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STRANDED: A WHALE OF A MYSTERY

Scientists generally agree that sonar can trigger strandings of certain whales, but no one really knows what leads these deep divers to the beach

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ELUSIVE CETACEANS

Scientists generally agree that sonar can trigger strandings of certain whales, such as Cuvier's beaked whales. But no one really knows what leads these deep divers to the beach. Click on the image for more.

A. Frantzis

Off the eastern edge of Andros Island lies the Tongue of the Ocean, a hundred-mile, inky blue swathe of sea over the Great Bahama Canyon. Bounded on the south and east by the shallow sands of the Bahamas banks, the seafloor drops precipitously from 3 meters near shore to more than 2,000 meters farther out.

While the region boasts a colorful history of pirates and shipwrecks, scientists will head there this summer seeking treasure of a different sort: beaked whales, some of the deepest diving and least known animals on Earth. The research aims to solve one of the most contentious mysteries in marine biology today — the relationship between military sonar and stranded, dying whales.

In recent decades, a string of whale strandings have coincided with military testing that uses mid-frequency sonar to detect the low murmur of diesel and nuclear submarines. Beaked whales have washed up on the beach, sometimes with blood in their ears and eyes, but often with no obvious cause of death. After scientists first drew the connection between sonar and the strandings, environmental groups took note, embarking on a campaign to restrict sonar use in certain times and places. The hostilities reached a crescendo this winter in a U.S. federal court. A judge rejected the Bush administration's attempts to override a ruling that ordered the Navy to take measures to protect marine mammals while conducting sonar exercises. Now the Supreme Court is scheduled to hear the Navy's appeal this fall.

The wrangling over the stranded whales brings home how science can get lost in the scuffle between advocacy and policy. It also illustrates the highly charged

nature of issues involving large, charismatic mammals. And then there's the attraction of simplicity — the Navy makes a tidy, singular foe. But there is no Moby Dick in this story.

Scientists agree that under certain conditions, sonar does trigger strandings of certain whales. But no one really knows why. Hypotheses, like fish in the sea, are plentiful. Sonar may be so forceful that it damages the whales' ears. Some researchers speculate that the sounds spur bubble formation in tissue, bringing on deadly embolisms. Or the sonar might distress and disorient the creatures, prompting them to surface too quickly and get the bends. Other researchers have suggested that certain frequencies of sonar might sound like killer whales on the hunt, stimulating beaked whales to seek shallower, safer waters.

Several research groups are trying to untangle what is happening, with the hope of developing strategies that minimize harm to marine life.

The National Oceanographic and Atmospheric Administration Marine Fisheries Service is partnering with the Navy to undertake some of the first controlled behavior experiments with beaked whales at a Navy Atlantic test center in the Tongue of the Ocean. Others are constructing computer models, looking at CT scans and studying beaked whale anatomy. There are efforts to compile stranding-related information in public databases.

In the meantime, providing policy-makers and the public with advice on how to alleviate the problem has been stymied by holes in the data big enough to swim a whale through. *Ziphius cavirostris*, or Cuvier's beaked whales — the animals most associated with the unusual strandings — are understudied, elusive creatures. They spend little time in surface waters and, until the strandings, people rarely saw these whales at all. Then there are ethical and practical concerns with experiments that involve 2 ½-ton mammals that spend much of their time nearly a mile beneath the surface of the sea.

The mystery is compounded by several factors. No one knows where the whales



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[Unusual beachings](#)

Scientists recognized a link between mid-frequency sonar and strandings after several Cuvier's beaked whales washed up on the Mediterranean coast in 1996.

A. Frantzis

are before they strand, so assigning safe distances from sonar is problematic. The strandings have been associated with specific geologic features, such as deep oceanic trenches near land, but by definition, stranded whales end up near or on land, so teasing out cause and effect is difficult. Because no one knows

where and when a stranding will happen, experts might not arrive on the scene until days after the event. By then tissues are often decomposed, as are clues to the animal's death.

"One of the problems is we've really only had information on single exposures — one sound, one mammal," says Brandon Southall of the NOAA Fisheries Service, who is leading the Bahamas study. "We really need more data."

Some environmental groups and scientists argue that waiting for such data is folly. It is better to act quickly — perhaps by banning Navy sonar altogether — than it is to wait. But others express frustration at the bulldog approach, and at the time and money tied up in lawsuits that might be better spent on research. And while blame is slung in the courts, marine mammals face many threats beyond sonar.

"It is absolutely critical that we understand what is going on," says Darlene Ketten, a senior scientist at the Woods Hole Oceanographic Institution in Massachusetts and a researcher at Harvard Medical School in Boston. "But when people ask, 'Why don't you shut down the Navy?' the answer is we're talking about five animals a year, and I have to balance that with over 100,000 deaths a year from fisheries interactions. I don't know that shutting down the Navy is going to do anything. And if you are worrying about noise in the oceans, how about the 3-decibel increase per decade from shipping?"

Signal from the noise

Scientists realized the link between whale strandings and mid-frequency sonar in 1996, several months after a stranding in the Mediterranean's Kyparissiakos Gulf. In early May, Cuvier's beaked whales began washing up along a 24-mile stretch of sandy beach. The spread of the 12 whales in time and space was unusual, but there was no smoking gun. The whales had stranded alive and appeared healthy — they had no obvious wounds, such as blunt trauma from a ship, and no signs of disease. A few animals appeared to be bleeding from their eyes, which prompted more questions than answers. There were various squid remains in the whales' stomachs — beaks, ocular lenses and flesh — suggesting that they had recently eaten.

"For a beaked whale to have been diving at depths great enough to find squids means they must have been healthy a few hours before they stranded," says Alexandros Frantzis of the Pelagos Cetacean Research Institute in Greece. The usual suspects — extreme weather, earthquakes, pollution, parasites, irregular geochemical or magnetic circumstances — were absent. "We had no idea what was happening," he says.

Several months later Frantzis discovered that around the time of the stranding event the NATO research vessel Alliance was performing "sound-detecting system trials" in the area of the strandings. Although the available data couldn't prove that the Alliance's sonar activities caused the event, the abruptness, timing and distribution of the strandings implicated sound, says Frantzis. He reported his conclusions in *Nature* in 1998.





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TESTING THE CONNECTION

in the Tongue of the Ocean's AUTC range, scientists are conducting some of the first controlled experiments on how whales respond to sonar using the Navy's interconnected grid of underwater microphones (inset).

B. Southall/NOAA

In the 10 years since Frantzis' write-up, scientists have linked about a dozen stranding events to military sonar, depending on whom you ask. But whales have been stranding long before the advent of mid-frequency sonar use, which became widespread around 1963. Ketten, who has been compiling records of whale strandings, estimates that since 1950, fewer than 300 whale deaths can be attributed to naval sonar. Other researchers put that estimate at fewer than 100.

Ketten did necropsies on several of the beaked whales whose fatal strandings were concurrent with Navy sonar exercises. These include the oft-cited stranding in the northern Bahamas of nine Cuvier's beaked whales and three Blainville's beaked whales, a stranding of three Cuvier's beaked whales in Madeira and two strandings off Puerto Rico.

The evidence from Puerto Rico was inconclusive. The response team buried most of the heads — standard procedure in tropical areas — but one that destroys crucial soft tissue. Scans of the one intact head suggested it was an old male who had suffered prolonged infection.

Necropsies from the Bahamas and Madeira were more telling. Beaked and other toothed whales such as dolphins have a large pad of fat inside their lower jaw. Sound may enter the whale's head through the fat, which surrounds a very thin section of the lower jaw next to the middle and inner ears.

"There were no blown-out membranes, no broken middle ear bones," Ketten says, which would have suggested direct acoustic trauma to the ears. But in a few of the animals, blood had leaked from the brain case, pooling around the ear bones and the fat pad of the lower jaw. This suggested stress and possible pressure-related trauma, she says.

Researchers have raised other pressure-related hypotheses as well — unusual gas bubbles have been found in the tissues of beaked whales that stranded off the Canary Islands. The bubbles hinted at decompression sickness — what SCUBA divers call the bends — but later reports of dolphin strandings off the United Kingdom found similar bubbles in tissues, which led many scientists to deem the bubble evidence inconclusive.

It's been difficult for scientists to understand pressure-related injuries in animals built for the crushing pressure of the deep sea. These whales spend more than an hour at depths greater than 1,200 meters — more than three times the height of the Empire State Building. Down where it is as dark as a starless night, the whales, like bats, hunt with their ears, not their eyes. Beaked whales have three times as many nerve cells devoted to hearing as people do, Ketten says. They

use echolocation — emitting sounds that bounce off objects and return to the whale, giving a “picture” of prey shape, size and location.

“These are acoustic animals in the way that we are visual animals,” Southall says.

Beaked whales also have a convoluted circulatory system that during dives sends blood to essential areas like the heart and brain, but cuts off flow to the extremities. Below roughly 70 meters the whales’ lungs collapse, preventing gases from diffusing into blood and tissue where they could cause embolisms.

“These animals have been around 35 million years,” says Ted Cranford of San Diego State University, who in April published in *The Anatomical Record* an analysis of how sound travels in and out of a beaked whale’s body. “It doesn’t make sense that a few nitrogen bubbles are going to cause chaos. Perhaps if the whales are at their physiological limit. But if it is nitrogen, why don’t we see it affecting other deep divers?” he says.

This question bothers other researchers as well. Beaked whales are often seen around the Navy’s testing site for mid-frequency sonar in the Bahamas. “So we know that marine mammals and beaked whales can live where there is sonar,” Southall says. “It is not like a death ray where as soon as they hear it, they swim to the beach and strand.”

Sound science

The ambiguous data suggest to many researchers that the sonar-related strandings result from a perfect storm of environmental, physiological and acoustic conditions. A recent analysis by Gerald D’Spain of the Scripps Institution of Oceanography in La Jolla, Calif., and colleagues, hinted at the role of surface ducts — areas in the water where sound waves are trapped.

Sound travels about four times faster underwater than in air — about 1,500 meters per second versus 340 m/s on land. It slows in colder water, but increases with pressure, speeding up with the weight of the overlying water column. These factors, along with others such as the topography of the ocean floor and surface winds and weather, may mean sound sometimes creeps up on and startles deep divers.

Under certain conditions, as sonar sweeps an area, the pings and clicks could get trapped in a surface duct, making them less audible from below. If a beaked whale is down deep, it might not notice the sound until the ship is quite close, which could prompt the whale to surface. If the animal emerged to surface-duct depth, it would suddenly find itself in an intense, confusing zone of noise, D’Spain says.

Experiments planned by Southall’s team for this summer in the Bahamas are designed to sift through these ideas and get at the peculiar set of circumstances that sends beaked whales to the beach. Using the Navy’s 600-square-mile grid of interconnected, underwater microphones at the Atlantic Undersea Test and Evaluation Center, researchers will continue playback experiments that began last summer, exposing the animals to low levels of sounds and tracking their responses.

The team is also investigating the notion that beaked whales confuse sonar with a pack of killer whales, which emit noises in a frequency similar to the mid-range Navy sonar. Beaked whales' primary predators, killer whales and great white sharks, tend to hang out near the water's surface, notes Peter Tyack of Woods Hole, a member of the NOAA investigation team. If beaked whales think they hear the enemy, they might embark on repeated shallow dives for quick escape. Work by Tyack and colleague Walter Zimmer modeling nitrogen bubble growth suggests that if the dives are too shallow, the whales' lungs may not collapse, a physiological safety mechanism that doesn't kick in until the animals reach depths of 70 meters. Then even these deep divers might get decompression sickness, and visible bubbles might form in the whales' tissues, the researchers reported in *Marine Mammal Science* last fall and June 30 at the Acoustics '08 meeting in Paris.

Hampered by storms, last summer's first field season yielded data from only 10 tagged animals, six Blainville's beaked whales and four pilot whales, Southall says. Pilot whales, which are deep divers and frequent stranders, have similar biology to the beaked whales. But they haven't shown up in the sonar-associated strandings, so tracking them could reveal important behavioral differences, he says.

"We're seeing some avoidance," Southall says. "The animals become quiet and move away from the sound."

If the behavioral experiments reveal that the whales stop shallow diving as soon as the noise stops, the duration of sonar transmission could be limited, which might limit harm. Precautionary measures such as holding off from sonar exercises when surface ducts are likely to form may keep the creatures from becoming startled and disoriented.

When the Bahamas study is done, researchers may have enough data to solve the stranding puzzle and give policy-makers, the Navy and the courts sound advice on reducing harm to whales.

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