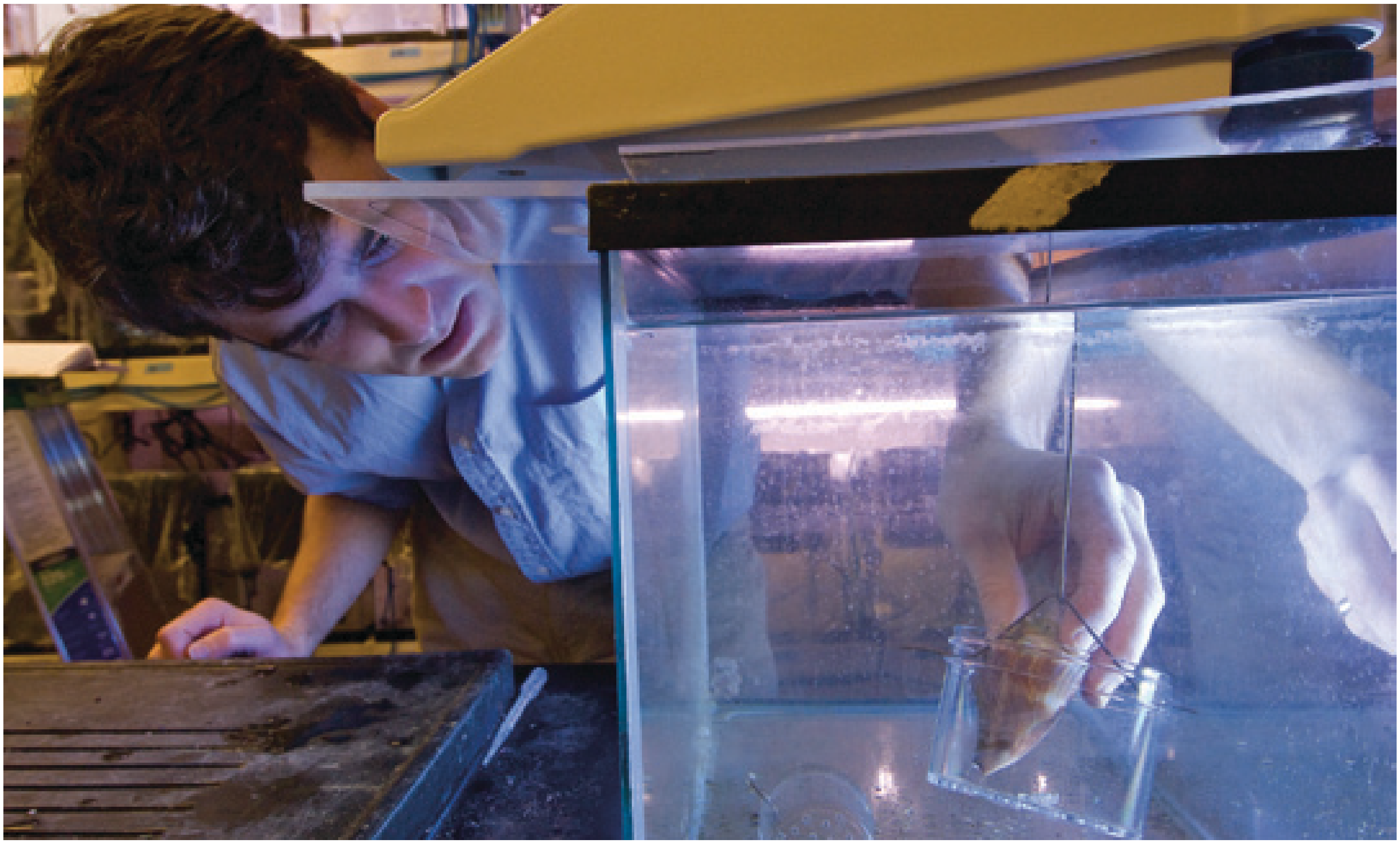

Tom Kleindinst, WHOI

WHOI scientist Justin Ries grew marine animals in tanks under today's atmospheric carbon dioxide levels and at higher levels forecast in the future.

# Ocean acidification: a risky shell game

A new study has yielded surprising findings about how the shells of marine organisms might stand up to an increasingly acidic ocean in the future, caused by the continuing buildup of carbon dioxide ($CO_2$) in the atmosphere.

Subjected to very high $CO_2$ conditions, the shells of clams, oysters, and some snails and urchins partially dissolved. But other species seemed as if they would not be harmed, and crustaceans, such as lobsters, crabs, and prawns, appeared to increase their shell-building.

Excess $CO_2$ dissolves into the ocean and is converted to corrosive carbonic acid, a process known as "ocean acidification." At the same time, the $CO_2$ also supplies carbon that combines with calcium already dissolved in seawater to provide the main ingredient for shells—calcium carbonate ($CaCO_3$), the same material found in chalk and limestone.

"Marine ecosystems—particularly those based on calcium-carbonate shell-building, such as coral or oyster reefs—could change with increasing atmospheric $CO_2$," said Justin Ries, a marine biogeochemist and lead author of the study, published in the December 2009 issue of *Geology*. In a future ocean that continues to absorb excess $CO_2$ from industrial emissions, deforestation, and other human activities, sensitive species could lose their protective shells and eventually die out, while other species that build stronger shells could become dominant.

While a postdoctoral scholar at Woods Hole Oceanographic Institution, Ries worked with WHOI scientists Anne Cohen and Dan McCorkle. In tanks filled with seawater, they raised 18 species of marine organisms that build calcium carbonate shells or skeletons. The scientists exposed the tanks to air containing $CO_2$ at today's level (400 parts per million, or ppm), at levels forecast by climate models for 100 years from now (600 ppm) and 200 years from now (900 ppm), and at a level (2,850 ppm) that should cause calcium carbonate in shells to dissolve in seawater.

The test tanks' miniature atmospheres produced elevated $CO_2$ in the tiny captive oceans, generating higher acidity. The researchers measured the rate of shell growth for a range of species from both temperate and tropical waters. They included organisms such as corals and coralline algae, which form foundations for critical habitats, and popular seafoods such as clams, oysters, scallops, conchs, urchins, crabs, lobsters, and prawns.

In water containing more $CO_2$, organisms have more carbon to use as raw material for shells. But they can benefit from the high $CO_2$ only if they can convert the carbon to a form they can use to build shells and can also protect their shells from dissolving in the more acidic seawater. The scientists found that different organisms responded in strikingly different ways to higher $CO_2$—from extremely positive to extremely negative, Ries said.

As expected, at the highest $CO_2$ levels the shells of some species, such as large, sturdy Caribbean snails called conchs, noticeably deteriorated. The spines of tropical pencil urchins dissolved away to nubs. And clams, oysters, and scallops built less and less shell as $CO_2$ levels increased.

However, two species of calcifying algae actually did better at 600 ppm (predicted for the year 2100) than at present-day $CO_2$ levels, but fared worse at even higher $CO_2$ levels. Temperate (cool-water) sea urchins, unlike their tropical relatives, grew best at 900 ppm, as did a temperate limpet.

Crustaceans provided the biggest surprise. All three species that were tested—blue crabs, American lobsters, and a large prawn—defied expectations and grew heavier shells as $CO_2$ levels rose.

"We were surprised that some organisms didn't behave in the way we expected under elevated $CO_2$," said Anne Cohen, second author on the *Geology* paper. "Some organisms were very sensitive [to $CO_2$ levels], but there were a couple [of species] that didn't respond until it was sky-high—about 2,800 parts per million. We're not expecting to see that [$CO_2$ level] any time soon."

Tom Kleindinst, WHOI

**The urchin on the right, grown under present-day conditions, is healthy and has normal spines. The urchin on the left, grown under higher $CO_2$ levels, is substantially damaged by more acidic seawater conditions.**

The scientists found that species with more protective coverings on their shells and skeletons—crustaceans, the temperate urchins, mussels, and coralline red algae—are less vulnerable to the acidified seawater than those with less protective shells, such as conchs, hard clams, and tropical urchins.

Justin Ries, WHOI

**In a surprising finding, American lobsters grown under very high levels of carbon dioxide (at right) grew larger, heavier shells than lobsters (left) grown under today's levels.**

All of the test organisms continued to create new shell throughout the experiment, said Ries, now an assistant professor at the University of North Carolina. But some suffered a net loss of shell because older, more massive portions of their shells dissolved under the highest $CO_2$ conditions.

The results, Ries said, suggest that the predicted rise in $CO_2$ over the coming centuries could cause changes in marine ecosystems, with some organisms building more massive skeletons and others becoming less successful at defending themselves from predators.

"Given the complex relationships that exist amongst benthic marine organisms," said Ries, "it is difficult to predict how even subtle changes in organisms' abilities to calcify will ultimately work their way through these ecosystems."

*—Kate Madin*

*Justin Ries is a former postdoctoral scholar of the WHOI Ocean and Climate Change Institute. This work was also funded by the WHOI Tropical Research Initiative and the National Science Foundation.*