# Sight in the Sea

## Exploring light and color in coral reef ecosystems

By RICHARD LIPKIN

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*Sea life settles on a head of coral (top) at Conch Reef, near Key Largo, Fla. There, schools of grunts, mangroves, snappers, and goatfish converge (middle). Nearby, a scuba-diving scientist, or aquanaut, peers through a window of the Aquarius habitat. In the background, Key Largo's coastal waters.*

Background photo: Lipkin

Tinting the surf's sapphire ripples with tangerine light, dawn over Florida's coral reefs summons sea creatures from within calcareous crags and cauliflowerlike mounds.

Cautiously, some of these creatures eye the seascape for predators and prey. A silvery 7-foot tarpon, a prized game fish, tears along, hunting for its morning meal, while an angelfish preens its yellow and black fins. Finger-long mantis shrimp tussle in a claw-snapping fight. And swarms of peach-colored fish, like dollops of sherbet, glitter in the light against a backdrop of swaying sea sponges.

The reef comprises a neighborhood little different in spirit from a rain forest ravine, where animals feed, play, and mate—tangling over dominion of food, shelter, and territory. But unlike a rain forest, this scene explodes with color. Why has nature painted such iridescent prairies in these shallow seas? With animals in nearly every other kingdom struggling to vanish into their surroundings, to camouflage themselves from predators, what makes tropical sea life so splendorous?

"They don't see the world as we do," says Thomas W. Cronin, a marine biologist at the University of Maryland at Baltimore. "Their visual systems have adapted to enable them to survive in a completely different world." Unlike humans—whose vision has been tuned for survival in rain forests—many ocean creatures view the world in ultraviolet (UV) and polarized light, perceiving aspects of light that humans cannot.

"Marine animals have evolved visual systems to distinguish predators and prey at long distances, in murky water, and in dim light, all of which are critical to their survival," Cronin explains. "It's another world for them."

"Our task is to understand better what it is that they see."

Since 1993, the National Oceanic and Atmospheric Administration (NOAA) has maintained an undersea laboratory 4 miles off the Florida coast, near Key Largo. The lab's mission: to address scientific questions pertaining to ocean environments and marine life. Planted 67 feet below the surface, bolted to a 200-ton platform on the seafloor, the 43-foot-long Aquarius habitat houses the world's only permanent underwater research station.

After Congress passed the National Marine Sanctuary Act in 1990, with the aim of protecting coral reefs and offshore U.S. resources, NOAA moved the habitat from the Virgin Islands to Key Largo. Now, eight teams of scientists per year can study sea life in the shallow Atlantic Ocean for up to 2 weeks.

"This program emerged out of a recognition that coral reefs in the Florida Keys are an important national resource," says Aquarius science director Steven L. Miller, a marine biologist with the University of North Carolina at Wilmington, which operates Aquarius. "Very little has been known until recently about the health or status of these reefs."

Researchers visiting Aquarius study, for example, black band disease, which kills coral and threatens sea life. Coral bleaching, another phenomenon seen worldwide during the past decade (SN: 12/8/90, p.364), has led habitat researchers to examine the impact of ozone depletion and the resulting increase in UV light passing through the atmosphere. Upsetting the belief that UV light does not penetrate deep into seawater, researchers measured enough UV exposure underwater to bleach corals at depths of 80 feet.

Fast spray, an azure sky, and a buzzing outboard engine herald the mid-June journey of *Strike Force,* a research vessel ferrying five marine biologists to Conch Reef, a sea shelf 9 miles northeast of Key Largo. Here, the researchers will spend 10 days studying underwater light and marine animals in their native habitat.

NOAA

*The Aquarius habitat.*

With *Strike Force* thwacking the waves, a shadowy speck grows on the horizon, revealing a great barge at anchor. The boat slows and the five scientists hop onto the barge's bobbing deck. Cronin and his four fellow aquanauts prepare for "saturation"—their 10-day residence in the laboratory 20 meters below. Leaping into the turquoise waters, the biologists spiral slowly down to the giant steel capsule. They stop momentarily at the "gazebo"—a small, air-filled enclosure in which they can communicate with the surface support staff on the barge—then move on.

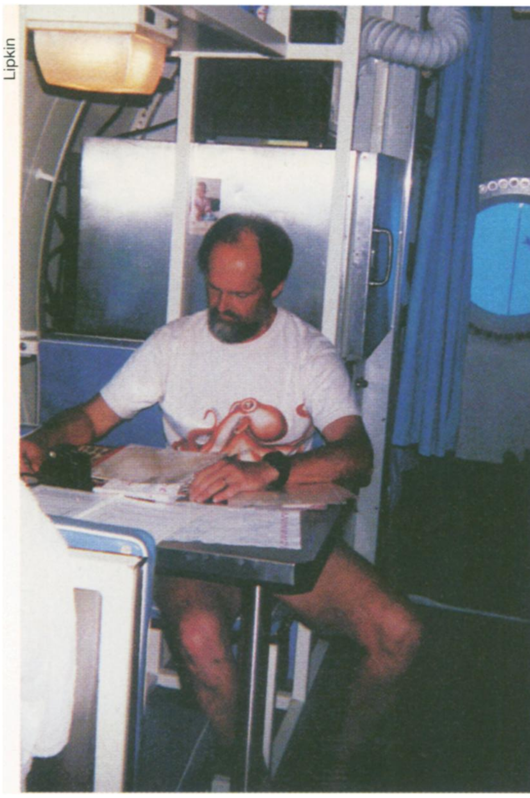
Throughout their mission, the scientists maintain two-way communication via microphones and video cameras with the support crew, who offer assistance or, in an emergency, help. "In many ways this is like a space mission," says Craig Cooper, Aquarius' operations manager. "We need to keep a close eye on them to make sure everything's okay. Anything they need, we get it to 'em."

In the habitat, the aquanauts bubble up from underneath the massive steel housing, doff their air tanks, fins, and weight belts, and rinse off. Onboard technician Glenn Taylor hands each aquanaut a towel. "Salt attracts moisture," Taylor says. "And we've got a lot of corrosive electrical equipment in here. So it's critical that everyone is totally dry and saltfree." Diving gear stowed, the scientists enter the habitat's main chamber, stepping through an airlocked door.

Aquarius's interior resembles a cross between a laboratory, a submarine, and a well-stocked Winnebago. At one end, computers, cameras, and sundry paraphernalia lie on lab benches. At the far end stand two tiers of bunks that sleep six scientists. In the midsection, life-support equipment hums behind a panel of switches, pressure gauges, radios, and monitors. Alongside a stunningly blue porthole a galley complete with stovetop and booth awaits. On the counter stand a box of cornflakes and a bottle of ketchup.

Roy L. Caldwell of the University of California, Berkeley, peers out the porthole. For him, a marine animal behaviorist, living underwater on a reef for 10 days is like a 12-year-old camping in Disneyland. As Caldwell meditates on sea animals, Cronin and Nadav Shashar, a researcher from Israel, assemble a finicky, handcrafted camera specially outfitted to measure and record the spectral distribution and polarization of ambient light on the reef.

"We have a decent understanding of marine animal vision," Cronin says. "But we know very little about the world in which these animals use their vision. What are they looking at? What do they perceive? Do they use UV and polarized light to enhance their



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*Seated at the galley of the Aquarius habitat, Roy L. Caldwell, a marine scientist, reviews his day's work.*

vision—and if so, how?

"The basic properties of light underwater are poorly understood," he adds. "We believe that various parts of the spectrum help animals see details at different distances. But which wavelengths most enhance the visibility of objects underwater? How do animals use visual cues to communicate with each other, particularly with colored marks on their bodies?"

At another bench in the undersea laboratory, Canadian biologist Daryl C. Parkyn of the University of Victoria in British Columbia prepares to capture fish using a dilute anesthetic. An astute observer of marine animals in their native habitats, he has honed an unusual method of collecting specimens. With a soft jug of anesthetic under his arm, he gently stalks a fish, then doses it. "We call this the bagpipe method," he says. Parkyn says that this method proved superior to a previous technique involving a Super Soaker, a toy water pistol that, owing to its forceful thrust, "blew the fish away—literally."

Meanwhile, neuroscientist N. Justin Marshall of England's University of Sussex tinkers with his computerized camera for measuring the spectral reflectance of fish. The system, sealed in an airtight housing, can be carried onto the reef to peer at marine animals. Marshall believes it will help decode fish color signals.

"We humans don't usually think about communicating with color," Marshall says. "By communication, I mean showing aggression, attracting attention, conveying a state of sexual readiness, or vanishing into the background." Though an angelfish appears colorful to our eyes, he notes, its markings succeed as camouflage underwater because of differences in animal vision.

To signal each other, marine animals flash concealed areas of their bodies, spreading fins or inverting claws to display markings that reflect UV light. "They can see UV and polarized light, which are invisible to us," Marshall says. "But by using a camera sensitive to ultraviolet rays, we can look at a fish's otherwise invisible reflections."

The evolution of color vision in animals depends not only on the animals' needs, but also on the light in their habitat, Marshall says. The visual systems of all organisms in an area evolve together, influencing one another. "For us, the colors of a coral reef are mind-blowing in their beauty," says Marshall. "To the creatures that live there, color signals help them manage life and death." The markings and visual systems of these animals, he explains, serve three primitive needs: eating, avoiding predators, and mating.

"We have no idea what an angelfish or mantis shrimp sees when it looks at an angelfish," Marshall says. "The only way to get some sense of what they *might* see is to use a nonsubjective method, like a camera that records UV reflections."

**B**ack on the surface, the operations crew watches the aquanauts on video monitors, then prepares a delivery pot—an airtight container of gear and snacks lowered overboard and ferried by divers to Aquarius.

A few hundred yards away, bobbing in 4-foot swells, Captain Catherine Liipfert anchors *Wild Card,* the transport boat now carrying Cronin's own surface support team. Donning their gear, Erik Herzog, Nerina Holden, and Pamela Jutte, all visiting marine researchers, prepare to dive 110 feet to collect specimens.

To extend their underwater time, each diver carries two tanks of specially blended gas, an oxygen-enriched version of compressed air that enables them to remain underwater longer than they could under ordinary scuba conditions. Working at great depth for long periods of time, divers must monitor nitrogen accumulations in their blood and body tissues. Under several atmospheres of pressure—one for each 33 feet of water—divers absorb more nitrogen than they expel. If they ascend too rapidly, the dissolved nitrogen can bubble up in their blood. This condition, known as decompression sickness, or the bends, can cause great pain, even death.

Descending along the boat's anchor line, Herzog and the support team vanish into a cloud of blue bubbles. During the day, they make three dives, delivering equipment to the aquanauts and chasing grunts with squirt guns. Grunts, colorful fish prevalent in the region, earned their name the sound they make when squeezing their water bladders.

"We want to know if fish have circadian rhythms—that is, whether external light cues or an internal clock governs their behavior," says Herzog. By observing the fish at various times of day and night and running a controlled experiment in the lab, Herzog can identify changes in the fishes' behavior.

"If they grunt or move around more at night than they do during the day," he says, "then that will tell us something about their circadian rhythm. Are the fish's behavioral patterns driven by daylight or an internal clock? We don't know the answer."

**A**t night, dark blue fades to black. Caldwell, intrigued by what he sees, decides to venture into the inky abyss. Toting a flashlight, bedazzled intermittently by luminescent sea creatures, he's on the lookout for the larvae of mantis shrimp—an obsession of his.

"They're very curious creatures, to the point of being stupid," Caldwell observes. "I often wonder why they come out to look at me, knowing that I present a threat. Of course, the answer is clear—they can't help it. They need the sensory information merely to make a decision."

Predatory crustaceans feeding mainly on shellfish, mantis shrimp—or stomatopods—dwell in seafloor burrows throughout the tropics. Though shy, often peering from behind coral, the 4-inch shrimp that Caldwell studies behave aggressively in capturing prey and defending territory. Wielding two large raptorial claws, they spear and smash their prey's outer shells, justifying their nickname of "thumb busters."

Indeed, with the striking force of a bullet, stomatopod claws can break the glass of aquarium walls. As evolutionary holdovers from the Jurassic era more than 135 million years ago, stomatopods have spawned more than 350 modern species, ranging in length from half an inch to more than 1 foot.

Among their distinguishing features are colorfully marked appendages and extraordinary eyes. "They have one of the most unusual visual systems in the animal kingdom," Caldwell says. "Whereas we humans have four visual pigments in our eyes, they have 16. They also make fine distinctions in the spectrum, including the ability to see ultraviolet and polarized light. So we think they can tell us a lot about underwater vision."

Cronin, Marshall, and Caldwell have all come to the conclusion that many secrets of undersea sight may reside in stomatopod eyes. "They have receptors for detecting long wavelengths of light," Cronin says. "They can see far-red and infrared wavelengths, light that many land animals can't see. And yet they're not supposed to have those receptors, because there's little long-wavelength light underwater—the water absorbs most of it.

"Clearly, they have these receptors for a reason. So we're presuming that long wavelengths of light convey relevant information, though we don't know what that information is."

Unlike the human eye—which presents a complete image to the brain by focusing light on the retina—the stomatopod's eye scans images somewhat like a television or fax machine, one line at a time, says Marshall. With visual receptors lined up in rows, the mantis shrimp bob their eyes up and down, scanning the scene before them. "It's an economical system, minimizing receptor duplication," Marshall says.

"Nature often solves problems with clever engineering."

**W**hy go to all this trouble to study thumb-busting shrimp? Who cares if fish signal each other with colorful signs or see in light so dim that to human eyes all appears dark?

"There are, of course, implications for human beings," Marshall retorts. "Much of what we know about our own brains and vision systems comes from studying more primitive forms of life, such as snails and squids." Studying the stomatopods' eyes may deepen our understanding of color vision chemistry.

The mantis shrimp have evolved a way to enhance images with polarized light, Marshall observes. Not surprisingly, military agencies find this research intriguing, particularly with regard to "seeing in the dark and not being seen by others," says Marshall. The ability to see details at greater distances, in low light, or underwater tantalizes agencies aiming to improve tactical defense.

The only way to understand how animals master environments that leave humans struggling is to enter their world, see what they do, and learn their peculiar ways, says Marshall.

"We have evolved, essentially, from nocturnal mammals in rain forests, so we have relatively poor color vision compared to many other animals. With stomatopods, their color vision has evolved over 100 million years. It's like an arms race. Animals evolve vision that's good at spotting camouflage. Then other animals respond by evolving colors that can't be seen. There's always a give-and-take, evolution and counterevolution.

"In a coral reef, the evolution of color has gone to an extreme." □