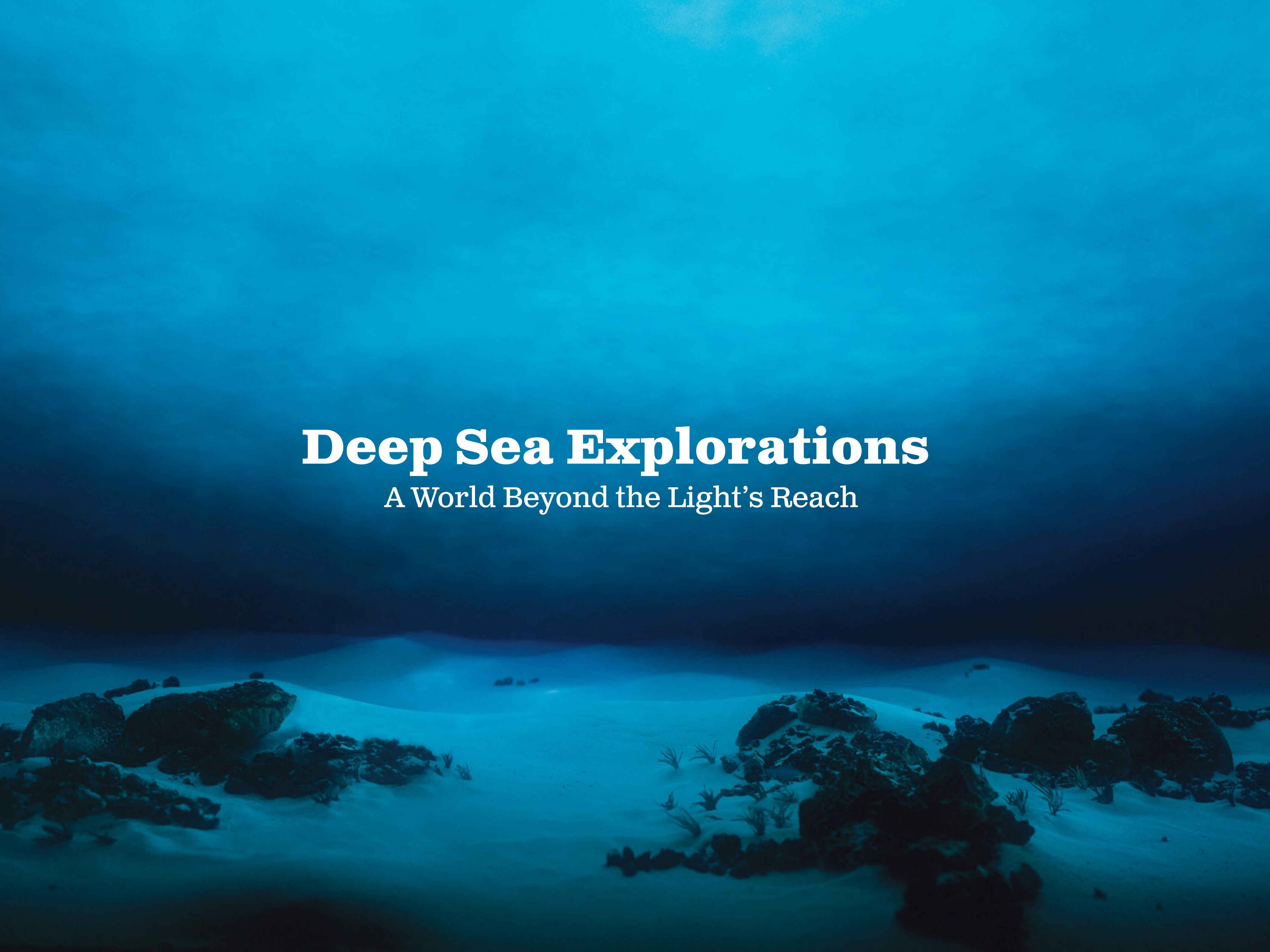
Deep Sea Explorations

A World Beyond the Light’s Reach



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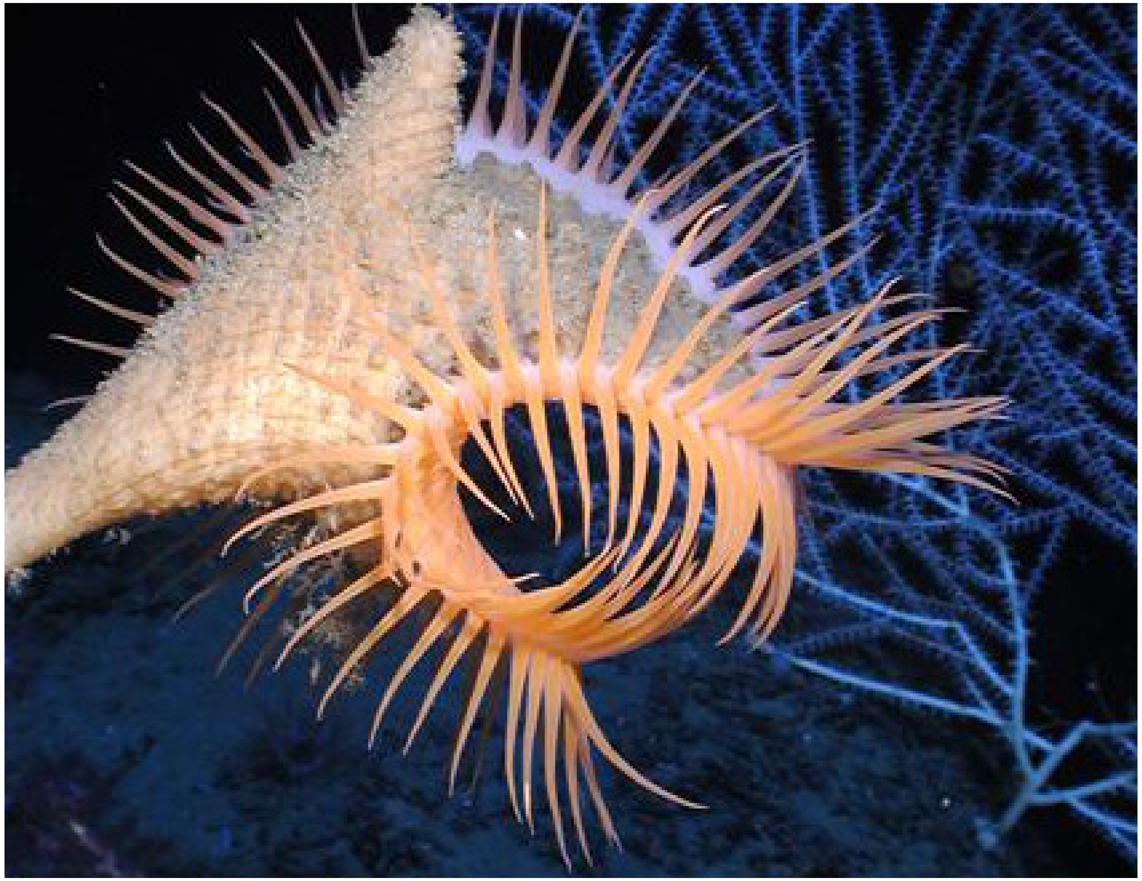

Creatures

In a deep, dark world anything that lights up stands out. But in fact, producing light in the deep is the norm rather than the exception. Some creatures produce their own light to snag a meal or find a mate in a process called bioluminescence.

Bioluminsecense

Animals can use their light to lure prey towards their mouths, or even to light up the area nearby so that they can see their next meal a bit better. Sometimes the prey being lured can be small plankton, like those attracted to the bioluminescence around the beak of the ***Stauroteuthis octopus***. But the light can also fool larger animals. Whales and squid are attracted to the glowing underside of the cookie-cutter shark, which grabs a bite out of the animals once they are close. The deep-sea anglerfish lures prey straight to its mouth with a dangling bioluminescent barbel, lit by glowing bacteria. In addition to feeding, creatures of the deep use light in flashy displays meant to attract mates. Or, animals use a strong flash of bioluminescence to scare off an impending predator. The bright signal can startle and distract the predator and cause confusion about the whereabouts of its target. The light can even attract a bigger predator that will eat the attacker. If an animal needs to blend in, bioluminescence can be used to help in camouflage with the use of counterillumination, a display of light that helps them blend into the background. In the deep-sea food is scarce, but it is also a great place to hide in the dark away from hungry predators. Some creatures have adapted a way of life that takes advantage of both the plentiful surface waters and the safety of the deep. It is called diel vertical migration.

Diel Vertical Migration

As the sun sets, fish and zooplankton make massive migrations from the depths up to the ocean surface. Despite their small size (some no bigger than a mosquito), these creatures can travel hundreds of meters in just a few hours. Under the light of the moon they feast on the phytoplankton that grew during the day. Then, when the sun comes out and there is enough light for predators to see them again, the zooplankton return to the deep darkness. Often, this repeats every single day.

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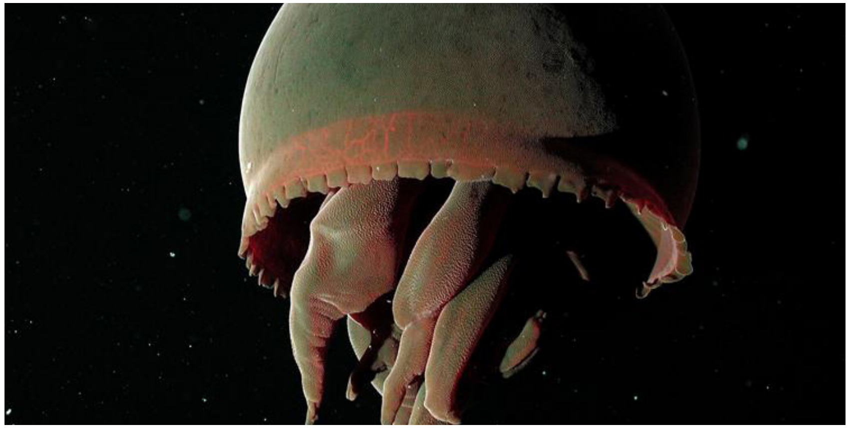
Diel vertical migrations are likely the largest daily migration on the planet. And while for many creatures partaking in the migration is a way to avoid predators, others take advantage of the reliable movement of potential prey. One tiny plankton, a ***foraminfera***, waits in the path of the migration and ensnares passing ***copepods***, a migrating crustacean, in a web of protruding spines. A layer of these plankton create a dense mine field for the tiny crustaceans to swim through on their path each day. In the arms race of evolution, it pays to be one step ahead. Diel vertical migrations aren't the only type of movement between the shallows and deep. Tethered to a life at the surface because they require breathable oxygen, many large animals will make impressive dives to the deep sea in search of their favorite foods. Sperm whales, southern elephant seals, leatherback sea turtles, emperor penguins, and beaked whales are especially good divers. A ***Cuvier beaked whale*** is known to dive 9,816 feet (2,992 m) deep, and can stay down as long and 3 hours and 42 minutes, making it the deepest diving mammal in the world.



Plant Life

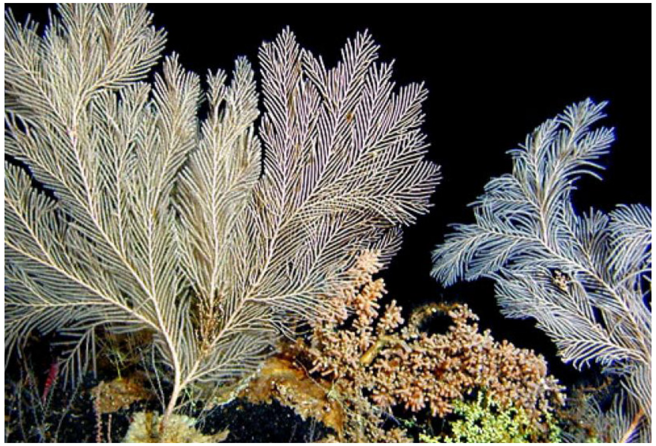
On land, life is almost completely dependent on photosynthesis. Plants utilize carbon dioxide and sunlight to produce organic matter. But not only the plants themselves benefit; they serve as the bottom of the food chain. Animals with a plant-based diet gain their energy from eating plants, and they in turn serve as energy source for meat-eating animals on top of the food chain. So, if there is no light, there is no food, and thus no life dependent on photosynthesis. Aside from life on land thriving due to sunlight, what happens in places completely drenched in darkness?

The oceans present a habitat almost entirely governed by darkness. Only the uppermost layer of the ocean is penetrated by sunlight and in the top 200 m photosynthesis is possible: In shallow, coastal areas, a range of marine organisms are capable of photosynthesis, taking on the role of plants on land. Far from

any coastlines, ***phytoplankton***, tiny marine organisms doing photosynthesis are the only photosynthetic source of organic matter. Thus, in the upper part of oceans marine life thrives, and organic matter produced through photosynthesis feeds a large variety of organisms. Below 200 m and especially in the deep sea on the other hand, marine life is less teeming. Down there it is dependent on organic matter from carcasses sinking down through the water column. Carcasses are leftovers of dead marine animals that depended on photosynthetically produced organic matter. Scavenging falling organic matter is not the only way to survive in the deep sea though; organisms independent of sunlight and carcass-scavenging live in so-called seafloor hydrothermal systems.

The diversity of marine life in these systems is surprising. One can find larger animals ranging from octopuses over fish, crabs, shrimp, and tube worms down to small crustaceans, as well as tiny microbes. It's generally the big that eat the small, with octopuses being the top predator in the deep sea. With that in mind, it is not surprising that microbes end up at the bottom of the food chain in these systems. But from what do the microbes gain their energy from to produce organic matter in these seafloor hydrothermal systems, independent of sunlight?

These systems are essentially hot springs on the seafloor, and they provide the basis for life in the deep sea independent of sunlight. Hot springs can only form when there is a heat source nearby to heat up water. Mid-ocean ridges are a prime candidate for such conditions: there, tectonic plates move apart below the oceans, forming new seafloor, and magma occurs comparatively shallow. Seawater can flow through cracks deep into the rocks below the seafloor and is heated by magma below. The heated seawater chemically reacts with the rocks below the seafloor and turns



into hydrothermal fluids carrying dissolved elements from the rocks. The fluids with temperatures of up to almost 400C rise upwards and where they reach the seafloor, fantastic structures called hydrothermal vents are produced that consist of minerals forming from the dissolved elements. Those systems were unknown until their discovery in the late 1970, and aside from producing mineral towers on the seafloor, the fluids contain hydrogen sulfide, hydrogen, and methane. These chemical compounds are the key to how microbes produce organic matter in seafloor hydrothermal systems and sustain life in the dark completely independent of other life forms and sunlight.

ChemoSynthesis

Specific microbes have adapted a process based on what is provided by the hot springs: chemical compounds. Most of those microbes are bacteria, and the pathway they are putting to use is called ***chemosynthesis***. Organisms capable of this process are called chemoautotrophs; they can oxidise hydrogen sulfide, hydrogen, and methane readily available from the hydrothermal fluids. The oxidation reactions create an energy surplus that the bacteria then use to produce organic matter from carbon dioxide in the seawater. These ***chemoautotrophs*** form thick bacterial mats on the hydrothermal vents where they have unlimited access to the material they need. And these bacterial mats serve as sole food source for the crustaceans, that then in turn are eaten by larger organisms, which then are also eaten by larger organisms. Ultimately, marine life in seafloor hydrothermal systems in the deep sea is diverse and thrives thanks to tiny, industrious microbes resorting to chemosynthesis in the complete absence of sunlight at depths of up to several kilometers below sea level.

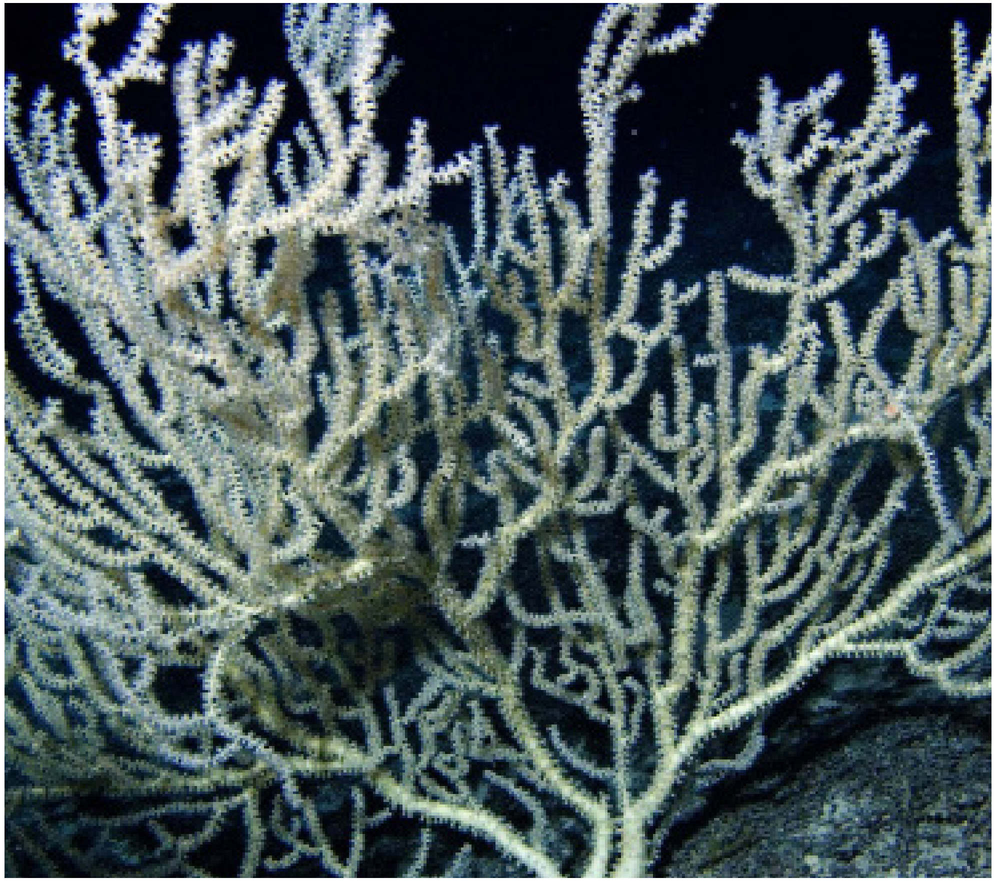
Chemosynthesis is the conversion of carbon (usually carbon dioxide or methane) into organic matter using inorganic molecules (hydrogen or hydrogen sulfide) or methane as an energy source. Most energy is initially derived from sunlight via plant photosynthesis. Chemosynthesis is usually found in places that are high in methane and low in oxygen, where bacteria can use these conditions to make energy. Some very specialized marine animals have bacteria in their tissues, which use the methane and/or sulfides to make energy that feeds the host, generally a type of clam, mussel or worm.

In some places, geological conditions create high levels of methane and sulfides, which seep out of the sediment. These are called ***cold seeps***, which are similar to the warm hydrothermal vents found near tectonically active margins and underwater volcanoes. Prior to our Atlantic Deepwater Canyons project, there were only two confirmed cold seep areas in the western Atlantic. In 2011-2013, NOAA identified 570 bubble plumes during

Corals

It may be the last place you'd expect to find corals, up to 6,000 m (20,000 ft) below the ocean's surface where the water is icy cold and completely dark. Yet believe it or not, lush coral gardens thrive here. In fact, there are as many known species of deep-sea corals (also known as cold-water corals) as shallow-water species.

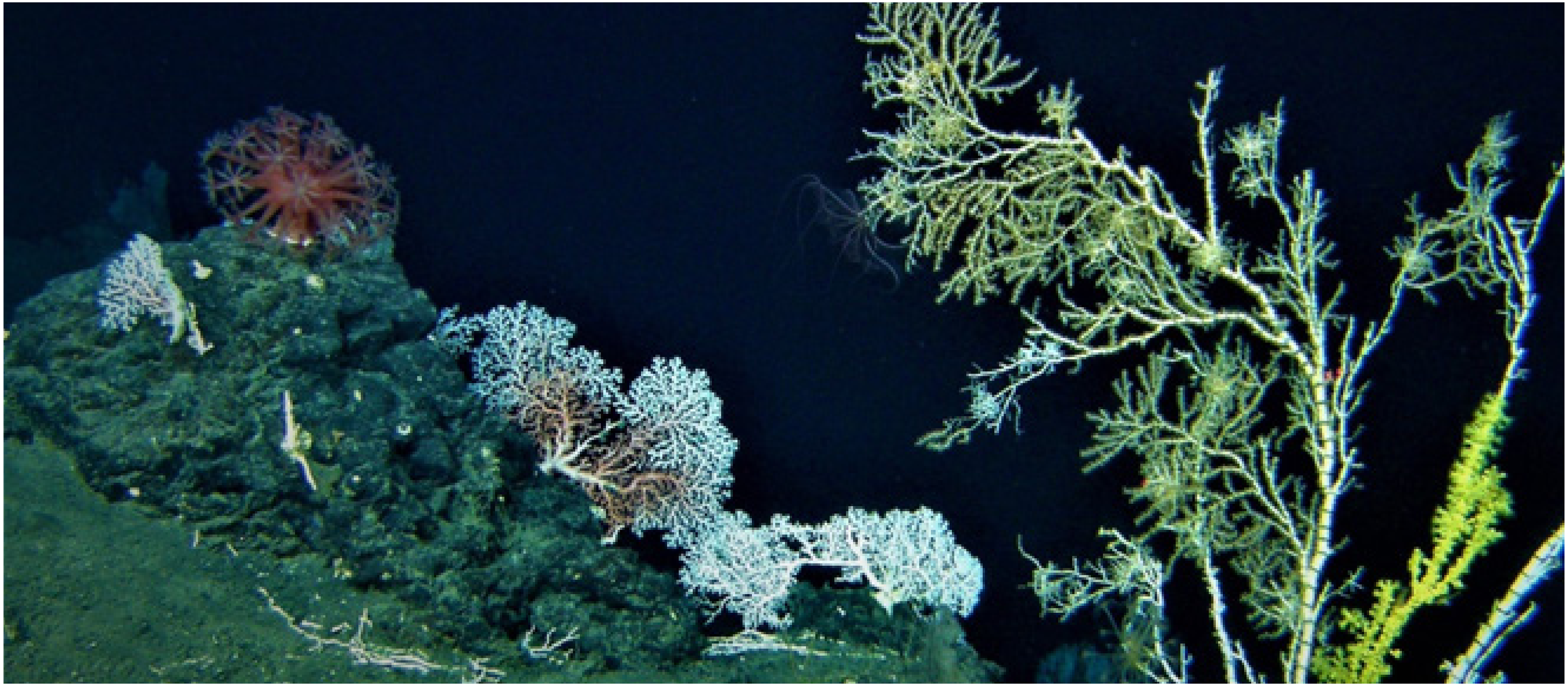
Like shallow-water corals, deep-sea corals may exist as individual coral polyps, as diversely-shaped colonies containing many polyps of the same individual, and as reefs with many colonies made up of one



or more species. They also serve as a habitat for deep sea creatures like sea stars and sharks. Unlike shallow-water corals, however, deep-sea corals don't need sunlight. They obtain the energy and nutrients they need to survive by trapping tiny organisms in their polyps from passing currents.

Exlporation

The ***Deep Reef Observation Project*** (DROP) is a Smithsonian research program launched to explore marine life and monitor changes on deep reefs in the southern Caribbean. Scientists turn to submarines to explore at depths too great for SCUBA gear. The Curasub is



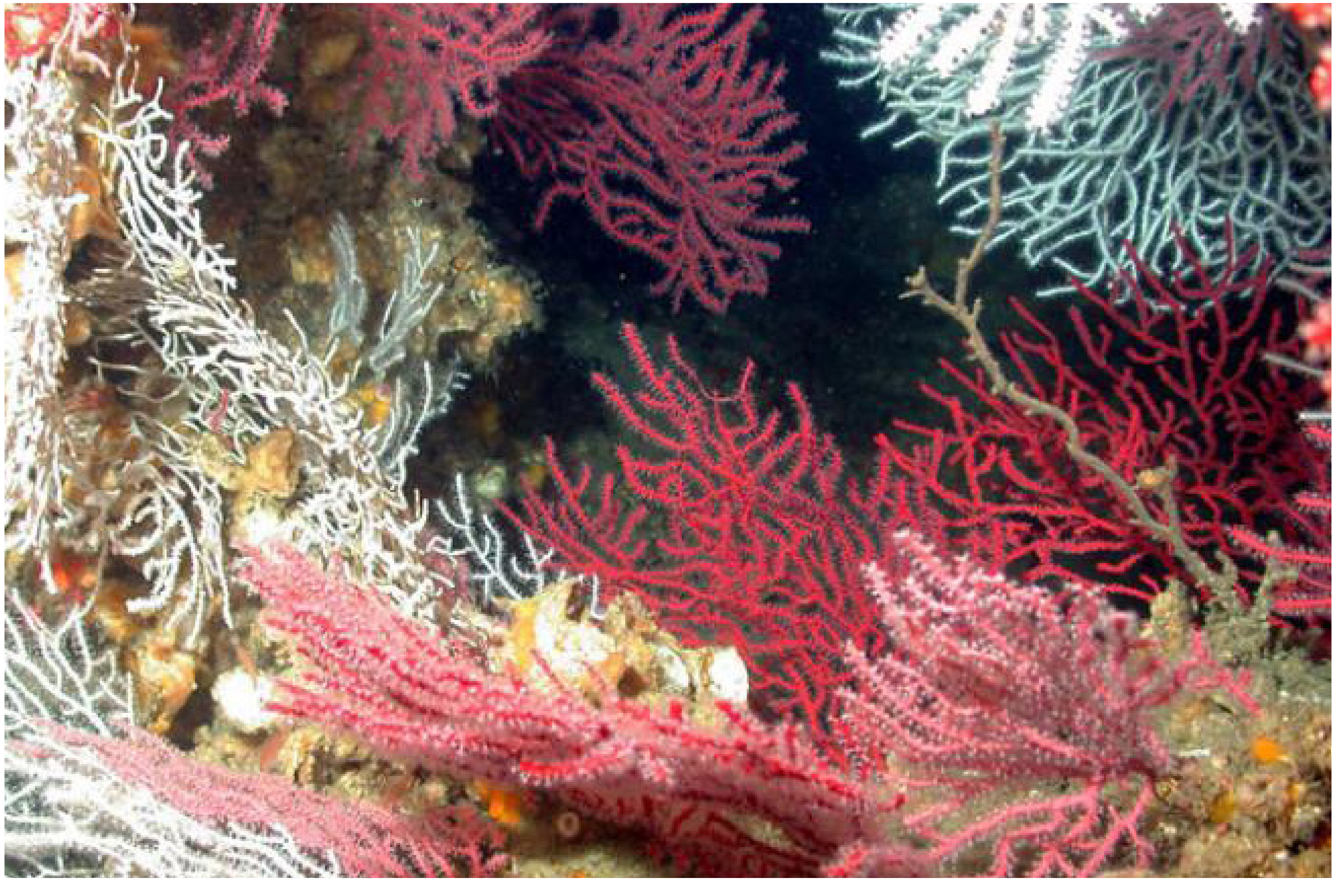
a 5-person manned submersible capable of descending to 1,000 feet. The state-of-the-art sub is equipped with hydraulic collecting arms that allow for the collection of marine life and the deployment of long-term monitoring devices on the deep reef.

Biological collections from the Curasub off Curacao have resulted in the discovery of numerous new and rare species of fishes, marine mollusks, echinoderms and crustaceans. This project utilizes the taxonomic expertise of more than a dozen Smithsonian scientists and employs modern molecular tools and digital photography and videography to document species and genetic diversity on deep reefs.

Preservation

Deep-sea corals are often found in areas of oil and gas operations, so there is potential for damage from drilling muds and oil spills. Deep-sea mining is fast becoming a reality, with vast areas of the high seas leased for exploration. These mining machines are large and may permanently remove large areas of deep-sea coral habitat. In addition, future impacts from climate change are not well understood, but increasing temperatures may shift species,Äô distributions and increasing acidity may weaken coral skeletons, particularly in deeper waters where the impacts of ocean acidification are thought to be greatest.

Most of the deep coral research in the Gulf of Mexico has focused on the northern region, which is where energy interests are focused, but the eastern Gulf is relatively unexplored. One of the primary objectives of this expedition is to explore and describe deep-sea coral communities on the west Florida slope. Earlier surveys in this area discovered abundant and thriving Lophelia reefs, as well as aggregations of large black corals. However, multibeam surveys have revealed vast areas where other promising features that have never been explored.



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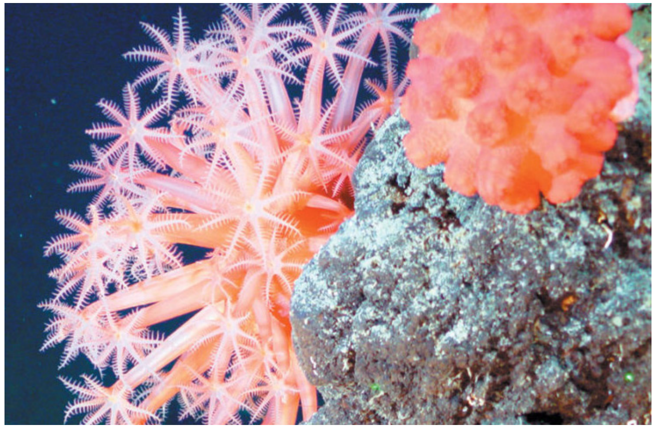
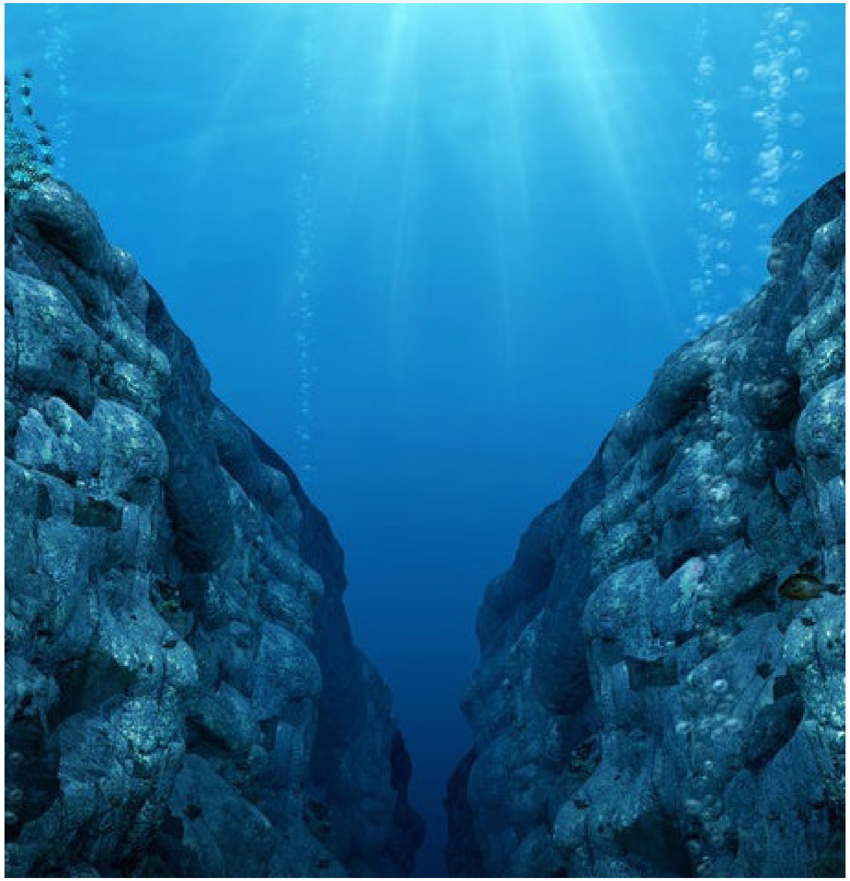


Some of the known coral habitats have been proposed as ***habitat areas of particular concern*** (HAPC) and any additional information we can provide will help support this process, as well as other management and conservation actions. While creating new protected areas cannot completely prevent damage from



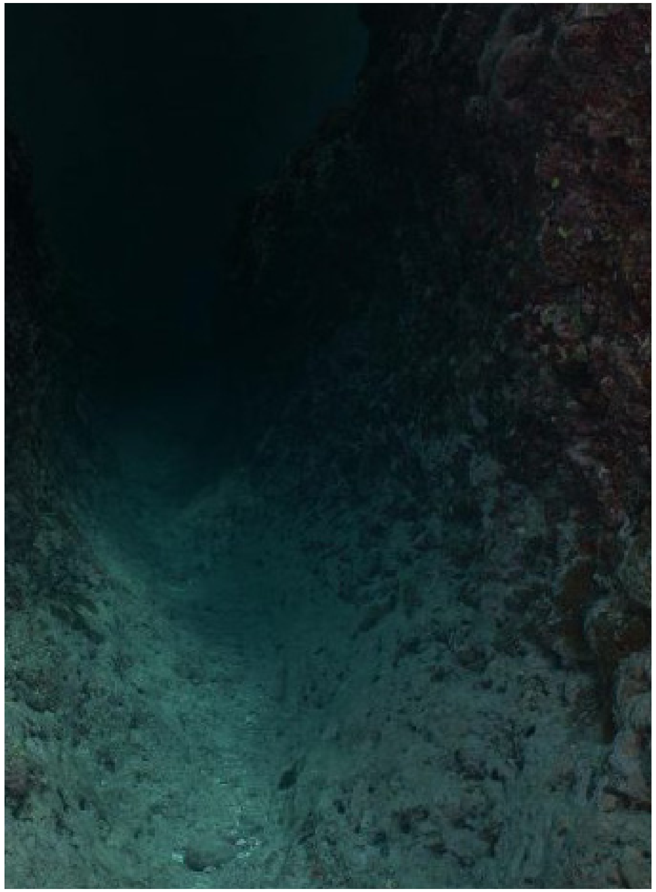
Landscape

Deep beneath the ocean's surface, towers spew scalding water from within the earth's crust. These are known as hydrothermal vents.

Hydrothermal Vents

Hydrothermal vents exist in volcanically active areas. Seawater makes its way through the cracks in the earth's crust until it reaches hot magma. As the water heats it absorbs metals like iron, zinc, copper, lead, and cobalt from the surrounding rocks. Hot water rises, carrying these minerals to the surface of the sea floor. There, it meets cool ocean water, an event that sparks chemical reactions and forms solid deposits. Over time the deposits create towers— forming the classic image of a hydrothermal vent. Some spew water filled with black iron sulfide and are aptly named "black smokers," while others spew white colored elements like barium, calcium, and silicon and are called "white smokers."

It seems like an impossibility—coming across a lake at the bottom of the ocean. But due to chemical and physical properties of water, this is, in fact, a reality. ***Brine lakes*** are super salty pools of water that sit on the ocean floor. The extreme saltiness causes significantly denser water than the average ocean water and, like water and air, the two do not mix. The salt difference is so definitive that sit-



ting above the brine lake, you can visibly see the lake's surface—even waves when the lake is disturbed.

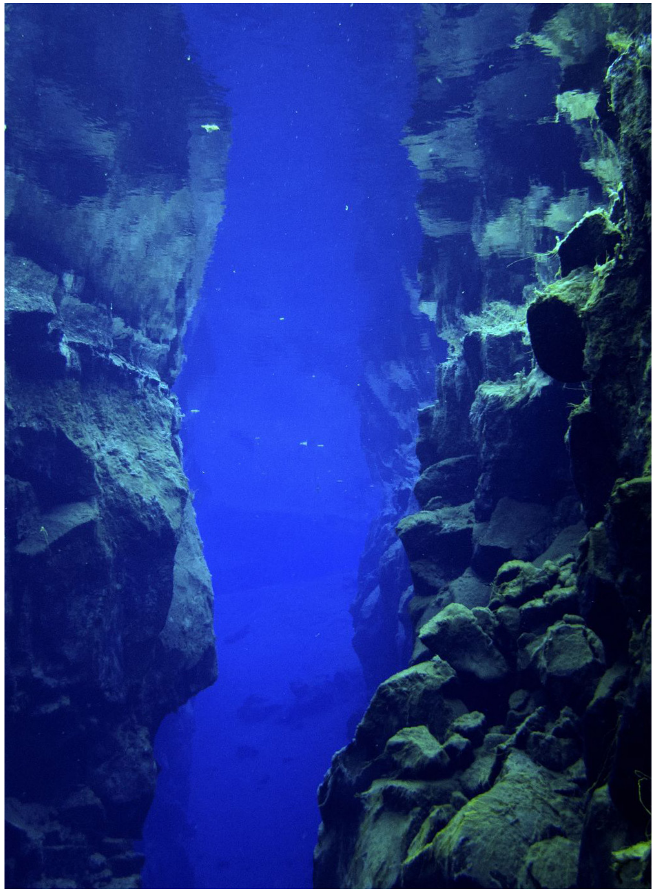
These brine lakes are a remnant of ancient seas that existed when dinosaurs roamed on land. Many brine lakes have been discovered in the Gulf of Mexico. Millions of years ago, during the Jurassic Period, a shallow sea existed where the Gulf of Mexico now sits. Cut off from the rest of the world's oceans, the

sea slowly evaporated, leaving behind a layer of salt up to 5 miles deep in some locations. By the time the ocean returned to that region, sediment had covered the salt, isolating it from the seawater.

But as the Rocky Mountains began to rise and subsequently erode, the extra weight of the sediment flushed into the Gulf of Mexico via the Mississippi River was enough to break the seal. Salt is naturally lighter than soil and as it became squeezed by the soil above, it began to rise. Near the earth's surface it began to mix with the seawater that was able to percolate into the sediment. This mixture though, was still many times the salinity of ocean water. The result is a brine lake.

Brine Lakes

Brine lakes are deadly for ocean creatures. The salt content is so high that creatures that "fall in" often die. Their carcass, pickled and preserved, serves as a warning of the toxic



landscape below. But for many creatures the risk is worth it. A brine lake is also an area high in methane and certain bacteria can use the methane in a chemical reaction to produce energy. Animals like mussels and crabs come to feed on the special bacteria by the lake's edge, and often there are whole communities that live along the shore. Along with the Gulf of Mexico, brine lakes have been discovered in the Red Sea as well as the coast of Antarctica.

Beyond the Light's Reach

The ocean covers nearly two-thirds of the Earth's surface and contains most of it's life, but little about this region is known and most of the ocean remains unexplored. In particular, the deep sea is highly mysterious and filled with unique and fascinating forms of life.