The Cacophony on the Coast

The Navy's deep-ocean acoustic detection methods don't apply in complex shallow waters

In the monotonous hush and uniform neatness of a library, it is quite possible to hear the soft echoes of a pin dropping many aisles away. But try it in the cluttered confines of a teenager's room, where a changing medley of music, cell phone rings, and television voices bounces off a jumble of strewn clothes, half-opened drawers, and scattered possessions.

Unlike light, sound travels efficiently through water, and the Navy uses sound to monitor what's going on in the ocean. To understand the sound messages transmitted through the seas, you need to understand the medium through which they are transmitted.

Like a library, the deep ocean is a structured environment with a few basic, reliable rules about sound. To monitor Soviet submarines during the Cold War, the Navy exploited the SOFAR channel, a persistent deep-ocean water layer whose properties efficiently transmit low-frequency sound waves over vast distances.

But when the Navy shifted its focus to battle zones near the coast, it found that shallower, coastal waters are as noisy and chaotic as a teenager's room. In recent years, several WHOI researchers have participated in pioneering cruises aimed at examining the complicated behavior of sound waves in shallow-water regions.

A complex environment

In 1996-97, many WHOI researchers (including Glen Gawarkiewicz, Ken Brink, Frank Bahr, Robert Beardsley, Michael Caruso, and James Lynch) joined naval researchers to conduct the Shelfbreak PRIMER experiment, funded by the Office of Naval Research (ONR). They deployed arrays of instruments over a 40-square-kilometer (25-square-mile) area 96 kilometers (60 miles) south of Martha's Vineyard, where the relatively shallow continental shelf begins to slope steeply into the Atlantic abyss. Some instruments transmitted sound waves, while others listened for them. Still other instruments measured the characteristics of the watery pathways through which the sound waves propagated.

Arthur Newhall, WHOI

HANG ON—Amid large waves crashing onto the fantail, WHOI Research Specialist Frank Bahr (left) and the bosun of the R/V Endeavor *hold on to WHOI's SeaSoar surveying instrument—and each other—during a 1997 Navy-sponsored research cruise.*

Unlike the deep ocean, the structure of water masses near the coast is neither simple nor stable. Within the narrow confines of the continental shelf, fresh water from rivers and cold water from coast-hugging currents confront warmer, saltier, deeper water masses near the continental slope. These water masses remain distinct—flowing, changing, and rearranging themselves, not unlike cold and warm fronts in our atmosphere.

These coastal water masses drive strong currents along the shelf edge, which rearrange water temperatures over the outer shelf as they meander. Temperature gradients between warm- and cold-water masses can also be altered by spinning, independent water masses within the oceans—called eddies or warm-core rings—that often form at the edge of the continental shelf. Warm or cold air can also change coastal water temperatures over seasons or days. All these phenomena can change water properties and shift coastal oceanic fronts, which, in turn, scatter or distort sound waves in unpredictable ways.

Waves *within* the ocean

The irregular shape of the coastal seafloor adds another variable. Funded by ONR, WHOI and Navy researchers participated in the 2001 Asian International Acoustics Experiment in the East and South China Seas. As part of the experiment, WHOI researchers Keith von der Heydt and John Kemp designed and deployed an autonomous hydrophone array that recorded the longest, highest-quality shallow-water acoustics data set ever collected.

Analyzing the data, WHOI scientists John Colosi and Tim Duda found that as tides move over steep seafloor canyons and ridges in shallow waters, they generate internal waves. These huge ripples in the interior of the ocean, formed along the boundaries of different water masses, add yet another factor that complicates shallow-water sound propagation.

"The coastal ocean is a much more energetic environment than the deep ocean, and small day-to-day changes produce large complications," said WHOI physical oceanographer Glen Gawarkiewicz. Oceanographers have just begun to learn how to extract distinct and useful signals from the coastal noise.

—Lonny Lippsett