Ocean Scientists Find Life, Warmth in the Seas

SAN DIEGO—About 2000 marine scientists gathered here at the 1998 Ocean Sciences Meeting from 9 to 13 February, during a relatively sunny respite from the El Niño–driven storms that have battered California. At the biennial gathering, hosted by the American Geophysical Union and the American Society of Limnology and Oceanography, El Niño for once took a back seat to other explorations of the state of the world's oceans and the life they contain.

Life Among the Whale Bones

Life on the floor of the deep sea is harsh. Sunlight is a distant memory, and there isn't much to eat—except for teeming bacteria at the oases where hot, sulfide-laden water spurts from the seabed, or cold oil and gas seep from sediments. But every so often, a huge source of food thumps to the ocean bottom: a whale carcass, blubbery manna from on high.

At the meeting, oceanographer Craig Smith and his colleagues at the University of Hawaii, Honolulu, presented research showing that an unexpected variety of marine organisms crowd in for these feasts. The skeleton of a single whale can support more species than are found at the richest hot-vent field, they found. Some of the animals apparently have evolved to live specifically on whale skeletons. "It's wonderfully exciting to discover yet another major community living in the deep sea," says marine biodiversity expert Robert Hessler of the Scripps Institution of Oceanography in La Jolla, California.

Working in kilometer-deep waters southwest of Los Angeles, Smith's team members have intensively studied two of the dozen or so known whale skeletons on the sea floor. They also have deliberately sunk three whale carcasses to similar depths and repeatedly visited them via submersible. The team found that the first stage in creating a whale-skeleton habitat happens fast: Hagfish, crabs, and perhaps an occasional shark reduce each body to bones within about 4 months, rather than the years researchers had expected.

Once the scavengers scurry away, bacteria take over. Whale bones are rich in oils, providing buoyancy while the whales live and a greasy bounty when they die. Slice open a bone, says Smith's graduate student, Amy Baco, and you'll see a substance "like a thick, white fat." On the sea floor, anaerobic bacteria decompose this material and emit hydrogen sulfide and other compounds, which diffuse outward through the bone. Another set of bacteria live off the sulfides, coating the bones in thick mats. These chemosynthetic bacteria in turn support a host of worms, mollusks, crustaceans, and other animals. Such communities can thrive for years—the first one, discovered in 1987, was still going strong in 1995, Smith found.

Smith and Baco were most startled by how many species can swarm a single skeleton. When they hauled up five vertebral bones from one whale off southern California, Baco counted 5098 animals from 178 species, even though the bone surface area totaled just 0.83 square meter. Among them were 10 species—limpets, worms, and other critters—that seem to live only on whale skeletons and apparently evolved in this habitat after large whales first appeared 40 million years ago, says Smith: "This is, by far, the most diverse deep-sea habitat on a hard surface yet discovered." In contrast, the most fertile known hydrothermal-vent field supports 121 species, and a single hydrocarbon seep might sport 36 species at most.

C. SMITH, A. BACO/UNIVERSITY OF HAWAII

No place like home. Whale bones on the deep, dark sea floor support a diverse and thriving community.

All these communities may be connected. At least 15 of the whale-bone species are also native to the other sulfide-rich habitats, says Smith. He feels that this bolsters his contention, first offered 8 years ago in *Nature*, that whale skeletons may serve as "steppingstones" for the dispersal of marine animals that depend on chemosynthesis. Otherwise, drifting larvae might not find these scattered, ephemeral habitats—especially some of the vent systems, which flicker on and off in decades or less.

Vent specialists applaud the finds but remain cool to the steppingstone scenario. Taxonomic analysis to date shows whale bones and hot vents share just eight species, perhaps too few to support that hypothesis, says biological oceanographer Lauren Mullineaux of the Woods Hole Oceanographic Institution in Massachusetts. And vents typically lie at depths greater than 1500 meters, Mullineaux says, whereas many whales—with the notable exception of sperm whales—live and die in the shallower, biologically richer waters along the edges of continental shelves. "We're also finding more and more vents every time we turn around," Mullineaux adds, so larvae may be able to hop among vents without steppingstones. Whether the whale skeletons are way stations or worlds of their own, she says, they show that dark, deep islands of life may be more common than anyone has imagined.

Sounding Out Pacific Warming

Sometimes the most clever theoretical ideas are the toughest to put into practice. By simply measuring the travel time of pulses of underwater sound, oceanographers have proposed, one could take the temperature of an entire ocean to watch how it responds to global warming. But for years this elegant scheme—now called the Acoustic Thermometry of Ocean Climate (ATOC) project—has endured delay because of concerns about whether the sounds would harm marine life, as well as doubts that it would work in reality. Now data presented at the meeting, from an extended trial run of the experiment, help clear away these scientific questions.

The new results show that temperature readings of the Pacific Ocean are even more precise than were projected, and marine mammals apparently aren't bothered by the sounds. But just as the project seems poised to fulfill its promise, another obstacle looms. Thanks to the rocky politics of funding long-term projects and a post–Cold War decline in ocean-acoustics studies, organizers aren't sure that ATOC will win the funding it needs.

Conceived 20 years ago by oceanographers Carl Wunsch of the Massachusetts Institute of Technology and Walter Munk of the Scripps Institution of Oceanography in La Jolla, California, acoustic thermometry exploits some basic physics of the oceans. Sound travels slightly faster in warmer water. And when a sound pulse travels through the deep ocean, distinct layers of salinity, temperature, and other physical factors combine to trap most of the energy within a specific channel of water, where it persists for thousands of kilometers. Sound therefore looks ideal for spotting long-term temperature trends in entire oceans. However, concerns about sound-transmitting properties at depth led some to question whether the idea would work in practice.

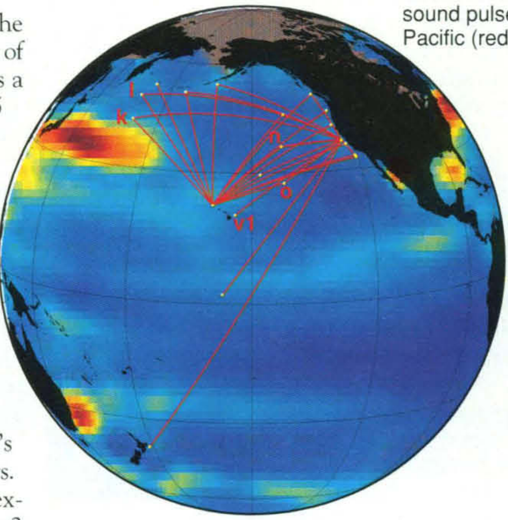
The answer, according to a report at the meeting by project director Peter Worcester of the Scripps Institution of Oceanography, is a resounding "yes." Data from the first 15 months, just submitted for publication, show that 195-decibel broadcasts from a source off the central California coast are picked up surprisingly well by arrays of sensitive hydrophones as remote as Christmas Island, 5000 kilometers away. ATOC scientists can pinpoint variations as small as 20 milliseconds in the hourlong travel time of the pulses. That's accurate enough to deduce the average ocean temperature along the sound wave's path to within 0.006 degree Celsius. "That's far better than we expected," Worcester says.

The acoustic patterns already reveal expected seasonal temperature cycles of about 2 degrees Celsius in the upper ocean. The new data "show that we could expect to see subtle, long-term climate changes in the ocean [with ATOC] long before any other means," adds Wunsch. But it's too soon to discern the mark of human-induced warming, which modelers project will amount to only a few thousandths of a degree per year in the deep Pacific. Teasing that out of background noise will require at least a decade of observations.

Meanwhile, ATOC's marine mammalogists have their own good news. Environmental groups delayed the project's launch for most of 1994 and 1995 by protesting that its long bass rumbles—mistakenly described in some media accounts as "blasts"—would deafen whales and seals. So sharp-eyed biologists have been monitoring whale and elephant seal behavior near the California sound source, 900 meters underwater and about 100 kilometers southwest of San Francisco. They've flown over it some 35 times during both "on" and "off" periods and haven't seen marked changes in the animals' swimming distributions, says bioacoustician Christopher Clark of Cornell University.

Researchers also released deep-diving elephant seals beyond the transmitter and used satellite tags to track their paths back to shore; the animals didn't swerve to avoid the sounds. "Biologically, [the source] is totally meaningless," says Clark. However, the verdict isn't in as to whether vocal whales will temporarily fall silent when exposed to the noise, as happens with explosions used for seismic studies. Clark's team is now recording vocalizations of several kinds of whales to see whether ATOC silences their songs.

Although the scientific doubts are largely cleared up, the project's original $40 million—a swords-to-plowshares grant from an environmental program at the Department of Defense—will dry up at the end of 1998. And prospects for a large-scale project, which Worcester says would require $5 million to $10 million a year, seem grim. "Everyone insists this is important research, but no one government agency is willing to stick with monitoring the oceans for 10 years," says Wunsch.



Ocean broadcasts. ATOC's sound pulses traverse the Pacific (red lines).

SOURCE: SCRIPPS INSTITUTION OF OCEANOGRAPHY

But at least one federal source proffers some hope. "I've seen some of their data, and it's really nice," says Jeff Simmen, program manager for ocean acoustics at the Office of Naval Research in Arlington, Virginia. Despite the long-term investment needed, he says the project "may get sufficient funding to continue," perhaps from a consortium of agencies, if scientists can clearly demonstrate ATOC's value.

RNA Can't Take the Heat

Many biochemists believe that the molecule most likely to have powered Earth's earliest life-forms was RNA. Only RNA seems capable of carrying out both of life's crucial functions: storing genetic information and catalyzing its own replication. But the molecule is notoriously fragile in warm conditions, and most scientists picture the early Earth as a steamy place. Research presented in an origin-of-life session at the meeting fuels those doubts by showing that RNA's chemical building blocks simply fall apart within days to years at temperatures near boiling—and may not thrive even in cooler environs.

Researchers already knew that RNA's chemical backbone is fragile, even at room temperature, but they speculated that other, alternative backbones might have held the molecule together in the early world. Now graduate student Matthew Levy, who works with origin-of-life specialist Stanley Miller at the University of California, San Diego, has shown that the information-coding units of RNA, its four nucleobases—adenine (A), cytosine (C), guanine (G), and uracil (U)—fare almost as badly. He found that at 100 degrees Celsius, half of each batch of nucleobases he tested would degrade in periods that ranged from 19 days (for C) to 12 years (for U). "We suggest that this makes an RNA-driven origin of life at 100 degrees very unlikely," Levy says.

The situation improves at the freezing point of water, where the half-lives for A, G, and U all exceed 600,000 years. But cytosine remains a weak link: It decomposes within 17,000 years. That may be too short for C to play a role in primeval life-sustaining reactions, as most biochemists believe that the first biological processes required high concentrations of the proper ingredients for a million years or so. (RNA and other frail molecules become far more stable once they reach the chemically sheltered womb of a cell.)

Levy and Miller argue that RNA's high-temperature infirmity implies either that it wasn't the first genetic material—and no one has yet proposed a viable alternative—or that the young Earth was a chilly place, perhaps layered by ice. But as noted by atmospheric chemist James Kasting of Pennsylvania State University in University Park in another talk at the meeting, most geochemical models still point to an ovenlike early Earth, blanketed in greenhouse gases—with "oodles of carbon dioxide"—for several hundred million years. "Then the whole planet is close to 80 or 90 degrees [Celsius]," he says—and there would be no "cold refugia" to harbor the sorts of frigid reactions that Miller envisions.

Worse, the early Earth weathered frequent comet and meteorite impacts, some of which could have heated the oceans to full boil and wiped out all nucleobases. Still, Kasting acknowledges, "no one has ruled out a cold Earth, because there are no data."

Biochemist Gerald Joyce of The Scripps Research Institute in La Jolla says it's more likely that some molecule other than RNA was the first carrier of genetic information. Joyce still thinks an "RNA World" preceded the DNA-protein paradigm of modern organisms—but that world probably evolved well after life's very beginnings. "You have to build straw man upon straw man to get to the point where RNA is a viable first biomolecule," he says. But if another self-replicating compound set the stage for RNA, it thus far has eluded the best efforts of researchers to find it.

–Robert Irion

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