

Castro did was very gutsy,” Valdés-Sosa says. “This is the beginning of the end of an absurd situation.”

Freer travel will aid the handful of U.S. researchers who have used private money in recent years to nurture collaborations in Cuba. Last year, ACC and AAAS (*Science*'s publisher) signed a memorandum of understanding seeking to expand such efforts in areas like neuroscience and infectious disease. One target is chikungunya, a mosquito-borne malady working its way through the Caribbean toward Cuba and the United States. “We have to face this virus together,” says Guadalupe Guzmán Tirado, an epidemiologist here at the Institute of Tropical Medicine.

As the awkward pas de deux takes shape, Cuba is seeking to bolster its own scientific capacity. Ever since the revolution, the government's unwavering policy has been to yoke science to societal needs: girding for the consequences of climate change, for example, or bolstering energy supplies. Researchers not pursuing such national priorities have had to fend for themselves. “You can study mathematics or basic science, but there's no money,” Llanes-Santiago says. “Everything is for applied science.”

That could change with the upcoming establishment of the Cuban NSF. Key details, including its budget and management structure, are still being worked out. But the science ministry has agreed that it will dole out a chunk of its R&D budget—a paltry 90 million pesos (\$4 million) in 2015—on competitive grants for basic research. “It's essential to have this fund,” Valdés-Sosa says. While most of Cuba's R&D budget will continue to go to “national needs,” Clark-Arxxer adds, “there must be space for creativity.”

Cuba remains a place of outsized ambitions. Castro's eldest son, Fidel Castro Díaz-Balart, for example, is leading an initiative to build a nanotechnology research complex on Havana's southern outskirts. The Center for Advanced Studies of Cuba hopes to carve niches in, for example, drug delivery and solar cells. “We will never be a power in nanoscience,” Clark-Arxxer acknowledges. “But we have to be proficient.” Seemingly defying poverty and the embargo, the center's labs are billed as having “ultralow vibrations without electromagnetic interference,” a “powerful computational infrastructure,” and “world-class laboratories for nanocharacterization.” Work on a nanofabrication facility is slated to begin next year.

Cuba's precision strike into a field dominated by the United States and other powers sounds a lot like guerrilla science. But until the embargo fades, that's the way it has to be, Castro Díaz-Balart says. “This approach,” he says, “is consistent with the economy and possibility of Cuba.” ■



Elkhorn coral has vanished in much of the Caribbean but hangs on in Cuban waters.

CUBA'S CORAL EDEN

Scientists rush to study what may be some of the last healthy corals in the Caribbean

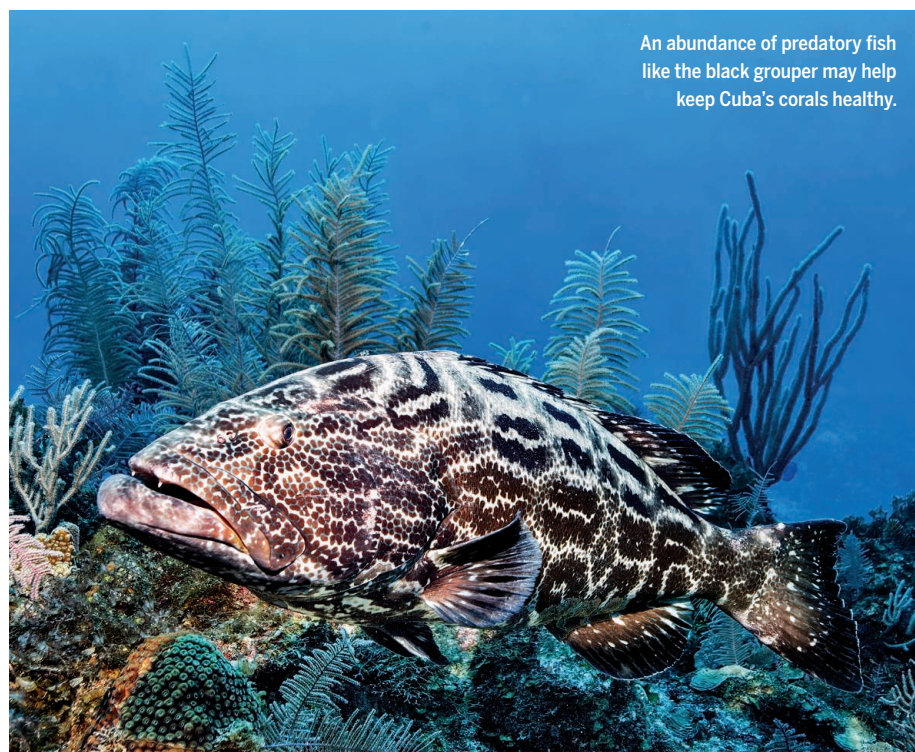
By **Elizabeth Pennisi**

Last month, Amy Apprill checked in for a 30-minute flight from Miami to Havana with 17 pieces of luggage stuffed with water filtration pumps, underwater cameras, an ocean acidity probe—even liquid nitrogen. To get anything done in Cuba, the marine microbiologist at Woods Hole Oceanographic Institution in Massachusetts had to bring everything with her. Cash, too: She had \$1500 stashed in her backpack to augment the \$15,000 that colleagues carried to Havana to pay for diesel fuel and the use of a research vessel.

Those hassles, Apprill hoped, were a small price to pay for an extraordinary opportunity. Thanks to limited development and extensive conservation efforts, Cuba has “the best

coral reefs of the region,” says Dan Whittle, an attorney in charge of the Cuba program for the Environmental Defense Fund in Raleigh. Many Caribbean reefs are dead or dying, he says, yet Cuba's remain “stunningly beautiful.” Apprill wants to know why.

She's not the only one. As Cuba-U.S. relations thaw, scientists are eager to size up the reefs before an anticipated economic boom has a chance to degrade them. “There's a little bit of a stampede to get there,” says Clare Fieseler, a graduate student at the University of North Carolina (UNC), Chapel Hill, who made it to Cuba several years ago and hopes to return to visit underexplored reefs. Also fueling a sense of urgency: Cuba's coral reefs may hold the cure for ailing reefs elsewhere in the Caribbean.



An abundance of predatory fish like the black grouper may help keep Cuba's corals healthy.

Though roughly the size of Florida, Cuba has four times as much coral reef, and much of its coast is underdeveloped. Cuba's Law 81 is a big factor, scientists say. Adopted after the late explorer Jacques Cousteau visited the island in the 1980s, the law created an environmental agency that set out to protect 25% of Cuba's lands and water—a goal that Cuba claims has been reached for its coastal regions.

The biggest jewel in Cuba's coral necklace may be the Jardines de la Reina, or Gardens of the Queen, a chain of 250 mangrove and coral islands 80 kilometers off southern Cuba. "Diving for 40 years, I have never seen anything like it," says David Guggenheim, a marine scientist and president of Ocean Doctor, a nonprofit in Washington, D.C., which helps U.S. scientists visit Cuba. The Gardens have healthy elkhorn coral, an endangered species that has virtually disappeared elsewhere in the Caribbean.

As a no-take reserve largely off-limits to divers and fishers, the Gardens brim with predatory fish—a rare sight in the region. John Bruno, a marine ecologist at UNC Chapel Hill, and his Cuban postdoc Abel Valdivia have measured 600 grams of fish per square meter, primarily shark, grouper, and snapper. That's six to eight times more fish mass than at most Caribbean reefs. An

abundance of predatory fish may help keep the Gardens healthy by reducing populations of fish that hurt corals.

Another protective factor may be the reef's tiniest members. Apprill has teamed up with the U.S.-based Cuba Marine Research and Conservation Program, Patricia González of the University of Havana, and other colleagues who last year began comparing Cuban reefs with different tourism and fishing pressures. They have found some that are as impressive as the Gardens. Apprill aims to determine whether healthy reefs have a different array of microbes—their microbiome—than unhealthy reefs in Florida.

Flourishing reefs

Cuba has four reef chains longer than 100 kilometers, including the Gardens of the Queen, the largest marine reserve in the Caribbean.



As part of the \$559,000, 5-year project, the team will drill into corals to extract cores that, like tree rings, enable them to peer back in time at environmental effects on coral growth. One core already in hand turns back the clock 200 years. Correlating growth with nitrogen levels recorded in the reef, for example, may reveal how corals coped with higher nutrient runoff during the Cold War, when the Soviet Union supplied Cuba with large quantities of fertilizer for sugarcane production.

Despite that history, Karl Castillo, a marine ecophysiologicalist at UNC Chapel Hill, believes that the coral reefs are relatively untouched. He wants to go to Cuba soon to collect his own cores, which he predicts will reveal "the impact of global warming with no impact of humans on coral reef." Castillo hopes to gather data before Cuba's coasts absorb a surge in tourism. "Baseline conditions could be quickly lost," he says.

Not all Cuba's reefs are an oceanic Eden, scientists caution. "There is much hype about the 'pristineness' of Cuba's reefs," Fieseler says. "In areas [of Cuba] that are open to fishing, those reefs are really, really overfished and that has a considerable effect on the health of corals." Even in the Gardens of the Queen, coral cover—a proxy for reef health—is "nothing special," averaging about 18% of the sea floor, compared with a Caribbean average of 16%, Bruno says. (On the best reefs, corals cover half the sea floor.) Staghorn and a stony coral called *Montastrea* are in trouble or have disappeared, he says, and it seems that few coral larvae are settling within the reserve boundaries.

The bevy of new projects hopes to paint a more nuanced picture of Cuba's reefs. Because the U.S. trade embargo prohibits spending federal funds on research in Cuba, U.S. efforts require private money. Guggenheim is an adept fundraiser—he leads 11-day dive trips running \$8000 a person—and promoter, having talked up the reefs on *60 Minutes*, on public radio, and in diver magazines. Ocean Doctor is putting on a fall workshop to take a dozen reef scientists to the Gardens to forge a plan for long-term monitoring of coral resilience.

Les Kaufman, a marine biologist at Boston University, is jumping at the chance to attend. Compared with the rest of the Caribbean, he says, "there's a better chance of Cuba hanging on to its healthy reef." A trip to the Gardens of the Queen, Kaufman says, will be worth the hassle. ■