TRAILS IN THE TRACKLESS SEA

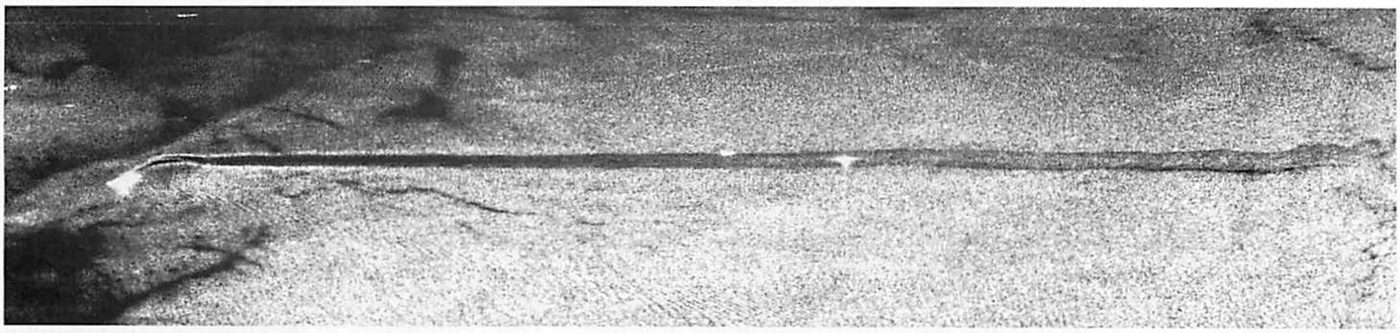
Look astern from the deck of a moving ship, and you may well see a paradox. In a ship's wake, you would expect the water directly astern—the water most roiled up by the propellers and by the passage of the hull—to remain unusually agitated. In fact, the water along the ship's path becomes *smoother* than the surrounding sea. In some cases this "smooth wake" forms a distinctive trail that extends for many kilometers behind the ship and persists for hours. The mechanism that gives rise to the smooth wake has lately come under investigation; surprisingly, the explanation seems to have much to do with events at a molecular scale at the water's surface.

The smooth wake shows up prominently in images made with synthetic-aperture radar operated from aircraft or spacecraft. Such instruments are sensitive to reflections from ocean waves, particularly when the wavelength of the water waves is near that of the radar beam. The smooth wake typically appears in a synthetic-aperture-radar image as a dark streak in a bright field, indicating that waves of the appropriate scale have been suppressed. The effect is most pronounced at shorter wavelengths—typically about a foot.

The mystery of the smooth wake is not so much how it forms as why it persists. Several factors contribute to the initial creation of calm water along a ship's path, starting with the mere presence of the ship itself, which obviously destroys the wave pattern within the area occupied by the hull. Turbulence caused by the motion of the ship and by the churning of the propellers also disrupts the prevailing waves. Still another possible influence, whose importance is not yet certain, is the bursting of bubbles when entrained air rises to the surface.

These factors could readily explain the suppression of short-wavelength surface waves over a distance of a few shiplengths. What is harder to understand is why the centerline wake sometimes remains smooth long after all these effects should have dissipated. One would expect the wind to raise new waves in the calm region. Even more important, one would expect waves from the surrounding sea to propagate across the smooth wake and quickly obliterate all traces of it. The persistence of the smooth wake suggests that wave motion continues to be actively suppressed in the wake region long after the ship has passed by.

The cause of this odd behavior has lately been investigated by Jerome H. Milgram of the Massachusetts Institute of Technology, Rodney D. Peltzer and Owen M. Griffin of the Naval Research Laboratory, and Richard A. Skop of the University of Miami. In two papers to be published in *Journal of Geophysical Research* they present observations of wake proper-



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Synthetic-aperture-radar image shows seven kilometers of the wake of a naval vessel, which is executing a turn at the far left; two bright blips within the wake are smaller research vessels.

ties measured at sea and devise a mathematical model meant to account for those observations.

The crucial finding to emerge from these investigations is the importance of surfactants, or surface-active molecules. It turns out that even an exceedingly thin film of such molecules—indeed, even a monolayer, a film one molecule thick—can have a significant effect on the growth and propagation of short-wavelength ocean waves. The effect is closely related to that of spreading oil on water to calm a stormy sea, a technique that has been known since antiquity. It may seem implausible that a molecular film could have much effect on waves a billion times larger in scale, but the phenomenon is well documented. The film modifies the boundary condition at the air-water interface and converts the energy of transverse water waves into the energy of longitudinal stretching and contraction in the film; much of this energy is then dissipated by viscosity in a thin layer of water just under the film. The shortest waves are damped the most by this mechanism, but longer waves give up some of their energy in regenerating the shorter waves, so that eventually the entire spectrum is damped to some extent.

What are the surfactant molecules responsible for the damping? Where do they come from? Molecules of biological origin are the leading candidates, most notably decomposition products of phytoplankton and other marine microorganisms. Some of these molecules, such as the phospholipids of cell membranes, have both hydrophilic and hydrophobic domains, so that they can form a stable layer at the air-water interface. Extensive chemical analyses of surface films, done by William R. Barger of the Naval Research Laboratory, have revealed a complex mixture of organic compounds, with a significant fraction of large-molecular-weight molecules that may include carbohydrates and proteins. Barger has found that every sample of seawater examined has a detectable quantity of surface-active material.

An unsettled issue is exactly how the passage of a ship alters the surfactant layer within the centerline wake. The simplest hypothesis is that turbulence and entrained air bring to the surface molecules that had been dissolved in the bulk of the water. There is some evidence for another explanation, however. In many cases the central part of the smooth wake is actually depleted of surfactants, but the edges of the calm band have a higher-than-normal concentration. A reasonable inference is that the ship pushes the surface film aside, rather like a snowplow piling up heaps of snow on either side of a road. The two parallel ridges of high surfactant concentration then serve as guard rails, excluding waves from the central band. Such parallel rails can be seen in some radar images.

Milgram and his colleagues made their measurements in the wakes of large commercial and naval vessels. They measured both wave energy and surface tension; the latter quantity serves as an indicator of surfactant concentration. Synthetic-aperture-radar images of the wakes were made at the same time from aircraft. The group observed unmistakable correlations between wave energy, surface tension and radar reflectivity at selected radar wavelengths.

The most dramatic indication that waves are being attenuated by something in or on the water came during experiments with a naval vessel off the coast of California. The ship made repeated passes along an east-west track about once every 50 minutes. During one run a current was observed to carry the smooth wake off to the south, away from the moored buoys that had been deployed to measure wave energy. An hour later, however, after another run, the current had reversed, and it brought the old smooth wake back across the array of buoys. The calm band was still discernible by eye, and it showed up clearly in the wave-energy recordings. Evidently, whatever depresses waves in the wake is not a pattern fixed in space but moves with the volume of water.—*Brian Hayes*

COLEOPTERAN CHILD CARE

The human species is not the only one that finds bearing and rearing children challenging. Imagine this prospect: Suppose that reproduction required first finding a large source of food, say a dead animal weighing up to 500 times your weight. Then suppose that you had to move the animal to a safe spot over a distance of perhaps 100 times your body length, and bury it at a depth six times your body length. Next you would have to copulate, produce eggs and feed and protect from predators the 30 or so children that would hatch. All this to take advantage of the one chance at procreation that is likely to come along in a lifetime.

Such is the reproductive struggle of a real species—and, surprisingly, an insect. In a class where parental care is a rare phenomenon, the burying beetles invest remarkable effort in becoming and being parents. Michelle Pellissier Scott, a zoologist at the University of New Hampshire, has been trying to understand why.

In the early 1980s Scott, an assistant professor of zoology at UNH, stumbled upon a burying beetle trying to stash a dead mouse in a wall of an old farmhouse that she was renovating in Jaffrey, New Hampshire. A few years later, Scott began investigating the reproductive behavior of these beetles.

Burying beetles belong to the family *Silphidae*, a group that feeds almost solely on carrion. They are large by insect standards—roughly one to two centimeters in length—and are common throughout the United States in both woods and suburbs. Scott began her work on the nocturnal