UNIDENTIFIED FLOATING OBJECTS

New sonar imagery reveals mysterious echoes to be enormous schools of fish

BY NICHOLAS MAKRIS
I was on the research vessel Oceanus some 200 kilometers south of Long Island, New York, searching for something I had been chasing for years. It wasn’t a white whale, but it was just as alive—and a whole lot bigger.

My scientific colleagues and I had jokingly referred to the enigmatic thing we were seeking as a UFO—for “unidentified floating object.” To find our elusive prey, we had engineered a new-fangled sonar system that operates at relatively low frequencies and installed it on this vessel, which is operated by the Woods Hole Oceanographic Institute. After days at sea, we finally got our big break—strong echoes emanating from about 20 km south of our ship, where the water was roughly 100 meters deep. On our sonar displays, it looked as though something the size of Manhattan was perched near the edge of the continental shelf.

In some places, the seafloor sports some pretty rough topography, but our charts showed it to be flatter than Kansas around where we were. And the mysterious echoes we were seeing with our new sonar weren’t apparent the previous day, so they couldn’t have come from any sort of uncharted seafloor ridge. What’s more, as we stared at the display for the next hour or so, we could see the structure it revealed gradually changing shape—which seafloor geology just doesn’t do.

This was definitely a UFO—one the size of a large city. Such things had been detected before with other long-range sonars—and most specialists at the time believed that these enigmatic echoes stemmed from irregularities on or beneath the seafloor. These acoustic ghosts came and went: it was thought because changes in the temperature or salinity of the ocean caused varying refractions and either strengthened or weakened the echoes. We had never believed that particular ghost story and suspected that these strange acoustic reflections in fact came from large groupings of fish. Here at last was our chance to find out.

We immediately radioed the news of our UFO sighting to colleagues on another ship that was equipped with conventional echo sounders—similar to the kind countless boaters use to check the depth of the water and to locate schools of fish. It took that ship hours to reach its target, but when it finally did, shouts came back over the radio: “It’s fish!” We were seeing a massive shoal—a community of oceanic fish—in its entirety for the first time. The echo-sounding equipment available on most ships has a limited range and is able to sense only tiny bits and pieces of such large shoals. So until that time, nobody knew what such a large shoal looked like.
We were all immediately struck by the implications. These fish had come together in one group that was more vast than any thing that had been seen before. And they were doing it in a very unexpected place: a shipping lane leading to New York Harbor, one of the busiest ports in the world.

I felt honored to have helped make this discovery in 2003, but almost immediately those feelings became mixed with ones of deep concern about how the new technology could be misused. These thoughts crystallized during a later expedition when our long-range sonar equipment detected strong echoes in the vicinity of Georges Bank off Massachusetts—which had been a prolific source of cod and halibut for centuries before overfishing caused those fisheries to collapse. As before, we radioed another vessel with conventional echo sounders to investigate, and it confirmed that the echoes were indeed coming from a giant collection of fish. But soon after the captain called me to the bridge and pointed to the radar screen. On it were blips that marked the position of dozens of fishing boats—which had converged on the spot of the enormous fish congregation after listening in on our radio communications—which we had naively sent on an open maritime channel.

That episode made it very clear that this new fish-finding sonar could wreak havoc on ecosystems around the world. Used responsibly, though, it could help marine biologists and fisheries managers follow fish populations in ways that were previously unimaginable.

The sonar system my MIT colleagues and I put together to chase UFOs is just the latest link in a long chain of technical developments that date back to World War I when submarines first went into widespread use. With the advent of undersea warfare came an urgent need to detect, localize, and image submerged objects, sometimes over vast oceanic regions.

Of course, light doesn’t penetrate far in seawater. The same is true for all but the longest radio waves. So the only practical way to sense distant objects is to use sound—which can travel great distances under water—a fact that has been known for hundreds if not thousands of years. That’s why governments around the world have for decades poured huge sums into studying the physics of long-range sound propagation and scattering in the ocean.

As a result, naval sonar systems grew increasingly sophisticated over the 20th century. By the late 1960s and early 1970s, some side-looking sonar systems were able to form images across sev-
A Fish’s-eye View

A second ship tows the receiving array at a depth of 24 to 35 meters. It measures the sound waves that bounce off fish. The sound travel time and the direction of the incoming waves provide the information needed to image fish shoals.

Acknowledgments: Figure 3 was prepared by Joe Fast of Jena Systems. For more information, see: http://fishingtoolbox.com/


Several kilometers of ocean—revealing the first hints of unidentified floating objects. Some people hypothesized that these echoes came from fish—but that surmise hadn’t been confirmed. By the 1980s and early 1990s long-range submarine hunting sonars gained the ability to scan the ocean in a full 360 degrees in azimuth: By this time the navies of the world started to be really troubled by the many ghostly reflections these systems were detecting—things that had no ready explanation.

At this point my group at MIT became involved in a large experimental program sponsored by the U.S. Office of Naval Research—which included deep ocean surveys around the Mid-Atlantic Ridge—the undersea mountain system that runs through the center of the Atlantic Ocean. There we found that previously uncharted ocean ridges caused many of the UFOs we were seeing on our sonar screens.

Our sponsors in the Navy were thrilled. And they were eager—to apply the lessons learned to explain sonar UFOs found in much shallower water above the continental shelves. The problem was that most of those shelves—the underwater extensions of many continents—are essentially featureless plains—and they are very well charted. So it made no sense to blame UFOs on unknown seafloor topography. Many people in the Navy concluded that hidden geologic features of the continental shelves—in particular buried river channels—must cause these ghostly sonar reflections to form.

To test that idea— the Office of Naval Research wanted us to use our long-range sonar to take snapshots of the ocean off of New York City. During the last Ice Age when sea level was much lower than it is today— the Hudson River and its various tributaries flowed over what is now the continental shelf. Our Navy contacts hoped to find out whether any unusual acoustic reflections appeared near buried river channels. We were skeptical. We even published a prediction that the channels of ancient rivers wouldn’t cause unusual sonar readings. According to our calculations— sound waves lose too much energy when traveling through the sediments that cover buried river beds. They couldn’t possibly appear as large floating objects on sonar.

It took us years of detailed survey work and analysis to show the Navy that there was no more than a random correlation between river channels and UFOs. So the former couldn’t cause the latter. This conclusion disappointed many researchers with an interest in studying seafloor geology—and put us in the hot seat. If not buried geology—what then was causing these strange echoes to form? For a while we had only our hunches. But the
waves is a string of what are essentially loud short range, typically over distances that are about equal to the fish-finding sonar would be nearly impossible.

The main drawback of these systems is that they work only at short range—typically over distances that are about equal to the depth of water you’re in. To detect things farther away you need to use lower frequencies. For our sonar system we use audio frequencies that go from roughly the G above middle C (392 hertz) to about two octaves above that (to 1570 hertz).

Our fish sensing sonar requires two instruments—one to transmit sound waves and one to receive their echoes. The source of the sound waves is a string of what are essentially loud speakers which hangs vertically below the first ship. The speaker array sends out short bursts of sound that travel in all directions.

These acoustic waves can go hundreds or even thousands of kilometers. On this scale the ocean can’t be thought of as an infinite abyss—its average depth is just a few kilometers. And over the continental shelves the water is only a couple of hundred meters deep at most. So the overall geometry resembles a puddle—only bigger. Any up or down going sound waves quickly hit a boundary—the surface or the bottom—and bounce back. In this way the thin veneer of ocean channels the sound energy we inject into it horizontally guiding the acoustic waves just as effectively as an optical fiber guides the light sent through it.

The sound waves we send out reflect or scatter off the objects they encounter and a long line of hydrophones (underwater microphones) towed horizontally behind the second ship pick up these echoes. Careful processing of the received signals allows us to figure out which direction the echoes are coming from and how long the sound waves took to make the round trip. With that information we can form a pretty good picture of what the ocean contains up to about 100 km away.

By taking frequent sonar images of the ocean over time we’re essentially gathering frames of a video: When we play it back it reveals what hundreds of millions of fish are doing across an area that’s hundreds of kilometers across. Modern computers have no problem handling the signals and image processing calculations needed to generate these moving images in real time so we can watch all the subsurface action unfold in front of our eyes.

Surveying an area that size with traditional fish-finding sonar would be nearly impossible.

Fish Species Found on the Continental Shelf South of New York

- Atlantic Herring
- Atlantic Mackerel
- Black Seabass
- Dogfish
- Red Hake
- Scup
- Silver Hake (Whiting)
- Spotted Hake

You’d have to send out a fleet of fast survey ships working around the clock. Nobody—not even the navies of the world—has money for that. That’s why after nearly a decade of surveys near the Georges Bank fishing grounds no one in the National Marine Fisheries Service ever knew that herring were amassing there each night during spawning season—something we quickly discovered with our long-range sonar.

Our 2006 sonar survey of Georges Bank to just two weeks chilling us with stiff breezes and gale-force winds while we were at sea. During the first week my colleague Purnima Ratilal of Northeastern University in Boston noticed a curious pattern. Each day a shoal of herring would form at roughly the same place and time. To prove it to the rest of us she said she knew precisely when would see a massive shoal emerge on the northern flank of Georges Bank. At around 4 p.m. that day she gathered several of us to the sonar display and said “just watch—just watch.”

From a sea of acoustic darkness little specks of high-intensity scattering began to show up on the display just where she said they would be. These specks quickly grew into lines their endpoints spreading about 10 times as fast as even the most athletic herring can swim. It would have been impossible to see this happen with ordinary fish-finding sonar even if you had many ships at your disposal. But with our system we were able to show in just a few days that these herring shoals formed rapidly like clockwork. Once the fish reached a critical population density they began slowly to migrate toward shallow spawning grounds on Georges Bank.

These observations—which were part of the Alfred P. Sloan Foundation’s Census of Marine Life—proved a fundamental theory about the behavior of many animals that travel in groups: They follow a simple rule: match the average velocity of your fellow fish or birds or caribou or whatever at least the ones you can see. When population density is low the animals’ spheres of perception don’t intersect: so they don’t move coherently. But as the population density increases they start to notice—and to mimic—one another. Chain reactions then cause their motions to become synchronized over the entire group.

The herring we were watching on our sonar were doing exactly that. Once we figured out what was happening we informed scientists on ships equipped with conventional echo sounders so that they could investigate these goings on in more detail. They found that herring generally hid near the seafloor during the daytime. Then at sunset they rose a few meters converged into large shoals and headed south.

Our best guess was that these fish were coming together each evening to find other herring in a similar reproductive state. Under the cover...
of darkness: they could then swim to their shallow spawning grounds; but they would return before the sun came up again so that predators could not find and eat them. Our sonar showed exactly how and when they did this—which made us wonder about how safe from predators—the human kind—these fish would be in the future if use of this new technology is not well regulated.

**ONCE WE CONFIRMED THAT THE NOVEL PROPERTIES** of our sonar could be used to locate large groups of fish—we wondered what else we could learn with it. Quite a lot it turns out—enough to distinguish fish of different species. That’s because many fish have swim bladders—air-filled sacs that help them regulate their buoyancy as they move between different depths.

The sound waves our sonar generates are longer than even the largest fish so they don’t bounce off a fish’s body the way they might reflect from a larger obstacle. But they do cause the fish’s swim bladder to resonate. This then scatters some of the acoustic energy in all directions. Our receiver picks a fraction of this scattered energy and from its frequency we can estimate the size of the swim bladder.

Small fish—like herring, capelin, or anchovies—have correspondingly small swim bladders—which typically resonate at frequencies of 1000 Hertz or more. Medium-size fish—say cod, hake, pollack, and salmon—have medium-size swim bladders—which generally resonate at frequencies of several hundred hertz. Fish that are larger still—for example Atlantic bluefin tuna—have large swim bladders—which usually resonate at frequencies below 100 Hertz.

With that information—and knowing a little bit about what kinds of fish live in the area—you can often determine what species you are seeing on sonar. It was from just this kind of consideration—for example—that we realized we were tracking herring and not Peruvian anchovies or Icelandic capelin over Georges Bank in 2006.

This ability makes our sonar system ideal for collecting information about changing fish populations. As Torrence Johnson, a colleague of ours at the Jet Propulsion Laboratory in Pasadena, Calif.—noted: “It’s like having Doppler weather radar for fish!” Use of a system this powerful would likely make it far too easy for commercial fishers to decimate fish populations. So a sonar like ours requires strict regulation. Perhaps the most straightforward approach for that would be to enforce existing government imposed limits on the amount of sound that can be injected into the ocean.

**WITH AN EYE ON THE REGULATIONS** that use of such sonar equipment would demand—we’re moving forward on the development of a next generation unit. Our first system was an awkward Rube Goldberg device—patched together from the spare bits of defunct Cold War hardware. It was cumbersome to operate at sea—requiring two ships with a large crew of handlers on each. The new system funded by the National Science Foundation Major Research Instrumentation Program is half the size and half the weight and takes just one ship and a handful of people to operate. We expect it to be ready in early 2012.

Many other research tasks await our attention. Some of the primary ones are to study fish species that have great ecological, economic, and societal importance—namely Barents Sea capelin, Alaskan pollack, Peruvian and South African anchovy, Atlantic bluefin tuna, Southern blue whiting, and Argentinian hake. In our own home waters of Massachusetts Bay and the Gulf of Maine—which boast centuries of celebrated fishing history—cod populations have yet to be accurately determined and we’ve been asked to help get better counts.

After that—we hope to build on one of our recent theoretical findings: that it should be possible to use a somewhat higher frequency sonar to image krill in the Southern Ocean. Antarctic krill—shrimplike crustaceans with largely transparent bodies—are vital to the marine food chain and are perhaps the most abundant animal species on the planet. But some scientists worry that they will suffer as the Southern Ocean warms. Our sonar might help determine if these concerns are well placed.

The oceans cover nearly three-quarters of the Earth’s surface; yet to this day they remain dark and largely unexplored. By casting some light on the ocean with wide-area sonar, we hope we can help to preserve marine life. Perhaps one day fixed sonar platforms will scan the ocean much as fixed radar stations currently monitor weather and bird migrations on land. If used responsibly—perhaps by delaying the release of the data for a month or two—the information gleaned would provide marine biologists with a valuable scientific resource without compromising the sea creatures it reveals.