But such calculations are based on water loss through stomata, and disregard the water vapour that passes directly through the cuticle. Hanson's experiments suggest that this is a workable approximation when water is plentiful — but when it is scarce, and the stomata close, a greater proportion of moisture is lost through the cuticle. Failing to adjust for this could throw off calculations of how well plants convert CO_2 to sugars during photosynthesis, Hanson says. "While stomata are closed, this small error is now a massive error," he adds.

Hanson first became aware of this in 2015, when plant physiologist John Boyer of the University of Missouri in Columbia approached him after a seminar. Hanson had just presented data showing his attempts to explain how properties of leaf cells can limit CO_2 capture. Boyer offered Hanson an alternative explanation — water loss through the cuticle — and described data that his lab had collected in the 1980s, but that had garnered little attention.

Boyer's team had found that water loss through the cuticle skewed calculations of CO_2 concentrations inside sunflower leaves to be 15% too high when water was abundant and stomata were open (J. S. Boyer *J. Exp. Bot.* **66,** 2625–2633; 2015, and D. T. Hanson *et al. J. Exp. Bot.* **67,** 3027–3039; 2016). And when stomata were closed, predicted CO_2 concentrations were six times higher than direct measurements taken inside the leaf.

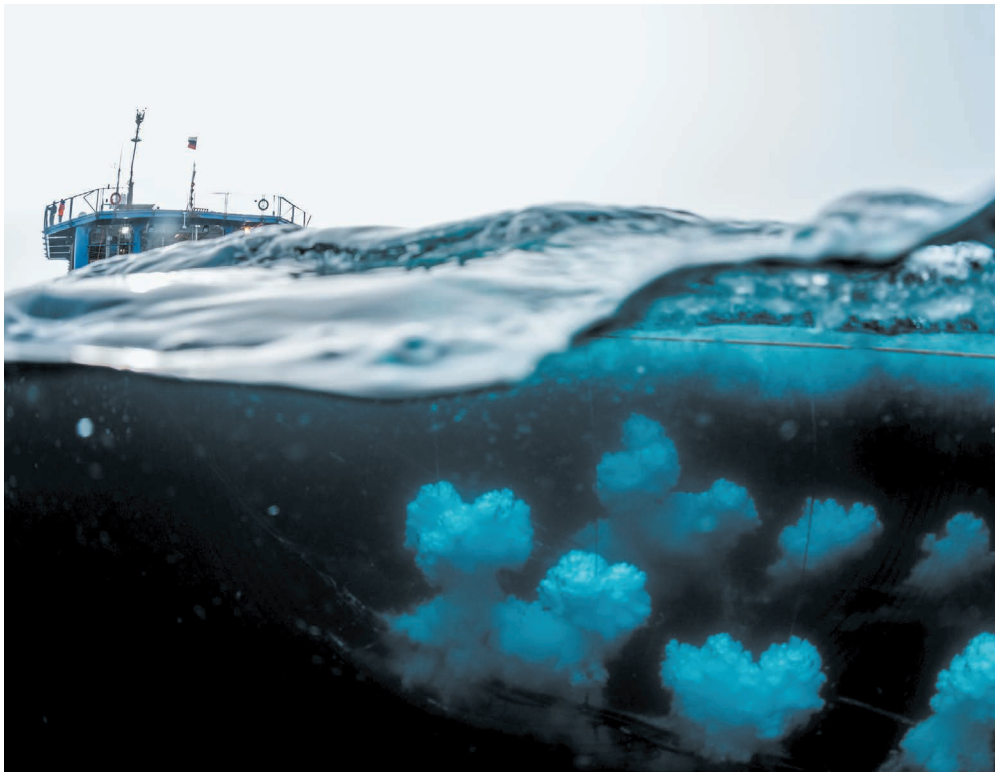
"Within six months or so of that talk, I started doing my first measures and said, 'OK, yes, this is a problem'," says Hanson. He is now working to simplify those measurements so that more labs can follow suit.

Until that happens, measurement errors could be affecting more than just individual lab experiments, says Boyer. "The carbon dioxide inside the leaf is a central feature of climate models and our understanding of how photosynthesis works," he says.

It is an intriguing issue, says Donald Ort, a plant physiologist at the University of Illinois at Urbana-Champaign. Ort suspects that water loss through the cuticle will be important only under conditions of extreme drought. "I don't see that it would be something that would impact how we're estimating global primary productivity, or have any consequence on breeding plants for greater yield," he says.

But Hanson says that in his unpublished studies of rapeseed (*Brassica napus*), a crop harvested for its oil, he found that measurements that did not account for the water lost through the cuticle overestimated water loss through the stomata by an average of 12.6%, even when the plants were well watered.

Even mild drought could be enough to affect water-use measurements, agrees Susanne von Caemmerer, a plant physiologist at the Australian National University in Canberra. "We have models that try to capture global carbon dioxide uptake and water loss," she says. "That's where this is really going to matter." ■



CHRISTIAN ÅSLUND/GREENPEACE

Research vessels use air guns to generate sound waves that probe the sea floor for natural resources.

ECOLOGY

Air-gun blasts kill plankton

Minuscule animals damaged by sound waves emitted from equipment used in oil exploration.

BY JEFF TOLLEFSON

Powerful sound waves created during offshore surveys for oil and gas can kill microscopic animals at the base of the ocean food chain, researchers find. And these lethal effects travel much farther than ecologists had previously assumed. Scientists fear that damage to these animals, collectively known as zooplankton, could harm top predators and commercially important species of fish that depend on the plankton for food.

"It could be that our focus has kind of been blinkered because it's been on whales."

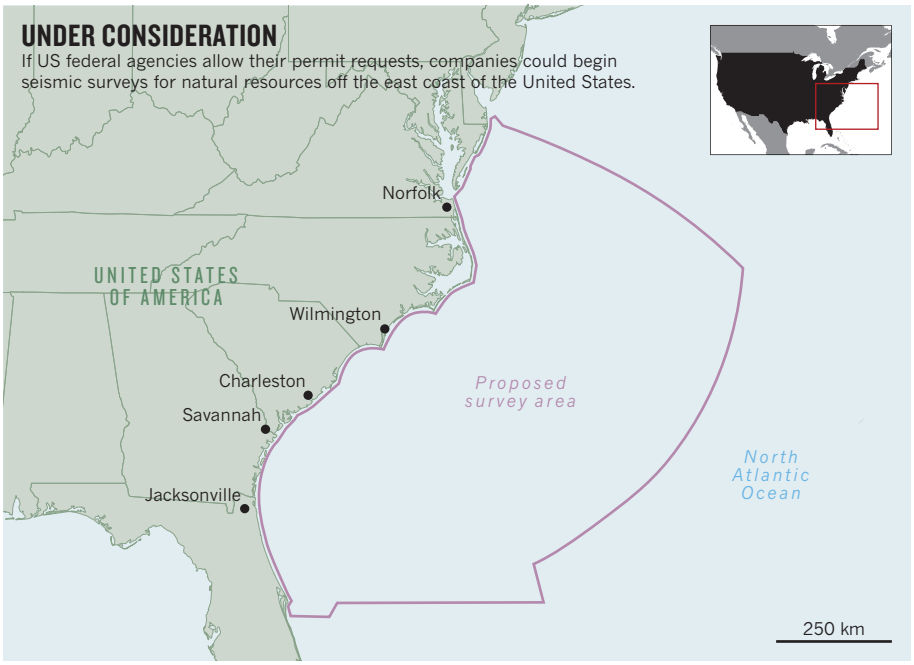
Seismic surveys blast compressed air to produce pulses of sound that can probe the sea floor thousands of metres down for natural resources. At 220–250 decibels, the noise produced by these air guns is louder than a Saturn V rocket during launch. Scientists have known for decades that whales and other marine mammals that use sound to communicate change their behaviour in response to such blasts[1]. There is increasing evidence that seismic surveys also affect fish[2] and marine invertebrates[3]. And now, researchers have found that the noise from air-gun blasts can kill zooplankton at distances of up to 1.2 kilometres away — more than two orders of magnitude farther than previously thought. They reported their results[4] on 22 June in *Nature Ecology and Evolution*.

"We were quite gobsmacked," says lead author Jayson Semmens, a marine biologist at the University of Tasmania in Hobart, Australia.

Semmens and his team conducted their study off the southeastern coast of Tasmania in 2015. They used sonar and nets to assess populations of zooplankton, including krill

larvae and tiny crustaceans called copepods, before and after firing a series of air-gun shots. The team found that zooplankton abundance dropped by 64% within one hour of the blasts. And the proportion of dead zooplankton increased by 200–300% as far away as 1.2 kilometres — the maximum distance the researchers sampled. This suggests that the impact of the blasts could extend well beyond such distances, Semmens says.

"Dead bodies in net tows don't lie," says Doug Nowacek, a marine ecologist at Duke University Marine Laboratory in Beaufort, North Carolina, who was not involved in the study. He suggests the next question for researchers is figuring out what this means for the ocean ecosystem. "If you start impacting the zooplankton population, that can cause a serious cascade through the food web."



SOURCE: NOAA

THE FORGOTTEN ONES

The results come as US President Donald Trump proposes opening up large swathes of the Atlantic coast of the United States to seismic surveys (see 'Under consideration'). The US Bureau of Ocean Energy Management is considering permit requests from six companies to conduct seismic surveys that were denied under former President Barack Obama. As part of that process, the US National Oceanic and Atmospheric Administration (NOAA) must also evaluate permit requests from those companies because their proposed activities could affect marine mammals. The NOAA permit requests are open for public comment until 6 July.

Although it's unclear if the companies will be able to start seismic surveys, initiating the permit process is part of a larger effort — laid out in an executive order that Trump issued in April — to expand US offshore energy development.

The Tasmania study didn't pin down precisely how air-gun blasts kill zooplankton, Semmens says, but the noise they produce probably damages the highly sensitive hair-like receptors that the animals use to navigate. The blast might not kill them all directly, but it could disorient them and make it harder for them to survive.

Semmens is planning a follow-on study with a full seismic air-gun set-up similar to that used in industrial activities to determine how far the effects of the noise extend. He and his team also want to look at what these blasts do to zooplankton physically. Although most research has focused on the impact of air-gun blasts on marine mammals, Semmens notes, perhaps it's the invertebrates that are most at risk. "It could be that our focus has kind of been blinkered because it's been on whales," he says. "Invertebrates are the forgotten ones." ■

1. Richardson, W. J., Greene, C. R. Jr, Malme, C. I. & Thomson, D. H. *Marine Mammals and Noise* (Academic, 1995).
2. Neo, Y. Y. *et al. Mar. Pollut. Bull.* **97,** 111–117 (2015).
3. Day, R. D., McCauley, R. M., Fitzgibbon, Q. P., Hartmann, K. & Semmens, J. M. Assessing the Impact of Marine Seismic Surveys on Southeast Australian Scallop and Lobster Fisheries. Project No. 2012–008 (Fisheries Research and Development Corporation, 2016).
4. McCauley, R. *et al. Nature Ecol. Evol.* **1,** 0195 (2017).

DRUG RESISTANCE

Modified viruses deliver death to antibiotic-resistant bacteria

Engineered microbes use CRISPR to turn a bacterium's immune response against itself.

BY SARA REARDON

Genetically modified viruses that cause bacteria to kill themselves could be the next step in combating antibiotic-resistant infections.

Several companies have engineered such viruses, called bacteriophages, to use the CRISPR gene-editing system to kill specific bacteria, according to a presentation at the CRISPR 2017 conference in Big Sky, Montana, this month. These companies could begin clinical trials of therapies as soon as next year.

Initial tests have saved mice from antibiotic-resistant infections that would otherwise have killed them, said Rodolphe Barrangou, chief scientific officer of Locus Biosciences in Research Triangle Park, North Carolina, at the conference.

Bacteriophages isolated and purified from the wild have long been used to treat infections in people, particularly in Eastern Europe. These viruses infect only specific species or strains of bacteria, so they have less of an impact on the human body's natural microbial community, or microbiome, than antibiotics do. They are also generally thought to be very safe for use in people.

But the development of phage therapy has been slow, in part because these viruses are naturally occurring and so cannot be patented. Bacteria can also quickly evolve resistance to natural phages, meaning researchers would constantly have to isolate new ones capable of defeating the same bacterial ▶