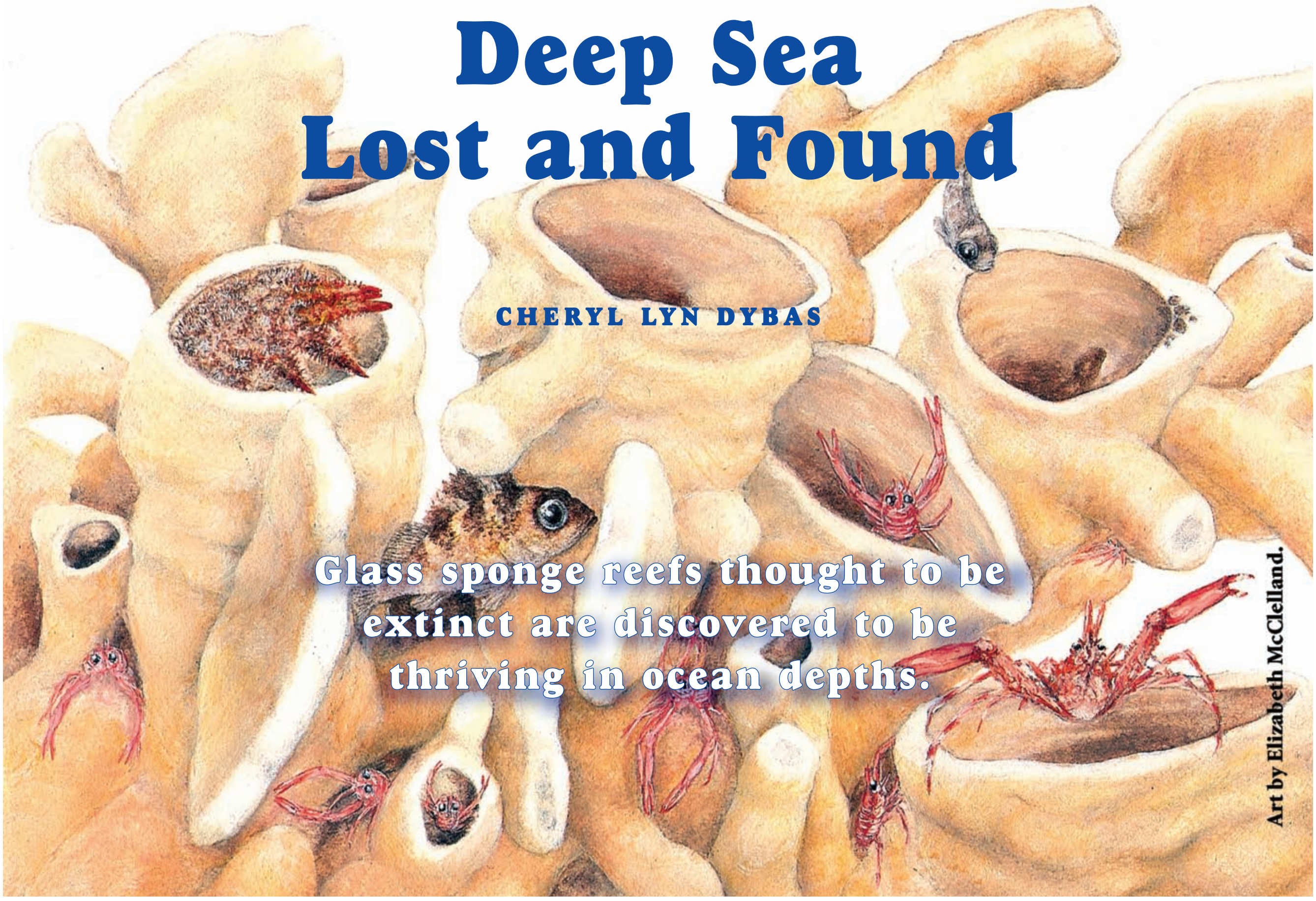
# Deep Sea Lost and Found

CHERYL LYN DYBAS

**Glass sponge reefs thought to be extinct are discovered to be thriving in ocean depths.**




Mummies, they're called, these strange shapes that form one of the largest structures ever to exist on Earth. Stretching some 2900 kilometers from Spain to Romania, the long, sinuous curve of millions of mummies—once-living, vase-shaped animals—is a fossil reef. In its heyday in the Jurassic, the reef dwarfed today's Great Barrier Reef off Australia's northeastern coast. Now it is visible only in rock outcrops dotted across a vast area of central and southern Spain, southwestern Germany, central Poland, southeastern France, Switzerland, and eastern Romania near the Black Sea. The ancient reef was made up not of corals but of deep-sea sponges called hexactinellids.

Hexactinellids, or glass sponges, use silica dissolved in seawater to manufacture a skeleton of four- or six-pointed siliceous spicules. Individual glass sponges, such as the beautiful Venus's flower-basket sponge (*Euplectella aspergillum*), are still found in the deep sea but are a different genus and species from the Jurassic reef-builders. Reef-building glass sponges, known only from fossilized remains, are thought to have gone extinct 100 million years ago, driven out by competition from newly arrived diatoms.

Diatoms also use the silica in seawater to build cell walls; however, these single-celled algae need the light of the sea's euphotic zone and so do not live in the deepest parts of the ocean. Though these nether regions remained an open niche for reef-building glass sponges, they were not colonized. Or so it was thought. "Nature had a few tricks up her sleeve," says Sally Leys, a glass sponge expert at the University of Alberta, Canada, "tricks that none of us could have imagined."

## The surprise find

The darkness beneath British Columbia's Strait of Georgia, Hecate Strait, and Queen Charlotte Sound concealed the next chapter in an eons-old tale. For decades, hints of something alive—something no one had seen before—washed up on the shores of Galiano Island in the Strait of Georgia. Walking along a beach on the island, long-time resident Elizabeth McClelland found pieces of an unidentified object in the tide line. "Every so often, I'd come across bits of flotsam that were very delicate but very sharp," says McClelland. "My granddaughter once found a fairly large piece of these unknown gifts from the sea."

Then came an odd clue at the bottom of Hecate Strait. During a 1984 seafloor mapping expedition, scientists from the Geological Survey of Canada, using sonar imaging, saw mounds over huge areas of the seafloor—areas that should have been completely flat. Similar acoustic anomalies, as geological survey scientists Kim Conway and Vaughn Barrie referred to them, were observed again in 1986 during a survey of Queen Charlotte Sound.

Reef-building glass sponges gave up their secret to Conway and Vaughn in 1987: underwater photography in Hecate Strait captured the sponges on film. Far from extinct, the sponges were thriving in the depths off British Columbia. Until the discovery, the study of glass sponge reefs by paleontologists such as Manfred Krautter, of the University of Stuttgart in Germany, was limited to the fossilized reefs of Europe. "When I first heard about the sponge reefs, I was electrified," says Krautter. "It was like finding a living dinosaur."

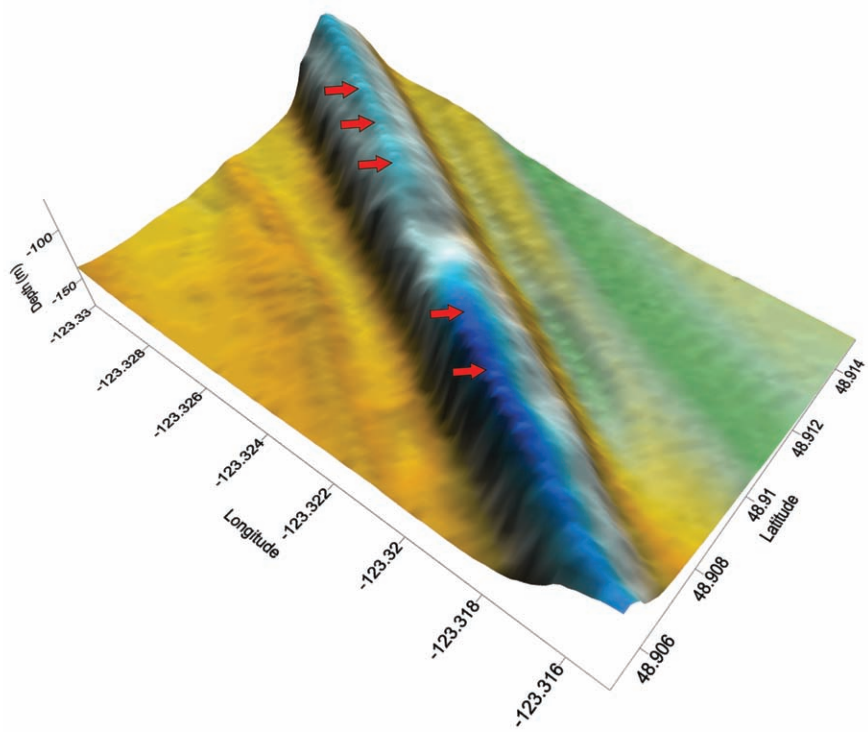
In 1999, Canadian and German scientists, including Conway and Krautter, descended in a submersible to the depths of Hecate Strait for a firsthand look. Glass sponges, they found, not only were alive but had formed reefs that extended as far as could be seen from a submersible porthole.

McClelland learned that she'd been finding pieces of a glass sponge reef, Galiano Island Reef. "Every time I look at the water," says McClelland, "I think it's incredible that these supposedly extinct reefs were right there all the time, sending out signals of their existence in what washed in with the tide."

The sponge reefs—some of which are 6000 years old, 18 meters high, and 700 square kilometers in surface area—are all below 150 to 250 meters of water, according to biological oceanographer Verena Tunnicliffe, of the University of Victoria. "What we know of these animals has been constrained by limited access to their habitat. That's why we didn't find them for so long. With developments in technology, such as remotely operated vehicles [ROVs], we now have 'eyes in the sea'—even in very deep waters."

The reefs occur as bioherms, or mounds, and as biostromes, or sheets. The sponge bioherms off British Columbia are steep-sided, six-story glass castles. The biostromes extend over distances many times the length of the island of Manhattan.

"As far as anyone knows, the glass sponge reefs in the Pacific Northwest are the only living such reefs in the world," says Tunnicliffe. "It's possible, however, that where there are favorable conditions for reef growth, such as along the Alaskan continental shelf and around the Bering Strait toward Japan, other reefs may exist."




*Reef mounds perch on the top of the knife-edge Galiano Ridge, a feature caused by glaciers some 5000 years ago. Along a 2-kilometer stretch of the ridge, the sponges form curious clusters (shown by the red arrows) like copses of shrubby trees, each about 100 meters across, only 100 meters from the surface. The multibeam bathymetry was kindly provided by Kim Conway of the Geological Survey of Canada (GSC Pacific). Graphic: Sally Leys, University of Alberta.*

*On the Fraser Ridge in the depths of the Strait of Georgia, glass sponges form very large mounds. The sponges grow on the skeletons of dead predecessors. Here, a large mound of the glass sponge* Heterochone calyx *displays two color forms: white and yellow. Photograph © 2004 VENUS Project, University of Victoria.*

*Although the glass sponges of Fraser Ridge live under sediment dumped by the outflowing Fraser River, they appear to keep very clean. Here, two species of reef-forming sponge show a variety of forms. The sponges seem to be growing from the sediment but are actually attached to dead sponge skeletons. Photograph: Sally Leys and Verena Tunnicliffe.*

## The making of a reef

"Two main types of glass sponges are known," says Leys, "those whose spicules are loosely held together—non-reef-forming species—and those that mold silica into a rigid, three-dimensional scaffolding that resembles a delicate glass palace—the reef-forming variety."

Individual glass sponges are found in the depths of the Caribbean, the Indo-Pacific, and the North Atlantic and South Atlantic oceans. In four places in the world, they're found in shallow, but deep-sea-cold, waters: Antarctica, the fjords of New Zealand, scattered caves in the Mediterranean, and the coastal waters of western Canada.

Glass sponges were first sampled in the late 19th century during the well-known early oceanographic exploration called the Challenger Expedition. "Use of modern techniques such as SCUBA, submersibles, and ROVs has vastly expanded our understanding," writes Leys in her book *The Biology of Glass Sponges*. "It's now possible to study the ecology and physiology of these sponges *in situ*."

Glass sponges fall into two main categories, based on the type of skeleton the animals produce: those with a loose spicule skeleton, called lyssacine sponges, and those with a fused spicule skeleton that forms a rigid exterior, called dictyonine sponges. Glass sponge reefs are made of dictyonine sponges.

The environment in the ocean off the Pacific Northwest offers an enticing locale for reef-forming sponges. More than 13,000 years ago, glaciers covered much of Hecate Strait and Queen Charlotte Sound. Icebergs scoured their way along the continental shelf, leaving behind berms of coarse gravel. It was on these berms that the sponges most likely began their construction.

Glimpsed through a submersible or ROV lens, today's glass sponge reefs loom out of dark waters as a forest of white, yellow, and orange bushes, says Leys. Some species have vast, gaping oscula, or openings, whereas others have undulating, billowing palmlike extensions. Still others are a mass of snow-white frills.

"The sponges turn silica from ocean water into long, sharp shards, which they mount together like a set of tent poles," Leys says. "Glass sponge reefs form just like coral reefs, with new generations growing on previous generations." The offspring of glass sponges are free-swimming larvae about a tenth of a millimeter in length, but no one yet knows when the larvae are released. "We've found juvenile glass sponges attached to skeletons of dead sponges in the summer months," Leys offers, which could be a clue.

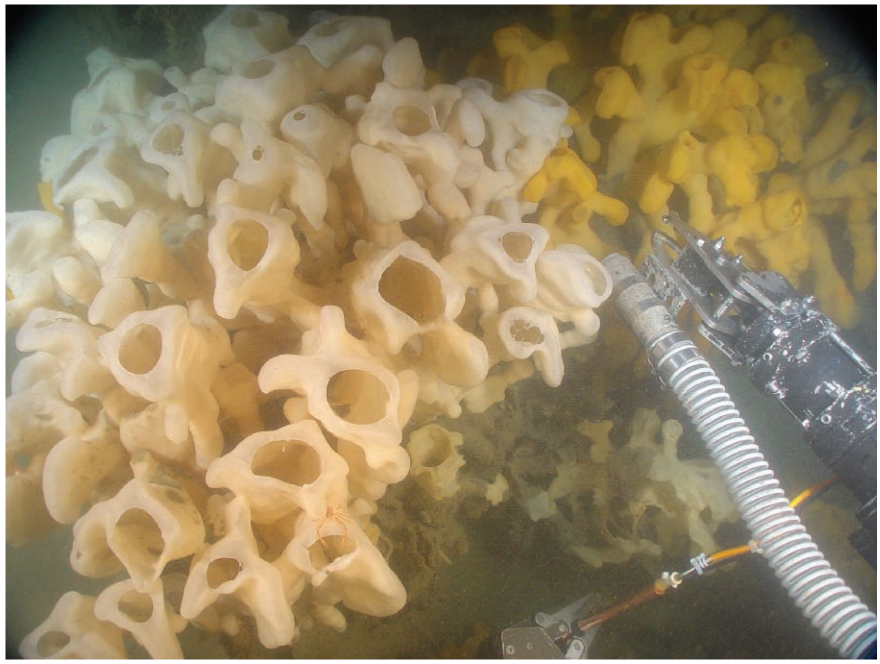
Three main species form the glass sponge reefs of British Columbia: *Chonelasma calyx,* the goblet sponge; *Aphrocallistes vastus,* the cloud sponge; and *Farrea occa,* which has no common name. Because these sponges are found in so few locations, there must be specific requirements for their growth, scientists believe. Cold water, low light, high dissolved silica concentrations, and low sedimentation rates are the keys. The first three are found throughout the coastal waters of the Pacific Northwest, says Tunnicliffe. Water temperatures at depths where reef-building glass sponges live are between 6 and 12 degrees Celsius, and little light reaches the sponge reefs.

"High silica concentrations are critical for the growth of these sponges, because so much silica is needed in their skeletons," says scientist Gitai Yahel, of the University of Victoria and the Ruppin Academic Center in Michmoret, Israel. Levels of dissolved silica are especially high in the waters off the Pacific Northwest.

"Because of glass sponges' extensive uptake of silica, the sponges may be a major unrecognized component of the global silica cycle," says Tunnicliffe, "forming a sink for dissolved silica that is comparable, if not larger than, that of diatoms." Glass sponge reefs therefore may be an important factor in much of the seas' biodiversity.

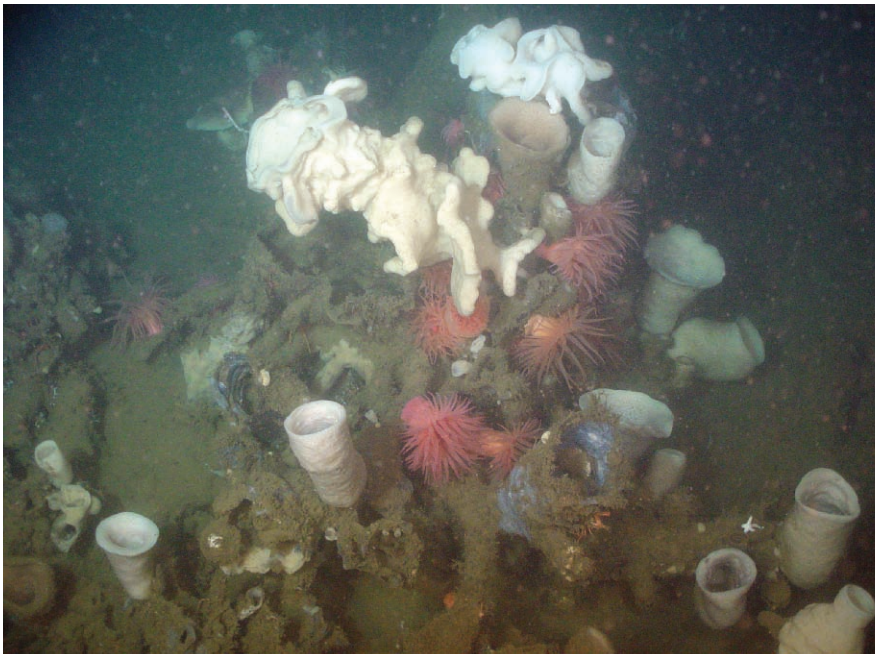
The role of sediment in the lives of glass sponges is more uncertain, says Yahel. "While some sediment is needed to cement the skeletons into a reef matrix, reef-forming glass sponges don't survive where there are a lot of fine particulates in the water." Most animals that filter water to feed—such as glass sponges—have ways of foiling sediment clogs before they happen.

"Glass sponges are particularly unusual animals because the majority of their soft tissue is made of one giant multinucleated cell, not individual cells like other animals," says Leys. "As a result, some species of glass sponges can send electrical signals through the whole animal, in much the same way that signals travel through nerves." The signals reach all parts of the sponge and cause it to stop filtering water for bacteria, its main



*The ROPOS (Remotely Operated Platform for Ocean Science) arm manipulates an oxygen sensor near bushes of goblet sponges. The brilliant orange betrays the presence of a hydroid symbiont that lives in* Heterochone calyx. *The symbiont is never found in* Aphrocallistes vastus, *so its tubes are always creamy white. Photograph: Sally Leys, University of Alberta.*

*The cloud sponge,* Aphrocallistes vastus, *is one of the most important reef-forming glass sponges. It pumps water through its walls and out a central opening. This species often forms "mittens" to increase its surface area. The gray patches are settling sediment from the Fraser River. Photograph © 2004 VENUS Project, University of Victoria.*



*Sponge reefs attract many other species of animals. Here, on the edge of Fraser Reef, 185 meters below the surface of the sea, two specimens of cloud sponge (*Aphrocallistes vastus*) represent the main reef-forming species, while numerous other sponge species, anemones, and squat lobsters enrich the community. Some of the wooly brown tubes are actually live boot sponges (most likely* Rhabdocalyptus dawsoni*). Photograph © 2006 VENUS Project, University of Victoria.*

food source. After a few minutes, the sponge will start filtering again, but if silt is still swirling around, the sponge will stop, thus testing the waters until they're clear of sediment.

Research on glass sponge distribution in four British Columbia fjords—Saanich Inlet, Howe Sound, Jervis Inlet, and Knight Inlet—showed that the sponge reefs are least abundant in Knight Inlet. This inlet has the most sediment input of the four studied, a result of runoff from the Klinaklini River. Few sponges were found near the head of Knight Inlet, and those that were discovered were "dripping in mud," stated researchers making observations from a submersible.

Juvenile reef-building glass sponges must settle on surfaces that aren't smothered by sediment, such as fjord walls or the surfaces of existing glass sponge reefs. Given this requirement, a recently found glass sponge reef on the Fraser Ridge off the mouth of British Columbia's Fraser River, a sediment-laden environment, is surprising. "But there's another factor at work here," says Leys. "Currents along the Fraser Ridge move fast enough to prevent the sediment from settling out." An important question, she adds, is whether the Fraser Ridge glass sponges are adapted to riding out spring sediment loads from snowmelt coming down the Fraser River, or whether the water is carrying more food than problem-causing sediment.

Reef-building glass sponges grow 2 to 7 centimeters each year. Some animals grow faster than others, perhaps because they're located in more promising feeding areas. Most grow more rapidly when they're young and slow down as they age. The largest sponges, 1 to 2 meters long and wide, are estimated to be 50 to 220 years old. The age of one glass sponge reef in Queen Charlotte Sound, some 5 meters thick, is estimated at 6000 years.

## More glass sponge secrets

Even after the spectacular discoveries of the late 1980s and 1990s, the glass sponges hadn't given away their entire story line. In June of 2007, geologist Paul Johnson, of the University of Washington, discovered large colonies of glass sponges thriving on the seafloor 30 miles west of Grays Harbor, Washington. This discovery extends the range of reef-building glass sponges into the open ocean, as those off British Columbia are all in nearshore areas.

The Washington glass sponge reefs, however, added yet another element to the story. "They appear to be thriving on specialized bacteria that consume methane gas, which we were surprised to discover flowing out of the sea floor in copious amounts," says Johnson. These reefs could be a new-to-science ecosystem on the Pacific continental shelf, one fueled by methane gas derived from ancient carbon in the sediments.

"Methane is a simple compound of carbon and hydrogen and is produced from ancient organic matter buried in Earth's crust," says Johnson. "While undersea methane seeps aren't unusual, the sponges off Grays Harbor are sitting right on top of one—very unusual indeed."

The bacteria on which these glass sponges feed may be methanotrophic, or methane-eating, bacteria. Methanotrophic bacteria extract energy from methane the way human cells get energy from sugars. "Methane is a tremendous energy source for many life forms," says Johnson. "Wherever you find methane seeps in the ocean, usually there are huge populations of methanotrophic bacteria."

Methanotrophic bacterial mats in other parts of the deep sea support animal communities dominated by tubeworms and clams. Johnson believes that methane beneath the Washington glass sponge reefs could be fueling an analogous food web, with methanotrophic bacteria feeding sponges and other creatures across a vast area of the seafloor.

"We don't have the right samples yet to prove that this 'island of life' gets its nutrients using chemosynthesis from methane, rather than photosynthesis from the sea surface," says Johnson, "but we're working hard to get them." He hopes to discover the link using carbon isotopes, because the ratio of carbon isotopes in the methane near the Washington reefs is distinctive. Johnson thinks the cells of organisms that depend on the methane seep will carry the same ratio.

"I've spent a lot of time looking at the exotic animals around hydrothermal vents," says Johnson, "but glass sponge reefs and the ecosystem they support are even more impressive."

## A deep-sea garden

"Glass sponge reefs provide habitat for an incredible variety of organisms," echoes Tunnicliffe, "and form the base of an ecosystem that extends well beyond the reef area." Benthic suspension feeders like glass sponges play a primary role in many coastal and ocean ecosystems. Where populations of these animals are dense, "they can have a major impact on the entire water column and even on the topography of the seafloor," Johnson says.

Reef-forming glass sponges are considered a "foundation species"—one that exerts a disproportionately large influence on the structure of a biological community through the creation and maintenance of a habitat. Marine reef-forming species, which include both glass sponges and corals, reduce physical and biological stresses in their semienclosed environment, limit the intensity of bottom boundary currents, modify nearby sedimentation, increase or decrease numbers of bacteria, influence species competition and predation, and change the chemistry of the near-bottom seawater, Johnson reports.

The production of new and complex habitat by glass sponges isn't limited to those areas of the reef containing living sponges, says Tunnicliffe. It extends to the adjacent nonreef areas and the dead reef skeleton framework, which, for some fauna, is more enticing than the sponge reefs themselves.

Wherever the seafloor is covered with sponge skeletons, openings of different sizes and shapes welcome many animals, including several that are commercially important. "Pregnant and juvenile rockfish, for example, are abundant in both the living and dead sections of the reefs," says Yahel, "indicating that all parts have a 'nursery function.'"

*A hairy-spined crab (*Acantholithodes hispidus*) hides in the creamy white osculum (vent) of a cloud sponge. Below, left, a tiny squat lobster (*Munida quadrispina*) waits for tiny fish or arrow worms (chaetognaths) to swim by. Photograph: Sally Leys, University of Alberta.*

Octopuses are often "arm to arm" in areas immediately adjacent to the reefs, "leading to the conclusion that their [the reefs'] biological productivity can support large numbers of predators," says Yahel. Crabs and other crustaceans also are common there, as are shrimp, prawns, euphausids, and squat lobsters.

"The glass sponge reefs off Grays Harbor are alive with zooplankton, sardines, crabs, prawns, and rockfish," says Johnson. "If you look at the reef and surrounding areas as one entity, it's like an overcrowded aquarium in an expensive Japanese restaurant."

## A shattered future?

All is not well in these deep-sea palaces of glass, however. Many glass sponge reefs have been damaged by trawl fishing and are further threatened by efforts to lift a moratorium on exploration for oil and gas resources off British Columbia. The future of these globally unique and fragile reefs hangs in the balance.

Glass sponge reefs have been heavily impacted by fishing gear, according to Conway. "Paired tracks of otter trawl fishing nets can be seen on side-scan sonar records. Given the fragile nature of the sponges, they wouldn't survive being dragged with this type of equipment."

A correlation exists between steep terrain, Conway and colleagues found, and the health of sponge reefs. "Steep glacial and rough bedrock slopes are where the healthiest glass sponge reefs are largely found, due to more difficult access by trawl-equipped fishing vessels," they write in a paper in the Geological Survey of Canada's *Current Research* series. "It's probable that reefs in deeper,

For more information, visit these sites:
*http://cpawsbc.org/pdfs/glass_sponge_reefs.pdf*
*www.ucmp.berkeley.edu/porifera/hexactinellida.html*
*www.porifera.org/a/ciopen.html*

low-slope-angle [flatter] seabed areas have been trawled."

In one reef Conway and others surveyed, "living but broken sponges and dead sponge debris were very common," they write in *Current Research*. "Trawling may accentuate the piling up of sponge debris." The near absence of rockfish at damaged sites, compared with undisturbed reefs where rockfish are very common, indicated that reefs had been subjected to trawling.

"A startling summary of observations from the British Columbia groundfish bottom trawl fishery has shown that between 1996 and 2002 about 253 tons of corals and sponges were harvested as bycatch," writes Leys in *The Biology of Glass Sponges*. "Because these are noncommercial species, it's thought that many additional observations went unreported." An analysis of the regions in which most bycatch occurred showed 12 patches where 97 percent of all coral and sponge bycatch occurred, many adjacent to and on the glass sponge reefs.

Voluntary avoidance of the reefs was agreed on by trawl fishers in 1999, but although fishing was reduced, landings continued in areas near glass sponge reefs. In 2002, the Canadian government stepped in and mandated trawl fishery closures directly over the reefs. Despite these closures, however, new impacts on previously unaffected reefs have been discovered.

Researchers in submersibles observed reefs in Hecate Strait with broken skeletons, the remains piled in mounds on the seafloor. Stumps of sponges, and sponges with abraded edges, also were seen during these dives. "It was a shock to find that the northernmost reef in Hecate Strait has been damaged," says Krautter. "What was once the most pristine part of these reefs will take thousands of years to recover, if it ever does."

McClelland shares Krautter's concerns. "Shrimp boats often ply the waters just above Galiano Reef," she says, "a worry for the future of the glass sponges. I hope the area around this reef, and others like it, will be completely closed to fishing or any other human activity." Without that protection, the glass sponge reefs of the Pacific Northwest may join their European counterparts, existing only in history. In death, their lovely silica glass bodies hollowed out and fossilized, they too will be mummies.

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