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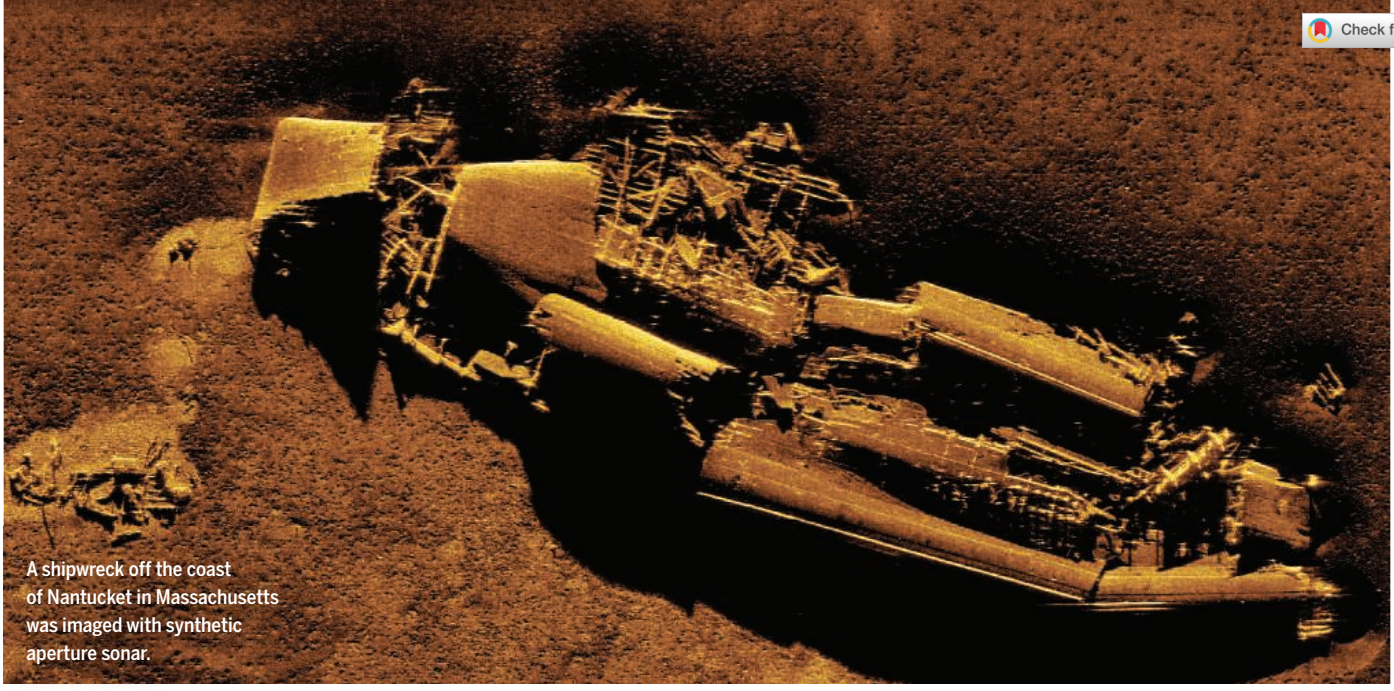

A shipwreck off the coast of Nantucket in Massachusetts was imaged with synthetic aperture sonar.

OCEANOGRAPHY

Sonar tool poised to map sea floor in fine detail

Researchers see promise in "synthetic aperture" devices that mimic giant acoustic cameras

RACHEL BERKOWITZ

An emerging sonar technology that scans the sea floor at centimeter-scale resolution is dazzling researchers with its potential. Commercial synthetic aperture sonar (SAS) devices, originally developed by the military to identify explosive mines, are now being deployed by scientists such as Yizhaq Makovsky, a marine geoscientist at the University of Haifa. When he first saw how SAS instruments could pick out the bumps of tiny seafloor burrows, he says, "We realized this was a game changer."

Only a Rhode Island–size patch of the world's deep-sea floors has been observed up close, according to a study published on 7 May in *Science Advances*. That imaged area is likely to grow with the adoption of SAS, which can efficiently reveal fine details in wide swaths of the sea floor, unmasking its biology and geology. It could also be crucial in upcoming fights between deep-sea miners and the environmentalists who seek to limit seafloor exploitation. "How do you decide what to preserve?" Makovsky asks. "How do you monitor it?"

Larry Mayer, an oceanographer at the University of New Hampshire (UNH), is excited by the technology's seemingly "magical" abilities, but cautions that its advantages are not always worth the complexity and price tag, which can run upwards of several million dollars for the device and an autonomous underwater vehicle (AUV) or ship-towed platform to carry it.

SAS is analogous to the synthetic aperture radar (SAR) systems on satellites that are increasingly being used to map Earth's surface. In SAR, a moving beam source focuses multiple "pings" on a single point on Earth's surface. The radar reflections are stitched together to create a picture equivalent to one taken by a much larger aperture antenna. SAS does the same thing with sound instead of radio waves.

Making the image requires knowing "exactly where the antenna is, and estimating its motion," explains sonar scientist Shannon Steele at Kraken Robotics, one of a handful of companies that sells SAS devices. The antenna must travel in a perfectly straight line, says Anthony Lyons, an underwater acoustics researcher at UNH. "Your navigation has to be phenomenally good." SAR satellites can calculate position and trajectory using the GPS system and the radar pulses themselves. But GPS doesn't work underwater, and sound travels slower than radio waves, making it a poor navigation tool.

Only in the past decade have companies been able to surmount these thorny difficulties in commercial SAS systems. "The magic trick is using the acoustic data itself to correct navigation," using algorithms that exploit time delays between adjacent pings to estimate motion, says Roy Hansen, an acoustic imaging researcher at the Norwegian Defence Research Establishment who in 2006 deployed one of the first consistently successful SAS systems.

Science is now benefiting. For John Jamieson, a geologist at the Memorial University of Newfoundland, SAS is the "holy grail" for understanding seafloor processes. In 2023, he and Ph.D. student Caroline Gini led a mission to the Galápagos Islands to see what an SAS instrument could show about hydrothermal systems—hot springs percolating up through the sea floor with nutrients that support marine life. The images revealed unknown vents and even some of the seafloor animals that lived near them. "You forget that it's not a photo, but an image re-created from sound," Gini says. Such detail about the vents could help refine models of how fluids flow through the sea floor.

Makovsky sees potential for marine ecology. In March, he and his colleagues reported the results of an SAS survey of the Bustan HaGalil ridge, a 150-meter-deep reef off Israel's west coast. A survey covering 5 square kilometers took just 6 hours, produc-

PHOTO: KRAKEN ROBOTICS

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ing images showing distinct sandy, rocky, and silty seafloor textures that allowed the researchers to classify the reef's different habitats. "You can even see algae growth on rocks," Makovsky says. Human divers guided by the images later performed a census of organisms in the different habitats—ultimately creating a machine learning tool that could be used to estimate ecological diversity from SAS data at other sites.

Meanwhile, Hansen and colleagues have put SAS to work in deepwater archaeology, hunting Allied cargo ships filled with bombs and mustard gas that were scuppered in the North Sea just after World War II. Using an SAS system onboard an AUV to map an area four times the size of Paris, Hansen's team found 54 wrecks, some of them unknown, and pinpointed individual bombs and barrels scattered around the wrecks that would have been too small for other sonar systems to see. The mapping could help guide future cleanup efforts. "These environmental problems are, for me, the best application," Hansen says.

Another kind of environmental monitoring could come as miners begin to target the sea floor. For example, SAS could help miners identify smokestacks of extinct hydrothermal vents, which hold rich metal deposits. And it could enable watchdogs to gauge the impacts of resource extraction.

When Israel opened the Palmahim Disturbance, a deep-sea landslide off the coast of Tel Aviv, for oil industry bids in 2021, the Society for the Protection of Nature in Israel approached Makovsky with concerns. He led an ensuing SAS campaign that, on the largely barren sea floor, revealed fluid seeps surrounded by animal burrows, brine pools, and even a deep-sea shark nursery. Makovsky calls it "a lavish oasis in the middle of the desert." The findings helped clinch the region's status as a new marine protected area in 2022.

Lyons points out that projects like these often benefit from access to military-purchased AUVs and SAS systems. "They're phenomenally expensive," he says. It's not just the equipment, he adds: You need crew to deploy them, and analysts who understand the data processing. But companies are beginning to offer commercial SAS services, hiring out both crew and SAS system to perform surveys. Progress and demand will drive price down, Hansen believes. He sees "an evolution not a revolution" in access and technology.

For now, Mayer believes, well-financed shipwreck hunters and companies prospecting for seafloor minerals will continue to be early adopters, along with scientists lucky enough to have major government support for ecology and biology.

"I see it as a niche thing, for people who can afford it," Lyons says. "I wish I had one to play with." □

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RESEARCH INTEGRITY

Low-quality papers surge thanks to public data and AI

Paper mills may drive "industrialization" of shoddy research

CATHLEEN O'GRADY

Last year, Matt Spick began to notice oddly similar papers flooding in for peer review at *Scientific Reports*, where he is an associate editor. He smelled a rat. The papers all drew on a publicly available U.S. data set: the National Health and Nutrition Examination Survey (NHANES), which through health exams, blood tests, and interviews has collected dietary information and other health-related measurements from more than 130,000 people. "I was getting so many nearly identical papers—one a day, sometimes even two a day," says Spick, a statistician at the University of Surrey.

What he was seeing at his one journal is part of a larger problem, Spick has discovered. In recent years, there has been a drastic surge in poor-quality papers using NHANES, possibly spearheaded by illicit money-making enterprises known as paper mills and facilitated by the use of artificial intelligence (AI)-generated text, he and colleagues reported in *PLOS Biology* earlier this month. The finding suggests large public health data sets are ripe for exploitation, they say.

Such free data sources allow almost anyone to take a known research method and swap in new variables to create fresh "findings" in a kind of "research Mad Libs," says Reese Richardson, a metascientist at Northwestern University who was not involved with the work. Other researchers have found similar "explosions" in a range of topics, he says, including various kinds of genetic studies as well as analyses of bibliometrics or gender disparities in different scientific disciplines.

The NHANES papers Spick was receiving all followed the same formula: They chose a health condition, an environmental or physiological factor that could be associated with it, and a population group—perhaps looking at the link between vitamin D levels and depression in men over age 65. "It felt like every possible combination was being worked through," Spick says.

To get a better understanding of how prevalent these studies are, he and his team searched two major databases of scientific papers, PubMed and Scopus, for studies using NHANES data that looked at single associations. They found 341 of these papers published in 147 journals, including *Scientific Reports*, *BMC Public Health*, and *BMJ Open*. Between 2014 and 2021, an average of four such papers were published per year—but a rapid increase kicked off in 2022, with 190 papers published in 2024 up to October, when the researchers did their search. The rise far outstripped the growth in health studies using large data sets generally, the authors report, suggesting some additional factor is driving the swell of NHANES studies.

The timing coincides with the widespread availability of AI chatbots such as ChatGPT that can generate readable text from simple prompts and uploaded information. Such tools may have been used to rephrase the same paper template with different variable combinations to avoid plagiarism detection, says Jennifer Byrne, a molecular biologist at the University of Sydney who peer reviewed the *PLOS Biology* paper. It's not possible to conclude with certainty that paper mills—entities that sell authorship on fraudulent or low-quality papers—produced the papers, she says, but the "timing and scale of the increase make you think there has to be some kind of coordination behind this."

Spick and his co-authors also found that the majority of recent NHANES papers were authored by researchers in China: Ninety-two percent of the papers published after 2021 had a first author affiliated with a Chinese institution, compared with just 8% of papers published before 2021. This also suggests paper mill involvement, Spick says, pointing to findings that the pressures and incentives facing researchers in China drive the use of paper mills.

Many of the more recent NHANES studies selectively analyzed portions of its data set without a clear

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