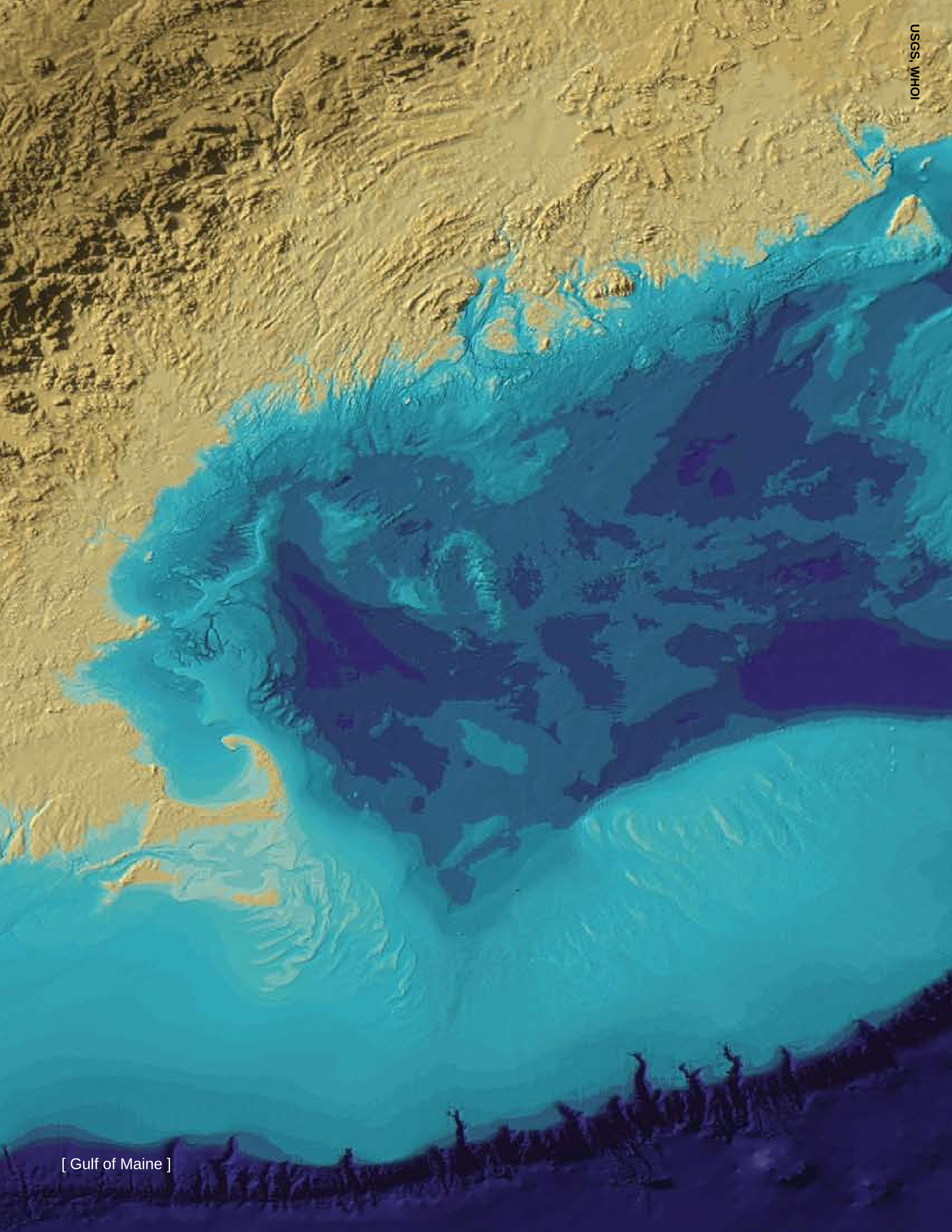

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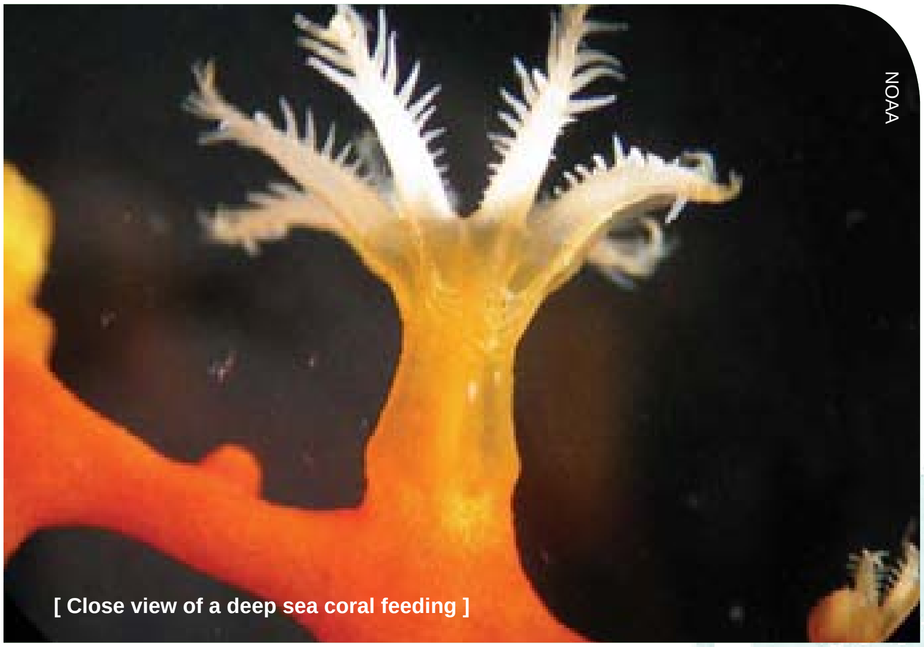
SEAFLOOR ECOSYSTEMS OF THE NORTHEAST



[Close view of a deep sea coral feeding]

From the streets of Boston or New York, it's hard to imagine that undersea mountains, submarine canyons, and deep sea corals are found just offshore. Yet a wealth of marine life blooms on the seafloor with brilliant colors in dark water.

The broad shoulder of the continental shelf from the Carolinas to Georges Bank has been a legendary fishing ground for centuries. Each continental curve and wrinkle supports these fisheries and the diversity of marine species by defining discrete homes for each animal.

Deep sea corals and sponges establish living structures which build on the underlying seafloor and offer even more habitat that can be occupied by distinct communities of fish. When undisturbed by fishing gear for many years, deep sea corals and sponges grow into elaborate gardens of increasing complexity, appeal, and ecological value. Fish seek out a series of these habitats throughout their life and at particular times of the year,[75] seeking prey, safety from predators, a place to attract a mate, or a nursery for their young.

Living seafloor habitat is extremely vulnerable to destructive fishing practices, and we must take action to protect healthy habitat and deep sea ecosystems. From a fisheries perspective, when more habitat is available, the fish can multiply more rapidly and build their populations. Conserving these seafloor habitats is critical to the long-term health of our oceans.


NOAA

[Gorgonian corals in the Gulf of Mexico]

DEEP SEA CORAL

Jewels of the Ocean

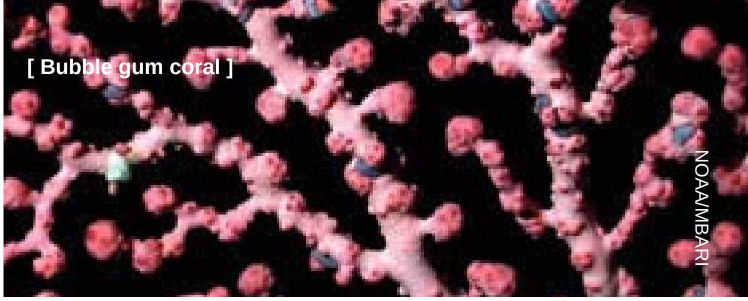
Thousands of feet below the waves, the delicate branches of deep sea corals slowly undulate in the current. Unlike shallow water corals, little is known of these magnificent organisms that anchor entire ecosystems of the deep sea.[69b] Yet two-thirds of all coral species live in cold waters of the deep.[26b] Growing as slowly as an eighth of an inch per year,[22] deep sea coral are the jewels of the ocean. These fragile, slow-growing treasures of the deep take centuries to develop.

Shallow corals draw energy from microscopic plants that rely on sunlight, but deep water corals flourish in the dark. Growing much more slowly than shallow corals, they trap and eat tiny organisms and miscellaneous particles that drift by on the current. Filter feeding is sporadic and their slow growth means that large corals of the deep can be hundreds if not thousands of years old.

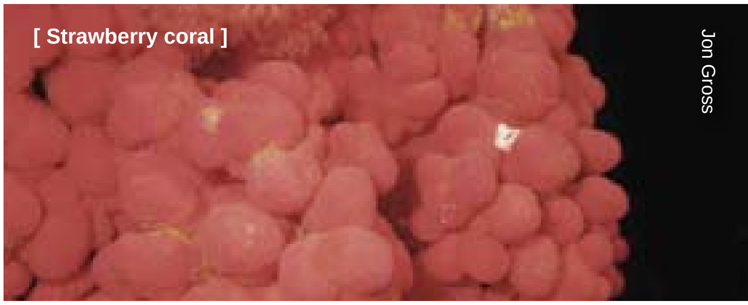
Deep sea corals are some of the oldest living animals known and include a great diversity of unrelated species known as soft corals, sea fans, stony or hard corals, black corals, red corals, and more. Over the course of centuries, individual coral colonies can develop into giant “trees,” and have long been recognized by fishermen that have dragged them up in their gear.[32] Other species build massive reefs that extend for miles and provide important habitats for a variety of species.

Corals in the Northeast have also been researched as important indicators of climate change. Coral skeletons are marked by striations that accumulate over time like tree rings and record variations in ocean conditions. In one example, Flabellum alabastrum revealed temperature change that occurred in a single spot over the last fifty years.[19]

Bamboo corals may provide a model for artificial synthesis of collagen and have been used to synthesize human bone analogs for grafting. The coral-based implants have many properties similar to bone and can be absorbed more quickly than bioceramics.[36]


[Bubble gum coral]
NOAA/MBARI


[Red tree coral]
NOAA


[Strawberry coral]
Jon Gross


[Dead men’s fingers]
Jon Loman, Rana Konsult


[Lophelia coral]
NOAA


[Sea pen]
IFE, URI, IAO, NOAA

> “Diving to the bottom of the ocean in a submersible is an awe-inspiring experience. It’s a bit like being at an aquarium, in that the animals are going about their lives without being aware that you are watching them, except that you are the one that is shut in.”
>
> – Dr. Susan Mills, Woods Hole Oceanographic Institution

[A deep water *Lamonema* fish explores the New England seafloor]

Mountains in the Sea Research Team, NOAA

Coral Residents, Parasites, and Associates

Deep sea corals are home to many fish, invertebrates, and sometimes even marine mammals. Coral ecosystems provide important stopping points for migrating animals of the deep sea, and individual coral colonies house many smaller animals within their branches.

Basket stars curl their arms around the branches of deep sea coral to anchor themselves against the current. These elaborate sea stars are simultaneously scavengers, filter feeders, and carnivores. Basket stars often consume the deep sea coral they live on, slowly devouring and using it as both food and shelter.[65]

Many other small invertebrates, from mites to polychaete worms, burrow in or crawl among deep sea coral branches and collect food in the passing currents. Shrimp are often found crawling along the surface of the corals. They may even be beneficial, cleaning sediment off the coral in return for shelter from predators.[65] Fish are attracted to feed on these small prey, on the coral itself, and on tiny drifting animals known as zooplankton. In the Northeast, the false boarfish has been observed feeding in this way behind or just above the deep sea coral.[16]

Cat sharks breed near deep sea coral and then lay their eggs within its shelter.[37b] These small, graceful, deep sea fish depend on coral and sponge communities from Georges

[Cerianthid anemones in New England]

Peter Auster

[Catsharks on living seafloor]

Alan Dacosta

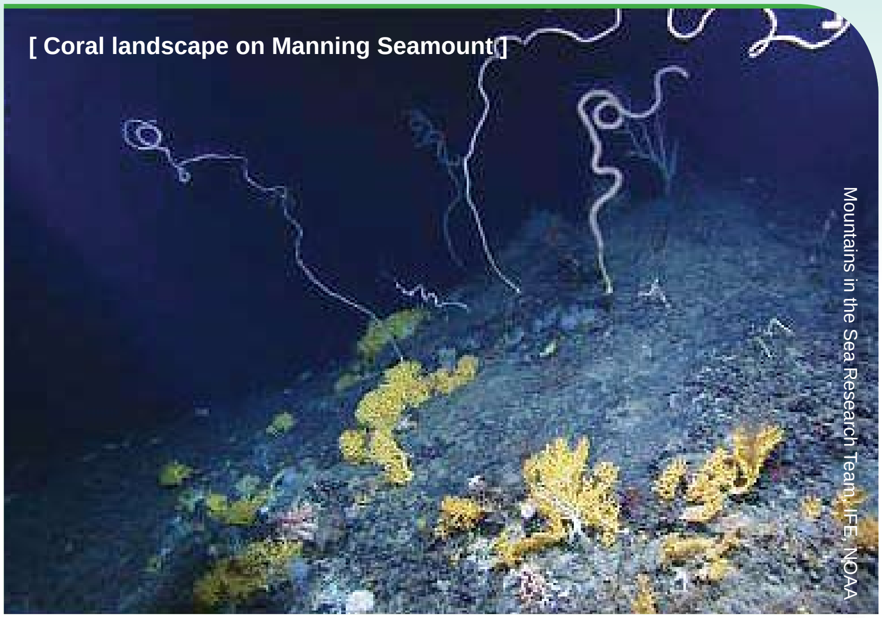
[Shrimp on Lophelia coral in Norway]

Institute of Marine Research, Bergen, Norway

Bank to the Gulf of Mexico. The cat shark egg case is called a "mermaid's purse," for the curled ends which wrap around the coral, securing it in place. The coral provides protection from predators while the juvenile cat shark grows for up to two years in the egg case.[58]

Deep Sea Coral Ecosystems

Corals are the most prominent of a whole community of deep-sea animals that provide the backbone for unusual ecosystems rich in marine life. These coral-like animals include sponges, sea pens, sea whips, anemones, and lace-forming animals called bryozoans. Together they form at least three kinds of deep coral ecosystems: dense stands of individual animals, coral gardens, and deep sea coral reefs. These ecosystems are in fact built by a diversity of invertebrates though they are referred to as "deep coral ecosystems" throughout this report.


[Coral landscape on Manning Seamount]

Mountains in the Sea Research Team, IFE, NOAA


[Georges Bank coral garden]

Page Valentine

Whip corals or sea whips are long, delicate colonies of soft coral that seem tenuously connected to the ocean floor. Despite their individual nature, they often form dense forests of spiraled stalks full of prey for larger fish. Some fish will rest or search for food in and above these sea whip forests.[24, 53]

Sea pens resemble feathers that stand up to two meters tall in the water, waving in the sea, filtering plankton. They can be food for nudibranchs and sea stars, and may provide camouflage and shelter for other animals escaping from predators.[14]

When solitary corals cluster together with sponges and other coral-like animals such as hydroids and bryozoans, they form a coral garden ideal for fish to live in. Sponges also form large reefs of their own, and fill out coral gardens as they grow on and among the coral. Hydroids grow like ferns in a branching pattern, while bryozoans festoon the garden with hard folds of lace.

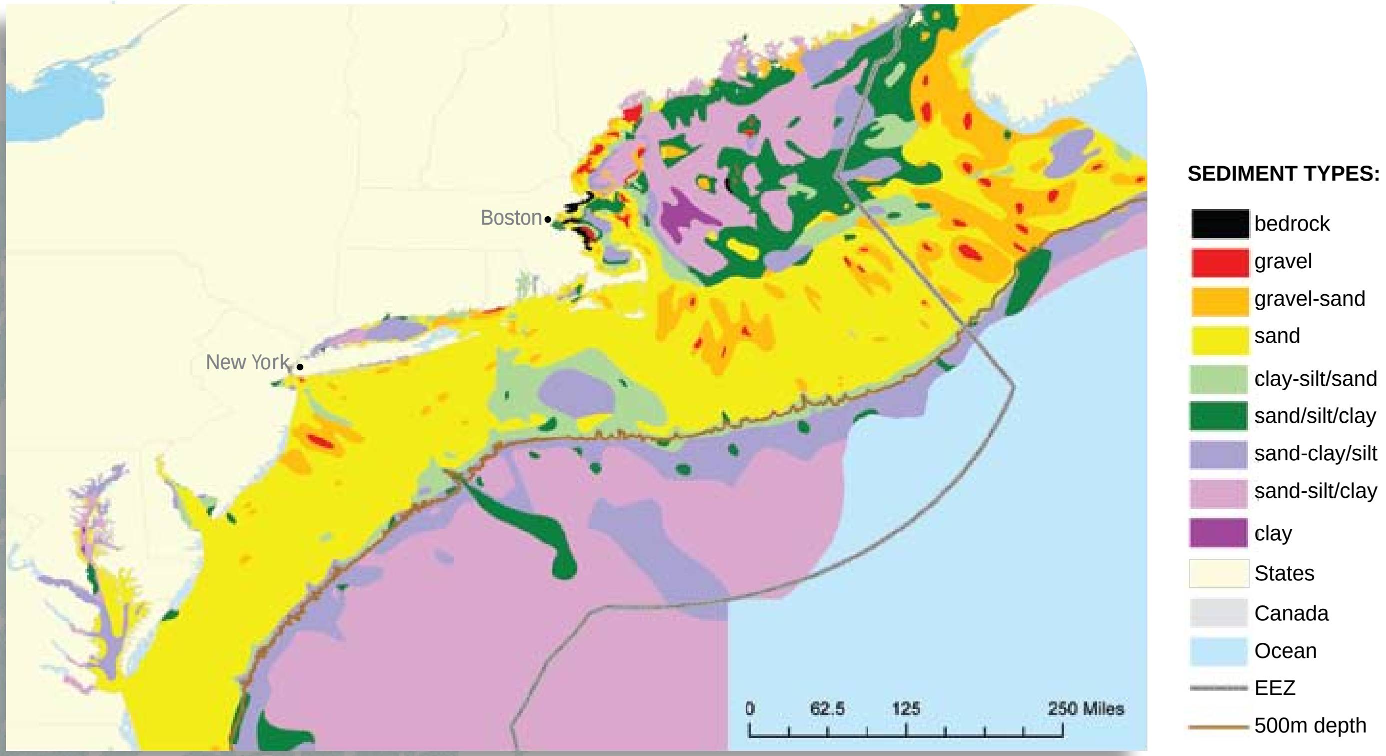
Reef-building deep sea corals form large structures that extend several meters above the seafloor. *Lophelia pertusa* was the first known reef builder in the deep sea, and in European Atlantic waters is known to support more than 850 species on or in its reefs.[70]

In addition to their role in the ecosystem, deep sea invertebrates also contribute to the pool of genetic diversity and potential innovation for humans. Compounds derived from deep-sea sponges are currently under development and in clinical trials for treatment of cancer and several other medical conditions.[47, 60, 66] The deep-sea sponge *Euplectella* also serves as a model for the development of more durable optic cables.[7, 77]

Other Seafloor Ecosystems

A stable ocean surface is integral to the development of deep sea coral ecosystems, enabling this living habitat to serve as a nursery area for juvenile cod and other fish. Relatively rare kinds of seafloor support these ecosystems, including bedrock, boulders, cobbles, and gravel in deep waters off the Northeast United States, as illustrated in Map A.

Exposed bedrock is found only in areas of strong current that sweep it clean of sand and other debris. Coral and sponges thrive on rocky outcrops and other areas of bedrock, which offer a stable place to grow and a current full of food. Some areas of bedrock may



MAP A [Seafloor types in New England]

be scattered with sand, gravel, cobble or boulders, but can still have a few patches where filter-feeding animals can become established. These small patches of hard bottom will frequently support a garden of coral, sponges, algae, tube-dwelling worms, and other invertebrates attached to the surface. Living habitats based on bedrock provide food, shelter, spawning and nursery areas for a large diversity of fish and invertebrates.[13]

Boulders and cobbles also provide enough resistance to the waves to support corals and living habitat. Large boulders are only rarely moved by severe storms and over time can be the ideal starting point for a coral garden, quickly becoming covered with living organisms. Lobster off the Northeast United States often use cobble sites as nursery areas for juveniles.[82] In and among the corals, sponges, and boulders live additional species of commercial interest such as crab, hake and shrimp.[25]

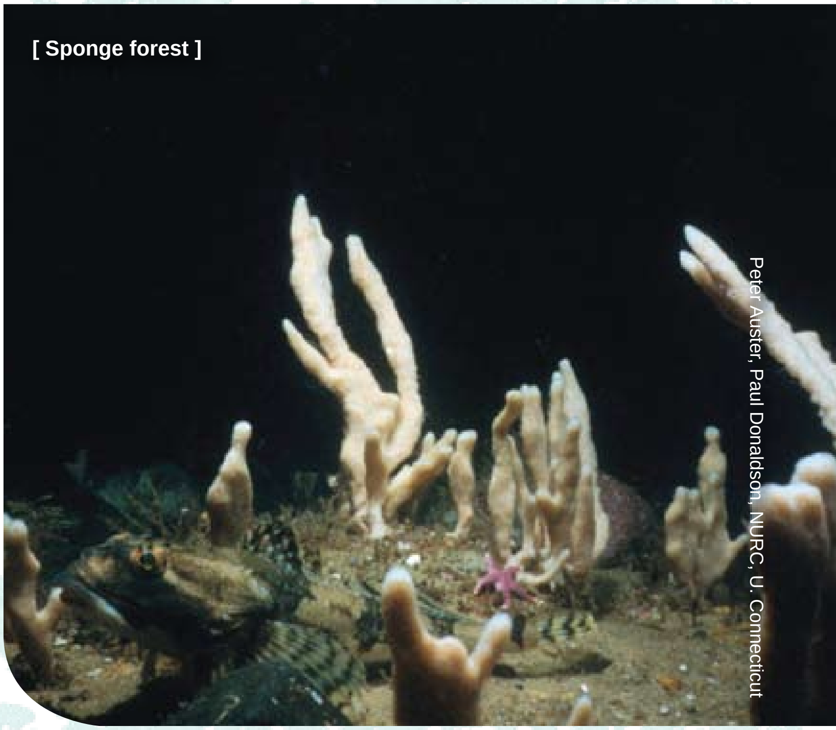
Gravel forms a stable pavement, where structure-forming invertebrates can grow. Meadows of sponges, anemones, sea pens, soft corals, and other structure-forming

[A forest of seapens rooted to the seafloor in temperate Pacific waters]

invertebrates spring up on gravel and attract more animals such as shrimp, brittle stars, and small fish.[30] Though not as solid as bedrock or larger cobbles and boulders, gravel pavement is not easily disturbed by storms or strong currents. Gravel-based habitat frequently serves as an important nursery area for juvenile fish,[29] providing an area in which to avoid predators and find prey.[30] Juvenile cod have improved survival in gravel habitats and herring also seek this firm foundation to attach their eggs.[30]

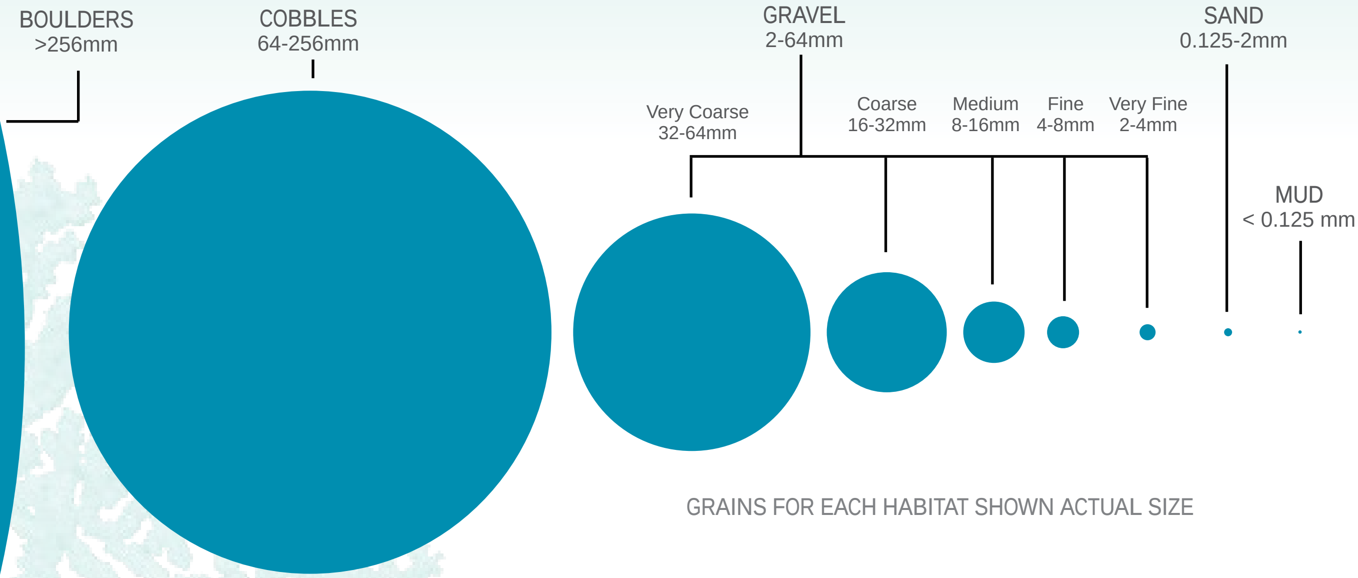
With some exceptions, sand habitats have relatively few coral-like animals. Sand and other soft sediments cover large areas of the seafloor, with increasingly finer grains the greater the distance from land.[29] Starfish, mollusks, and worms make their home here, as well as several species of fish, including hake, flounder, and rays which may bury themselves in the sand.[74]

Muddy seafloor is a mix of water, fine silt and clay particles, and bits of waste which have fallen to the ocean floor.[45] Mud does not support the growth of coral-like animals, though many other organisms live in tubes or within the seafloor itself. [25, 3] Though some deep sea mud habitats are highly diverse, a study of the Atlantic off the Northeast U.S. found that rocky outcrops and gravel boasted many more species than muddy seafloor in the same region.[29, 42]



[Sponge forest]

SEAFLOOR HABITATS OF NEW ENGLAND



GRAINS FOR EACH HABITAT SHOWN ACTUAL SIZE

HIGH Natural Disturbance Level:
often moved by waves

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LOWER Natural Disturbance Level: moved only by large storms

CORAL creates a range of different habitats that provide oases of biodiversity and brilliant color on the seafloor. Coral colonies can be solitary and house one or two small invertebrates or can grow in more complex gardens or reefs where fish and invertebrates often congregate in large numbers.

BEDROCK is found exposed only in areas of strong current that sweep it clean of sand and other debris. Coral and sponges thrive on rocky outcrops and other areas of bedrock, with a stable place to grow and a current full of food.[13]

BOULDERS also provide enough resistance to the waves to support corals and living habitat. Large boulders are only rarely moved by severe storms. They quickly become covered with living organisms and over time can be the idea starting point for a coral garden.[28]

COBBLE is home to many species of commercial interest such as crab, lobster, hake and shrimp. Lobster in the New England Atlantic area often use cobble sites as nursery areas for juveniles.[84]

GRAVEL forms a stable pavement where some soft corals, sea pens, and invertebrates can grow. Meadows of sponges, anemones, sea fans, and other structure-forming invertebrates spring up on gravel, serving as an important nursery area for juvenile fish, providing an area in which to avoid predators and find prey.[33]

Photos: Peter Auster, Dan Blackwood, Page Valentine, USGS
Line drawings: FAO, NOAA, H.M.S. Challenger Expedition

"Under given sets of conditions, i.e., microtopography enhancing current speeds, corals and sponges become more dense and provide color and substrate for other animals (crinoids, brittle stars, shrimp, crabs, fish) and produce a lively, colorful scene amidst a rather barren landscape, much as one might imagine an oasis in a desert."

– Dr. Scott France on submersible diving in the North Atlantic

New England and Mid-Atlantic Deep Sea Corals

The Northeast United States is home to several deep sea hard and soft corals, including over 25 different species.[42] Soft corals and sea fans are especially abundant in this part of the world, including the striking pink fans of Primnoa coral. Much remains to be discovered about even the most abundant species of the Northeast, but all grow beautiful structures and provide habitat for other species.

[Bouquet of Corallium deep-sea coral found at Balanus Seamount in the New England Atlantic]

Mountains in the Sea Research Team, IFE, NOAA

One bright orange colonial coral, *Acanella arbuscula*, is known for its ability to glow with soft lights generated by bacteria, an example of bioluminescence in the deep sea.[22] This phenomenon is unusual, though bioluminescence is also seen in deep sea fish and microscopic algae that accumulate seasonally in coastal areas.

Diverse coral stands are often found in clusters on features such as canyons or seamounts, though large reefs are uncommon in this region.[84] Forests of whip corals as high as 13 feet tall are found in abundance on Balanus Seamount in the New England Seamount Chain.[78] Corals of New England are also thought to be important nursery areas for diverse species of fish, and eggs have been found attached to their branches.[78]

While individual corals are difficult to track, it is clear that deep sea coral populations on this side of the North Atlantic are dwindling. As scientists continue to probe the reproductive workings of deep sea corals, initial findings suggest that their population growth and ability to recover from depletion is extremely low.

Pal Mortensen

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[Some of the most abundant deep sea corals in the Northeast United States]

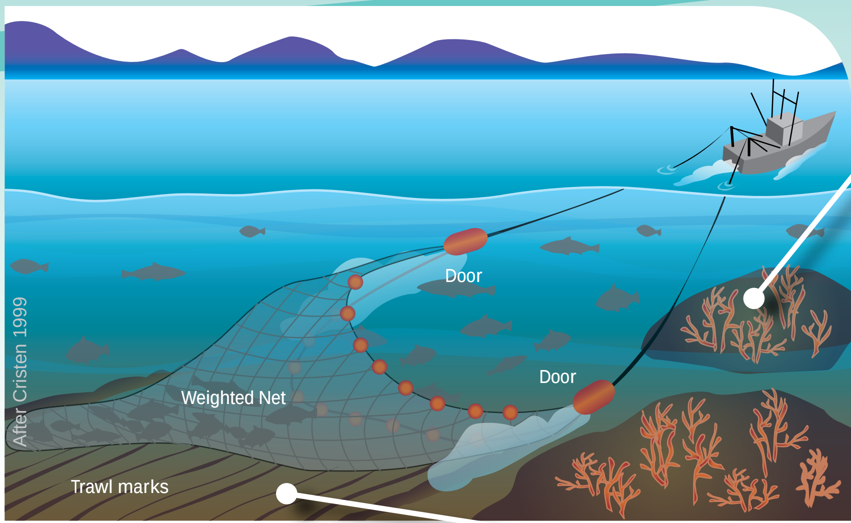


FIGURE 1

[An untrawled site with a redfish among Lophelia coral and anemones]

[Coral rubble in a trawled Lophelia habitat]

Threats to Deep Sea Corals

Deep sea corals are extremely sensitive to destructive fishing practices because of their fragile branches and extremely slow growth. Fishing gear that disturbs the seafloor can be fatal to these corals, and is especially harmful to deep coral ecosystems, sponges, and sea whips when conducted on a large scale. In the Northeast United States and around the world, bottom trawl and dredge fisheries have wreaked havoc wherever they overlap with deep sea corals [Figure 1].

[The trawl doors and chain can weigh more than two tons]

Bottom trawling is a method of fishing that involves dragging weighted nets and trawl doors - large, flat metal panels weighing several hundred pounds - across the ocean floor. The fish are captured in the back of the net which is held open by the two trawl doors several yards apart from each other.

When the trawl doors are dragged along the seafloor, everything in their path is disturbed or damaged if not completely destroyed. Fragile and slow-growing deep sea corals are extremely sensitive to this physical disturbance.

In addition to the trawl doors, weighted metal balls called bobbins or hard rubber wheels called rollers are often attached to the foot rope of the net, to plow through any obstacles in their path.[64] This heavy trawl gear will reduce most coral to rubble, with little chance of recovery.

The effect of trawling on all seafloor habitats is homogenization of the physical environment,[55] destruction of any attached living coral, and disturbance of associated fish and marine life. Dragging bottom trawl gear reduces the complexity and upright structure of the seafloor and limits the possibilities for regrowth.

One of the most notorious examples of adverse impacts of bottom trawling is on the Oculina Banks of Florida, the only known location of extensive reef-building by the ivory tree coral, *Oculina varicosa*, in the world. These reefs were explored by submarine, and later expeditions documented destruction of the majority of the reefs. Bottom trawl tracks could be seen through the coral in some cases.[50] Trawling for undersized rock shrimp in this area is thought to be responsible for the destruction of Oculina colonies up to ten feet in diameter[50] and the majority of a unique deep sea coral reef bank.

A study of trawl impacts in the Gulf of Alaska found that seven years after a single trawl in a habitat with deep sea coral, seven of 31 colonies in the area were missing 80-99 percent of their branches. The boulders in the area, which had provided habitat for coral, had been detached and dragged, removing the fragile coral and disrupting the delicate ecosystem. All damage was restricted to the path where the trawl net had been dragged.[84] When the coral is destroyed, regeneration is often impossible or so slow that it is difficult to measure. Additional research from the North Pacific found that sea whips can also be broken or uprooted by trawl gear.[6]

Research on Georges Bank found significantly lower production of seafloor animals on gravel areas that had been trawled compared to unfished areas. After trawling, the urchins, bivalves, and brittle stars began to return but were not as abundant as in untrawled areas.[44] Recovery on gravel and other consolidated seafloor types is also much slower than in sand or mud, and trawling or dredging several times per year is enough to cause long-term alteration of the seafloor.[31]

[Black coral on Retriever Seamount]

Mountains in the Sea Research Team, IFE, NOAA

MOUNTAINS OF THE DEEP

Extinct drowned volcanoes, known as seamounts, project upwards of 3,000 feet from the bottom of the sea and are cloaked in deep sea corals, invertebrates, and fish found nowhere else in the ocean. Chains of undersea mountains are defining features of the seascape and striking oases of biodiversity.[35] Seamounts provide spawning grounds for deep sea fish and resting points for migrating whales, with a density and diversity of marine life that is unusual so far from the coast.[51]

to their isolated nature. As the underwater mountains have been populated over time, new species arise in isolation and in some cases are specially adapted to that individual seamount.[76] With an estimated 30,000 seamounts around the world,[56] there remains considerable potential for future discoveries of new species. On the most well-studied seamounts, in the Pacific, as many as 12 to 36 percent of the species found there are unique to that particular location.[68]

["Visiting a seamount once can give us a great glimpse of what is there, but it's really important to revisit, and revisit at different seasons to really understand."

– Dr. Rhian Waller, Woods Hole Oceanographic Institution]

[The diversity of life is remarkable on seamounts such as this community pictured on Nashville Seamount in the New England Seamount Chain]

NOAA

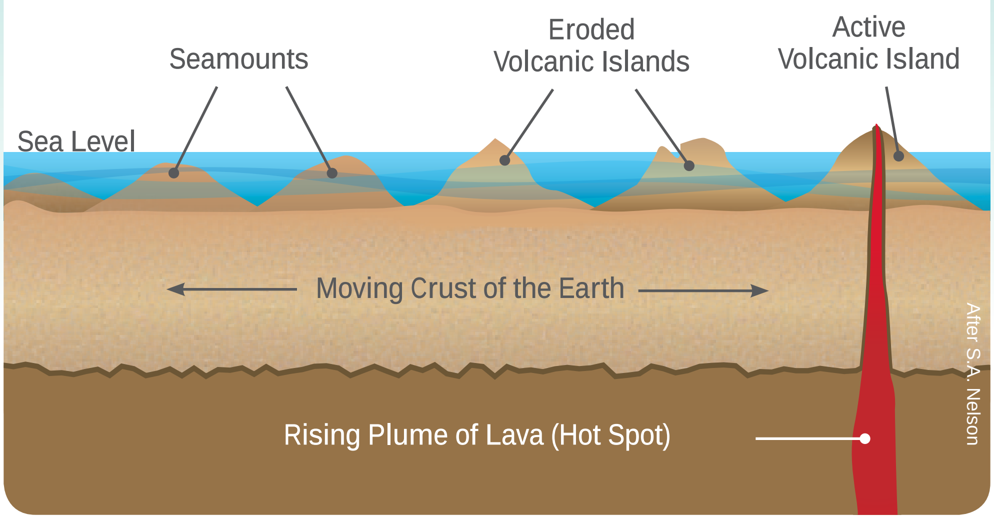
The sides and top of each underwater volcano are often covered by carpets of coral and filter feeding invertebrates. As rich currents sweep around the seamount, these animals opportunistically draw on the nutrients, minerals, detritus, and other waterborne food sources. The seafloor habitat and steady source of food create an ideal nursery for larval and juvenile fish to thrive in during early stages of development.[35]

Seamounts deflect deep sea currents and create their own environmental conditions. This current deflection tends to concentrate and circulate nutrients around the seamount, trapping the microscopic animals that are a major food source for many fish and marine mammals.[48] On seamounts, the potential for development of new species is high due

In the South Pacific, unusual squid have also been found on recent seamount expeditions.[46]

The discovery of new species and high biodiversity of corals and other marine life are often appreciated simply for their beauty and inherent value. However, biodiversity is also an important source of creativity and resilience for natural systems, increasing the chance that at least some species will survive under changing conditions. These are the tools for persisting in the face of climate change, fishing impacts, or extreme weather. Humans also draw on biodiversity, particularly in the sea, as a source of innovation in drug discovery and genetics.[57]

FIGURE 2



> "Diving on the New England Seamounts was particularly exciting, because when we were first out there… no biologists had ever dived on them and so everything we observed was new."
>
> – Dr. Susan Mills, Woods Hole Oceanographic Institution, on submersible diving

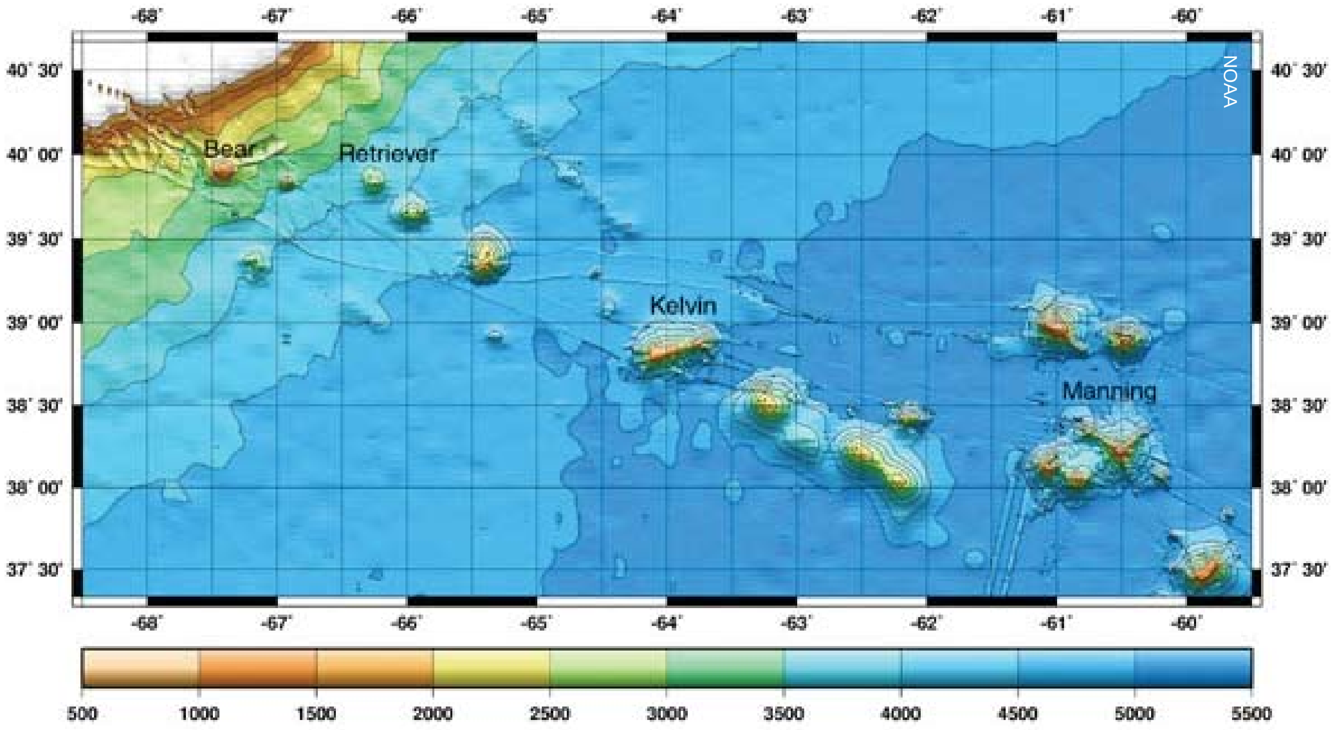
The New England Seamount Chain

The Atlantic Ocean holds more than 800 seamounts, though it is not as volcanically active as the Pacific Ocean.[37, 56] The longest seamount chain in the North Atlantic is referred to as the New England Seamount Chain [Map B] and contains more than 30 extinct volcanic peaks.[62] This chain of seamounts formed approximately 100 to 80 million years ago as a result of a hot spot or pulse of molten rock flowing upwards from beneath the earth's crust to form a volcano. As the tectonic plates in the earth's crust shifted over time, this volcano moved away from the hot spot and became extinct, while a new one began to form farther down the chain. Over time the current chain of seamounts formed as illustrated in Figure 2.[83]

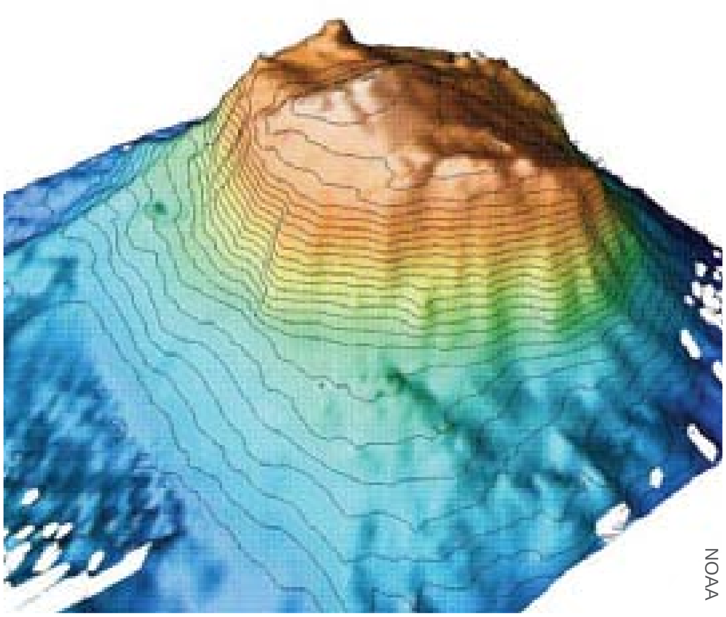
[Deep sea coral and crab on Balanus seamount in New England]

Four seamounts in the New England Seamount chain fall within the 200 mile range of United States waters known as the Exclusive Economic Zone (See Appendix 1 for a full definition of the Exclusive Economic Zone).[18] These seamounts are called Bear, Physalia, Retriever, and Mytilus. Fishing vessels from the United States operate on a limited scale around these and more distant seamounts.

All four seamounts provide important habitat, prey, spawning grounds, and nurseries for diverse ocean life and are a vital link in the ocean community. The New England seamounts were found to have many rare and endemic species during research cruises in the area, with a wide range of deep sea corals, unusual fish, crustaceans, and other varied invertebrates. At least 39 species of coral have been identified on these seamounts, several of which were previously unknown and live nowhere else in the world.[17]



MAP B [Thirty volcanoes of the New England Seamount Chain reach far from the coast]



MAP C [Bear Seamount]

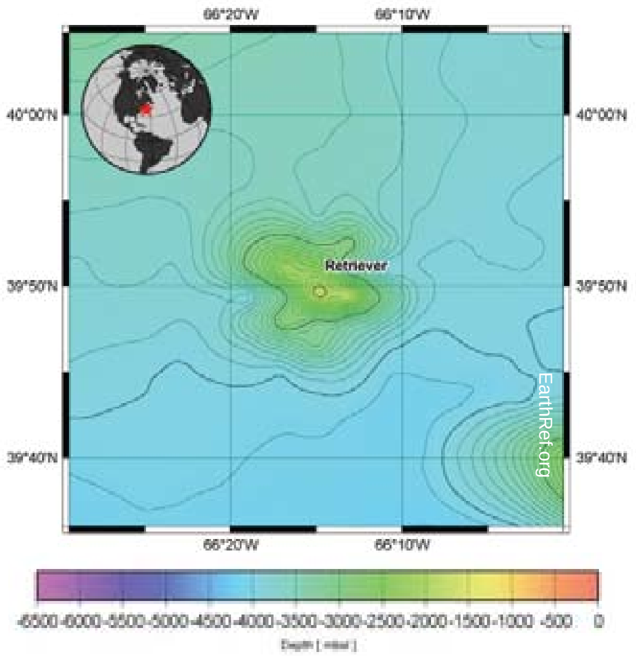
Although not trawled at the moment, these seamounts support deep sea fish that are targeted for exploitation in commercial fisheries in nearby areas. Bear and Physalia Seamounts contain essential fish habitat for red crab[61] and it is thought that Retriever and Mytilus Seamounts have similar environmental conditions and may also support the red crab.

Bear Seamount [Map C] is the oldest of the underwater mountains in the New England Seamount Chain, rising about 1.2 miles above the ocean floor to a wide, flat top. Located about 200 miles offshore from Boston, Massachusetts, its summit lies 3,609 feet below the surface of the sea.[59] Bear Seamount is the nearest to shore and its close proximity to the continental shelf allows marine mammals to easily cross between the shelf and New England Seamounts. In 2002, 2003 and 2004, scientists explored Bear Seamount on research surveys. They encountered at least 214 species of invertebrates and 203 species of fish living on and around Bear Seamount.[18]

Retriever Seamount was explored in 2004 by research scientists on a NOAA expedition [Map D]. Retriever is the same height as Bear Seamount, rising from a round base on the abyssal plain to a sharp peak 1.2 miles above the ocean floor,[38] and approximately 1.13 miles below the sea surface.[18] During the NOAA expedition, researchers were able to identify many species of sponge, coral, sea spider, crab, and other invertebrates[18] and capture photos of the individual corals and coral gardens covering the sides of Retriever Seamount.

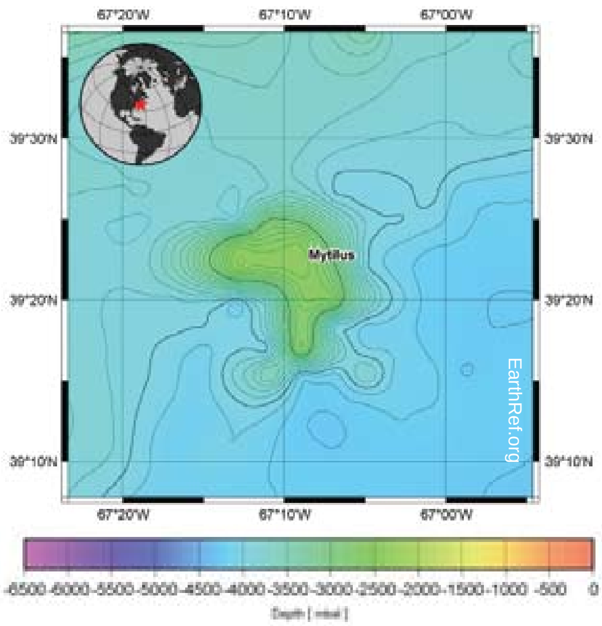
> "It was only the second ever dive on [the] seamount and we saw many wonderful, fantastical-shaped corals of various sizes and colors, and were very successful at sampling tissues from many of them. It was a very productive dive, and much more like a grand adventure than work."
>
> – Dr. Scott France on exploring the New England Seamount Chain

[A white sponge on Retriever Seamount is home to small invertebrates called crinoids]

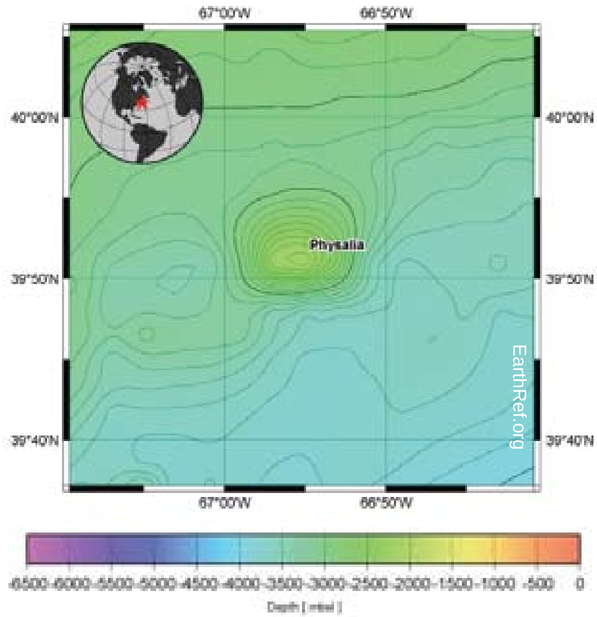


MAP D **[Retriever Seamount]**

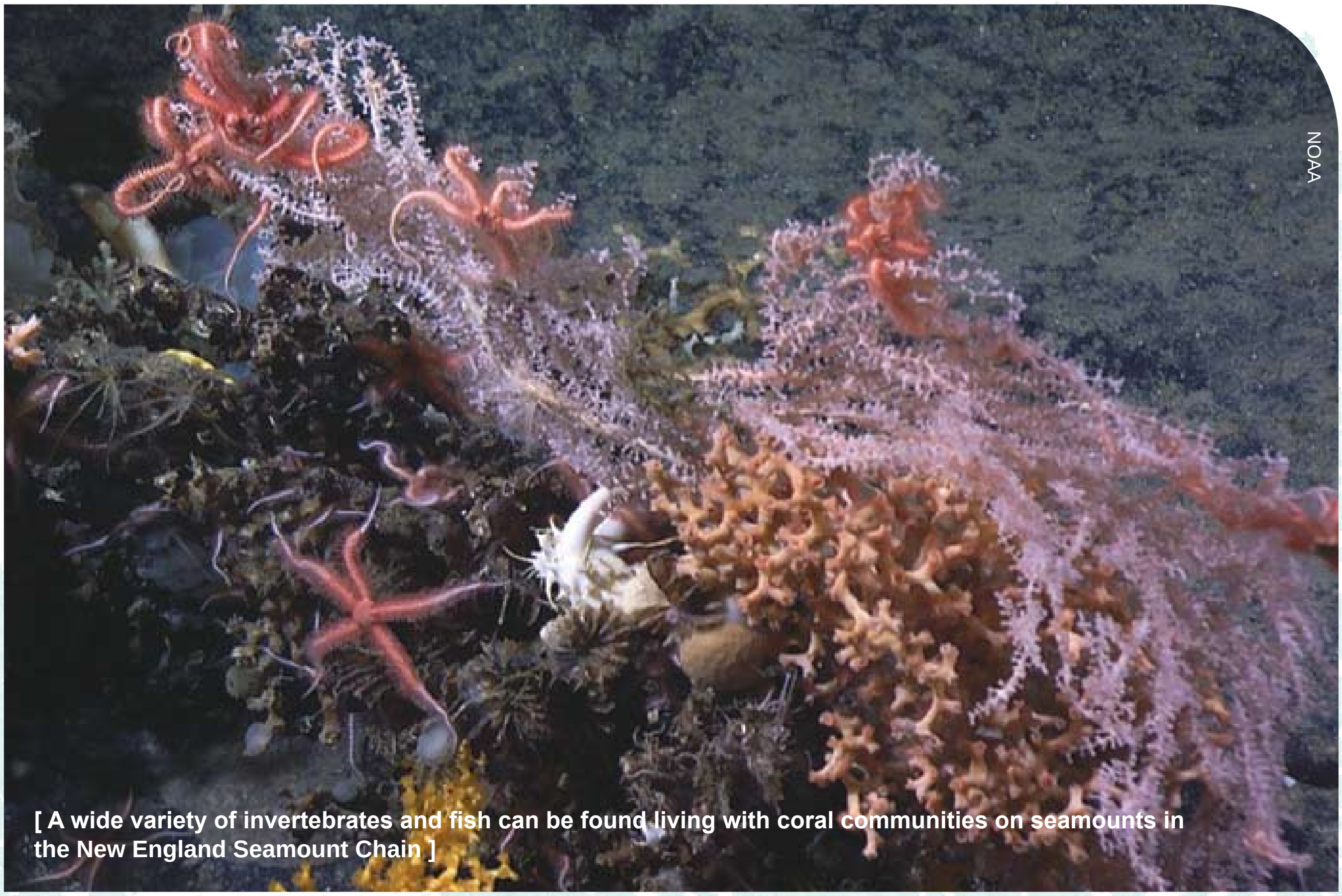
Mytilus and Physalia Seamounts [Map E, F] have been mapped, but not explored as thoroughly as Bear and Retriever Seamounts. Physalia is also the scientific name for the bright blue stinging jelly known as Portuguese man of war. This seamount is located about 1.15 miles below sea level,[18] adjacent to Bear Seamount. Its close proximity to Bear and the continental shelf suggests that it could be a stepping stone connecting seamount and continental slope species to the shelf and coast.[8] Physalia's formation and full biodiversity remain unknown.



MAP E [Mytilus Seamount]



MAP F [Physalia Seamount]



[A wide variety of invertebrates and fish can be found living with coral communities on seamounts in the New England Seamount Chain]

Mytilus Seamount shares the name of a common edible mussel found in the Northeast and in other parts of the world. At 1.4 miles beneath the sea,[18] Mytilus Seamount is thought to host a diverse ecological community similar to its neighboring seamounts in the New England chain.

Trawl and Dredge Impacts on Seamounts

Seamounts and other deep sea environments are increasingly affected by human activities as developments in technology make it possible to fish at greater depths.[63] The most severe effect on seamounts is that of bottom trawling in sensitive habitat. Seamounts are home to several species of deep sea fish and crustaceans of commercial interest to less destructive fisheries as well as to bottom trawling fleets.

Many of the species that live on and around seamounts are long-lived and have low productivity.[52] These fish do not mature for many years and often do not reproduce frequently, limiting their potential for population growth. As a result, these species can only support extremely low levels of fishing and may not reproduce fast enough for any fishing to be sustainable. Research suggests even fishing for as little as five percent of a

[A piece of fishing net discarded in the coral on Manning Seamount]

NOAA

[Spiraling Iridogorgia coral on a New England Seamount]

particular population could be unsustainable for such slow-growing fish.[21] Recovery from overfishing is even slower, taking decades or centuries and risking permanent loss of these unique communities.

The most notorious international example of overfishing on seamounts is the rapid decline of South Pacific populations of orange roughy, a deep sea fish typically found on or near seamounts. In many regions around the world, populations of this fish have been nearly extinguished. This long-lived, slow-growing fish collects in large numbers on top of seamounts, making it extremely vulnerable to fishing. In Namibia, 90 percent of the orange roughy population was removed in only about six years.[23] In New Zealand and Australia, more than 85 percent of the South Pacific population was depleted by fishing by 2002.[20] It has been suggested that no more than one to two percent of an orange roughy population should be fished in order to remain sustainable.[52]

In addition to the threat to orange roughy themselves, trawling for this fish has torn up other marine life on the underlying seamounts, leaving broad swaths of damaged reef and bare rock where living habitats once thrived.[52] A study comparing trawled seamounts and those that remain untrawled in New Zealand found that fished seamounts had 97 to 98 percent less coral cover.[28]

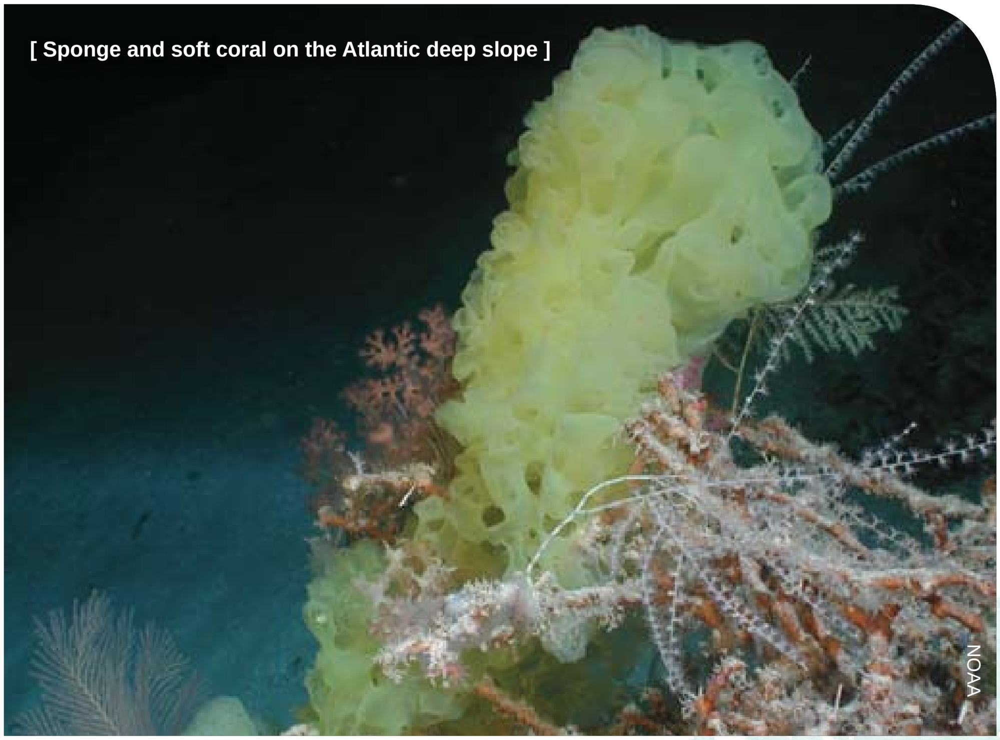
Seamount Conservation

Bear and Retriever Seamount were recognized in 2007 as Habitat Areas of Particular Concern (HAPC) by the New England Fishery Management Council and Mid-Atlantic Fishery Management Council (Appendix 1). The Councils are also developing management measures for each HAPC that could protect the two seamounts from deep sea bottom trawling in the future. Though two seamounts, Physalia and Mytilus, were not named as HAPC, they could be protected by the Councils through their authority to conserve deep sea corals as recognized in the reauthorized Magnuson-Stevens Act.

Other seamounts in U.S. waters have been protected in the past when identified as vulnerable and essential habitat for various species, and for their own merits. The North Pacific Council identified 16 seamounts in the EEZ off the coast of Alaska as HAPC in 2005. No bottom contact fishing gear is allowed in the HAPC, conserving their delicate and unique ecosystems and the fisheries that rely on this habitat. The largest area of protected seamounts is in the Northwestern Hawaiian Islands with 66 seamounts and 341,000 km² in a national monument closed to fishing.

[A Squat lobster and brittle star]

SUBMARINE CANYONS


[Sponge and soft coral on the Atlantic deep slope]

NOAA

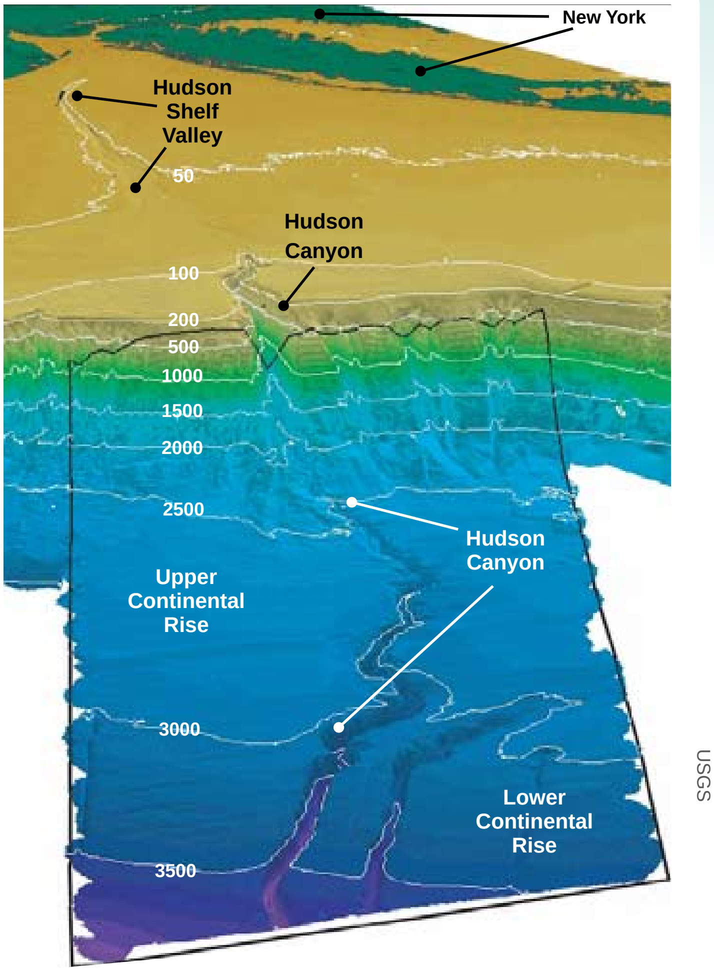
"…[W]e could see large schools of small fish being attacked by a phalanx of large squid. The water was filled with flashes of scales as the fish were being eaten and crabs with very long arms reached up from the bottom to grab remaining bits of fish before other bottom feeders."

– Dr. J. Frederick Grassle, Rutgers University, on diving Hudson Canyon with the ALVIN submersible

Craggy, meandering canyons cut into the continental shelf and slope as they drop steadily toward the abyss. With steep walls that extend up to 200 miles long and three miles deep,[10] submarine canyons were historically difficult to fish and even now can provide natural refuges for deep sea corals and other marine life. To hover at the edge is like standing at the edge of the Grand Canyon, though darkness reveals only glimpses of their breathtaking slopes and valleys. Several canyons have been explored in deep sea submersibles to collect data on these yawning crevices in the continental slope.

Scientists debate the fundamental process under which submarine canyons are formed but many believe they are carved by powerful currents that flow from rivers or earthquakes in the seafloor. Strong sediment-filled currents can generate underwater landslides that erode the continental slope, carrying the debris to the deep sea.[27] Worms and other underwater creatures dig and burrow into their walls, further shaping the canyons.[25]

Several canyons are associated with large rivers that once flowed down the continental slope in the geologic past, when sea level was 200 meters below what it is today. In this way, sediment flowing from the Hudson River is thought to be the original sculptor of Hudson Canyon.[85]



MAP G [Map of Hudson Canyon, depth shown in meters]

Map G of Hudson Canyon highlights this land-sea connection. Many canyons were formed by multiple causes, and their complicated histories are still being explored.[39]

Life in the canyons is defined by fast-flowing currents which run along their steep walls, removing waste and delivering microscopic food for deep sea creatures.[81] Canyons support lush deep sea coral growth because of these currents and the exposed rock outcrops. Many deep sea corals, sponges, and invertebrates require hard surfaces to become established. Submarine canyons are frequently nurseries for many species and home to particular communities of fish that take refuge in the coral growing there.[42, 73]

Mid-Atlantic and New England Canyons

The continental slope of New England and the Mid-Atlantic holds approximately 70 canyons of varying shapes and sizes.[33] Many of these canyons cut into the continental slope of Georges Bank, a large plateau that separates the Gulf of Maine from the Atlantic Ocean and rises more than 100 feet above the surrounding seafloor. Fifteen of the largest and most important canyons are home to rare and biologically significant deep sea fauna.

Once an island and home to prehistoric animals,[4] Georges Bank was drowned as the sea level rose over thousands of years. Now Georges Bank is an excellent site for breeding and feeding for fish and shellfish. For this reason, Georges Bank has been heavily fished and is renowned for its populations of cod, herring, flounder, lobster, scallops and clams. On the Atlantic side of Georges Bank and along the mid-Atlantic slope, fifteen canyons host deep sea coral ecosystems or environmental conditions supportive of corals. These canyons provide areas for fish to escape from predators,and feed and spawn.[4]

Coral canyons on the south face of Georges Bank include Heezen, Lydonia, Gilbert, Oceanographer, Hydrographer, and Veatch, as illustrated in Map H. Among the Georges Bank group, Heezen Canyon is filled with both hard and soft coral species observed as deep as 1,550 meters beneath the sea.[42]

Oceanographer Canyon on Georges Bank has been studied and explored by scientists more than most other canyons on the New England Coast.[33] It is about 300 kilometers off shore,[72] eight kilometers wide, and 1,200 meters deep at its mouth.[33] Oceanographer is home to several species of coral[42] and other invertebrates such as lobster and crabs.[72] The varied habitats found in the canyon on rock, gravel, and sand support a broad range of marine life.[79]

East of Oceanographer, Lydonia Canyon has been explored to a depth of about 2,100 meters.[43] Large numbers of deep sea coral are found on hard rock, surrounded by associated species.[42] The depths of Lydonia Canyon reveal sponges and sea pens, brittle stars, shrimp, quill worms, hake, red crab, and other organisms.[54]

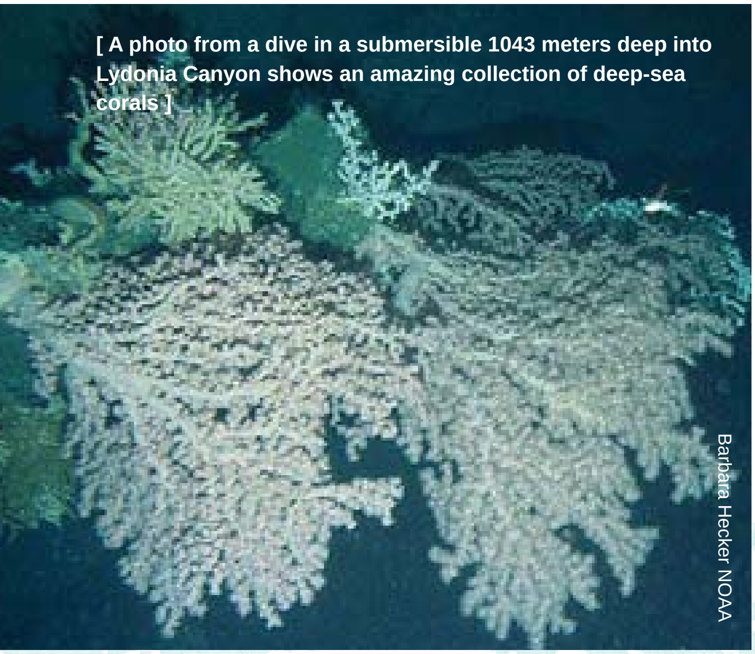
Alvin and Atlantis Canyons are named for the original scientific submersible (Alvin) and attending research vessel (Atlantis) that explored many of the undersea canyons in this region and around the world for the first time. Deep sea coral and sea pens have been photographed and documented at varying depths of Alvin Canyon.[41] This pair of canyons is appropriately located almost directly south of Woods Hole, Massachusetts, the home port of their namesakes.

Along the Mid-Atlantic slope, Norfolk, Washington, Baltimore, Wilmington, Toms and Hendrickson, and Hudson Canyons bear the names of nearby cities and landmarks. Though Baltimore Canyon has fewer hard surfaces and corals than Oceanographer and Lydonia, various corals and at least 135 marine species have been identified at different depths.[42,49] Several fish and shellfish species have been found in Baltimore Canyon as well, including hake, whiting, and crab.[1]

South of Hudson Canyon in the Mid-Atlantic area, both Toms Canyon and an adjacent, smaller canyon have been shown to have a variety of coral living on their walls.[1] Hendrickson is the next canyon south, off New Jersey,[51] and supports dense populations of both hard and soft coral at depths up to 2,080 meters.[1]

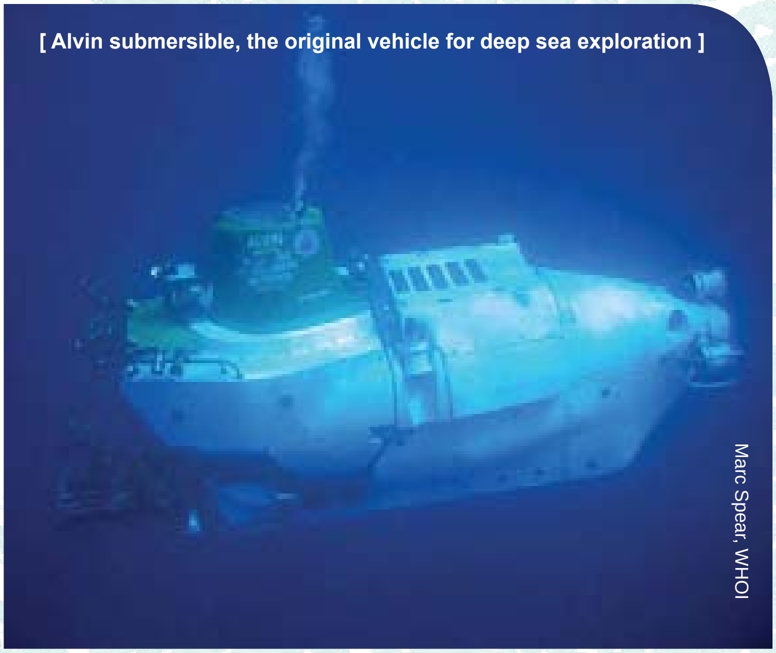
At the southern end of the Mid-Atlantic slope, approximately 96.5 kilometers off the coast of Virginia, Norfolk canyon reaches nearly 56 kilometers long [15] and 2,350 meters deep in places. Diverse coral species were found at many levels of this canyon.

Many submarine canyons have yet to be fully explored. While there have been initial surveys of biodiversity and habitat in these canyons, relatively little is known about their ecological communities as a whole. It is also difficult to determine clearly the population status and trends of species within the canyons. However, the ones that have been explored reveal highlights of seafloor biodiversity and fish that take refuge in these canyons.



[A photo from a dive in a submersible 1043 meters deep into Lydonia Canyon shows an amazing collection of deep-sea corals]

Barbara Hecker NOAA

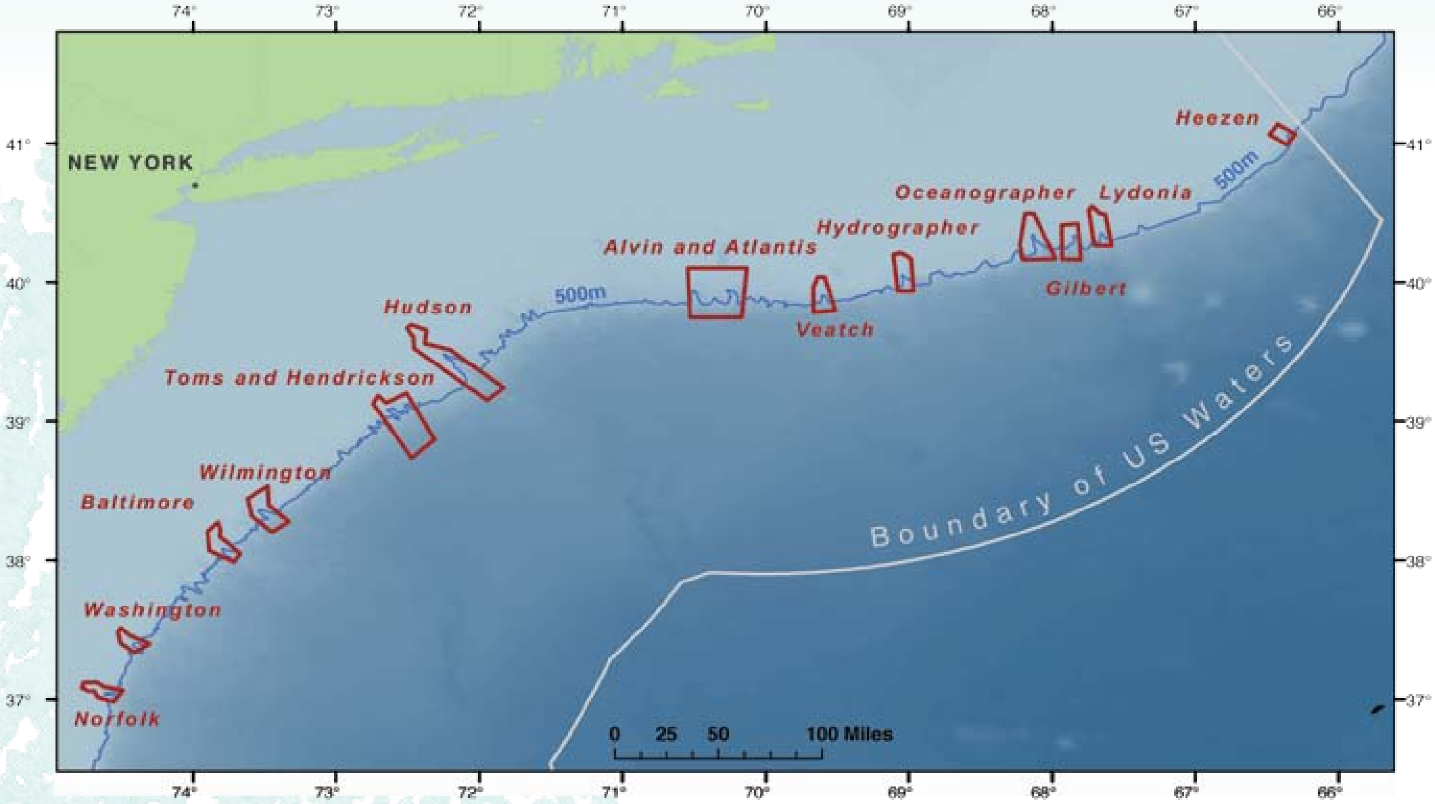


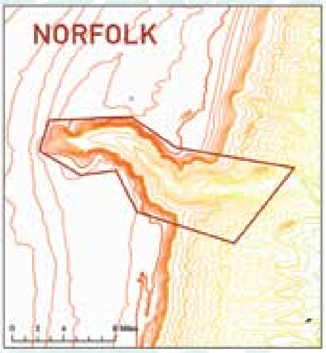
[Alvin submersible, the original vehicle for deep sea exploration]

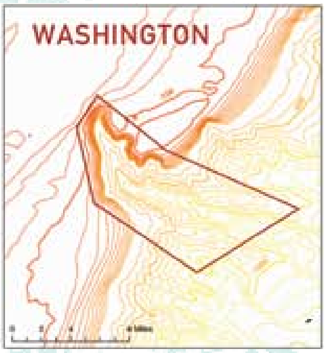
Marc Spear, WHOI

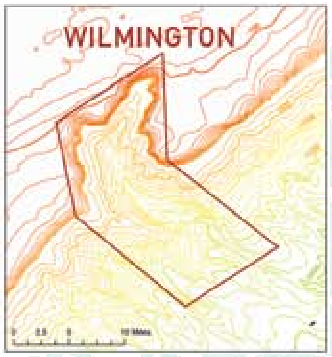
CANYONS OF THE NORTHEAST

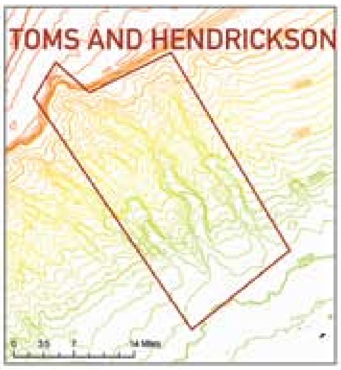
MAP H

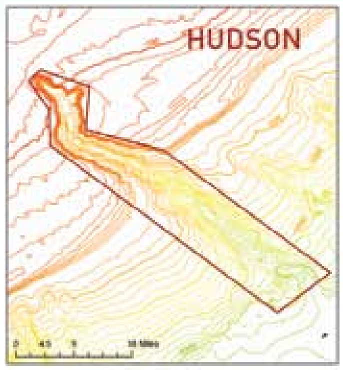


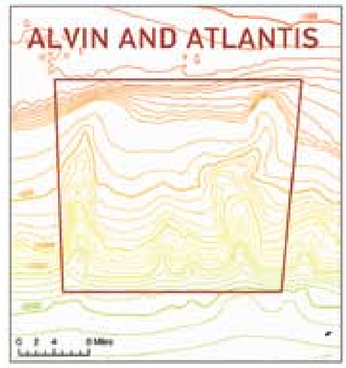


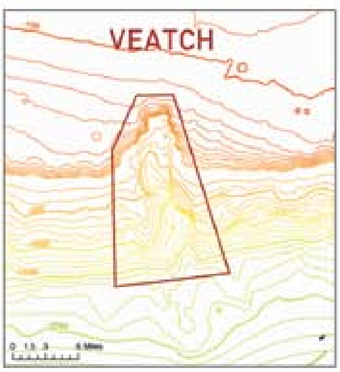


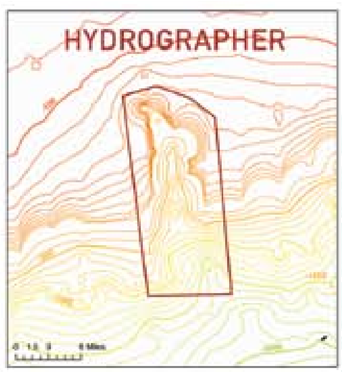


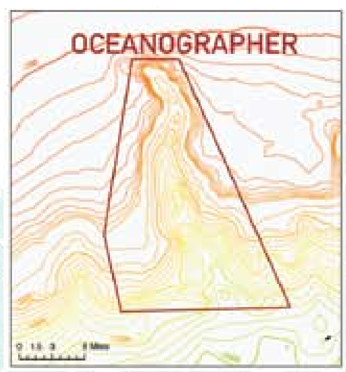

TOMS AND HENDRICKSON

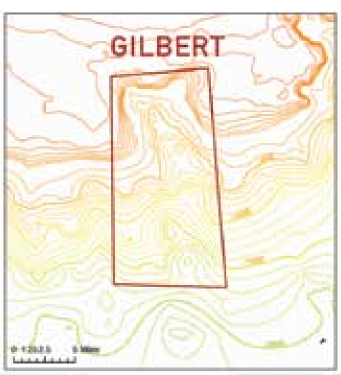

HUDSON

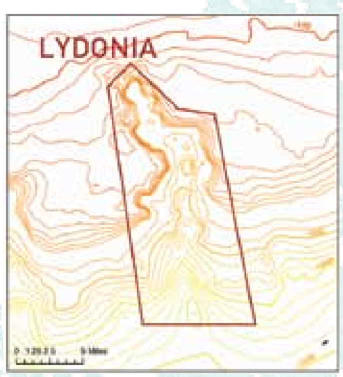

ALVIN AND ATLANTIS

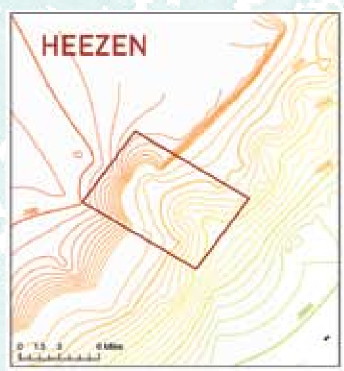

VEATCH


HYDROGRAPHER


OCEANOGRAPHER


GILBERT


LYDONIA


HEEZEN

Trawl and Dredge Impacts on Canyons

[Large rollers like those prohibited on Mid-Atlantic monkfish trawls]

David Hall

The physical characteristics of canyons mean they often prove difficult to fish and offer safe havens for organisms that live in them. However, the technology of deep sea fishing and capacity of bottom trawl and dredge fleets have expanded dramatically from their humble beginnings to threaten canyon populations, habitats, and ecosystems.[69] More specifically, the development of stronger winches, engines, and gear specifically engineered for canyon fishing has pushed out the depth at which trawls and dredges can be dragged.

Fish targeted in other areas by deep sea commercial trawl vessels such as hake, flounder, skate, and monkfish, are also found in canyons and deep water that are now becoming accessible. Acadian redfish also seek shelter from predators in sea bed structures that often include corals.[65]

Expansion of the fishery may also create gear conflict with other fisheries targeting American Lobster and other species that live in untrawled canyons as their habitat. Proactive attention to habitat will ensure that these refuges for fish and coral continue to support the fishery and surrounding ecosystem into the future.

Submarine Canyon Conservation[12, 34]

In 2005, the New England Fishery Management Council and Mid-Atlantic Fishery Management Council enacted two significant protections for submarine canyons in Amendment 2 to the Monkfish Fishery Management Plan. This action closed Oceanographer and Lydonia Canyons to monkfish trawling, protecting their well-documented concentrations of coldwater corals and sponges.

The amendment also prohibited the use of hard rubber wheels, rollers, or rockhoppers larger than six inches on monkfish trawls in a portion of Georges Bank and all of the waters of the Mid-Atlantic. This action effectively protected areas of large boulders and cobbles.

Fifteen canyons in the North Atlantic were recognized by the New England Fisheries Management Council in June 2007 as Essential Fish Habitat (EFH) and “Habitat Areas of Particular Concern” (HAPC), as outlined in red in Map I. The council made this designation due to the abundance of long-lived deep-sea corals, soft corals, sea fans and sponges in these canyons. This designation opens the way for conservation of corals, invertebrates, and fish in these canyons, which are extremely sensitive to disturbance by bottom-tending fishing gear. For more about this designation, see Appendix 1.

This suite of canyons includes Lydonia, Oceanographer, Baltimore, Toms, Carteret, Hendrickson, Alvin, Norfolk, and Heezen, which have all been explored by submarine or with research vessels documenting the presence of deep sea coral. The proposed suite also protects canyons with similar ecological characteristics, including Gilbert, Washington, Wilmington, Atlantis, Hudson, Hydrographer, and Veatch.

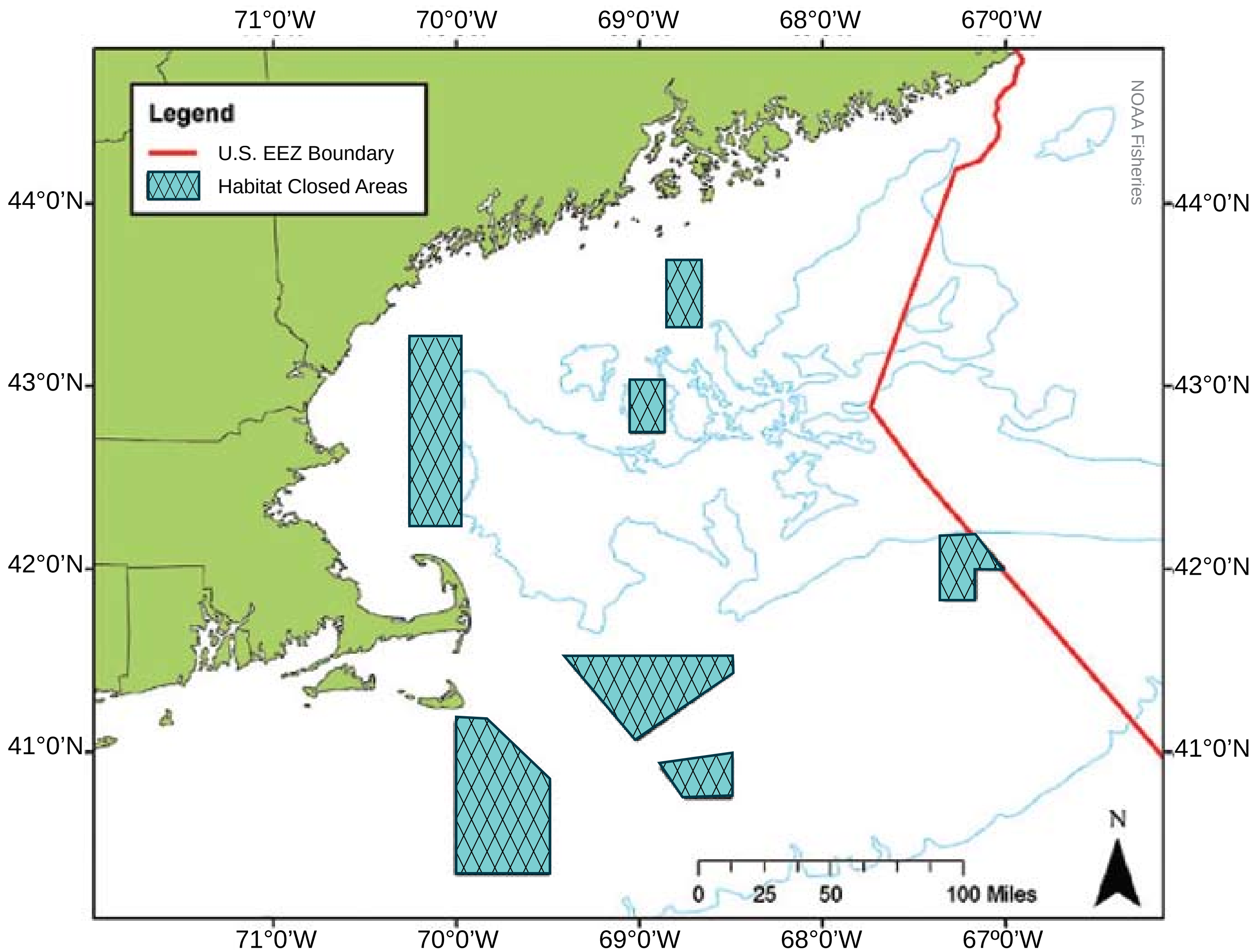
Most of these canyons are not currently being fished actively by the commercial fleet and protection of these areas as HAPC would conserve sensitive coral communities with minimal economic impacts to the fishing industry.

NORTHEAST HABITAT PROTECTION

Seven small management areas have been set aside by the New England Fishery Management Council to protect Essential Fish Habitat (EFH) from the effects of trawls and dredges [Map I]. Though most were not designated based on the location of deep sea habitat, one small area at the northeastern edge of Georges Bank represents the only current HAPC for juvenile cod.

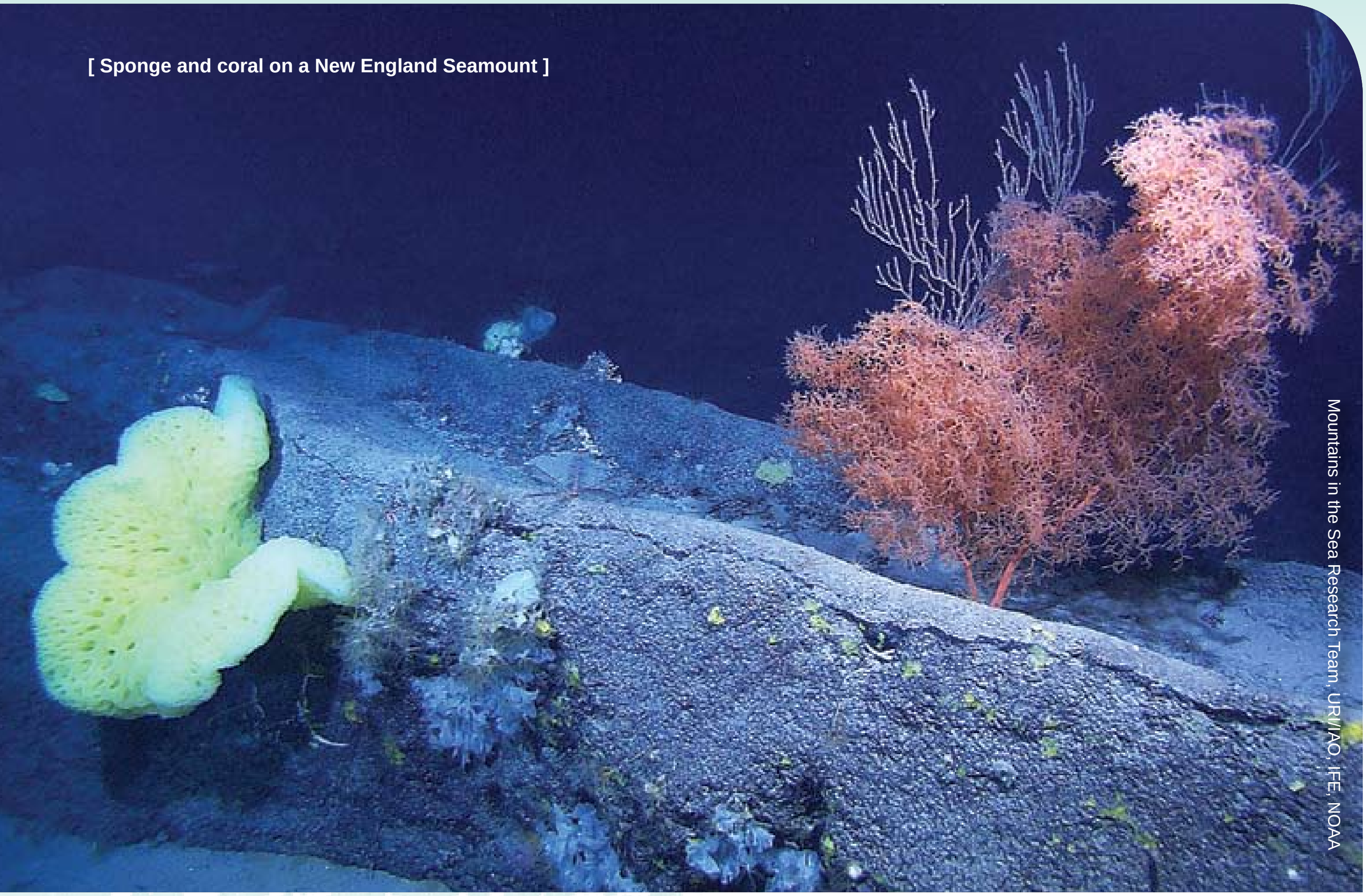
These areas were established between 1999 and 2004 through various management actions related to the New England Multi-species fishery management plan and the Sea Scallop fishery management plan. Although they explicitly restrict the use of trawls and dredges, other fishing gears that are less harmful to seafloor habitats are allowed within these areas. These gears include traps, anchored longlines, anchored gillnets, midwater trawls and purse seines.

While these limited areas are protected from the use of otter trawls and scallop dredges, the majority of vulnerable deep-sea corals, gravel, and other important marine habitats are not yet included. In 2007, the New England Fishery Management Council identified important marine habitats as HAPCs based on proposals from Oceana and other stakeholders. These areas will receive special consideration from the Council as management actions are developed to protect EFH.



MAP I **[Existing Closure Areas For Essential Fish Habitat]**

[Sponge and coral on a New England Seamount]



Mountains in the Sea Research Team, URI/IAO, IFE, NOAA

A VISION FOR THE FUTURE

[Healthy habitat leads to healthy fish and fisheries.]

Coldwater corals and seafloor ecosystems of New England and the Mid-Atlantic support oases for deep sea species and offer significant potential for the development of future medicines. These living structures also provide homes that allow fish and other marine life to grow, thrive, and produce the next generation. In other words, healthy habitat leads to healthy fish and fisheries.

Where a fish calls home includes deep-sea coral, seamounts, canyons, gravel, and other hard seafloor habitats. These habitats are found in discrete locations within the Northeast seascape and require special protection from the impacts of bottom trawls and dredges. Their protection as unique reservoirs of biodiversity will also yield direct benefits for fishing communities and the long-term health of the deep sea ecosystem.

There is an increasing need to protect untrawled habitats and move toward a more vibrant, healthy, and productive marine ecosystem. For New England and the Mid-Atlantic, recognition of EFH and HAPCs is an important first step to save deep sea coral and homes for fish. The next step is to conserve these areas by limiting the use of bottom trawls and dredges in the most vulnerable areas.

APPENDIX 1.

Timeline for Habitat Protection in the New England and Mid-Atlantic Fishery Management Councils

1976 Magnuson Stevens Act closes waters within 200 miles to vessels from other nations, gives regional fishery management councils broad discretionary authority to protect marine habitat.

1996 Sustainable Fisheries Act requires fishery management plans to identify Essential Fish Habitat (EFH) and protect essential fish habitat to the extent practicable.

2000 Federal court orders National Marine Fisheries Service to reevaluate the adverse effects of fishing on essential fish habitat in five regions across the country, including New England.

2001 Federal government agrees to satisfy Court's order through Environmental Impact Statements and new Fishery Management Plan amendments, if necessary.

2002, 2004 New England Multispecies and Scallop Fishery Management Plans modify existing time/area closures and for the first time justify significant closures on Georges Bank on the grounds that they are necessary to protect essential fish habitat.

2005 New England Fishery Management Council and Mid-Atlantic Fishery Management Council begin work on Omnibus Essential Fish Habitat Amendment 2 to reassess EFH designations and closures and to develop HAPCs for the regions.

2005 Federal court invalidates attempt of Scallop Framework 16 to decrease the area protected by EFH closures established in Scallop Fishery Management Plan, establishing the principle that framework actions must be consistent with the policy established by the fishery management plan, and cannot significantly change that policy.

2005 New England Fishery Management Council and Mid-Atlantic Fishery Management Council protect marine habitat in Oceanographer and Lydonia Canyons from the impacts of monkfish trawling gear.

2007 New England Fishery Management Council and Mid-Atlantic Fishery Management Council designate HAPCs for the region from Maine to North Carolina.

2008 New England Fishery Management Council and Mid-Atlantic Fishery Management Council expect to complete a Gear Effects Evaluation and Determination of adverse impacts of fishing gears. Councils expect to begin crafting management measures to minimize the effects of fishing on EFH.

2009 Both Councils scheduled to select management measures for EFH in the Northeast region.

2010 On-the-water changes in habitat management in the Northeast region take effect.

APPENDIX 2.
Legal Tools for Seafloor Protection

The Magnuson-Stevens Fishery Conservation and Management Act, adopted in 1976 and amended significantly through the Sustainable Fishery Act Amendments of 1996 and the Magnuson-Stevens Reauthorization Act of 2006, governs commercial and recreational fishing in the United States Exclusive Economic Zone (EEZ).

The Sustainable Fisheries Act significantly clarified and strengthened requirements to conserve the marine ecosystem, including requiring fishery managers to identify important marine habitat as "Essential Fish Habitat," (EFH) and requiring that Fishery Management Plans protect EFH to the extent practicable.[71]

The 2006 Reauthorization Act further clarified and strengthened the Magnuson-Stevens Act, reaffirming the authority of fishery managers to protect deep-sea corals. This authority should be used to protect additional seamounts and any other deep sea coral areas in New England.

The statutory tool of Essential Fish Habitat is used to identify an area that is "necessary to fish for spawning, breeding or growth to maturity." EFH may consist of a particular substrate, sediment, or even a water column with important biological or chemical properties associated with biological communities.[11] Congress intended that the EFH designation be used to protect significant marine habitat and promote healthy ecosystems.

The Fisheries Service created, through regulation, a special classification, termed a "Habitat Area of Particular Concern" (HAPC) to designate a subset of EFH which may be particularly vulnerable to degradation by fishing or especially vital for one or more species' productivity.[2] An area is classified as a HAPC based on several criteria including rarity, ecosystem function, sensitivity to degradation, and development activities surrounding the habitat site.

In several regions of the United States, regional fishery management councils applied the EFH tool to protect important areas of the seafloor, including South Atlantic Sargassum seaweed, Alaska corals and seamounts, and Pacific rocky reefs. In New England and the Mid-Atlantic, the fishery management councils voted to designate deep-sea coral, canyons, and seamounts as HAPC in 2007.

[A delicate, spiraled, deep-sea coral in the New England Seamount Chain]

DASS Science Team, IFE, URI-IAO, NOAA

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