



WHALE FALL

The fatty bones of dead whales provide rich pickings for creatures on the sea floor. Amanda Haag meets the scientists who go to extreme and unpleasant lengths to study the unique ecosystems on these corpses.

In 1987, a manned submersible called *Alvin* was making a routine dive along the muddy plains of the deep sea when its pilot spotted what he thought was the fossilized remains of a dinosaur. Instead of an exotic underwater beast, it turned out to be the 21-metre-long skeleton of a blue whale. But atop this mass of bones the pilot did find something exotic: a carpet of creatures, including bacteria and worms, similar to those found on the flanks of underwater volcanoes.

The *Alvin* team had happened upon what have since become known as 'whale falls' — communities of creatures that thrive among the sulphur-laden ooze of decaying whales. Just as windfalls deliver a sudden bounty of ripened fruit, whale falls see the death of a whale bring a host of nutrients to the sea floor. The falls are few and far between, and difficult to track and study, but researchers are learning ever more — sometimes through extreme measures — about the new species to be found among the remains. Some 39 of the species discovered so far are thought to be especially suited or even unique to this environment.

In the barren depths of the open ocean, a fallen whale carcass is a veritable feast. Scavengers such as sleeper sharks, hagfish and squat lobsters can dine for months to many

years on the soft tissue of a single whale, depending on its size. As bits of whale tissue spread around the carcass, the enriched seafloor sediment provides nutrition for opportunistic worms and crustaceans. As anaerobic bacteria further the whale's decomposition, they create a sulphide-rich environment allowing sulphur-loving creatures to move in. Worms, clams and mussels, to name but a few, all take up residence, each getting their metabolic fix

from the chemical energy provided by the fat-rich marrow in whale bones¹.

Such complex communities have not been reported on the bones of other marine mammals, says Craig Smith, a whale-fall expert from the University of Hawaii at Manoa. This is probably because whale bones are so much larger and fat-rich, he says.

Scientists now estimate that a whale-fall community can survive for up to a century by sucking the fats and sulphides from these bones. The bacteria that make their home on whale falls are so good at degrading fat in cold waters that the biotechnology company Diversa in San Diego, California, is looking to see whether their enzymes

might prove useful in cold-water detergents.

For scientists such as Smith, studying whale falls presents some inherent challenges — not least of which is finding a body to examine. Many whales die when female whales or newborns, stressed by the process of birth, make their annual migration. In the Pacific, for example, there are often casualties on the long trek north to Alaska from birthing grounds along the Baja Peninsula of Mexico. Although whale carcasses tend to accumulate along these migratory paths, they fall at random locations and can be spaced very far apart.

Body hunt

"They're hard to find because you can't just follow a particular geological feature on the sea floor and drive up to them like you can with hydrothermal vents," says Smith. In the early 1990s, the US Navy surveyed more than 300 square kilometres of the Pacific sea floor in search of a lost missile and found eight whale skeletons. The navy contacted Smith, but didn't take exact coordinates of where the skeletons were located. When Smith's team returned to the site, it could find only one of the eight.

So far, ten natural whale falls have been investigated by the dozen or so scientists who study them. And another 20 have been

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— Thomas Dahlgren

Food for thought: the decomposing carcass of a whale can support a whole host of organisms.

weigh it down with up to 3,000 kilograms of scrap metal, from train wheels to anchor chains. It can take two days to get a whale from the shore to the sea floor — and all those involved agree that it is a highly unpleasant process. “We often throw away our clothes because you can’t get the smell out,” says Smith. “It’s one of the hazards of the job.”

Researchers have so far sunk about 20 whales this way. They return to these whale falls regularly to monitor the colonization of organisms on the remains. Smith’s group placed a time-lapse camera on one carcass, which took pictures more-or-less continuously for eight months. Others send submersibles to the sites, which can pick up rib bones and vertebrae and bring them to the surface with the communities still alive and mostly intact.

Thomas Dahlgren, a population geneticist at the Tjärnö Marine Biological Laboratory in Strömstad, Sweden, has been fortunate enough to sink a whale near his lab. The whale falls that have been studied off the coast of California tend to be 1,200–3,000 metres deep and at least half-a-day’s cruise away from the nearest lab; Dahlgren’s whale is 125 metres deep and just half an hour from his office. “We’re not stuck on a ship in the Pacific bobbing around with a limited time until the cruise is over,” says Dahlgren. He and his team can sample the whale fall as often as once a week.

Dahlgren’s lab also keeps whale bones with live specimens in a seawater tank.

Unlike creatures found at hydrothermal vents, which can only survive at the high pressures found at the bottom of the deep sea, some whale-fall organisms seem to adapt quite well to life on the surface. “Whale bones are hanging in our cold room with cultures of these whale bacteria stuck all over them,” says Dahlgren.

Crunch time

Such research has unveiled a number of strange creatures. Perhaps the prize find so far is a newly described worm genus, *Osedax*² — Latin for ‘bone-devourer’ — which has a clever metabolic strategy. With no mouth, stomach or eyes, *Osedax* has evolved a root system to excavate the fat out of whale bones. The worms tunnel into the bones with their green, fleshy roots and turn them into “Swiss cheese”, says Smith. The worms then rely on bacteria

within their tissues to digest fats and oils from the bone marrow. Although the bacteria are similar to those found in oil slicks, this sort of microbe has never been found in a symbiotic partnership with another creature before.

So far, researchers have found five species of *Osedax* — four in the Pacific and, most recently, one in the Atlantic, implying that the worms have a worldwide distribution. Two of the species have a matriarchal society of sorts, in which all of the female members are about the length of an index finger, and the males are mere microscopic threads that live inside the females’ oviducts. A single female can hold up to 111 males.

Another oddity is a whale-fall worm nicknamed ‘Pinky’, which at first evaded identification by its

researchers, including Greg Rouse at the University of Adelaide in Australia. After much head-scratching, it became apparent that Pinky was just a polychaete worm — the class that includes ragworms and lugworms — albeit much larger than its shallow-water relatives. “Pinky is a giant,” says Rouse. “He’s more than one centimetre long, whereas his relatives are of the order of a couple of millimetres. Pinky’s also quite fat.” The worm measures a whopping one to two millimetres across.

Many mysteries about the whale-fall communities remain. For one thing, scientists are trying to find out how larvae from whale-fall organisms that are spawned into the water live long enough to find their way to another bone. “It is really clever. We don’t know how they do it, but they do it,” says Paul Tyler, a deep-sea ecologist at the Southampton Oceanography Centre, UK.

Scientists guess that the creatures in whale-fall communities probably date back some 35 million years. But in the past few centuries they have faced a serious threat. Smith estimates that whaling in the 1800s and 1900s reduced whale-fall habitat by up to 95%, potentially wiping out up to half of the species that were specialized to live on whale carcasses in some ocean basins³. Each time a whale was dragged aboard a ship, it not only depleted the live stocks, but also those of the dead falling to the sea floor. It’s not just the whales that needed saving, notes Smith. If hunting had continued apace it might have wiped out not only the great whales, but Pinky too.

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1. Smith, C. R. & Baco, A. R. *Oceanogr. Mar. Biol. Annu. Rev.* **41**, 311–354 (2003).
2. Rouse, G. W., Goffredi, S. K. & Vrijenhoek, R. C. *Science* **305**, 668–671 (2004).
3. Smith, C. R. in *Whales, Whaling and Ocean Ecosystems* (ed. Estes, J.) (Univ. California Press, Berkeley, in the press).



Sinking feeling: intrigued by *Osedax*, a newly discovered genus of bone-eating worms (top and inset), and other odd creatures, scientists tow dead whales to the deeps for study.

sampled accidentally by trawling fishermen. In an attempt to increase these numbers, whale-fall researchers have resorted to sinking beached dead whales. But sinking a four-tonne juvenile grey whale, or a 35-tonne adult, is a major undertaking, says Smith.

When researchers get a call about a washed-up whale, they mobilize their teams and ships. By the time they reach the whale it is often bloated with gases from decomposition. To get it to sink, the scientists have to