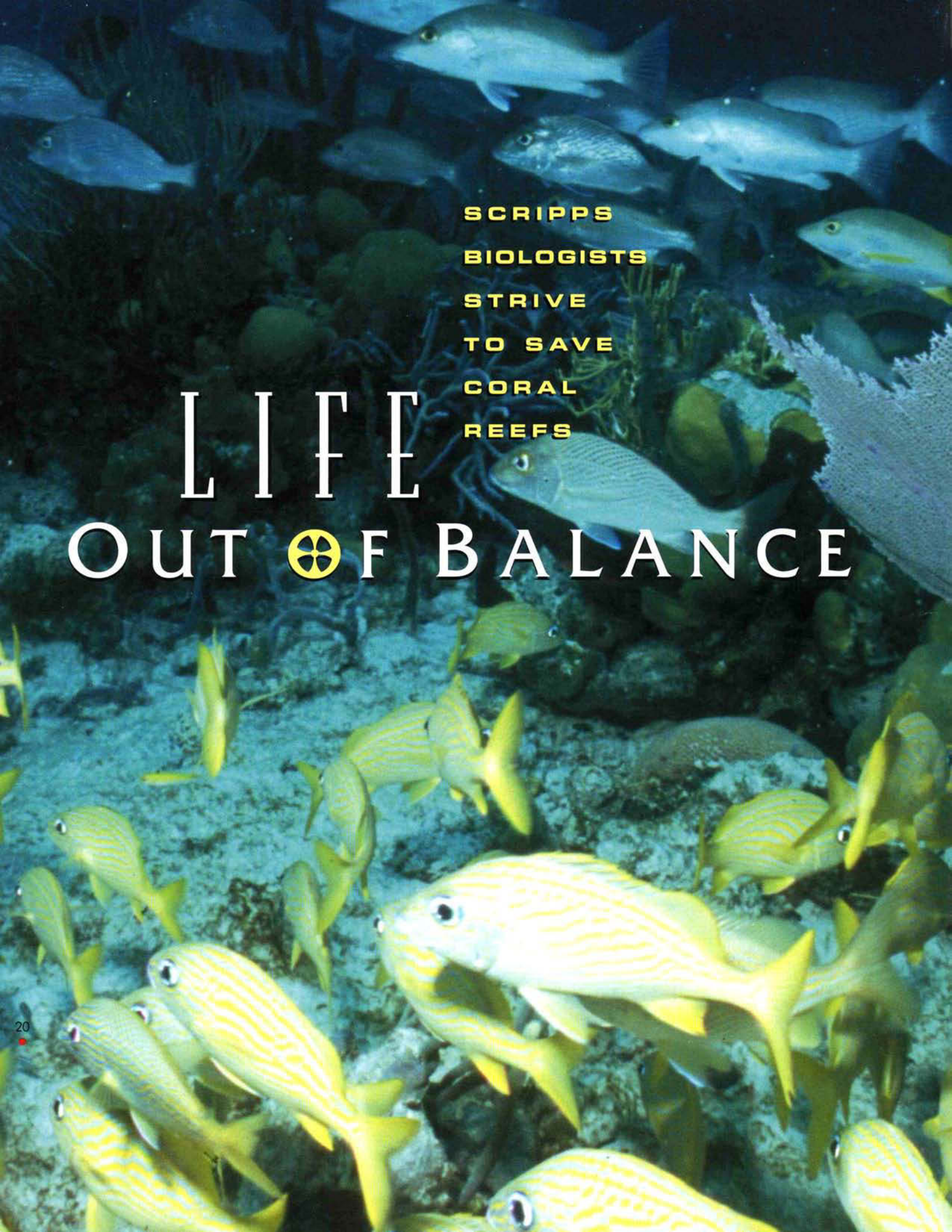


SCRIPPS BIOLOGISTS STRIVE TO SAVE CORAL REEFS

LIFE OUT OF BALANCE

BY CHUCK COLGAN

Opposite page, *Fifty of the 57 known Caribbean corals thrive at Bocas del Toro.* **Above,** *The Smithsonian Tropical Research Institute.* **Right,** *A storefront in Bocas town.* **Below,** *Scripps graduate student Davey Kline and Smithsonian researcher Neilan Kuntz check reef samples between scuba dives.*

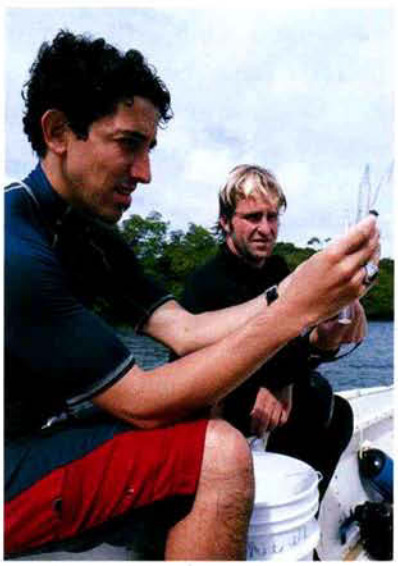
BOCAS DEL TORO, PANAMA, SEPTEMBER 2003 – Everywhere Scripps Institution of Oceanography graduate student Davey Kline goes in this remote tropical location, he runs into someone he knows. His American friends here humorously call him "*el alcalde de Bocas*," the mayor of Bocas town, a small village left over from banana plantation enterprises that moved elsewhere in the 1950s.

Today Bocas del Toro is a budding international tourist destination popular with scuba divers, fishermen, and eco-tourists seeking something off the beaten path. Situated on the northwestern coast of Panama near the Costa Rican border, Bocas offers lush jungle habitats, a national park, and clear, beautiful Caribbean waters.

Bocas del Toro consists of a strip of mainland and a group of small islands that form an archipelago. Bocas town, with a population of only a couple of thousand, is the regional capitol. It's on one of the islands and can only be reached by air or sea. Wooden dugout water taxis are the primary transportation between islands.

Like many tropical regions, there are only two seasons—rainy and rainier—but when the sun is shining, Bocas del Toro is a bit of paradise. One problem though, is that as it grows and develops, its natural beauty is increasingly jeopardized.

Davey Kline has been in Bocas often during the past five years and lived here full time for the past year. On what might appear to be an extended vacation, he has in fact been working in conjunction with the Smithsonian Tropical Research Institute to monitor the health of local coral reefs. Although Bocas still has some of the most pristine reef areas in the Caribbean, it faces the same ecological threats that affect virtually every coral reef near populated areas and tourism setting—increased sedimentation, altered ocean food webs, and the emergence of coral disease.



"Overall, the Caribbean reefs are in an incredibly sad state," Kline said. "In the next 20 to 30 years, if things continue as they are presently going, it's possible that there will be no more healthy reefs at all."

THE CORAL DOCTORS

Kline's concern has led him to join scientific efforts to better understand how the things people put into the ocean affect

Left, *Typical Bocas town storefronts lining the main street; houses built over the lagoon; a young local boy with his dog.*

corals and associated reef organisms. As a student in the Center for Marine Biodiversity and Conservation at Scripps, he works closely with renowned marine microbiologist Farooq Azam and Nancy Knowlton, an expert on coral ecology. Together with biologist Forest Rohwer of San Diego State University and others, they form the nucleus of a team of "coral doctors" who use cutting-edge molecular biology research techniques to examine not only the health of corals, but also the microbial communities associated with them.

Individual corals, called polyps, are basically mouths surrounded by tiny tentacles that grow in colonies that often number in the thousands, building upon the dead, limestone skeletons of past generations. Most corals depend on the symbiotic algae zooxanthellae to supply them with life-giving nutrients. In exchange for their photosynthetic products, the algae receive access to sunlight and protection from the elements. Over the past 20 years, scientists have discovered that corals also harbor many different species of bacteria, fungi, and other microorganisms within them and on their surfaces, but the corals' interactions with these microbes are not well understood. Only a few of the bacteria have been identified, and researchers estimate that millions of species remain unreported and unnamed.

That's why one focus for the coral doctors is to meticulously describe the diversity and distribution of coral-associated bacteria. In the 1990s, while a graduate student at UCSD and later as a postdoctoral researcher at Scripps, Rohwer was among the first to use DNA sequencing techniques to identify coral bacteria. He found a much greater number of bacteria than expected associated with the species of coral he was studying and discovered that samples of the coral taken at separate reefs each contained their own specific bacteria. This confirmed that corals possess distinct bacteria. Rohwer's laboratory now has a database of more than 3,000 bacterial sequences, representing the largest sampling of marine bacteria to date.

The team is also attempting to understand how human impacts cause coral disease. Specifically they want to know whether pollution and other environmental stresses are causing coral diseases directly or indirectly by affecting their symbiotic microbial

The results of coral disease are profound throughout much of the Caribbean. **Right,** *Healthy stag horn corals have a rich brown coloring.* **Bottom right,** *This stag horn is dead from white-band disease.*

communities. Knowledge of the difference could lead to strategies and treatments for combating coral disorders. Finding potential cures may be a long shot, but it also may be the only hope for coral reefs. Of the 29 known coral diseases, pathogenic sources are known for only two.

Clockwise from left, *The sawmill in Bocas town; houses are built off the ground to avoid flooding; entrance to the Smithsonian research facility; mountain star coral, the principal coral in Davey Kline's studies; Kline taking coral mucus samples.*

AT THE RESEARCH STATION

On a typical day, Kline leaves his house, which is perched on a dock extending over a local cove, and bicycles to the Smithsonian research station nearby. He rides along a pothole-filled road through neighborhoods where most of the small houses sit atop poles to avoid flooding and he waves greetings to many local friends won over by his charisma and openness.

A few miles from town, the station sits in the midst of a dense jungle on a thin isthmus bordered by sandy beaches and an inlet. The station offers modern laboratories, computer rooms, a dive facility, and a dock—all of which are available to visiting researchers from around the world.

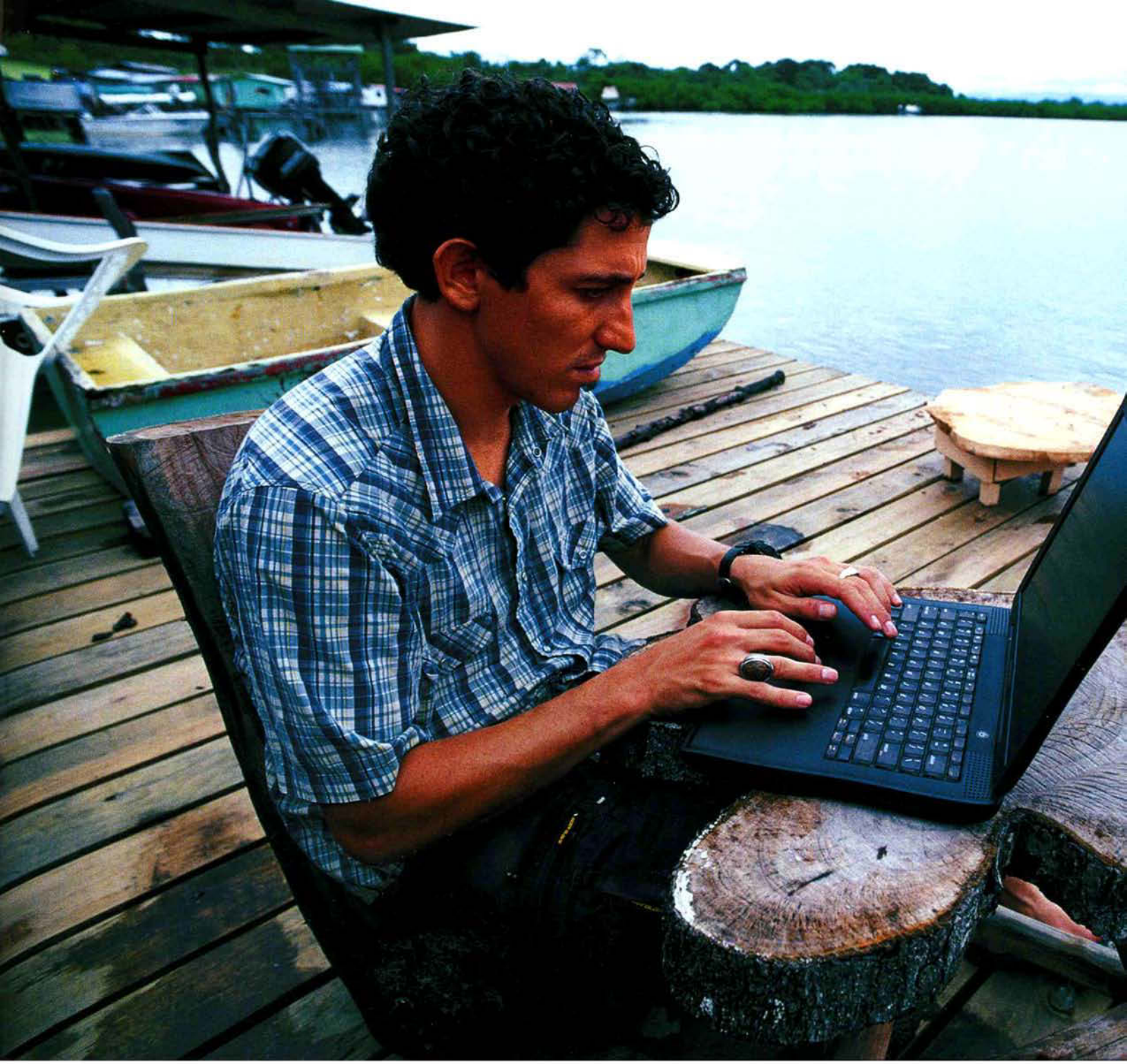
At the station, Kline joins Neilan Kuntz, a Smithsonian research associate, to motorboat out to a local reef for the day's collection of living coral samples. They

are on or in the water every day. Scuba diving in shallow waters, they carefully chip off small pieces of monastrea annularis, or mountain star coral, one of the most common Caribbean reef builders, to bring back to the lab.

The Bocas reefs have a high diversity of corals, with some areas containing up to 50 of the 57 known Caribbean species. Because the area is near the mainland, there is a much greater runoff of sediments than found at most other Caribbean reefs, making the water less clear than around most islands. Although this condition reduces diving visibility, it forces deeper-water corals to grow at more shallow depths so that they can get sufficient sunlight, making the easily accessible reefs more robust. An incredible variety of tropical fishes, colorful sponges, brittle stars, and other organisms can be seen while diving, including some of the Caribbean's last remaining patches of elkhorn and staghorn corals.

On the Smithsonian's dock, Kline and Kuntz have constructed a unique aquarium called the aquatic automated dosing and culturing system (AADACS), developed by Kline, Rohwer, and Teqcom Industries, a manufacturer of fluid and gas-handling components in Santa Ana, California. The room-sized AADACS provides a way for the researchers to mimic the corals' natural environment while subjecting them to levels of stress similar to what they would encounter from pollution, including components of sewage, asphalt, runoff, sediments, and pesticides.

The AADACS is seemingly simple, yet its performance is deceptively complex. A Jacuzzi pump at the end of the dock brings in water from the reef that passes through two filters that remove particles, then collects in a plastic reservoir. Another pump draws water from the reservoir for six seconds per minute and feeds it into manifold valves that are set to



intermittently mix in concentrated chemical pollutants at various dosages. The dosed seawater is then delivered to a series of large tubs in which small coral samples live in flow-through cups. Using the system, the researchers can assess the effects of 40 independent chemicals on 400 corals at a time. A typical testing period takes four to eight weeks, at which point different corals and compounds are introduced into the system.

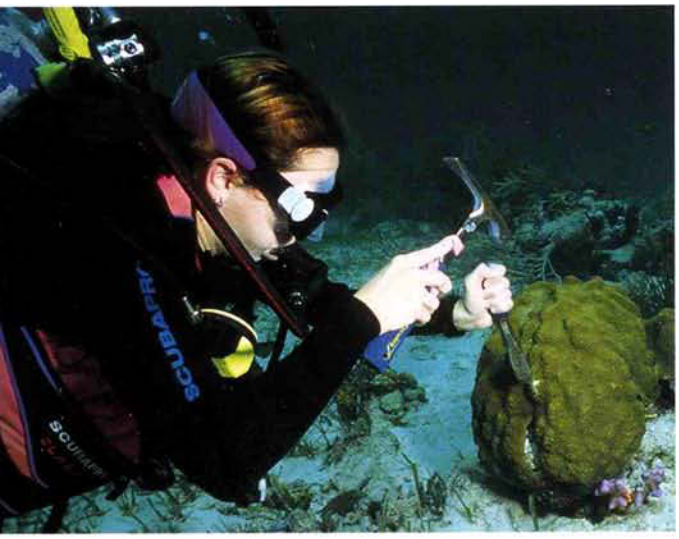
So far, research with the AADACS confirms that common environmental pollutants found on heavily impacted reefs do in fact kill corals. According to Kline, some of these contaminants appear to be

Opposite page, *From left, Neilan Kuntz prepares a chemical solution for the aquatic automated dosing and culturing system (AADACS); exterior of the AADACS laboratory on the Smithsonian's dock; Davey Kline and Kuntz in the laboratory; dugout canoes are common transportation; most houses are built along the shore.* **Above,** *Kline on his deck working.*

Below, *Small samples of boulder star coral are chipped off to take back to the lab.* **Far right,** *Davey Kline bags pieces of asphalt from a local road to test its toxicity to corals.* **Middle,** *Brain coral with unknown disease.*

killing the corals indirectly by disrupting the balance between the corals and their associated bacteria. Understanding how this loss of equilibrium within the microbial community triggers coral diseases could lead to treatments, he said. One difficulty would be to identify antibiotics that kill only the disease-causing bacteria and not the symbionts necessary for the corals' well-being.

An unexpected result of the studies regards sewage. Ecologists have long known that untreated and primary-treated sewage provide excess



nutrients to seawater when dumped in the ocean, which at reefs smothers corals and leads to excessive growth of algae. The ADAACS tests showed that dissolved carbon, in the form of sugars associated with sewage, caused the most dramatic upsets to the balance between the corals and their symbionts, leading to disease and mortality. As recently as 1995, the Pan American Health Organization reported that only 10 percent of sewage from Central American and Caribbean countries was being properly treated before disposal at sea.

The researchers have also confirmed that hydrocarbons kill corals quickly. They

SEA ANEMONE

SOFT CORAL

TUBE SPONGE

CHRISTMAS TREE WORM

GORGONIAN CORAL

are trying to determine which types are most harmful—whether from roads, roofing, or motor oil—so that recommendations can be made for less-harmful compounds to be used in the future.

"From our research, it's pretty clear that most of the stuff being dumped into the water is going to affect the reefs," Kline said. "And if people don't think about what they do with their sewage water, what they do

Above, *Sunset over the mainland at Bocas del Toro.* **Below,** *Davey Kline with local children during a Kids' Day talk at the Smithsonian.*

with runoff from farms and the land, then we're going to lose the diversity associated with reefs."

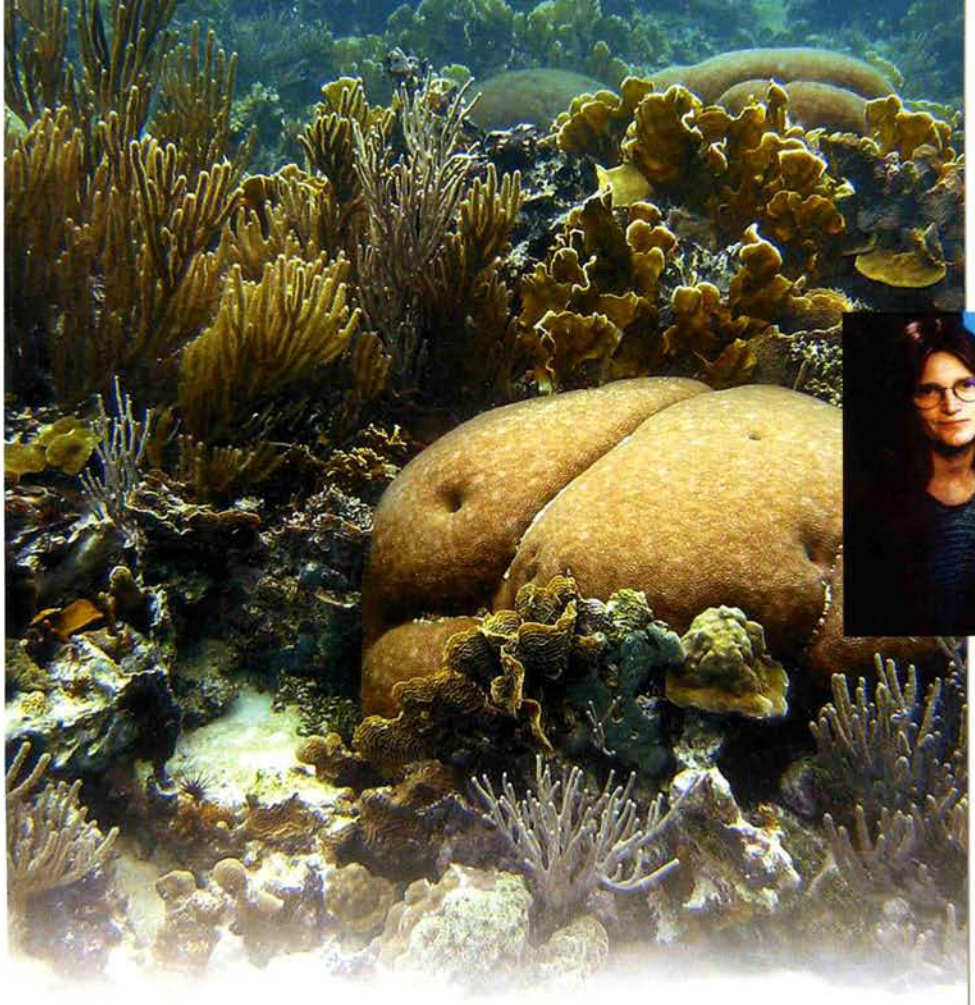
COMMUNICATING THE CONCERNS

One of Kline's greatest concerns is that people who live near coral reefs often do not realize how their actions affect the marine environment. For most populated areas in the Caribbean, the environmental impacts of human activities are already well above the limit, making adjacent reefs unsustainable. Even if sewage and other pollution sources were treated properly, it would take decades for new corals to settle and grow. Naturally, Kline is eager to share his research with the people of Bocas del Toro.

One afternoon he presents a Kids' Day talk at the Smithsonian for local school classes. Scientists at the station give such talks regularly so that the children can learn more about their local ocean neighborhood. The kids are always eager to find out what Kline is doing and to see his underwater slideshow.

Kline has also given presentations to Bocas community groups and local Panamanian officials. They know that their future depends on tourism, and they fear major negative environmental impacts may send their community into the same economic downturn that resulted when the banana industry left.

A recent study showed that throughout the Caribbean, reefs have declined by about 80 percent over the last three decades. In Bocas del Toro and other such remote areas, coral reefs are faring much better than those in many locations, yet the potential for disaster remains. It will take the concentrated efforts of citizens, scientists, and officials to set a course for new policies to help protect and maintain coral-reef habitats.



CORAL DISEASE THREATENS CARIBBEAN CORAL REEFS

BY DAVEY KLINE

THE INCIDENCE OF CORAL DISEASE has risen dramatically since first reported in the early 1970s. Increasing numbers of coral colonies and species across an ever wider area have been affected by disease, resulting in extensive mortality throughout the Caribbean.

Despite the major ecological impact of coral disease, the cause of most coral diseases remains unclear. Coral colonies host unique microbial communities that are diverse, species specific, and similar to those bacteria in corals located in distant reefs.

The nature of the relationship between corals and their bacteria has yet to be established. At the Center for Marine Biodiversity and Conservation at Scripps, we have developed methods to determine how characteristics of the bacterial community change as a result of anthropogenic stress and disease.

Our research indicates that the bacterial community in coral reefs is tightly regulated, possibly through nutrient limitation, and that this regulation breaks down with added carbon (glucose) and disease.

One of the greatest scientific challenges facing society today is understanding, protecting, managing, and restoring biodiversity in our oceans.

The rich ecological communities on coral reefs are a good place to start.

"Coral reefs are the most diverse marine ecosystem on the planet; they are basically the rainforests of the sea. So, in a biodiversity sense, the problem is that we are going to lose literally millions of species if we lose coral reefs."

—NANCY KNOWLTON
Director, Center for Marine Biodiversity and Conservation at Scripps