

Sassy Scallops

HOW WILL SHELLFISH FARE AS OCEAN CONDITIONS SHIFT? *by Elizabeth Halliday*



Here's looking at you. Silvery eyes line the edges of scallops' shells, helping them sense light and movement.

Months of experiments gave Meredith White ample time to observe her laboratory subjects: scallops. And perhaps for them to observe her, too. Resting in their trays, drawing water across their gills for food and oxygen, the scallops reveal rows of shiny eyes ringing the edge of their shells.

"You just feel like they're watching you," White said. "And they do react to shadows and movement." Pass a hand over their trays, and they instantly close up. Take them out, and they just might squirt seawater in your face.

"Sometimes I'd wear the same old clothes in the lab day after day, because I didn't want all my clothes to get salty," White said. In her research as a graduate student in the MIT-WHOI Joint Program in Oceanography, she got well acquainted with scallops' idiosyncrasies.

"Scallops have the most personality of any bivalve," she said.

Clams and cockles bury themselves in the sand, oysters cement themselves to a rock or reef, and mussels use their "beards" of strong byssal threads to anchor themselves on rocks or pilings. But scallops rest on the seafloor and use their formidable (and delicious) adductor muscle to clap themselves through the water by opening and closing their shells.

This mobility seemingly enables them to air their grievances in the laboratory. A scallop may become restless sitting in one spot and will swim around the tank to scout a new location.

"Sometimes, a scallop will just clap itself around and settle back exactly where it was," White said, and in the process rile up all its tankmates into a kerfuffle of clapping.

But personality won't carry the day as scallops confront a precarious future. The oceans are becoming more acidic, threatening shellfish's ability to build shells. White took a close look at *Argopecten irradians*, the commercially valuable bay scallop. In particular, she focused on how changing ocean conditions might affect scallops during their sensitive, crucial larval stages.

The first hours and days of life

Since the Industrial Revolution, humans have pumped huge amounts of greenhouse gases into the atmosphere, and the ocean has soaked up 30 percent of the excess. "Thirty years ago, I know I thought that was a good thing," said Dan McCorkle, a marine chemist at Woods Hole Oceanographic Institution (WHOI) and White's co-advisor. "But now, there is a growing understanding that the changes in acidity, although small, might not be insignificant."

Carbon dioxide reacts with water to form carbonic acid and bicarbonate. That not only makes seawater more acidic, it makes carbonate less readily available for corals, shellfish, and some plankton to build their calcium-carbonate shells or skeletons. Plants and animals that have evolved in an ocean where the pH hadn't changed for millennia may not readily adapt to rapid shifts.

Average world ocean pH has dropped from 8.2 to 8.1 over recent decades and is expected to drop to 7.8 by the end of the century. Some coastal waters, however, already surpass the acidity prognosis for 2100 because of a double-whammy of human impacts: excessive atmospheric carbon dioxide *and* excessive nutrients entering the ocean from fertilizer, sewage, and septic tank runoff.

The nutrients fertilize blooms of algae, which die and provide a banquet for bacteria. These decomposing organisms crank up their metabolism the same way we do, gobbling up oxygen and releasing carbon dioxide, which acidifies waters to a pH as low as 7.4 in summer months. These summer pH dips coincide with scallop spawning season.

Twelve to 24 hours after fertilization, the larvae begin the critical task of using calcium and carbonate to calcify a shell. Importantly, this task is fueled by the energy reserves put into the egg by the parent scallop; the larvae can't eat, because they have yet to develop mouths! As the larvae float in the ocean, growing and transforming their minuscule bodies, they simultaneously

face a gantlet of predators, limited food reserves, and dwindling time to find a place to settle down and grow.

"Really big changes happen early in life as they go through stages of development on time scales of hours," said WHOI biologist Lauren Mullineaux, White's Ph.D. co-advisor.

White's spawn shop

White grew up spending summers exploring the shores around her family's rustic cottage in Harpswell, Maine, with a keen eye to the tides to maximize time scooping up sea urchins and other animals in shallow waters. As an undergraduate, she majored in chemistry.

So she was well-suited for graduate school fieldwork. White bundled up in chest-high neoprene waders, layers of sweatshirts, and gloves for wintertime expeditions to collect scallops on Cape Cod shores. She used a plexiglass "look-box" to get a clear view down to the sandy bottom and towed a floating basket for her specimens.

"Scallops in this region naturally spawn in the spring, when the water temperature increases and triggers gametogenesis, the development of eggs and sperm," White said. "So I collected them in the winter, before they had gone through this process, and would bring them into the lab to get them to spawn."

White isolated spawning scallops in deli-style plastic containers to capture the eggs and sperm and carefully raised water temperatures. She initiated their fertilization in an aquarium environment in which she could monitor and control carbon dioxide levels and acidity.

For seven days, White grew a subset of larvae in only ambient seawater; a subset spent their first 12 hours in ambient seawater and then were subjected to more acidic seawater with a pH of 7.4; another subset of larvae grew only in acidified water; and a final subset spent their first 12 hours in acidified seawater and then were switched to ambient water.

"These classic 'switch experiments' are often used by ecologists to test questions about a community," Mullineaux said, but they hadn't been applied to ocean acidification research.

Developmental delays and deformities

White measured the survival rate and shell size in larvae to test whether larvae spending their first days of life in normal seawater fared differently than larvae spending their first days in seawater acidified with high carbon dioxide. She also wanted to learn if any impacts are reversible, since larvae in coastal waters can be swept between polluted, acidic coastal areas and open ocean areas within spans of days or even hours.

Across the board, "any exposure to the acidified seawater consistently decreased survival," White said. Among the larvae

that survived in all experiments, she found striking differences in their shells. She targeted her investigations on the critical 12-hour window in which the larvae initiate shell calcification.

Larvae raised in ambient seawater, as well as larvae that had been switched from acidic to ambient seawater before calcification began, had bigger shells than larvae raised in the acidified seawater or switched into acidified water before calcification began. Even though all the larvae subsequently grew at similar rates, the ones with initially stunted shells never fully compensated for those undersized shells later on.

"Small shell size usually means the larvae inside are small as well," Mullineaux said, and that delays their metamorphosis into juveniles. This delicately orchestrated process relieves larval scallops from the threats they face as helpless plankton, so acidic waters that cause them to be smaller effectively extend their most vulnerable period. And even if they make it to the juvenile

stage, they may still be at a disadvantage because of their relatively later start as juveniles.

"Even more surprising than the impact on shell size was the very different effect that ocean acidification has on the shell before it's even set down," said Mullineaux. Measuring shells so small that it took a scanning electron microscope, White noticed that some shells had an unusual dark spot. These were strange indentations at the shell's hinge, and this hinge deformity was always more frequent among scallops that had been in acidified water during their first 12

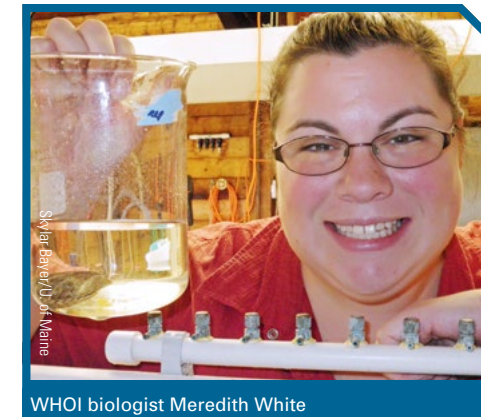
hours of life, before calcification even begins.

"It's a really obvious effect," White said, although the scientists are unsure how pH causes the deformity. "If the deformity impedes the opening of the hinge, it could impede the larvae's ability to collect food and have indirect effects on survival."

"Typically, larvae that have any kind of deformity are toast," Mullineaux said, "so I suspect that kind of deformity could have a big influence on long-term survival." The fact that this happens even before the critical exposure period for shell size shows the complexity of predicting how animals will respond to a more acidic ocean.

In June 2013, White earned her Ph.D. and headed back to her beloved Maine coast and the Bigelow Laboratory for Ocean Science, where she is studying the effects of ocean acidification on coccolithophores, a kind of phytoplankton. Like scallops, they have calcium carbonate shells. But, as far she knows, they don't squirt or clap.▲

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WHOI biologist Meredith White