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Photograph © Stephen Nett

Magnificent northern California cliffs loom over a growing marine disaster that could reshape the nearshore ecosystem. Purple sea urchin densities found in coastal waters north of San Franciso are greater than 60 times their historic density. The urchins are voracious consumers of kelp and other algae, and the unprecedented expansion of populations threatens to change the ocean bottom from a lush and diverse kelp forest ecosystem to what is known as an urchin barren.

Story by **Stephen Nett**

Abalone Lost

Off the coast of northern California, the marine invertebrate—and the kelp forests where it's found—may be nearing the threshold of annihilation

In the wilds of California when something goes horribly wrong in an ecosystem, there are no sirens or alarms. The unfolding disaster is usually discovered by a small number of sentinels, the people who go to work each day with the goal of exploring and protecting nature's inhabitants. What they see are signs: pieces in a complex, moving puzzle that they must somehow fit together. A disturbance that appears in the familiar patterns. Gaps opening in the living network. In the worst case, the gaps grow and merge and the whole system comes apart.

Out at sea aboard a rolling boat off the rugged northern California coast of Timber Cove, California Department of Fish and Wildlife senior environmental scientist Dr. Laura Rogers-Bennett and CDFW environmental scientist Dr. Cynthia Catton splashed into the chilly 53-degree blue Pacific and dove toward the ocean floor. It was September 2017, and the two scuba divers were there to count red abalone in kelp beds, rock outcrops and rocky reefs. They were searching for abalone because something had gone terribly wrong.

Abalone are sea snails, marine gastropod mollusks in the family *Haliotidas* recognizable by their thick convex shell. The outer dome has several small holes or respiratory pores that expand as the shell grows. The inside of the shell is lined in iridescent mother of pearl, which shimmers in an array of colors and makes it a favorite of earring and jewelry designers. Even more so, abalone hold prestige as a fine-dining delicacy worldwide—especially in Latin America, parts of Europe and throughout Asia.

Scores of abalone species live in the world's oceans. Along the Pacific coast they are found from Alaska southward to Baja California. They live in kelp beds and are found attached to rock outcrops and reefs that are anywhere from a few inches to more than 60 feet below the surface.

Red abalone (*Haliotis rufescens*) is the largest of seven species and occur in appropriate habitat along the entire California coastline, while pink abalone (*H. corrugata*), green abalone (*H. fulgens*) and white abalone (*H. sorenseni*) are associated with the warm, temperate waters south of Point Conception in Santa Barbara County. Black abalone (*H. cracherodii*) occur from just north of San Francisco to Baja California, Mexico. The less common flat abalone (*H. walallensis*) and pinto abalone (*H. kamtschatkana*) are predominately found north of Point Conception, where water temperatures are generally cooler.

Abalone grow within a single shell and anchor themselves tight to rocky surfaces with a single round muscular foot. They feed on algae but prefer bull kelp (*Nereocystis luetkeana*). They're a long-lived species, living between 30 to 40 years, and decidedly slow-growing.

Studies show it takes abalone at least three to seven years to reach maturity. As adults, abalone reproduce by casting sperm and eggs into the drifting current where fertilization takes place. In coastal areas with high-density populations, this method has worked without a problem. But the inherent weakness is exposed when the number of reproducing adults in an area decreases below a certain level or when the distance between adults becomes too great. In the past, commercial divers had swept through areas rich with abalone, leaving behind a remnant of what was once there. When the remaining abalone are too far apart, the natural fertilization method is assured of failing and the fishery is doomed to collapse.

That calamity has happened in abalone beds everywhere along the coast south of the Golden Gate Bridge. The results forced widespread closures to all abalone take in the waters off the southern half of the state.

North of San Francisco Bay, things are different. In the remote coves of northern California where bull kelp sways in luxurious undersea forests, red abalone has remained relatively abundant. In these beds the reds grow larger than anywhere else in the world, with massive oval shells nearly a foot long.

CDFW Photograph by Cynthia Catton

Rogers-Bennett and Catton are among the handful of CDFW marine biologists on watch at the University of California, Davis Bodega Marine Laboratory to see that the abalone continue to thrive there.

But on that fall day in September when Catton and Rogers-Bennett dove Timber Cove, they discovered an unnerving sight—nearly as many empty, dead abalone shells as living specimens. Everywhere they looked, rather than a waving brown forest, thick and rich with marine life, the canopy of kelp was either entirely missing or a mere skeleton of what it once was. Large areas of the uneven rocky bottom had been scoured bare, down to a pink layer of hard coralline algae. A closer look showed the coral alive with hundreds of spiny purple urchins (*Strongylocentrotus purpuratus*).

The same stark scene played out at 10 other survey sites that stretch 100 miles along the coast of Sonoma and Mendocino counties—the heart of the largest remaining abalone fishery in the world.

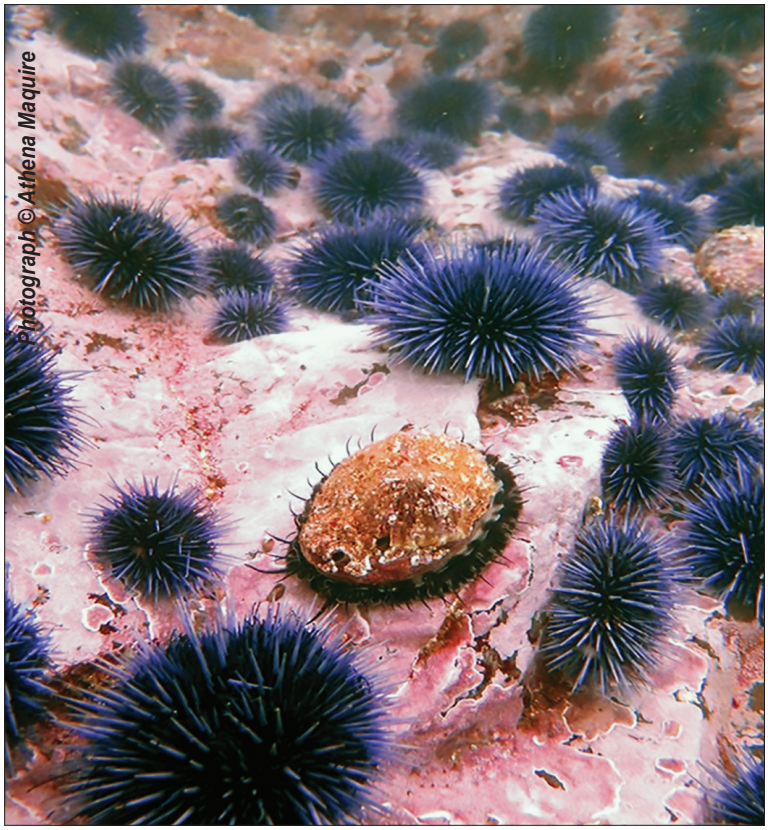
To the motorists who travel the coast-hugging Highway 1 from the Golden Gate Bridge to Humboldt County, the kelp beds that float just below the surface are largely invisible. Noticed or not, the floating canopies are as fundamental and iconic to California as the ancient redwood forests that cloak the nearby ridges.

Beneath rolling ocean swells, kelp can anchor an entire ecosystem. While it might look like a plant, kelp is a species of algae, which thrived along northern California's narrow rocky coastal shelf for a special reason. Every year, driven by winds, ocean upwelling lifts cold water masses loaded with nutrients up from extreme depths below.

Bull kelp is an annual species, meaning it re-sprouts anew each year from the ocean bed. At the end of the season when it distributes its spores, it dies. Nature compensates for this abbreviated lifespan with a phenomenally robust growing period. Kelp can grow up to 10 inches a day, its long rubbery stipe lifting as much as 50 feet in a season, hosting a fringe of 30 to 60 leaf-like blades. By the hundreds, kelp forms submerged forests that provide a nursery and shelter for small fish. The kelp's interlaced blades have long supported a multitude of marine life, including abalone.

Abalone have been abundant in California waters since humans first walked this land. They have been harvested from the beginning, but it wasn't until modern times with widespread overfishing that the populations plummeted. By 1996, the state ended all commercial harvesting of abalone in California waters. Just north of San Francisco, 150 miles of coast were left open

Opposite page: scuba diver Dr. Cynthia Catton, a California Department of Fish and Wildlife environmental scientist, examines a section of ocean bottom where a kelp forest once swayed in the ocean currents, now scoured down to rock by hundreds of voracious spiny purple urchins. Below, alone on an empty layer of hard coralline algae, a single red abalone appears surrounded by hordes of urchins. At right, kelp beds normally thrive offshore, but along a 150-mile stretch of California's coast north of San Francisco, only isolated patches like these now remain. Nearly 95 percent of the bull kelp forests has disappeared.



exclusively to recreational divers, under the guidance of the California Fish and Game Commission's Abalone Recovery and Management Plan. To protect abalone in deeper waters, the plan allows no breathing apparatus, only divers holding their breath. The size and number of abalone that could be taken were carefully limited.

The changes put in place by the Commission's plan helped curb the damage done to the resource, but it never dampened the enthusiasm of those who sought them. A dedicated cadre of ab-lovers, some of them three generations of free-divers, have continued diving every year along the coastlines of Sonoma and Mendocino counties. In 2017, despite a shortened season, CDFW issued more than 25,000 permits for abalone.

Since the beginning, the fishery has experienced good and bad years. In 2011, a devastating toxic algae bloom washed ashore piles of dead abalone in Sonoma County. Persistent poaching continues to chip away at abalone populations. Despite the vigilance of wildlife officers along the coast, poachers continue to break the law for the commercial demand from places as far away as China.

In nature there is a dynamic balance, ever shifting and vulnerable to disturbances found in changing conditions. In 2013, one such disturbance arrived and tested everything. That year, National Marine Fisheries Service scientists became aware of exceptionally warmer water that spanned the Gulf of Alaska. The oceanographic occurrence was caused by a persistent atmospheric ridge of high pressure, which concerned marine scientists because as the atmospheric pocket spread, coastal water temperatures along the West Coast rocketed upwards. Scientists believed the disturbance locked California further into the grip of its severe drought at the time and increased water temperatures as much as 3 degrees Celsius (5.4 degrees Fahrenheit) warmer than average.

In the Bodega Bay Marine Laboratory, Rogers-Bennett was familiar with the dangers of a warming ocean. She'd conducted a study years earlier to see how red abalone might fare if temperatures rose. Her experiments found that male abalone reproduction was suppressed once above a certain threshold water temperature, and failed entirely after 12 months exposure to water above 16 degrees C (61 degrees F).

Catton, the abalone effort project lead, along with Rogers-Bennett and other team members, watched and gathered data as the sequence of hammer blows began to take their toll in the marine environment. In the warming Pacific, another hazard

A CDFW diver surveys abalone on rocks next to kelp stipes stripped bare by urchins. Abalone live among kelp beds along rocky coastlines around the world, and are found from just a few inches beneath the surface to more than 60 feet deep.

was spreading, a viral disease that attacked multiple species of sea stars. Some, like the Sunflower sea star (*Pycnopodia helianthodes*), were nearly wiped out. Their loss had removed a key predator of another animal grazing in the kelp beds, the purple urchin.

"The Sunflower sea star is a voracious eater of urchins," Catton said. "Before the wasting disease we used to see at least one or two Sunflower stars in every survey. But last year we only saw two, total. That was for all surveys."

The sea star's prey, the purple urchin, is a remarkably resilient creature as it eats nearly anything. Even when food is gone the urchin can take in nutrients directly from seawater. Interestingly, studies have shown urchins continue to reproduce even when starving. And along the north coast as the sea stars died, that's exactly what the urchins did.

Increasingly unchecked, the purple urchin population increased as much as 100 times their normal numbers. Urchins are voracious consumers of kelp. In large numbers these small but hardy herbivores can easily wipe out vast expanses of kelp and other algae, changing the landscape from a lush and diverse kelp forest ecosystem into what is known as an urchin barren.

Soon divers at locations like Fort Ross or Point Arena and Timber Cove found large undersea sections of empty reefs covered in pink coralline algae and swarms of purple urchin.

"Coralline algae is calcified, hard and not easily eaten. But the purple urchins were so desperate they even targeted it," Catton said.

If scientists knew what to expect when urchins were left unhindered, they were unprepared for the scale of the devastation. "In the past, an urchin barren stretched a quarter-mile or a mile, but this was 100 miles of barrens," Catton said.

Then another challenge hit the kelp habitat. The years of unusual atmospheric conditions that had kept California dry also subdued the sea winds that drive the turnover of ocean water along the coast. When the winds weakened, the cold nutrient-rich upwelling from the offshore depths faltered. As hordes of hungry urchins ravaged the elegant underwater forest along California's coast, the combination of warm water, reduced surface winds and nutrients hammered the struggling kelp. In 2014, scientists recorded a dramatic decline in the bull kelp forests as the beds shrunk by 93 percent. The following year, the devastation continued with an additional 33 percent gone.

Catton described it best. "For the kelp, it was a perfect storm," she said.

And then the abalone began to starve.

Catton first began to study abalone in 2002 at the Scripps Institution of Oceanography in Southern California. Part of her responsibilities as one of CDFW's lead project scientists for the north coast abalone includes collecting and providing information and recommendations to commissioners, who are responsible for setting take limits and seasons. As a scuba diver, she and other CDFW researchers will dive an average of four designated test sites during a normal year. The team's method is to note abalone at arbitrary points and random depths along a 100-foot swath and little more than 6 feet wide.

Counting abalone is normally a routine task, said Rogers-Bennett. But the declining numbers they registered changed everything. Catton added, "I never thought I would ever see such low densities on the north Coast."

By 2017, the abalone count in the 10 sample areas had fallen an average of 56 percent in Sonoma County, and 65 percent in Mendocino County. At the Russian Gulch site over the course of three years, the abalone density plummeted by 88 percent.

The alarming trend heightened concerns about the ability of the remaining abalone to reproduce. As part of their investigation, in June 2017, Catton, Rogers-Bennett and their team traveled back to a popular abalone diving spot in Mendocino County at Van Damme State Park. There, under a fog-shrouded morning, the team pitched a blue awning tent and prepared laboratory equipment they would use to perform a range of tests. By afternoon, wet-suited snorkelers waded ashore toting the abalone they had carried up from the depths. The scientists approached and asked permission to examine the divers' catch. With a brief explanation as to why, willing cooperation became the norm. By cataloguing weight, tissue samples and size of each abalone, the team hoped to gauge the abalone's health and reproductive capacity.

When an abalone starves, the size of its foot shrinks and the animal no longer fills its shell. At Van Damme, the beach assessments found that at least a quarter of the catch showed signs of serious starvation.

Unlike urchins, when abalone starve they reproduce less. Studies have shown that by the time an abalone loses 20 percent of its body mass, its ability to reproduce has fallen by 60 percent to 90 percent. And without the ability to reproduce, future genera-

tions of the mollusk are jeopardized.

By December 2017, the data gathered from the surveys, the samplings and the personal observations had led to dramatic conclusions. The entire fishery was compromised by an unprecedented environmental disaster and the population of abalone was likely crashing toward the threshold where it could no longer sustain itself. "The population is in free-fall", Catton said.

Sonke Mastrup, the Marine Region program manager for CDFW's Invertebrate Fisheries, was clear in his warning to the Commission. "We've never seen a decline like this over a short period of time," he said.

Commissioners concluded that the population had crossed the officially designated management trigger and took steps to close the fishery and give the abalone a chance to recover.

Since the closure, diver groups and concerned marine agencies on the north coast and elsewhere have mobilized in frustration and concern. Since 2016, with Catton's guidance, ocean stakeholders have explored ideas to shelter areas of remaining bull kelp from the urchin hordes. By creating protected spots that feature healthy bull kelp, they hope to help the floating forest to reach maturity and reproduce.

On Memorial Day, 80 volunteers dove and collected more than 7,000 pounds—nearly 57,000 urchins—from the waters of Ocean Cove. In July, the same group of volunteers and divers duplicated the effort near Albion.

While the grassroots effort may be a longshot, it has brought together a diverse group of people with a wide range of resources to protect the fishery, the kelp and the abalone.

And CDFW scientists like Catton and Rogers-Bennet, who have devoted their careers to the study and preservation of the marine environment, recognize the power of such effort, are hopeful that the determination of these groups will generate greater community action across the state toward conservation.

Stephen Nett is a freelance writer who lives in northern California. His stories have appeared before in Outdoor California.