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Ripple Marks

The Story Behind the Story

SPECIAL SECTION: SUMMER AT THE SHORE

BY CHERYL LYN DYBAS

Stingray City: Underwater Free-for-All?

Stingray City, it's called, this sandbar in the Cayman Islands that lures one million human visitors each year to feed and touch a congregation of southern stingrays.

The rays have received handouts since the 1930s, when fishers first cleaned their catches there. Tourist operations began in 1986 on the sandbar, allowing people to stand in the shallows to interact with the rays. For those looking to make eye contact, snorkeling and scuba diving are on the menu.

Stingray City has gained global recognition; it's said to be the most popular dive site in the world.

Tour operators "call in" the rays by hand-feeding them packaged California squid.

But now an undersea upset may be happening in this city-beneath-the-waves, say scientist Mahmood Shivji of Nova Southeastern University and colleagues.

Shivji studied the southern stingray population to assess how ecotourism affected the rays' behavior.

"Striking changes are happening," he says. "These animals have become homebodies, essentially, in a relatively tiny area."

Stingray City's rays show very different activity patterns than their wild counterparts, which aren't exposed to daily feedings or human contact.

Wild stingrays are active at night and are solitary. After sundown, they forage over large distances to find food and rarely cross paths with other stingrays.

To discover whether Stingray City's rays show altered behavior, the researchers tagged and monitored wild and fed stingrays for two years to compare their movement patterns.

"A major change was that fed stingrays reversed their natural rhythms, becoming active during the day and resting at night—a complete contrast to their wild counterparts," says Brad Weatherbee, a scientist at the University of Rhode Island.

Shivji, Weatherbee, and other researchers published their results in March 2013 in the journal *PLOS ONE*.

Fed stingrays seemed content to be in close proximity with other stingrays. Some 164 rays abandoned their normal behavior and crowded together in less than a quarter square mile of undersea space.

The rays showed up at least an hour before tourist boats and the start of feeding. Once people arrived, the rays formed schools and partook of food wingtip to wingtip. Fed stingrays mated and became pregnant year-round rather than during a specific mating season. They also showed signs of aggression, biting each other more often than their wild counterparts. At times they "mobbed" humans.

"Human-wildlife interactions are expanding all over

Crowds with stingrays. *Photo credit: Guy Harvey*

the world," says Weatherbee, "so it's important to think about how these activities are affecting the biology of what are ultimately wild animals."

The results indicate that food offered by people can dramatically change how large, mobile ocean species behave. There may be long-term costs for the stingrays, the scientists believe, which could pose problems for the rays' health.

Previous studies at Stingray City have found that fed stingrays show altered physiological markers, with different fatty acid profiles than their wild counterparts.

The congregation of stingrays may also influence the structure of the marine animal community, not only through the rays' roles as predators, says Shivji, but as prey.

"Large hammerhead sharks—predators of these and other rays—are often seen in the vicinity of Stingray City," says Shivji. "They're likely attracted in greater than normal numbers by the availability of so many stingrays—'easy prey.' The stingray feeding operation has the potential to alter the entire local marine ecosystem."

Stingray City brings major tourist revenues to the Cayman Islands. Each stingray may be "worth" as much as $500,000 each year in ecotourism dollars. How will that play out in the future?

"We plan to continue to monitor the rays," says Shivji, "and to track the effects of humans."

At this time, the scientists say, there are no regulations on feeding at Stingray City.

When tourists are absent, researchers have glimpsed stingrays foraging on their own. So the rays may not be totally dependent on giveaways.

How much of the rays' diet at Stingray City comes from ecotourism? No one knows, but Shivji and others hope to find out. Before the ecosystem is forever altered and stingrays disappear, leaving humans the last ones circling the sandbar.

A school of rays. *Photo credit: Matthew D. Potenski*

Hanging by a Thread On Rocky Shores

Imagine trying to pitch a tent in a stiff coastal wind. You just have it secured, when a gale lifts the tent—stakes and all—and carries it away.

That's exactly what is happening to species that are ubiquitous along the rocky shores of both the US West and East Coasts: blue mussels.

Mussels make use of what are called byssal threads—strong, silky fibers—to attach to rocks, pilings, and other hard substrates. They produce the threads using byssus glands in their feet.

But the effects of ocean acidification are turning byssal threads into flimsy shadows of their former selves, leaving mussels tossed about by wind and waves.

At high levels of atmospheric carbon dioxide—levels in line with expected concentrations over the next century—byssal threads become weaker, found scientists Emily Carrington, Michael O'Donnell, and Matthew George of the University of Washington. Blue mussels are less able to attach to rocks.

The researchers published their results in February 2013 in the journal *Nature Climate Change*; O'Donnell is the lead author.

The scientists hope the information will be used in decisions about siting of marine protected areas and for improved placement of aquaculture farms.

The waters in which blue mussels and other marine species dwell are turning more acidic (pH dropping) as Earth's ocean is absorbing excess atmospheric carbon dioxide from human-caused emissions.

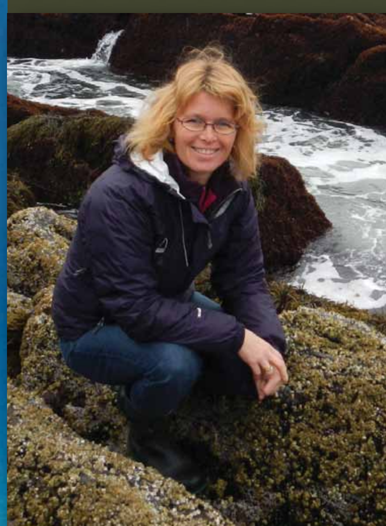
For now, however, visit the land between the tides, and you'll see waves crashing on boulders tinged dusky blue by snapped-closed mussels.

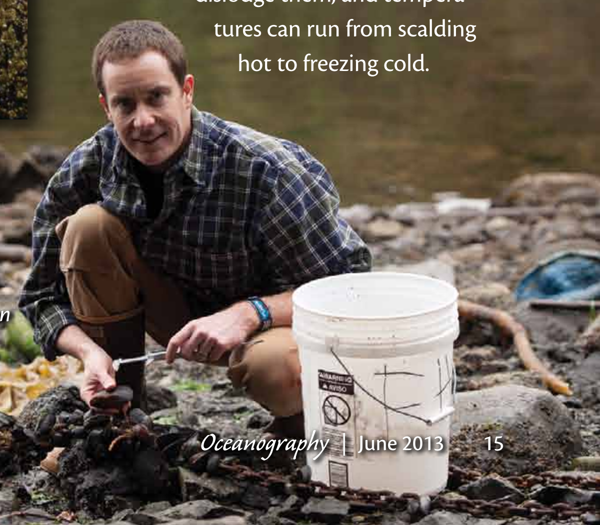
"Their shells are a soft color, the misty blue of distant mountain ranges," wrote Rachel Carson more than 50 years ago in her best-selling book *The Edge of the Sea*.

For blue mussels trying to survive, the rocky intertidal zone indeed may be akin to scaling a mountain range.

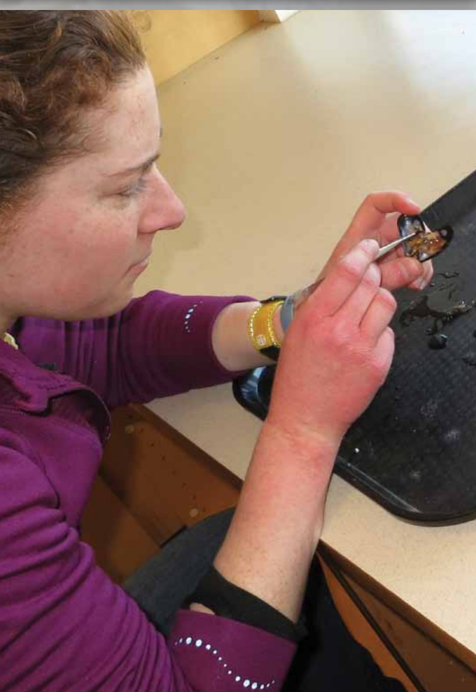
The rocky intertidal is above the waterline at low tide and underwater at high tide—the area between tide marks. It is home to animals such as starfish and sea urchins, and seaweed such as kelp. All make a living from what floats by rocky cliffs and boulders.

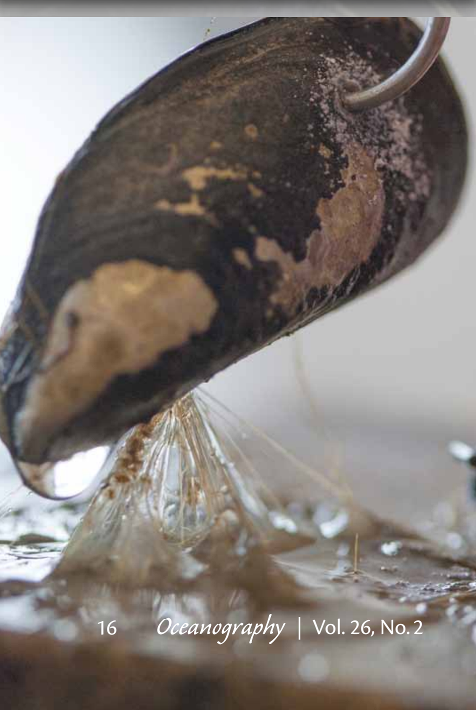
It can be a hard go. Rocky intertidal species must adapt to an environment of harsh extremes. Water is available when the tide washes in; otherwise residents of this no man's land between sea and shore are wide open to the elements. Waves can dislodge them, and temperatures can run from scalding hot to freezing cold.





Biologist Emily Carrington (above), marine scientist Michael O'Donnell (right), and colleagues study the effects of ocean acidification on blue mussels. *Photo credits: (above) Amy Johnson; (right) Suzanne Cowden*





"For some reason," says Carrington, "byssal threads become weaker in summer. They seem to rot away quickly at that time. We don't know for sure what's causing this seasonal change, but it could be a combination of warming water temperatures and coastal eutrophication." Ocean acidification may be the crowning blow.

In the rocky intertidal, blue mussels are hanging on for dear life.

Combining results from laboratory experiments with those from a mathematical model, Carrington and colleagues show that at high carbon dioxide concentrations, blue mussels can be dislodged by forces 40% lower than what they are able to withstand today. Those forces include wind and waves.

Mussels with this impaired ability, once displaced from their homes, could cause ecological shifts in the rocky intertidal zone—and huge economic losses in a global blue mussel aquaculture industry valued at US $1.5 billion each year.

"Mussels are among the most important species on rocky shores worldwide," says O'Donnell, "dominating ecosystems wherever they live. The properties in their byssal threads are also of interest to biochemists and have been studied as possible adhesives."

Blue mussels may make important contributions to the fields of medical and materials science, says Carrington. In fact, they already have, in a gel that can be painted onto the walls of blood vessels, forming a protective barrier with life-saving implications.

Biochemist Christian Kastrup of the University of British Columbia and colleagues developed the "mussel goo," as it's been called, to shore up weakened blood vessels at risk of rupturing. The gel's formula is similar to the amino acid that enables mussels to stay put in churning waters. By forming a barrier between flowing blood and vessel walls, the gel also counteracts the inflammation that happens when a stent is inserted to widen a narrowed artery.

The scientists, who recently published their results in the journal *Proceedings of the National Academy of Sciences*, hope their invention may go one step farther: to preventing the rupture of plaque in blood vessels. "By mimicking the mussel's ability to cling to objects, we've created a substance that remains in place in a very dynamic environment with high flow velocities." That environment, it turns out, could as easily be the human circulatory system as the global ocean system.

Some species of mussels, says Carrington, are experts are gluing onto sea grass, some to other shells, some even adhere to rocks in the harsh conditions of deep-sea hydrothermal vents. "Each may have different genes that code for different proteins," she says, "so the adhesives vary."

Will their potential be realized? Carrington, O'Donnell, and George have found a disturbing answer.

The scientists allowed mussels to secrete byssal threads in a range of ocean water chemistries from present-day through predicted near-future conditions, then tested the threads to see how strong they were.

At levels considered reasonable for a near-future coastal ocean (given current rates of acidification), byssal threads were less able to stretch. Further experiments revealed that the problem was caused by dissolution of the threads' glue where it attaches to rocks and other hard surfaces.

"Much ocean acidification research has focused on the process of calcification," says Carrington, "through which animals and some plants make hard parts such as shells."

In an acidifying ocean, marine species that depend on calcium carbonate have a more difficult time forming shells or, in the case of coral reefs, skeletons.

"But there's more to marine communities than calcified parts," says O'Donnell. Other species such as mussels and their byssal threads, he says, are equally important.

"Understanding the broader consequences of ocean acidification requires looking at a variety of biological processes in a range of species."

A need that didn't exist when Rachel Carson wrote *The Edge of the Sea*.

"When we go down to the low-tide line, we enter a world that is as old as the Earth itself—the primeval meeting place," mused Carson, "of the elements of earth and water."

And of mussels and rock. Fifty years hence, will the mussels still be here?

Blue mussels and the researchers who study the mussels' threatened byssal threads.
Photo credits: (top and middle) Emily Carrington; (bottom) Michael O'Donnell

Where's the Sunscreen? Look on a Coral Reef

Where's the sunscreen? In summer, the question echoes up and down coasts, from rocky shores to sandy beaches to coral reefs.

For an answer, the best bet might be: on a coral reef.

New research has found a mechanism by which corals use pink and purple hues as screens to protect themselves against harmful sun rays.

Most reef corals need light to survive; the corals benefit from sugars and lipids produced by their light-dependent symbiotic algae, or zooxanthellae. But in shallow waters, light levels are often higher than the corals need, so sunlight can become a turncoat.

Light stress is a major reason why corals "bleach," turning white from the loss of zooxanthellae.

A team of scientists has found evidence that corals' pink and purple chromoproteins, as they are called, can act as sunscreens for zooxanthellae by removing parts of the light that might otherwise be harmful.

Jorg Wiedenmann of the University of Southhampton in the UK and other researchers ventured to Australia's Great Barrier Reef to make their discovery.

"Corals' beautiful pink and purple pigments are biochemically related to the green fluorescent protein, or GFP, of the jellyfish *Aequorea victoria*," says Wiedenmann. "But in contrast to their green-glowing counterpart, these pink and purple chromoproteins take up substantial amounts of light and don't re-emit it."

GFP-like proteins were thought to contribute to the protection of corals and their symbionts from too much sunlight. But the process was unclear. "At least for chromoproteins," says Wiedenmann, "we now know that they indeed have the capacity to fulfill this function." Wiedenmann and colleagues published their results in January 2013 in the journal *Coral Reefs*.

Corals inhabit a range of light environments, from shallow waters to deep reefs.

"Even at the scale of a single shallow-water colony," the scientists write in their paper, "there are large variations in light exposure of the coral's tissues. Those variations are controlled by factors such as seasonal and daily changes in surface irradiance, changes in absorbing and scattering materials in the water column, and orientation of the tissue surface relative to the incident irradiance and wave-focusing effects."

For corals in the direct path of the sun's rays, without chromoproteins, it would be sink or swim.

The findings have uncovered a possible explanation for another mysterious phenomenon: why some corals accumulate high amounts of chromoproteins in growing areas such as branch tips and in healing wounds.

"These coral parts have no symbiotic algae [zooxanthellae], so much of the light is reflected by the white coral skeleton rather than being used by algae," says Wiedenmann. "The resulting increased light intensities in new parts of the coral are a potential danger for the zooxanthellae cells that need to colonize these areas."

But corals use a clever trick to help their symbionts. The higher light intensity "switches on" genes responsible for producing chromoprotein sunscreens.

"The screening effect of the chromoproteins then helps the symbionts enter the new tissue," Wiedenmann says. "Once the zooxanthellae are established or re-established, light levels in the tissue again decrease as the algae use most of the light for photosynthesis."

The chromoprotein genes are switched off, allowing corals to save energy.

The research contributes to a better understanding of corals' response to environmental stress. "Knowledge of corals' resilience is important to predicting the fate of reefs exposed to climate change and other human-caused disturbances," says Wiedenmann.

Whether corals hold the biochemical key to the next sunscreen for humans is, for now, hidden beneath the waves.

(ABOVE) Staghorn coral (*Acropora*) accumulating high amounts of a purple chromoprotein in the growing branch tip. (LEFT) *Pocillopora damicornis* from the Red Sea expressing a pink chromoprotein. *Photo credits: Jorg Wiedenmann.*

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