NICHOLAS WOODS

GREAT SOUTH CHANNEL DINER

When swarms of tiny organisms aggregate every spring, they create a hotspot where whales come to feast

Amy Caracappa-Qubeck, WHOI

When people are hungry, they go to a place where they know they can find their favorite food. Right whales do much the same thing.

In the Great South Channel, a deep-water passage between Nantucket and Georges Bank, thick swarms of tiny marine organisms known as copepods appear every spring. Basking sharks, cod, haddock, and endangered North Atlantic right whales all feast upon these dense patches. In a way, the Great South Channel is like the right whales' favorite restaurant, and they keep coming back every year.

Nobody knows how these patches form. But understanding why they do would certainly help policymakers design marine protected areas and fisheries regulations to help conserve marine animals. This is why we are at sea aboard the research vessel *Tioga* at the crack of dawn. Our team from the Autonomous Systems Laboratory at Woods Hole Oceanographic Institution (WHOI) is helping to untangle the combination of physical and biological processes that form these dense copepod patches.

Above the steady drone of the engines, a loud "beep" penetrates the air on the bridge. The tone indicates that we are close to an underwater glider that has been surveying the area for the past two weeks. It's 8 a.m. on a Saturday morning in mid-May, and everyone is in position to recover the glider.

Back ashore in the lab, Dave Fratantoni, a WHOI physical oceanographer and my Ph.D. advisor, checks the glider's most recent position and relays the information to the rest of us in the field. Captain Ken Houlter, at the helm, guides the ship toward the waypoint. Ian Hanley, the first mate, rigs the deck for recovery. I huddle over a computer with Ben Hodges, our lab's research assistant, reading the data stream that accompanies the tone, trying to discern the range and bearing to the vehicle. We relay the information to Houlter, who alters course accordingly. Then we begin to scan the horizon for the glider's little yellow tail, a flag smaller than a sheet of paper marking not only the location of the vehicle but also a new piece to the puzzle of plankton patchiness.

At the mercy of currents

Scientists have known for many years that right whales and other predators feed on copepods in the Great South Channel, but what makes this place so special remains a mystery. In fact, biologists don't know how whales even find these dense patches. Past research has suggested that the physical environment—the currents, tides, and possibly the bathymetry of the ocean floor—might play roles in creating these important feeding areas. However, no one has yet identified the specific mechanisms—physical, biological, or a combination—by which dense copepod patches form.

The waters of the Great South Channel are extremely dynamic. A fairly steady coastal current flows south along the east coast of Cape Cod's forearm and into the Great South Channel. When it reaches the channel, some of this coastal current flows south around Nantucket Shoals, while another part turns toward the east and joins the northeastward flow along the northern flank of Georges Bank.

To the south, part of another current, flowing southwestward along the southern flank of Georges Bank, turns north into the Great South Channel.

On top of all this, strong currents driven by winds and tides are also flowing. At any given moment, these may be twice as fast as the steady currents. The copepods are at the whim of these complex flow patterns. To determine where the copepods will go, we must understand the flows that move them around.

A multipronged approach

The complex nature of the currents in the Great South Channel demands that we employ a variety of different techniques and tools to study the ocean circulation. Each is better suited for studying some aspects of the physical oceanography than others; combining methods allows us to understand more of the picture than any one method alone.

Research ships serve as platforms from which we deploy our vehicles, but they also take useful measurements of the water near the surface, including temperature and salinity. Meteorological moorings provide data on wind speed and direction at locations around the Great South Channel. These data tell us how winds move the surface waters. In addition, satellite-tracked surface drifters deployed in the region throughout the past thirty years give us an idea of how the surface water flows.

Another useful tool is the autonomous underwater glider. These underwater robots "fly" through the ocean by shifting their buoyancy, alternating between sinking and rising in the water. The wings on their sides provide lift, which allows them to glide for many days at a time.

They can fly under any weather conditions, including rough seas that would send an oceanographic vessel back to port. They collect temperature, salinity, and optical data that we can use to look for phytoplankton, which is fodder for copepods. They also can be equipped with acoustic instruments that can measure ocean velocity and look for copepods or listen for whales. The vehicle we are attempting to recover is one of these.

We know from our biologist colleagues that copepods enter into the Great South Channel mainly via the coastal current that flows along Cape Cod seashore and down into the channel. The glider we're chasing has traveled back and forth across this coastal current four times in ten days. The coastal current is fresher than surrounding waters, which makes it easy to identify using the salinity sensor on the glider.

We are interested to see that each of the glider crossings displayed a different salinity pattern: During the first transect, the fresher water was confined to a small area on the western edge of the Great South Channel. During the next three crossings, however, the fresher water spread farther across the channel, and during the last crossing, the coastal current water was saltier. Changes in the coastal current may lead to changes in the supply of copepods it delivers to the Great South Channel, so we are trying to figure out what controls the coastal current.

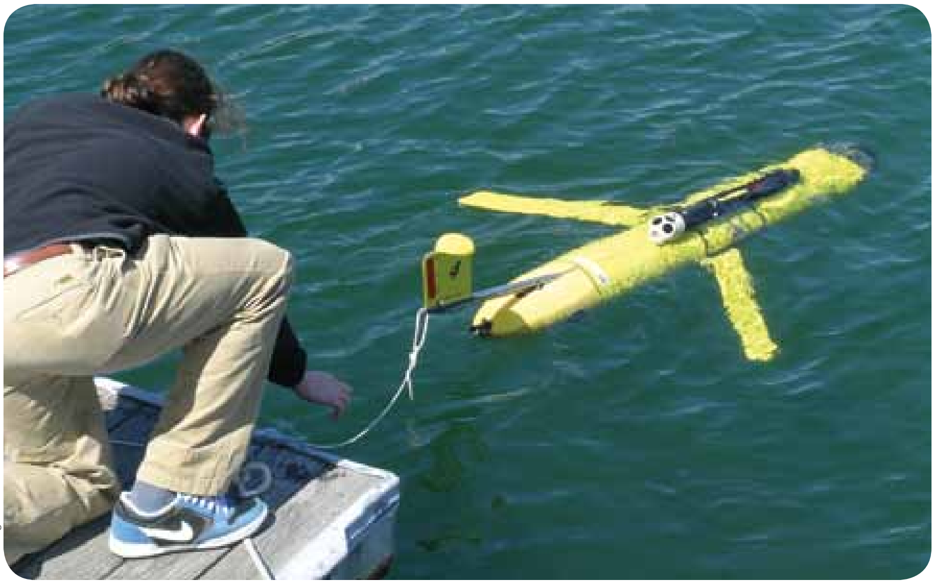
Storms mix it all up

One potential factor we are investigating is surface wind. Wind at the sea surface may partly determine how wide, fast, and deep the coastal current flows. As the wind blows over the surface, it pushes the current around, bringing it closer to the beach or farther offshore; or accelerating it into the Great South Channel or slowing it down; or making it deeper or shallower.

But the wind can also have other effects on the coastal current. If the wind blows hard enough, the current—and all the copepods within it—may get mixed up with surrounding seawater. The winds during strong nor'easter storms drastically affect the coastal current.

In 2005, a strong storm on Mother's Day weekend did exactly that. Before the storm, a well-defined coastal current flowed near the surface, and lots of right whales were sighted in and around the Great South Channel. After the storm, however, the current had mixed vigorously with the water surrounding it, and right whales were not seen in the area.

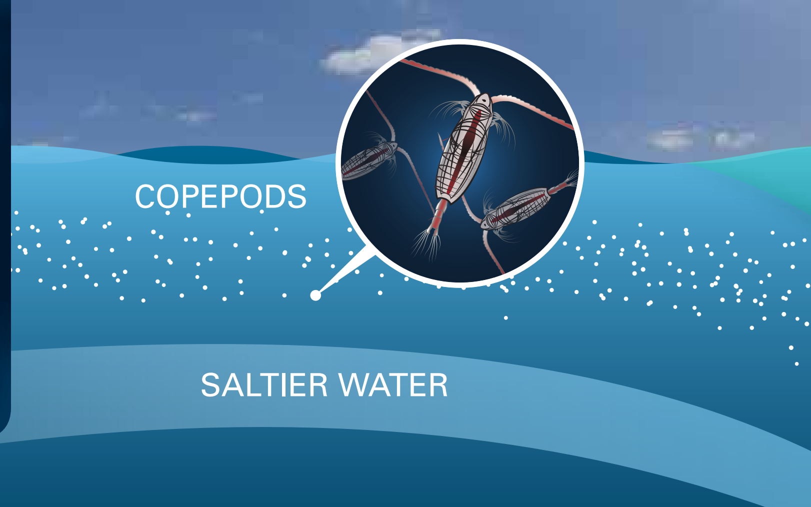
We have data from both gliders and a research ship in Great South Channel before and after the storm. We also use



Ben Hodges, WHOI

To unravel the combination of circumstances that creates rich feeding areas for marine animals, scientists use autonomous underwater gliders. These vehicles "fly" through the ocean, collecting data on water temperature and salinity, currents, copepod clusters, and whale sounds.

WHERE THE WHALES ARE



The Great South Channel is an undersea canyon between shallower Nantucket Shoals and Georges Bank. A relatively fresh coastal current flows south along the New England coast, bringing copepods along with it. In the channel, the coastal current collides with saltier, denser water to form an ocean front. Denser, saltier water sinks beneath the lighter, fresher water. Copepods sinking with the water swim back toward the surface, aggregating in dense patches along the front.

a numerical model that incorporates all known physics about fluid flow to simulate the ocean's circulation during the storm. Together, these help us piece together how the storm affected the shape of the current.

Ocean fronts

If ocean currents can sweep copepods into the Great South Channel, other ocean motion may actually cause the organisms to cluster. Copepods typically cannot swim fast enough to overcome swift horizontal currents in the ocean, but vertical water motion is much slower, and copepods are able to swim up and down in the water. Past theoretical studies have suggested a mechanism by which the copepods' swimming ability can combine with a certain pattern of currents to result in an aggregation of the animals.

Suppose there is a region in which the surface currents all horizontally converge on a spot. Unable to fight the horizontal motion, copepods would drift with the flow toward the spot. Since the water can't pile up in that place, it would be forced to sink. The copepods in the area of these converging currents would all seek to stay near the surface (to feed on phytoplankton, for example). They would swim upward to buck this downward motion, and they would remain in this spot.

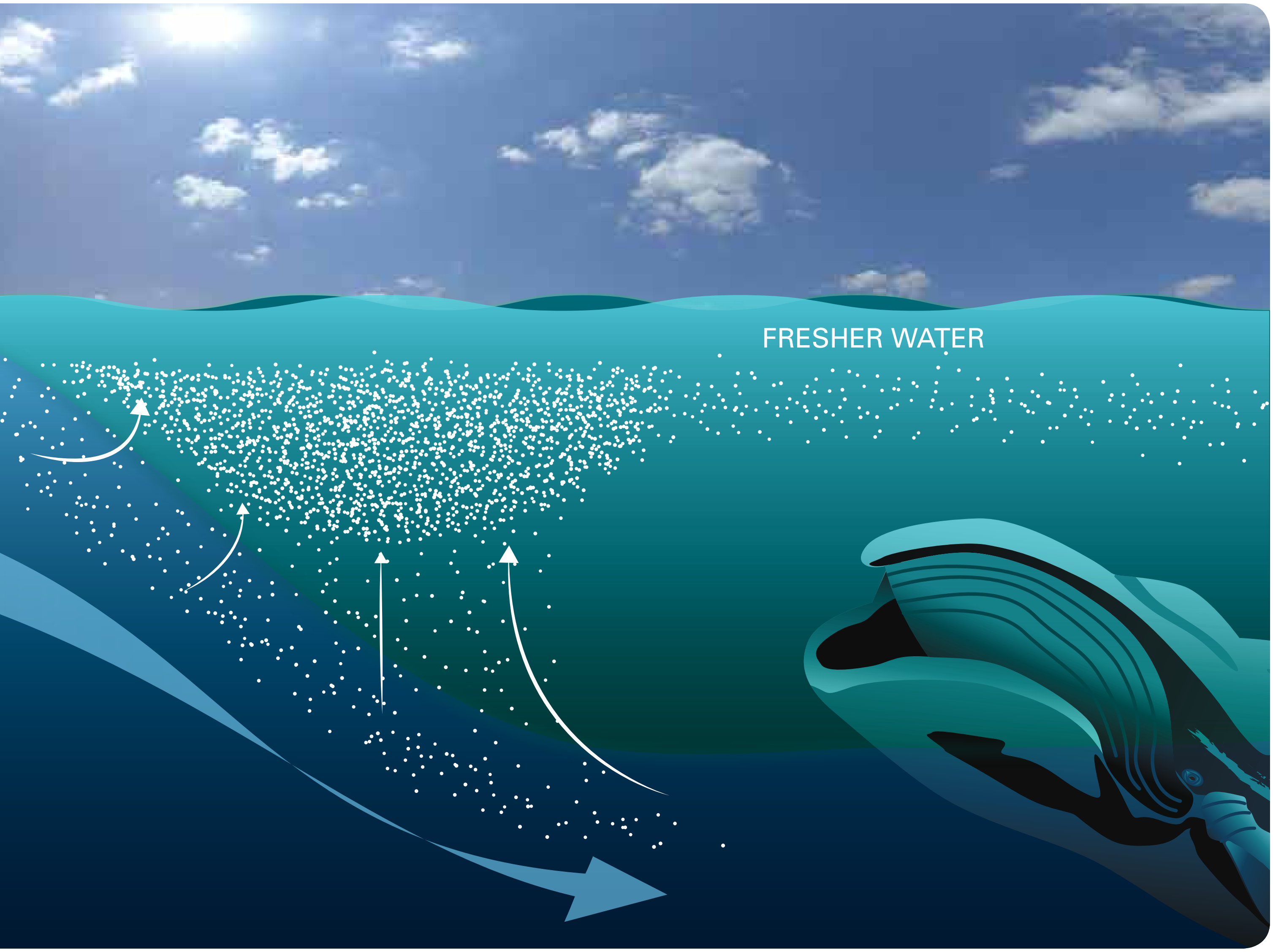
As more and more copepods drift to this location and stay there, the density of copepods would increase. This type of mechanism, if it were to occur in the real ocean, would create a hotspot for whales, birds, fish, and anything else that feeds upon copepods.

Just as the atmosphere contains boundaries between warm and cold air known as fronts, which determine weather, the ocean also has fronts between warm and cold or salty and fresh water. If the surface water converges at ocean fronts in the Great South Channel, we might expect to find copepods clustered there.

Complex processes such as these are not

David Fratantoni, WHOI

The atmosphere has boundaries between warm and cold air called fronts. The oceans has fronts, too, where currents with different temperatures and salinities collide. You can sometimes see the outline of fronts by the material that tends to accumulate along them.



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likely to be well-characterized by a single observational technique. Using our suite of methods, instruments, and vehicles, we are taking steps to answer important questions about how this critical ecosystem works. Since copepods are food for so many different animals, the factors affecting how and where they aggregate influence the overall health of the marine ecosystems they sustain. So our work will provide fundamental information that resource managers need to make decisions on regulating fisheries and designating marine protected areas.

This research was funded by the Coastal Ocean Institute at WHOI, the NOAA National Marine Fisheries Service Northeast Fisheries Science Center, and the Office of Naval Research Marine Mammals and Biology Program.

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Nick Woods grew up in Chapel Hill, N.C., and spent a great deal of time in, on, or around the ocean. In his senior year at the University of North Carolina-Wilmington, he was exposed to physical oceanography, which blended his passion for the ocean with his interest in physics. In 2007, he started in the MIT/WHOI Joint Program and works with his Ph.D. advisor David Fratantoni in the Autonomous Systems Laboratory. When not at his computer or tinkering in the lab, he enjoys playing a plethora of sports and spending time with his girlfriend and two cats. His mentor for this article was Peter Spotts, science correspondent for *The Christian Science Monitor*.