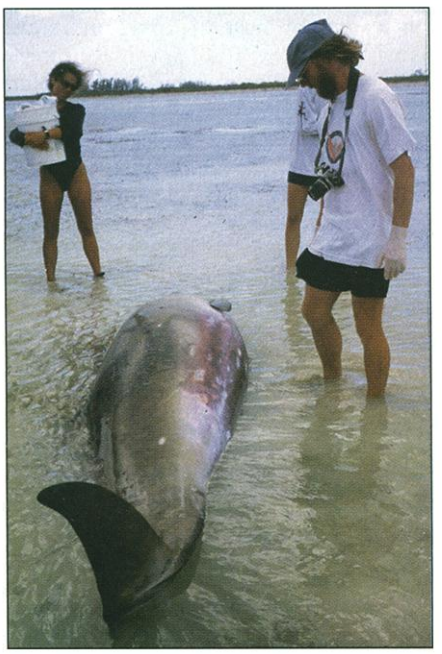
An unusual whale stranding and controversy over a new U.S. Navy sonar system have increased interest in studying how noise affects marine life

A Roaring Debate Over Ocean Noise

Marine mammal researchers Ken Balcomb and Diane Claridge awoke to a disturbing sight one morning last March: a beached whale lying in the shallows off their seaside home on Abaco Island in the Bahamas. The stunned scientists quickly recognized the 6-meter-long cetacean as one of their study subjects, a rare Cuvier's beaked whale that they had tracked just weeks earlier as it cruised the cobalt canyons offshore. But now, the whale "was very confused," recalls Balcomb. "It kept making big left turns as we tried to move it to deeper water."

Within days, the scientists had documented 16 nearly simultaneous groundings—including eight beaked whales that died—along a 100-kilometer arc in the region. "We realized that something highly unusual was happening," says Balcomb, who has spent the past decade working in the Bahamas, where typically just a few whales strand each year. Other researchers soon arrived to help inspect the carcasses and carve off tissue samples—including whole heads—that might offer clues to the mass stranding.



Noise victim? Beached Bahamas whales may provide the first conclusive evidence that routine sonar exercises can threaten some whales.

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Those remains are now at the center of an increasingly raucous debate over the threat that humanmade noise poses to whales and other sea life. Many researchers believe that the samples—especially ear tissues taken from the dead whales—will provide the first solid proof of what they have long suspected: that the pinging noises produced by some sonars can deafen and daze some kinds of whales, leaving them vulnerable to stranding and shark attack. If the researchers are right, the finding could disrupt routine naval operations and complicate the U.S. military's plans to field a powerful sonar system that is the subject of a major new study. It could also put pressure on shipping firms and oil and gas drillers, whose activities produce different kinds of potentially problematic noises.

Even if the evidence is inconclusive, the Bahamas incident has helped turn up the volume on marine noise research. Funding for the field is rising, with an international group of researchers launching bids to understand how marine mammals respond to sounds of different frequencies and durations. They also aim to tally up the many noise sources—from volcanoes to jet skis—responsible for the growing racket beneath the waves. "Interest is up, and there are a lot of unanswered research questions," says biologist Roger Gentry, who tracks acoustic research for the National Marine Fisheries Service (NMFS) in Washington, D.C.

Echoing the past

The Bahamas stranding is not the first event that has focused attention on marine noise. In the 1970s, researchers discovered that seismic surveys—which use pulses of reflected sound to map oil and gas deposits—were disturbing ringed seals and bowhead whales in Alaska. Noting that the animals were protected from harassment under the Marine Mammal Protection Act (MMPA), some environmentalists asked the U.S. government to intercede. Although noise was not an issue when the MMPA was passed in 1972, U.S. officials have since struggled to determine which kinds of sound, which can range from the steady whine of an outboard motor to explosive blasts used to battle-test new warships, require a government permit to "take"—harass or kill—whales, dolphins, and seals.

The debate became particularly heated in the early 1990s, when some marine biologists opposed plans to use seabed transmitters off California and Hawaii to produce rumbling, low-frequency pulses that would help geoscientists measure global ocean temperatures. The bass beat produced by the Acoustic Thermometry of Ocean Climate (ATOC) project, they worried, might drown out the love songs of breeding humpback whales and disturb other leviathans. Although the conflict caused headaches for earth scientists, it proved an opportunity for whale researchers to undertake some of the first major studies of whale responses to low-frequency noise. The ATOC project moved forward in 1996 after studies suggested that the sounds had no significant short-term impacts on large whales, and last month NMFS signaled its readiness to give researchers a new 5-year permit to operate the sound source. Still, "ATOC became a lightning rod" that energized the field, says biologist Bob Hoffman, including a 1994 report from the National Academy of Sciences that stressed the uncertainty about the long-term environmental impacts of low-frequency marine noise. Until recently Hoffman served as the Marine Mammal Commission's (MMC's) chief scientist.

The next year a new controversy sprang up around plans by the U.S. Navy to build a powerful new ship-towed sonar system to track increasingly quiet submarines. The multibillion-dollar system, known as SURTASS LFA, would also fire far-traveling low-frequency sounds into the ocean, then listen for the echoes off distant submarines. Environmentalists, led by the Natural Resources Defense Council and the Humane Society of the United States, have opposed deployment, saying the Navy knows too little about its potential impacts on sea life. They also attacked another Navy proposal, known as LWAD, that aims to use a combination of sound-producing technologies in near-shore combat.

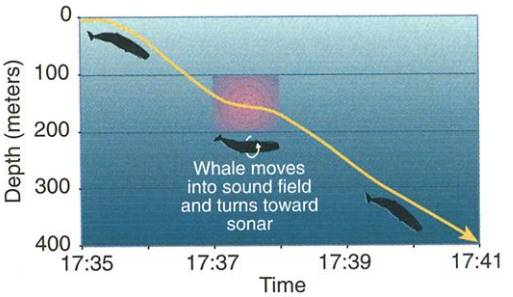
Navy officials say they are aware of the issues, noting an increase in research fund-

New Sensors Provide a Chance To Listen to the Leviathan

One of the biggest challenges in studying the impact of noise on marine mammals is observing how the animals behave when they are under water and out of sight. A new sensor, designed by researchers at the Woods Hole Oceanographic Institution (WHOI) in Massachusetts, allows scientists to tag along as whales and other sea-dwelling mammals forage in the deep sea. The sensor, about the size of a computer mouse, allows scientists to record "what an animal hears and what it says, coupled with exactly how it is moving," says WHOI's Peter Tyack, who developed the device with engineer Mark Johnson.

A preliminary test last year aboard a NATO vessel in the Ligurian Sea offered a provocative preview of what information the sensor can provide. Tyack's team used a 5-meter-long carbon-fiber pole to attach the suction-cupped device to a surfacing sperm whale. Then the researchers activated a low-powered sonar during two of the animal's long feeding dives. After recovering the sensor, which detaches and floats to the surface after a few hours, the researchers got an "unusually information-rich look" at the whale's behavior, says Tyack.

According to data from one dive (see graph), the whale was about 150 meters down when it moved into the sonar's sound field. For the next minute, it suspended its dive, rolled over onto its back, turned toward the sonar, and then issued a "trumpet" call.



Deep insight. New sensor reveals how a diving sperm whale reacts to sonar signals.

Tyack and other researchers don't know yet what such behavior means. But they are excited by the chance, for the first time, to observe conduct long hidden from a scientist's prying eyes. "We went into this wondering if we could even get the [sensor] on a sperm whale and ended up with some real surprising results," says Tyack. **–D.M.**

ing and agreements to alter some practices to protect wildlife, such as delaying "ship shock" explosions if wildlife is spotted in the vicinity. "We know we are a major source of noise ... and are taking steps to mitigate potential problems," Elsie Munsell, then a top Navy environmental official, told the MMC last year.

Once again, the debate has proved to be a boon for cetacean researchers. The Navy in recent years has provided a group of scientists with ample funds, ships, and state-of-the-art equipment to conduct what team member Peter Tyack of the Woods Hole Oceanographic Institution (WHOI) in Massachusetts calls "some of the first large-scale, meaningful, controlled experiments." Acoustics engineers and whale biologists, for instance, bathed blue, fin, gray, and humpback whales in different parts of the Pacific with SURTASS LFA signals, then observed their reactions.

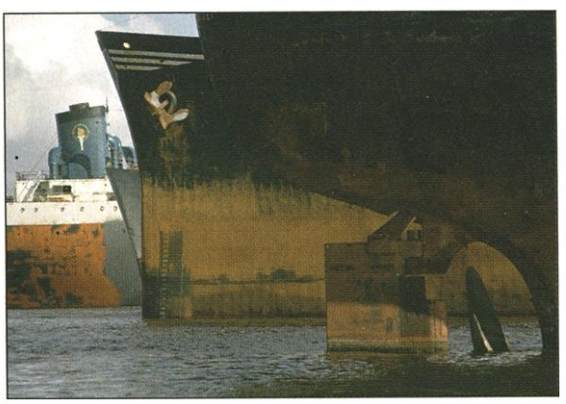
As with ATOC, however, the results were rarely clear-cut or widely applicable to many species or ocean environments. Some kinds of whales shifted course to avoid the signals, for instance, while others seemed to ignore them. And none of the observed behavioral effects was permanent. Tyack and three WHOI colleagues reported last year, for instance, that male humpbacks on their Hawaiian breeding grounds sang, on average, 29% longer when the sonar was operating, but returned to normal solos shortly after the signals ceased. The longer songs probably compensated for interference from the sonar, they speculated.

CREDITS: (TOP TO BOTTOM) PETER TYACK AND MARK JOHNSON/WHOI; JAMES L. AMOS/CORBIS

But the controversy continues. This week the Navy was expected to issue an environmental impact statement that concludes SURTASS LFA will pose little threat to marine mammals if operated, as planned, away from important cetacean habitats. Critics, however, say the analysis is incomplete and misleading, and they urge the government to withhold the "takings" permit needed to proceed. The major problem, say environmentalists, is that researchers still don't know enough about the system's long-term impacts on animal feeding and breeding habits.

Bahamas mystery

The Bahamas strandings have put the Navy under even more scrutiny. A small Navy fleet in nearby waters had conducted antisubmarine exercises using standard tactical sonars, which operate at higher frequencies than SURTASS LFA, just before the strandings began. The timing raised suspicions that the whales had been disoriented by "barotrauma," or pressure injuries to sensitive ear and brain tissues caused by sound waves. Since the 1970s there have been at least three reports of unusual strandings of beaked whales in close proximity to military exercises, but researchers collected little physical evidence that might confirm a link. In the Bahamas, however, researchers noted that many of the stranded whales were bleeding from their ears. And dissections and computerized tomography scans of the salvaged tissues by WHOI's Darlene Ketten, an expert on marine mammal hearing, found hemorrhaging and other telltale signs of barotrauma.



The din of commerce. The amount of marine noise from ships is under scrutiny.

Ketten's final report on the injuries won't be ready until later this year, in part because beaked whale ear bones are so dense that they require months to decalcify for histological analysis, which can reveal the microscopic shearing and compression injuries indicative of barotrauma. But last November Navy acoustics experts assembled a computer model that lent more credence to the theory. It showed that a "surface duct," or layer of water with salinity and temperature properties that transmit sound especially well, may have spread or concentrated the sonar pings in unusual ways. Whales within the sound field, researchers speculate, may have been injured as the sound energy reverberated and reflected off the ocean floor. The question now "is whether this was an unusual event created by a unique set of environmental conditions, or something more general," says Hoffman. Other researchers wonder whether beaked whales, which routinely dive to extreme depths when feeding, might be particularly sensitive to sound injuries due to their anatomy or behavior.

The Navy—already the world's leading supporter of marine noise research at about

$10 million per year—is funding an array of new studies to find answers. The Office of Naval Research (ONR), for instance, has nearly doubled its spending in the field over the last 5 years to about $6.5 million annually. This year, its agenda includes research to pinpoint the level at which noises begin to temporarily degrade the hearing of some marine mammals. It is also beginning to build a three-dimensional computer model that can predict how some kinds of whales will react to sounds. "We want to be able to swim a simulated whale through a sound field and have it behave realistically," says ONR's Bob Gisiner.

In a related effort, the Pentagon's environmental research program wants WHOI's Tyack to help it improve efforts to track whales by the sounds that they make, partly so they can move potentially harmful activities away from the animals. In research directly related to the Bahamas stranding, Tyack also hopes to place on the back of a beaked whale a new sensor that gives scientists detailed information about a whale's underwater behavior (see sidebar on p. 577). Other Navy agencies hope to equip ships with computer software that will warn captains when they are operating in whale-rich waters.

Air-gun assault

Other government agencies are also pursuing sound studies. At the National Oceanic and Atmospheric Administration (NOAA), researchers plan to work with the shipping industry on building quieter vessels; they would also like to compile an accurate marine "sound budget" of all the noise in the sea. Chris Fox, a marine geophysicist at NOAA's Pacific Marine Environmental Laboratory in Newport Beach, Oregon, is hoping the agency will fund an examination of old Navy records that might show how ocean noise has changed over decades and that it will build a multimillion-dollar listening network to put such data in a global context. A National Academy of Sciences panel will also start assembling an "ambient noise" research agenda, with recommendations expected next year.

Preliminary NOAA studies using listening posts moored along the mid-Atlantic ridge have already produced some surprising results, Fox notes. The hydrophone arrays, designed to listen for underwater earthquakes and volcanoes, have sometimes been overwhelmed by low-frequency pulses produced thousands of kilometers away by oil exploration ships using pressurized air-gun arrays. "A single seismic survey vessel can sonify the entire North Atlantic," he says.

Such seismic studies also interest the Interior Department's Minerals Management Service (MMS). It has a small research program aimed at understanding how the spread of oil drilling into the deep waters of the Gulf of Mexico might affect sperm and other whales living in the area. In part, MMS is reacting to past studies, done off Europe and Australia, that have shown that some whales avoid exploration activities.

There is also a move to make companies a bigger part of future studies. Jack Caldwell, an oil industry researcher at Core Laboratories in Houston, Texas, helped organize a scientific panel that later this year will offer recommendations on possible areas of support. The goal, Caldwell said at an MMC meeting last year, is to produce "nuts-and-bolts, practical information," such as exactly which species of marine mammals are likely to be sensitive to air guns, and where they are likely to be found.

In the meantime, Balcomb continues to document the aftermath of the Bahamas stranding. Before the beachings, he notes, his team had spotted about 50 of the unusual Cuvier's beaked whales in the study area. But since "that unforgettable morning" last March, he says, researchers have seen just one. **–DAVID MALAKOFF**

MEETING AMERICAN ASTRONOMICAL SOCIETY

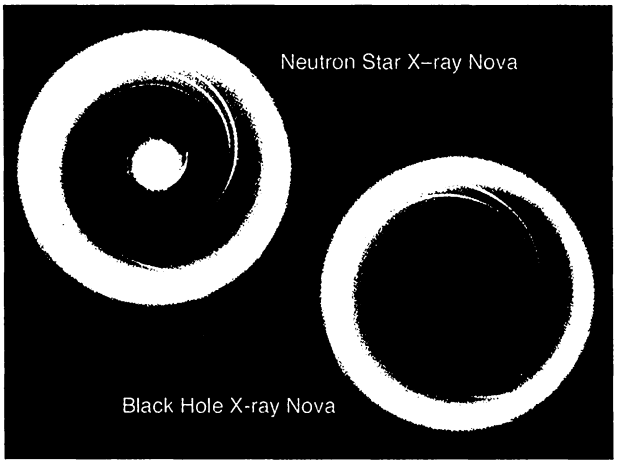
Celestial Zoo Gains Some Exotic Specimens

SAN DIEGO—In the second week of the new millennium, nearly 3000 scientists and educators gathered here for the 197th biannual meeting of the American Astronomical Society, held in conjunction with the American Association of Physics Teachers. Just a few kilometers from the city's world-famous zoo, speakers added bizarre new members to the cosmic bestiary.

Staring Into a Black Hole's Abyss

According to astrophysical theory, a black hole has no surface—just an immaterial "event horizon" that acts as a one-way passage from our universe to oblivion. Matter and radiation crossing this point of no return are lost forever. Now, two major space observatories may have found the first evidence that event horizons indeed exist. According to Ramesh Narayan of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts, the results confirm one of the most remarkable predictions of general relativity.

The first glimpse of the abyss comes from the Hubble Space Telescope. Joseph Dolan of NASA's Goddard Space Flight Center in Greenbelt, Maryland, spent 8 years analyzing old data from the High Speed Photometer on board Hubble. In far-ultraviolet observations of Cygnus X-1, a binary system consisting of a normal star and a black hole, Dolan noticed millisecond flickerings that grew quicker and fainter with time. These "dying pulse trains" behave just as you would expect from a blob of gas spiraling into a black hole, Dolan says: brightening and dimming faster and faster as the gas's ever-tightening orbit swings it toward and away from the observer many times a second, and finally fading out as the gas disappears beyond the black hole's event horizon. If instead the gas blob were slamming into the surface of another type of compact object, such as a neutron star or a white dwarf, the last radiation pulse would be the brightest.



Telltale difference. Swirling gas clouds glow as they strike a neutron star, but they just vanish into a black hole.

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Dolan admits that the dying pulse trains—if that's what they are—are almost completely masked by random brightness fluctuations in the steady emission of Cygnus X-1. "They are needles in a haystack," he says. "We need to follow up on these observations with ultraviolet or x-ray instruments. If we find more of them, that would be a smoking gun."

Meanwhile, what looks like stronger evidence comes from NASA's Chandra X-ray Observatory. Narayan, together with his CfA colleagues Michael Garcia, Stephen Murray,