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Society and Climate Change in Latin America and the Caribbean

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Abstract
This issue of Hemisphere examines some of the steps that are being taken to conserve marine, terrestrial and urban ecosystems for the biodiversity they contain and the human communities that depend upon them for sustainable livelihoods. The invited contributors to this issue work at NGOs, botanic gardens and universities in The Bahamas, Barbados, Cuba, Mexico, El Salvador and the United States. The articles not only raise concerns for the social, economic and environmental consequences of climate change in the region, but also explore avenues for facing these challenges and offer clear case examples in which imperative actions are needed.

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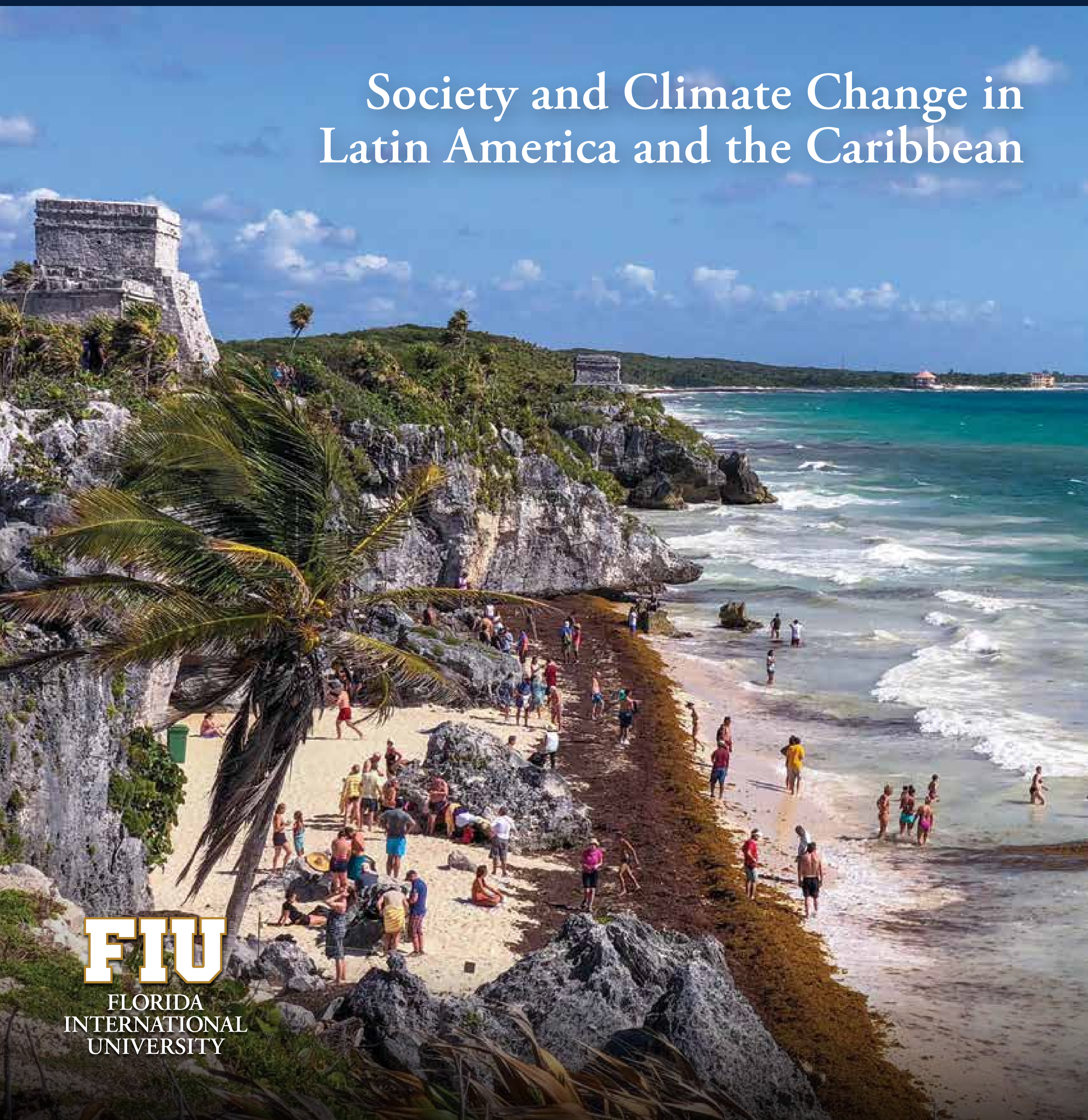
Society and Climate Change in Latin America and the Caribbean



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IN THIS ISSUE

Hemisphere

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COVER IMAGE: Sargassum algae and tourists choke Playa Ruinas at Tulum, Quintana Roo, Mexico, 2018. MARIA KUZKINA/iStock by Getty Images.

FROM THE EDITOR

Dear *Hemisphere* readers:

This issue on the social, economic and environmental consequences of climate change in the Americas is long overdue. At a time when even the science of climate change is on trial, the editors and authors of this issue go beyond its destructive effects on the environment to highlight its impact on cultural diversity, disaster mitigation, agricultural production and tourism. I am grateful that Professors Javier Francisco-Ortega and David Bray of Florida International University's Departments of Biological Sciences and Earth and Environment, respectively, enthusiastically agreed to be guest editors of this important interdisciplinary issue.

The guest editors have brought together an outstanding collection of authors from FIU and external institutions to not only examine the impacts of climate change but also provide solutions that national and local governments, as well as communities, can implement to address the threat to Latin American ecosystems. The interdisciplinary approach of this issue underscores the multifaceted effects of rapid climate change on economic and cultural development, agriculture and urban settlements in vulnerable societies facing poverty, inequality, political uncertainty, citizen insecurity and limited access to quality social services.

The convergence of structural political and socioeconomic challenges in Latin America and the Caribbean, and the multidimensional effects of climate change on the flora, fauna and overall livelihood of the region, generate a mix of reinforcing threats that are difficult to measure and understand. The stability and sustainability of political, social, economic and environmental ecosystems depend not only on understanding the effects of climate change but also on adopting appropriate interdisciplinary policy solutions today.

The Kimberly Green Latin America and Caribbean Center (LACC) remains committed to supporting its faculty and students in their interdisciplinary research and will use *Hemisphere* as a platform to explore and promote theoretical and public policy issues facing the Americas. Given the impact climate change and global warming are expected to have on virtually all aspects of life in the region and around the world, they are sure to remain the themes of future LACC programs and publications.

Frank O. Mora
Director & Professor
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FROM THE GUEST EDITORS

Climate change is upon us. It is estimated that human-induced warming reached approximately 1.8°F from pre-industrial levels by 2017 and is likely to increase an average of around 0.4°F per decade in the coming years. This would quickly put us well beyond the 2.7°F that the Paris Accords set as the aspirational limit for warming. The consequences for Latin America and the Caribbean include decreased plant and animal species diversity, coral bleaching, changes in ecosystem composition and biome distribution, the melting of most tropical glaciers in the near future (2020-2030), and severe impacts on coastal and riverine areas. This special issue of Hemisphere examines some of the steps that are being taken to conserve marine, terrestrial and urban ecosystems for the biodiversity they contain and the human communities that depend upon them for sustainable livelihoods.

The invited contributors to this issue work at NGOs, botanic gardens and universities in The Bahamas, Barbados, Cuba, Mexico, El Salvador and the United States. The ten articles we present not only raise concerns for the social, economic and environmental consequences of climate change in the region, but also explore avenues for facing these challenges. They aim to increase public awareness of climate change and effective conservation measures targeting species threatened by global warming. Within this context, inter-institutional partnerships across national boundaries are clearly necessary. These partnerships include biological conservation research, community involvement, outreach for environmental ethics, and educational initiatives. The conservation steps they take go beyond the urgent need to preserve ecosystems in natural reserves to encompass plants and animals in recognized and certified botanic gardens, bird conservation centers and 'coral arks.'

The articles in this issue offer clear case examples in which imperative actions are needed. For example, climate change and nutrient enrichment are causing enormous blooms of brown algae that threaten the tourism industry of the Mexican Caribbean coast and other regions. In the Bahamas chain, entire islands and ecosystems are becoming inundated and altered. The consequences of climate change are also having detrimental effects inland, affecting the flow of rivers, forest composition and soil dynamics. These changes in turn affect socioeconomic realities, cultural diversity and environmental dynamics. Sustainable agriculture and community forest management can provide an alternative for populations in these areas, particularly within fast-changing environments.

One common theme of the articles presented in this issue of Hemisphere is the importance of finding solutions involving all stakeholders. All voices are necessary to address the multiple effects of the greatest threat to Latin American ecosystems, and the nations and communities that depend on them. The consequences of climate change go beyond the unique flora and fauna that these ecosystems harbor, posing direct challenges to regional livelihoods.

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Idyllic Playa Ruinas without sargassum in 2011, Tulum, Quintana Roo, Mexico. LUNAMARINA/iStock by Getty Images.

Partnerships between Botanic Gardens and Universities in a Changing Caribbean World

by Javier Francisco-Ortega, Brett Jestrow & M. Patrick Griffith

Human activities have had a major impact on the flora and fauna of our planet. Human-driven climate change and the current move to a global economy are among the main factors contributing to the current path towards species extinction, and the resulting "biodiversity crisis" has had a particularly strong effect on island ecosystems.

The Caribbean Islands are no exception to the extinction trend. Major concerns have arisen regarding the impact that a global economy and warmer temperatures will have on these insular systems. Historically, the islands have been a major center for trading because of their central location in the hemisphere and the development of sugarcane as the region's main cash crop, although the latter is now in decline. Since the expansion of the Panama Canal, West Indies ports have become particularly attractive as hubs for global trading, and their tourist resorts are among the most popular destinations for holidaymakers from North America and Europe. One of the main results of this massive movement of people and cargo is an increase of urban and agricultural development, and the subsequent risk of introducing non-native invasive species into their environments.

Regarding climate change, Caribbean countries are facing two immediate challenges. The first is sea-level rise, which is having an immediate impact on seashore habitats. Territories like the Bahamas archipelago and several of the Lesser Antilles and Virgin Islands sit at low elevations, and their very existence as political entities is threatened. A second concern is how the species composition of these islands will be modified as global temperatures rise and species are forced to migrate to higher elevations.

A botanical consortium in Miami

Florida International University (FIU) and Miami's two largest botanic gardens (Fairchild Tropical Botanic Garden, or FTBG, and Montgomery Botanical Center, MBC), are developing partnerships to contribute to plant species conservation in the islands and to mitigate the effects of globalization and climate change on the flora of the West Indies. Currently, two FIU faculty members (the first author and Dr. Hong Liu) have formal assignments and appointments at FTBG. All of our plant initiatives are conducted in close partnership with in-country botanists and institutions and prioritize channeling direct resources to them. Additional partners are the USDA Subtropical Horticulture Research Station of Miami, led by Dr. Alan Meerow, for molecular genetic projects; and the International Center for Tropical Botany (ICTB), a collaboration between FIU, the National Tropical Botanic Garden (NTBG) and the Kampong Gardens, led by FIU's Dr. Chris Baraloto.

Florida International University has higher education and research in its mission, and the two botanic gardens have research as a key component of their programs. In addition, they have extensive experience in conservation horticulture and have established a large network of garden members and volunteers. The living plant collections of these two gardens are unbeatable. FTBG has a large array of tropical plants, whereas MBC has one of the most significant programs for cycad and palm conservation worldwide, based on the cultivation of multiple populations of endangered species. FTBG also has the most extensive herbarium in the Miami metro area and a repository of material collected in the field.

The Caribbean partners: training and capacity building

Our efforts to contribute to botanical knowledge in the region have concentrated on graduate education for both Caribbean and US students. An official Memorandum of Understanding between FIU and the University of the West Indies (UWI) facilitates joint supervision of students by faculty at the two universities.

Two students from UWI at Mona (Tracy Commock and Keron Campbell) are currently enrolled in this program, with major advisor Dr. Phil Rose of UWI and the first two authors as co-major advisor and committee member, respectively. A project led by Commock concerns plant genera only found in Jamaica, while Campbell's research focuses on the conservation status of Jamaican endemics. The baseline information generated by these two studies will be critical to our understanding of how climate change can affect the population dynamics of individual plant species.

William Cinea, Director of the Botanic Garden of Les Cayes in Haiti, provides a training at a plant systematics workshop at the Garden.

US graduate students are also a relevant part of these activities. Michael Calonje, the cycad biologist at MBC, is currently pursuing a PhD in systematics and the evolutionary history of the cycad genus *Zamia* through an agreement between FIU and MBC. Part of his research involved extensive fieldwork in the Greater Antilles and the Bahamas under the guidance of Dr. Meerow. Three students advised by FIU faculty hosted at FTBG are working on the taxonomy of Frangipanis and guava relatives and on the conservation ecology of Caribbean orchids (See article by Haydee Borrero in this issue).

Plant exploration

Plant exploration activities are the basis for subsequent laboratory research, understanding conservation challenges, developing horticulture practices, and eventually establishing living collections in botanic gardens. Over the years, the authors have been conducting fieldwork in the Greater Antilles and Bahamas. Most recently, Dr. Jestrow has led studies of the Bahamian endemic palm *Coccothrinax inaguensis* (in partnership with Dr. Ethan Freid from the Bahamas National Trust, see article in this issue) and on the flora of northern Haiti (in partnership with William Cinea of the Botanic Garden of Les Cayes and Brígido Peguero of the National Botanic Garden of the Dominican Republic). The collected material is being cultivated at FTBG and MBC, with duplicates at Caribbean botanic gardens. Similar initiatives target the Critically Endangered palm *Attalea crassispatha*, a relative of the oil palm restricted to a few scattered populations in southern Haiti. Extensive field surveys have collected seeds for conservation off site at FTBG, MBC and the botanic gardens of Hispaniola. Plant conservation biologists agree that Haitian plants and animals are high priorities for conservation. Jestrow has led two expeditions to northern Haiti, including the island of Tortue and Môle-Saint-Nicolas, in the northwestern corner of the country. During these trips, FIU botanist Dr. Alan Franck discovered a new species of cactus, and the existence of the enigmatic genus *Tortuella* was confirmed. This genus, a member of the coffee family, is extremely rare and known to exist only on Tortue.

Ex situ conservation

This term refers to the practice of preserving threatened species of plants in botanic gardens or seed banks. A recent ex situ conservation initiative, led by Dr. Griffith in partnership with colleagues from the Bahamas National Trust, targeted Caribbean plants threatened by sea level rise, especially the Critically Endangered *Zamia lucayana*. Seeds were collected, and their progeny (101 plants) are currently part of

Palm collection at the lowlands of Montgomery Botanical Center in Miami, Florida. Photo by M. Patrick Griffith.

the living collections of MBC. The authors have also led six plant-hunting expeditions to the Bahamas, Haiti, Dominican Republic, the island of Mona (Puerto Rico) and Dominica to further in situ conservation of the Caribbean palm genus *Pseudophoenix*, the research subject of FIU master's student Rosa Rodríguez of the Dominican Republic.

Our research involves a battery of tools, including DNA protocols, scanning electron microscopy, anatomy and histology, morphology, and horticulture propagation procedures. Among the groups studied are the Cuban genus *Feddea*, restricted to the nickel-rich soils of regions of eastern Cuba. Extensive fieldwork led by collaborator Ramona Oviedo (Instituto de Ecología y Sistemática, Cuba) located a single population in the province of Guantanamo. Subsequent DNA research showed *Feddea* to be a relict component of the sunflower family.

Environmental education and outreach

Botanic gardens find their identity through the connection of their mission with the general public. Both FTBG and MBC have popular magazines or newsletters that regularly share their Caribbean activities with the broad community of plant enthusiasts from the region. A great proportion of their findings have also been published in the brochures and magazines of Caribbean partners. Building on the gardens' partnership with the Bahamas National Trust and the College of the Bahamas (currently University of the Bahamas), the first symposium on plant conservation and biodiversity of the Bahamas was organized in October 2012. In January 2017, Dr. Jestrow, in collaboration with Dr. A. Franck and colleagues from the Botanic Garden of Cayes, led a one-week workshop on plant systematics that aimed to increase plant identification skills among local professionals and students in the forestry and conservation fields.

The synergy from our partnerships has led to the training of nine FIU graduate students working on plant conservation and the taxonomy of West Indian plants. Our team has conducted more than 30 plant exploration expeditions across the Caribbean Islands and produced more than 68 publications, 19 of them aimed at the general public. Thanks to our efforts, the living collections of FTBG and MBC have added more than 100 accessions of palms, cycads and several other seed plants.

Climate change will have an impact on us all, but it has potentially dire consequences for Miami's botanic gardens. They are located close to the shoreline, and it is uncertain to what extent their living collections can tolerate massive saline intrusion of their aquifers. Other Caribbean island gardens face similar environmental challenges. The ultimate aim of our initiatives is to contribute to the urgent need for conservation of the plant heritage of the Caribbean islands. The education, research and conservation missions of botanical gardens are crucial for assuring that endemic and endangered plant species survive climate change and the other threats that besiege them, preserving them for future generations of the peoples of the Caribbean and the world.

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The flower of the mule-ear or oreja de burro orchid (Trichocentrum undulatum). *This orchid species can be found throughout Cuba and as far north as Everglades National Park in Florida, where it is on the state list of endangered species. Photo by Mario Cisneros.*

The Shared Natural Heritage of Southern Florida and Cuba: Orchid Conservation across Borders

by Haydee Borrero, Matt Richards, Dennis Giardina, Julio C. Álvarez, Ramona Oviedo Prieto, Emily E. D. Coffey & Hong Liu

Relations between Cuba and the United States have morphed and changed over time. Whatever the sociopolitical climate, one group remains blissfully unaware: the region's shared flora and fauna. Species do not adhere to the anthropogenic borders humans create to separate our cultures and peoples. The movements of large mammals across swaths of land and the migrations of birds across oceans make our efforts at artificially demarcating the landscape ineffectual. Similarly, the spread of orchids throughout the Caribbean and Florida by wind dispersal of small, lightweight seeds shows that while political systems may differ drastically, we have much to gain by cooperating through ecosystem management and conservation. When considering a changing climate, the ability to pick up and move might be a species' only option to avoid extinction, a reality that poses a greater challenge to plants than it does to animals. Understanding a species' movements is critical to its conservation, but just as important is how it reproduces and survives under varied environmental challenges, particularly climate change, in different parts of its range.

The study of existing populations and their ecology helps researchers understand how species persist in one place, a factor that becomes more significant given the inevitability of global change. Throughout a species' range, different adaptations provide a buffer against environmental changes such as cold snaps, droughts, and shifts in localized species assemblages and interactions. Preservation of adaptations through conservation projects across a species' range will play a prominent role in future global biological conservation projects. If a species must move, either with human assistance or on its own, diversity in adaptations will preserve its evolutionary potential.

Southern Florida is the northernmost distribution for 56 species of orchids that can also be found in Cuba. The majority are threatened, endangered or locally extinct in southern Florida, but still plentiful in Cuba. The regrettable loss of habitat due to urbanization, historical extraction and poaching in the United States has created a need for baseline ecological data for the remaining orchid populations in Florida and those that can now only be found in Cuba. From charismatic flowering varieties such as the ghost orchid (*Dendrophylax lindenii*), which has captivated the attention of authors, collectors and filmmakers, to drabber species like the rat-tail orchid (*Bulbophylum pachyrachis*), all play a role in their ecosystems and are valuable to society. The challenge is to establish methods and programs for successful species management, restoration of declining populations, and conservation to buffer extinctions in a changing climate. To succeed, such efforts will require the exchange of information, the creation of relationships, and the fostering of conservation programs between the two countries.

The importance of monitoring

The establishment of baseline data by comparing observations of healthy, intact populations with declining or threatened ones throughout a species' distribution is a critical component in conservation and restoration projects. Currently, Dr. Hong Liu's tropical plant conservation laboratory at Florida International University (FIU) is studying the significant damage done to an endangered local species, the mule-ear or *oreja de burro* orchid (*Trichocentrum undulatum*), in Everglades National Park. Only one

A visit to the coastal forests near Yaguajay, Cuba, in the spring of 2018. From left to right: Dr. Emily Coffey (ABG), Dr. Hong Liu (FIU), Armando Méndez (Parque Nacional Caguanes), field technician (Parque Nacional Caguanes) and Haydee Borrero (FIU).

reproductively viable population of this species is left in the United States and it has been observed to be severely affected by a fly (*Melanagromyza miamensis*) that consumes the flowering stalks, hindering the production of fruits and seeds. The Everglades population has been relatively well studied over the last decade, but how are populations faring elsewhere in the species' range? How are management decisions to be made if we do not know whether a biological interaction seen in one population is an anomaly or within the normal spectrum of interspecies interactions? Some of the answers to these questions can be found in Cuba, where the mule-ear orchid grows in every province in a variety of habitats.

Preliminary work by the tropical plant conservation laboratory at FIU and Cuba's Instituto de Ecología y Sistemática has shown that mule-ear orchids on the island are being attacked by the same species of fly that inhibits reproductive ability in Florida. The attack rates observed in Cuba are less than those documented in the Everglades, however, leading us to believe that habitat conditions may be quite different in Cuba. This suggests that the future of the population in Florida may be dependent on the knowledge yet to be gained by studying the healthier populations in Cuba. With a changing climate and rising seas, Cuban orchid populations may be key to avoiding the species' extinction in the United States.

Perseverance and shared ideals

Some of South Florida's orchids have gone extinct locally due to large-scale changes to the region's natural areas in the twentieth century. The culprits include logging and development, as well as extraction and poaching from the wild. The Lost Orchid Project (LOP), led by the Atlanta Botanical Garden (ABG) in collaboration with the FIU tropical plant conservation laboratory and Fakahatchee Strand Preserve State Park, advocates the reintroduction of four orchid species not seen in the United States since the early 1980s, using seeds sourced from Cuba.

The LOP aims to gather baseline population data for focal species from their remaining localities in Cuba and to collect seeds for propagation at partner institutions in Cuba and ABG. The project's success is tied to the education and training of local garden staff and community groups through workshops on how to propagate orchids using standard methodologies developed by ABG.

Collaborative projects such as the LOP can have a significant impact on local biodiversity restoration through the reintroduction of extirpated species and play an important role in the overall success of global biodiversity conservation. In the cases of species with broad ranges and distributions spanning multiple borders, each partisan side may understand only a piece of the whole. An exchange of research, ideas and knowledge is necessary to protect and improve the health of threatened species. Establishing cross-border partnerships not only has a positive effect on the resilience of wild orchid populations in the Caribbean region but also upon the survival of flora and fauna globally. Biodiversity conservation actions can range from small-scale local projects to larger-scale international collaborations that begin with an exchange of ideas and end with actions that may ultimately ensure the continued survival of rare, threatened and endangered species.

A Cuban stamp of Encyclia fucata *from the 1980 "Cuban Orchids" series. ALEXANDERZAM/iStock by Getty Images.*

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Coral Reefs under Threat

by Cynthia Lewis & Mauricio Rodríguez-Lanetty

Coral reefs, frequently referred as "the rainforest of the sea," are the most diverse marine ecosystems on the planet. Comprising about 0.1% of the Earth's surface, coral reefs provide habitats for more than 90,000 known species, including 800 species of hard coral worldwide. Beyond their biodiversity value, coral reefs also provide nearly US$9.9 trillion a year in economic and ecosystem services that directly benefit about 500 million people. The high biodiversity and productivity of these ecosystems is, at first glance, perplexing, considering that coral reef organisms grow in nutrient-poor waters at subtropical and tropical latitudes. Corals have thrived in these environments due to highly efficient nutrient cycling provided by their symbiotic relationship with photosynthetic, single-cell microalgae that live inside the cells of the actual coral host. In this system, the coral animal captures and ingests zooplankton and dissolved organic nutrients from the surrounding water to maintain its own metabolism. Chemical byproducts of the coral metabolism, such as ammonium and carbon dioxide, are made available to the associated microalgae, which use them as a nutrient source for their own cellular growth. Astonishingly, during this process these microalgae can provide the coral with up to 95% of their carbohydrate needs produced through photosynthesis.

The rugged structure of coral reefs often provides the first line of defense, absorbing wave energy from storms. Additionally, these reefs also provide essential habitat for diverse marine life which, in turn, are a significant food source. Despite the importance of these reef ecosystems to human societies worldwide, they have experienced dramatic declines in recent decades due to a variety of natural and anthropogenic disturbances occurring both at the local (e.g. overfishing, nutrient loading and diseases) and global (e.g. climate change and ocean acidification) levels. An apparent major driver of coral mortality, and thus coral reef decline, is coral bleaching, the massive loss of photosynthetic algae living within the coral tissue caused by abnormal increases in seawater temperatures —a phenomenon linked to climate change and exacerbated by high light intensities.

An estimated 20% of the world's reefs have been lost in the last 50 years, and scientists anticipate that more than 60% may be gone by 2030. These projections have accelerated following the 2014-2016 El Niño Southern Oscillation (ENSO), one of the strongest warming phases on record in this cyclical shift in the ocean and atmosphere, and the cause of staggering losses to coral reefs worldwide. In the Caribbean, declines in live coral cover since the 1970s are estimated at more than 80%, leaving less than 5% live coral cover on many reefs. In addition to coral bleaching, more frequent and intense hurricanes and new disease

Dr. Cynthia Lewis monitoring a large colony of healthy pillar coral (Dendrogyra cylindrus) *at Sombrero Reef, January 2014. Photo by Dr. Karen Neely.*

outbreaks affecting more than half of the 61 endemic Caribbean coral species have further degraded these reefs. The Florida Reef Tract (FRT), stretching nearly 320 km from Biscayne Bay to the Dry Tortugas and the only living barrier reef in the continental United States, has experienced alarming declines in live coral cover and diversity. Like the orchid populations that occur in both Cuba and the US (see the article by Haydee Borrero in this issue), this reef links South Florida and the Caribbean. Efforts to conserve it have strong implications for both regions.

Is there still hope for coral to adapt to climate change?

In geological terms, coral reef ecosystems have experienced a remarkable period of long-term stability. In recent years, however, increasing environmental threats associated with climate change are affecting these ecosystems at a rate not observed previously.

When faced with new selection pressures imposed by increasingly rapid climate change, coral populations can respond in three basic ways. First, they can evade damage by dispersing to suitable habitats elsewhere. Second, they can stay and adjust to the changed conditions by means of phenotypic plasticity without altering their genetic constitution. Third, they can adapt to the changed conditions by means of genetic changes through the process of evolution. A combination of these responses is also possible, perhaps even likely. For instance, some genetic change has been accomplished through the appearance of new symbiotic algae species living within the coral that can provide more resistance to the detrimental effect of ocean warming. But while these new microalgae can impart increased survival to corals under thermal stress, they may also reduce the productivity of the coral animal, and not all corals are able to shift and/or re-shuffle their association with the algae that they host.

Several studies have shown that some corals may have adaptive potential to adjust to the current environmental threats linked to climate change, offering some degree of hope for these species. At the same time, recent large-scale investigations in the Great Barrier Reef using data collected over the last 20 years suggest that past exposure does not lessen the severity of current bleaching. This indicates that the continued worsening of environmental changes seems to be outpacing the ability of the corals and their symbionts to adapt to climate change. Consequently, scientists have called for immediate global action to curb future warming to secure a future for coral reefs. The question now is, how do we buy time and save those resilient organisms still alive within these ecosystems given the US government's failure to take aggressive action to slow and reverse the progression of climate change?

What we can we do to save the corals

One immediate solution is to create living genetic banks, or "coral arks," to protect and preserve rapidly dwindling coral diversity on our reefs. Land-based, temperature-controlled systems can provide a safe haven for some of the most threatened species. The iconic and morphologically unique pillar coral, *Dendrogyra cylindrus*, occurring in historically low abundance throughout its Caribbean range, is currently faced with local extinction on the Florida Reef Tract. This could happen within the next five years, meaning the species is in dire need of intervention. These ancient monarchs of the reefs were listed as Vulnerable in 2008 based on the International Union for Conservation of Nature Red List criteria for species conservation, due to disease and declining water quality. In 2014, the pillar coral was federally listed as Threatened under the US Endangered Species Act because of population declines in US waters. These listings initiated studies to more clearly define the situation of Florida's population and gain a better understanding of the environmental factors causing the decline.

Since the 2014 and 2015 mass bleaching events associated with the ENSO, Florida's pillar coral population has experienced catastrophic collapse, declining from approximately 745 known colonies to fewer than 75. Fortunately, first author Dr. Cynthia Lewis (Florida International University) and Dr. Karen Neely (Nova Southeastern University) sounded the alarm in December 2015 and began a coordinated effort, through the National Oceanic and Atmospheric Administration's (NOAA) Protected Resources Coral Division, to rescue Florida's remaining pillar coral. They harvested pillar fragments and transferred them to land-based facilities at Keys Marine Laboratory, Florida Aquarium's Center for Conservation, and Mote Marine Laboratory. Many colonies were already ravaged by white plague (now termed stony coral tissue loss disease), an aggressive, fast-moving disease capable of killing an entire large colony in a matter of months. While a specific pathogen or suite of pathogens has not yet been identified, it is likely bacterial and possibly viral in nature. Badly diseased fragments of rare individuals were transported to NOAA's National Ocean Science Hollings Marine Laboratory in Charleston, North Carolina to explore antibiotic treatments and protocols to arrest the disease under controlled aquarium conditions. With approval from the US Food & Drug Administration's Center for Veterinary Medicine/ Minor Use Minor Species Division, application of antibiotic treatments was further tested in the field on wild diseased pillar coral with some success, using a targeted, time-release paste to stop the advance of disease.

Dr. Cynthia Lewis monitoring and sampling a severely bleached pillar coral colony at Tennessee Reef, September 2014. Photo by Dr. Karen Neely.

Since the beginning of this rescue effort in January 2016, nearly 400 fragments representing 89 distinct genetic groups, identified by Dr. Andie Chan and Dr. Iliana Baums (Pennsylvania State University), have been successfully stabilized in the already established "pillar coral genetic ark." More than half of these rescued genetic groups are now extinct on the Florida Reef Tract. Unfortunately, an additional 60 unique genetic groups were lost to disease before they could be rescued. The pillar coral living genetic ark could provide the foundation for future restoration efforts of this species if and when reef conditions improve and divers can return the samples to the reef. Meanwhile, scientists are excited about successful land-based pillar coral reproduction within the genetic arks in August 2017 and 2018. Such experiments are especially challenging for this predominantly gonochoric (separate male and female colonies) species. Not only does pillar coral, like many other corals, require genetic diversity for reproductive success, but it also depends on the presence of male and female colonies to create the next generation of baby corals. Within these new coral recruits may be individuals that are more resistant and resilient to thermal stress and disease and better adapted to reef conditions in the current human-dominated age of the Anthropocene. Lessons learned from land-based genetic arks, disease treatments and restoration techniques can be applied to other vulnerable pillar coral populations throughout the Caribbean, as well as to other threatened coral species around the world.

There is growing consensus among scientists that aggressive intervention actions are needed to save and preserve coral diversity. For the time being, however, reducing greenhouse gas emissions remains the priority as the only way to restore stability to the oceans and climate, giving coral reefs a chance to regenerate.

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The Imperial Parrot or Sisserou, Dominica's national bird, is the largest and oldest of the Amazon parrots. Photo by Paul Reillo.

Saving Dominica's Parrots in a Changed World

by Paul Reillo

Dominica, the resplendent, mountainous Nature Island of the Caribbean, was forever changed on September 18, 2017 by Hurricane Maria, which struck as a Category 5 cyclone. Having lived in South Florida for nearly 30 years, and working closely with Dominica's Forestry, Wildlife and Parks Division (FWD) for the past 20, I can personally attest to the fury of hurricanes, but also to nature's resilience afterward. Although Dominica's post-Maria story has been eclipsed by the media's intense focus on Puerto Rico and her many tragedies, the Nature Island's saga is noteworthy in its own right.

For decades, scientists considered Dominica to be a Caribbean model for homegrown wildlife conservation and sustainability. In particular, the iconic, endemic national bird, the Imperial Parrot (a.k.a. Sisserou, or *Amazona imperialis*), the largest and oldest of the Amazon parrots, has long been a conservation flagship for biodiversity protection. After Maria, many conservationists feared the shy, beautiful Sisserou might be gone for good. Amazingly, despite Maria's wrath, this majestic parrot survived the storm along with its more common endemic congener (member of the same genus), the Jaco parrot (*A. arausiaca*). A year after Maria, Dominica is once again green and lush with emerging vegetation, but the parrots' small world has been irrevocably changed. Maria will not be the island's last hurricane, and critical species there face an increasingly uncertain future.

Nature's previous major assault on the island was from Hurricane David in 1979, just a year after Dominica achieved independence from England. That storm, which hit as a Category 4, reduced the Imperial Parrot population to perhaps 50 individuals, prompting international NGOs and the Dominican government to initiate recovery and protection measures for the bird and its oceanic rainforest habitat. Dominica's parrots survived Maria thanks to progressive, continuous conservation investments by the FWD and its NGO partners over the past 30+ years. FWD has governing authority over all wildlife matters, as specified in Dominica's Wildlife Act, and serves as a Scientific Authority for the international Convention on International Trade in Endangered Species of Wild Fauna and Flora (also known as CITES). Its efforts, in addition to national pride, have largely protected the parrots from hunting and exploitation for the pet trade, which has undermined many parrot conservation efforts in the Caribbean and American tropics.

The Rare Species Conservatory Foundation (RSCF) initiated the Wildlife Conservation Partnership with FWD in 1996. Our collective goal was to provide tangible benefits to Dominica's endangered parrots and other endemic species through on-site research, habitat protection, material and technical support, educational outreach (e.g., the annual Caribbean Endemic Birds Festival) and FWD capacity building. Over the past 20+ years, and millions of dollars later, the program has achieved numerous conservation milestones, highlighted by the creation of Morne Diablotin National Park, the Sisserou's stronghold. This joint program is responsible for virtually everything we know about the parrots' ecologies, behavior, reproduction and recovery potential.

As the strongest cyclone to hit Dominica in the island's recorded history, Maria caused catastrophic damage to its infrastructure and forests, and significant loss of human life. Yet, thanks to its healthy pre-hurricane population size (>1200 individuals), the Jaco parrot is now sighted throughout Dominica, including villages and settlements, foraging on natural and agricultural foodstuffs. This species is social and gregarious. With a clutch size of 2-3 and an early age of sexual maturity (~5 years), it exhibits a high reproductive rate. Even after heavy losses from David, the Jaco rebounded steadily, and we are witnessing a similar

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trend following Maria. Like the Sisserou, the Jaco is fully protected by Dominican law and is listed as CITES Appendix I.

The secretive and cryptic Sisserou likely numbered ~350-450 birds prior to Maria. Over the past year, occasional sightings have been confirmed in the Northern and Central Forest Reserves, and in patches of forest habitat within and adjacent to the Morne Trois Pitons and Morne Diablotin National Parks. FWD's parrot team, championed by a forester recruited into Dominica's first parrot research project in 1981, has sighted multiple Sisserous, with others revealed by their haunting vocalizations. This large parrot reaches sexual maturity at ~10 years and reproduces slowly, typically fledging one chick every other year. Even with Dominica's strong forest protection ethic and comprehensive post-David conservation measures, nearly 25 years were required for the Sisserou to reestablish its pre-David range. While most of Dominica's primary parrot habitat is protected, much of the mature forest is now devastated. The Sisserou's recovery post-Maria will be markedly slower than the Jaco's, likely requiring several generations.

Today, Dominica is a fragile country and its wildlife is vulnerable to exploitation. Immediately post-Maria, surviving parrots were weak and food-limited, foraging in exposed areas for anything they could find to eat. While life is now better for those left, their recovery hinges on habitat protection and reducing threats for the foreseeable future.

The world of parrot conservation in Dominica was recently shaken by a major controversy. In March 2018, 12 of 18 parrots kept at Dominica's government-run aviary—including two Sisserous—were secretly exported to a private parrot-breeding facility in Germany known as the Association for the Conservation of Threatened Parrots (ACTP), contradicting decades of scientifically sound, on-island parrot-conservation measures. Eleven of the birds were being rehabilitated for release back to the forest. Disguised as a need to "rescue" the parrots from a post-Maria Dominica, this export was arguably as damaging to the parrots' futures as the hurricane itself.

Given the Sisserou's biology, initiating a captive breeding program under any conservation pretext would require collecting most or all of the wild population. Such an aggressive action is widely considered unethical, scientifically indefensible and unnecessary—a view expressed in two published letters signed by numerous international conservation NGOs and credentialed scientists following the birds' export to Germany. Dominica's parrots have survived hurricanes for millennia, and wild populations have rebounded thanks to broad-based, on-island conservation measures. It bears emphasizing that all of the captive birds on Dominica survived Maria.

After a seven-month investigation, *The Guardian* newspaper revealed that, in addition to glaring financial, governance and scientific transparency issues at ACTP, its principal officers are convicted criminals, with offenses ranging from kidnapping and extortion to illegal wildlife trade. As investigations into ACTP's activities and parrot transfers continue, an international petition to demand corrective actions by Germany's CITES authority is under way, with more than 55,000 signatures.

When safety net captive populations for Caribbean Amazon parrots are warranted, they can and should be accomplished in their natural ecosystems within a network of officially protected areas. One such successful effort was the US Fish and Wildlife Service's recovery program for *A. vittata* on Puerto Rico, initiated in parallel with Dominica's FWD program more than 30 years ago. In contrast, no ex situ captive population of any Caribbean parrot species—at zoos, aviaries, or research facilities—has successfully recovered a native wild population. In practice, ex situ captive populations of Caribbean parrot species have long been associated with private collectors and the wildlife trade, and they do not provide for the sustainable preservation of these birds in their West Indian habitats.

Real parrot conservation on Dominica starts with recognizing the island's amazing conservation history following the devastating effects of hurricane David, opportunities post-Maria, and the many holistic, practical and landscape-level protective measures that enable parrots to recover naturally without export for breeding or captivity. Responsible NGOs should unconditionally support the country's conservation needs, including enhancing FWD's professional capacity and physical infrastructure. Exporting wild birds to distant foreign aviaries under a pretense of "saving species" paralyzes ongoing conservation successes that take generations to achieve.

Resources and funds used to create ex situ parrot populations can establish sustainable captive populations for reintroduction into nature programs—again, as needed—that bolster pride and retain species in the country of origin where they belong. The Parrot Conservation and Research Centre, established in 1999 in Dominica's Botanical Gardens, has long served as a protected home for non-releasable parrots and as a rehabilitation center for birds to be returned to the forest.

Dominica's experienced parrot team is now conducting GPS-based surveys to quantify parrots across challenging terrain strewn with forest debris. Much outside support is needed to ensure long-term wildlife and habitat health. As a resilient and proud nation, Dominica will forge a path to recovery as new and progressive energy, communications, water and transportation systems are developed. Dominica's government has launched an unprecedented campaign to make the island the first climate change-resilient country—a tall order for a speck of an island in the Atlantic hurricane belt. Her wildlife must be given the fullest opportunity to recover on its own and within Dominica's sovereign borders.

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Dominica's parrots have survived hurricanes for millennia, and wild populations have rebounded thanks to broad-based, on-island conservation measures. Photo by Paul Reillo.

Co-author Hazel A. Oxenford stands amid mountains of sargassum on a beach in Barbados, 2015. Photo by Jehroum Wood.

Algal Blooms in the Caribbean: Unpredictable Responses to Climate Change

by Ligia Collado-Vides, Marta García-Sánchez, Hazel A. Oxenford, Rosa Rodríguez-Martínez & Brigitta I. van Tussenbroek

The world's scientists are calling for immediate action to curb the causes of climate change, based on unequivocal data and models. The current sequence of natural disasters around the globe (wildfires, coral bleaching, algal blooms, floods, droughts) is clear evidence that we are living with the consequences of increased temperatures at the global level. Further, there is ample evidence that humans have altered the dynamics of ecosystem functions and services that ensure sustainable development for our civilization. For example, we do not know how many species are becoming extinct or fully understand the impacts of nutrient enrichment of our oceans, so it is difficult to predict with any certainty what effects these alterations will have. Exacerbating the situation is the recent rise in micro and macroalgal blooms, among the most disturbing of the new phenomena.

The Caribbean feels the heat

Like all regions of the world, the Caribbean Sea is suffering the effects of climate change. Massive die-offs of keystone species, widespread coral bleaching and associated mortality, and shifts from coral- to algal-dominated reefs are becoming commonplace in the region. With slightly different local trends, the general health status of the major coastal marine ecosystems (mangroves, seagrass meadows and coral reefs) has been declining since the 1970s, as detected by long-term monitoring programs. These negative impacts are being met with significant efforts to recover and protect coastal and marine ecosystems. For example, governments have increased the number and extent of marine protected areas (MPAs) since the 1990s. These ecosystem-based management efforts are playing an important role in the conservation and sustainable use of marine resources in the region by regulating the local impacts of tourism development and fishing pressures while increasing stakeholder knowledge and participation. However, these efforts are not enough to combat the impacts of global stressors such as climate change and ocean-wide nutrient enrichment. Some MPAs have succeeded in increasing local fish populations and supporting the recovery of coral reef areas (e.g. Hol Chan in Belize), but many other sites, such as the Florida Keys, have lost more than 50% of their coral cover since 1970, despite their protected status and significant management efforts.

Algal blooms are here to stay

Linked to climate change and region-wide eutrophication, microalgal blooms are increasing in frequency and persistence all around the world. These single-celled aquatic organisms can multiply rapidly in high-nutrient, warm conditions and at night. During decomposition, they take up so much oxygen from the water that many other species, especially fish, actually suffocate, resulting in massive fish kills. Some microalgae species release toxic compounds, forming harmful algal blooms (HABs) that result in massive die-offs of fish, shellfish and other invertebrates, as well as being toxic to air-breathing marine mammals and humans. Examples include the well-known "red tides" on Florida's coastlines caused by the microalgal dinoflagellate *Karenia brevis*, capable of massive blooms when temperatures, nutrients and dissolved organic matter increase. As global warming trends continue, we can expect more frequent and more extensive microalgal blooms, with their associated costs to the environment, economy and society.

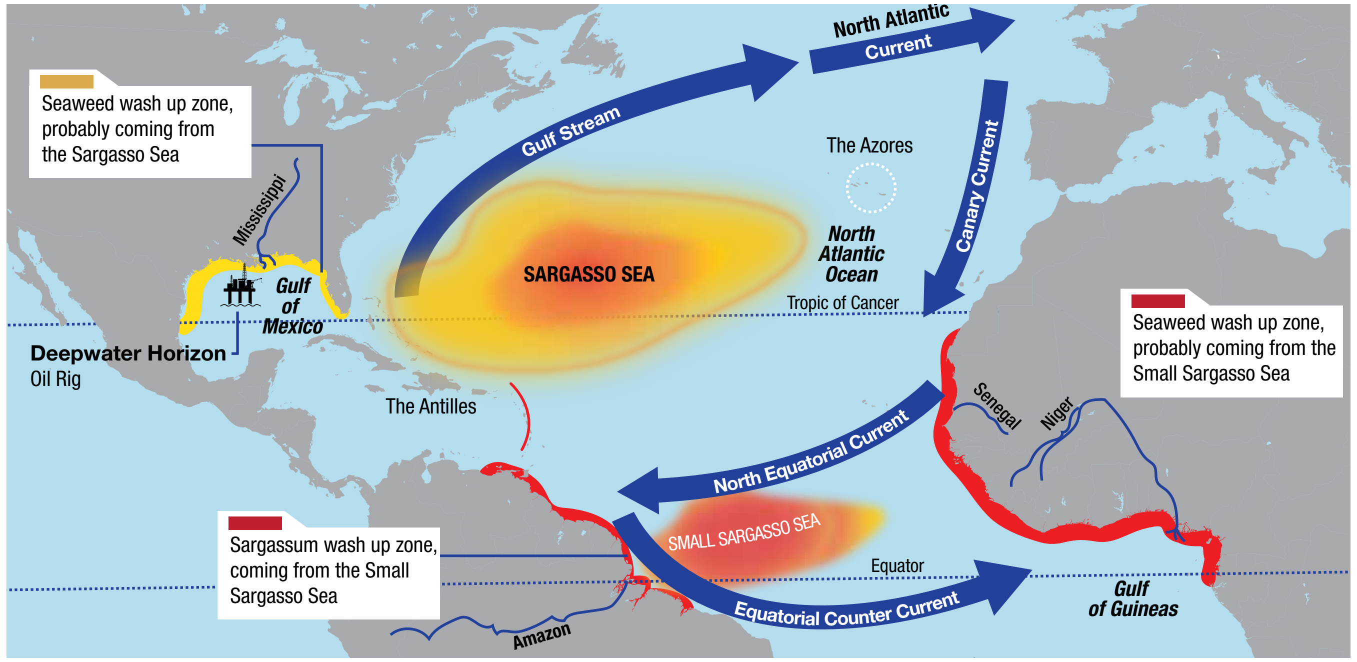
Around the world, we are also witnessing a large increase in blooms of macroalgae (seaweed), again associated with increasing temperatures and ocean enrichment. A good example is the "green tide" formed by the seaweed *Ulva prolifera*, which cost China approximately US$100 million in damages in 2008. Right here in the Caribbean, massive influxes of sargassum seaweed pose one of the most serious challenges to the seashore ecosystem.

The new sargassum tide

Floating sargassum seaweeds (comprising two species of brown macroalgae, *Sargassum natans* and *S. fluitans*) are native to the North Atlantic Ocean. They are well known and treasured in the Sargasso Sea, and also present seasonally in the Gulf of Mexico. However, what we are witnessing now are unprecedented influxes of floating sargassum from a new source region, stretching across the entire North Atlantic equatorial recirculation region from Brazil to the Gulf of Guinea. Washing up along the shorelines of West Africa, Brazil, the Caribbean and Central America, unprecedented beach strandings of seaweed are causing great difficulties for small-scale fishermen and enormous damage to nearshore ecosystems and the tourism industry.

In 2011, massive influxes of floating sargassum started entering the Caribbean Sea and washing up along windward beaches, reaching monumental build-ups in some areas. The rapidly accumulating seaweed soon became a major environmental management problem, one that unprepared stakeholders were ill equipped to handle. Huge piles of algae covered white sand beaches and stained turquoise waters with a muddy brown color, ruining the signature aesthetics of the tourism industry and preventing visitors and locals from enjoying beaches or accessing the sea. Left unattended and trapped in the nearshore water, the seaweeds experienced anaerobic decomposition and released a foul-smelling hydrogen sulphide gas to add to the misery. Nesting sea turtles and emerging hatchlings were also negatively affected. At night, the oxygen was sucked out of nearshore water by the rotting sargassum and resulted in fish kills; the death of many invertebrates, including corals, and the smothering and suffocation of protective seagrass meadows. Furthermore, rotting sargassum released high levels of nutrients, suspended organic matter and brown stain (phlorotannins), further contributing to the environmental degradation.

Once the winter season came, the sargassum was gone, but it returned in 2013, and in 2014-2015 it reached massive proportions. The worst influx seen to date occurred in the summer of 2018, leaving a severe negative signature across the entire Caribbean region. Scientists in Mexico have now demonstrated that the impact on seagrasses was similar to or greater than that caused by the category-five Hurricane Wilma on the same ecosystem in 2005. Hotels in Cancun removed a monthly average of ~5,600 m³ of sargassum



Map of ocean currents and sargassum presence. Courtesy of Ocean Treasures Memorial Library (otlibrary.com).

per kilometer of beach between January and October 2018, doubling records set in 2015. Some hotels in the eastern Caribbean islands were even forced to close down completely during this period. A virtual collapse of the flying fish fishery in Barbados and the appearance of new fishery species, such as the almaco jack, are just a few examples of the unexpected consequences around the region.

Struggling to cope

Hard lessons are being learned as the region struggles to share and coordinate best management practices for processing algae strands along shorelines and to develop a strategic action plan that recognizes both the challenges and opportunities posed by sargassum influxes. Regional meetings, guideline booklets, posters and fact sheets have gone a long way toward helping to share appropriate responses, but more action is needed to create financially sustainable solutions and avoid further negative impacts to beaches and their associated flora and fauna. The tourism and fishing industries have already suffered significant impacts, but scientists have yet to provide a clear or consistent quantification of the ecological, economic and social impacts or opportunities. A comprehensive, coordinated approach to regional and local forecasting is lacking, and in situ monitoring programs and biological study of the species affected are urgently needed to develop effective strategic management plans and adequate response.

A new reality

The Caribbean is the most tourism-dependent region in the world, with a total contribution of US$57.1 billion (15.2% of total GDP) in 2017, and an estimated rise of 3.3% in 2018. Keeping a tourism-based economy healthy in this region depends on the protection of the marine and coastal environment. The negative impacts of microalgal blooms on iconic Caribbean beaches and critical coastal ecosystems are a direct economic threat to the region.

Climate change and nutrient enrichment are triggering unpredictable and difficult futures that call for rapid and coordinated action from all sectors of society and a clear commitment from governments. The massive influx of sargassum is a response to changes in ocean conditions related to global warming and human-induced decrease in coastal water quality. Living in an uncertain world is the new norm, and denial of reality is not an alternative.

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In Situ Conservation Efforts in the Commonwealth of The Bahamas

by Ethan Freid, Lindy Knowles & Shelley Woodside-Cant

The Commonwealth of The Bahamas is a far-flung archipelago of low-lying limestone islands spreading over approximately 900 kilometers (21-27° N) along a succession of shallow banks and deep ocean canyons. The archipelago, including the Turks and Caicos Islands, is in the Atlantic Ocean north of Hispaniola, northeast of Cuba and east of Florida. Biological conservation programs in an island nation so vast have both their challenges and benefits. This is particularly evident today, as few other Caribbean nations face the consequences of global warming and associated sea level rises as directly as The Bahamas and the Turks and Caicos.

The commonwealth's islands differ substantially in terms of size, land tenure, history of disturbance, distribution of citizenry, and the locations and population sizes of species in need of protection. Land tenure is one of the biggest obstacles to creating terrestrial protected areas, since some islands have very little Crown (government) land that can be easily set aside for protection. In the central and southern islands, most land is held privately or is considered "generational" or communal. At the same time, the central and southern islands are the least populated by humans, with extensive terrestrial areas that have experienced little to no disturbance, and therefore lower threat levels to the species occurring there.

The territory covered by the Bahamas is predominately marine, with only ~5% of the nation classified as terrestrial. It includes ~2700 islands and cays, including large land masses such as Andros (ca. 6,000 km²) and many small rocky shoals. They range in elevation from barely emergent at high tide to the highest peak in the archipelago, Mount Alvernia on Cat Island (63 meters above sea level), but more than 90% of the land is a low-elevation coastal environment.

The current human population of the commonwealth is estimated at ~400,000, with substantial variation between islands. The capital island, New Providence, is home to ~245,000 people (~60% of the total). Many other islands have less than 2500 inhabitants and, in some cases, the population numbers only in the hundreds.

The dominant vegetation type in the southern and central islands is Caribbean Dry Forest/Shrubland (locally known as Coppice), and Pine Woodlands in the northern islands and the Turks and Caicos. The larger islands are mostly located in the north, where they receive greater precipitation and therefore hold larger freshwater reserves compared to the smaller islands to the south. With so much biological variation throughout the archipelago, broad conservation efforts are needed for terrestrial and marine species, as well as targeted initiatives at specific locations for individual species that have highly restricted distributions.

In situ conservation refers to the safeguarding of species and their ecosystems inside a network of protected areas. Two government agencies, the Department of Marine Resources and the Forestry Unit, and a non-governmental organization called the Bahamas National Trust (BNT) are the main entities in charge of implementing this conservation strategy. The BNT has expanded from a single park in the central Exuma chain to 32 national parks covering 8,900 square kilometers of land and sea. As noted above, 95% of The Bahamas is a marine environment and therefore accounts for the majority of protected habitat. The largest national park is West Side National Park on Andros, where more than 6.070 km² of land and sea have been designated a protected area. Globally, The Bahamas stands out for its strong partnerships between government and non-governmental agencies to implement nationwide in situ biological conservation.

Primeval Forest National Park in southwestern New Providence, Bahamas. Remarkably undisturbed, it is one of the best preserved plots of old-growth woodland in the country. PJOTRAVELER.

The parks and what they protect

Of the 32 national parks, six are entirely marine and another 15 are at least partially so. The parks vary in size, ranging from Andros West Side to the smallest, the 8,083-square-meter Black Sound Cay National Park. They were designed to protect representative ecosystems and species, with connectivity between sites to ensure the long-term survival of key marine species. The marine national park and protected area system will be expanded in the next few years as The Bahamian government aims to achieve its goal of 20% of nearshore protection and management.

Ten other national parks are entirely terrestrial and contain freshwater, and another 18 have at least some portion that is terrestrial. Most of the entirely terrestrial parks are small; seven of them together total up to only 0.65 square km. Regardless of size, they are all largely intact natural systems.

Eighty-nine endemic vascular plants are known to exist in The Bahamas. Of these, 50 exist on only one or two islands in the archipelago. Many have small population sizes and habitats, occur on privately owned land, and are unlikely to be protected in situ. Unfortunately, little work has been conducted to establish conservation priority categories for plants using the Red Listing system of the International Union for Conservation of Nature (IUCN). However, the available IUCN categories show that endemic species of cycad (*Zamia lucayana*), agaves and cacti rank as Vulnerable to Critically Endangered and are the highest priorities for conservation initiatives.

Nineteen endemic species are known to be protected within at least one existing park, including one single-island and two double-island endemics. As most of the parks have not had a full Botanical Assessment of their flora, it is likely that more endemic plant species are already under in situ protection.

Fortunately, many of the animal species that need in situ protection have restricted ranges or breeding grounds. This has allowed for the targeted establishment of preserves early in the development of protected areas, with parks dedicated to the protection of the natural habitats of iguanas, flamingos, seabirds and parrots.

Threats to biological conservation programs

Two main factors threaten conservation programs in marine and terrestrial ecosystems, both of them related to global warming and globalization: invasive species and climate change.

Invasive species

Marine and terrestrial invasive species occur throughout The Bahamas but are concentrated in the northern islands. These islands have greater connectivity to the US mainland and have experienced more ecosystem disturbance from development pressures. They are also more influenced by global economic trends, as they are major hubs for international trading. Marine Protected Areas have been invaded by the Red Lionfish (*Pterois volitans/miles*), which originates in the South Pacific and degrades the reef systems' biodiversity. On land, Australian Pine (*Casuarina* sp.) and White Ink Berry (*Scaevola taccada*) have aggressively invaded coastal dune systems.

Climate change

Among all of the conservation challenges, increasing global temperatures will have the greatest effect. The rising sea levels associated with global warming will flood coastal areas and force the islands' groundwater up and out of the porous limestone. Critical low-lying infrastructure will be inundated and destroyed. Roads, airports and many marinas will become non-functional, and access to many parks and protected areas for conservation and management purposes will become increasingly difficult.

The consequences for The Bahamas and Turks and Caicos Islands are existential in nature. Entire islands and ecosystems will be inundated and altered. For terrestrial organisms, the greatest consequence of sea level rise will be decreased island size, reducing available feeding and breeding habitats. Areas such as the Pine Woodlands, which occur less than a meter above groundwater level, may completely flood, eliminating entire ecosystems. The potential toll includes the ground-nesting Bahamian parrot of the Pine Woodlands on Abaco and the iguana populations of small offshore cays such as the Exumas, Nurse Cays and Booby Cay. For marine organisms, ocean warming and acidification (a change in seawater chemistry due to uptake of carbon dioxide) will lead to continued degradation and decline of the protective reef system and most of its accompanying organisms.

Little can be done to help the archipelago adapt to climate change given the speed with which the changes are occurring. Organisms that can migrate may survive, while those that cannot will likely be lost in the wild and exist only in ex situ conservation situations located on higher ground. More urgent and theoretically possible is mitigation of climate change by reducing CO_2 emissions from the burning of fossil fuels and deforestation, but for that The Bahamas depend on action from the rest of the world.

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The two greatest threats to conservation programs are climate change and invasive species. The Red Lionfish, which originates in the South Pacific, has invaded Marine Protected Areas and degraded the reef systems' biodiversity in The Bahamas and throughout the Caribbean. BESJUNIOR/iStock by Getty Images.

Conservation and Climate Change in the Caribbean

Freshwater fishes are a primary source of income and protein across much of Central and South America. Many fish are migratory, moving between different freshwater environments to complete their life cycle. Photo by Alvaro del Campo, The Field Museum.

Rivers of Latin America and the Caribbean: Centers of Biological and Cultural Diversity at Risk from Climate Change

by Elizabeth P. Anderson

Rivers are a defining feature of the Latin America and Caribbean region, used to mark political boundaries, move people and goods, shape cultures, supply water and food, and sustain ecosystems. But they are also under threat from climate change. Here, I explore the importance of rivers in the region and discuss what's at stake in an uncertain climate future.

By global standards, the Latin America and Caribbean region is considered water wealthy. In large part, this abundance of water can be attributed to the many rivers, and particularly the high number of globally important fluvial systems that crisscross Central and South America. For example, the Amazon Basin—the world's largest river system as measured by volume of annual water flow—drains roughly 40% of South America. The Orinoco and the Paraná-Paraguay River systems also rank as major basins, traversing northern and southeastern parts of South America, respectively. In Central America, large rivers form borders between countries; the San Juan River divides Costa Rica and Nicaragua, and the Usumacinta River demarcates Mexico and Guatemala. Thanks in part to the water contained in these river systems, renewable water resources are well above internationally accepted thresholds for water stress or water scarcity in almost all Latin American countries.

Latin America and the Caribbean is also a region of extraordinary biological diversity, much of which is linked to rivers. Parts of Central and South America harbor more species per unit area of plants, birds, amphibians and mammals than any other place on Earth. The global center of species richness in freshwater fish, for example, is the Amazon Basin. Approximately 2300 fish species have been described there, but the real number may be as high as 3000 or 4000. Nearly 100 new freshwater fish species are documented each year from the region. One of the explanations for such a high number of freshwater fish species is the abundance and diversity of rivers. Those draining Caribbean islands, Costa Rica and Panama tend to be short and steep, rushing water quickly out of mountainous areas and to coastlines. Many fish in these areas move between marine and freshwater environments to complete their life cycles. In South America, rivers draining the Andes carry sediments and nutrients from the mountainous landscape toward lowland environments. This highland-lowland connection is vital for freshwater species, many of which migrate from the lowland areas of large rivers, such as the Amazon, Orinoco and Magdalena, up into the foothills or headwater areas for feeding or spawning. An extraordinary example is the Goliath catfish (*Brachyplatystoma* spp.): In its adult stage, it moves from the mouth of the Amazon near Belém, Brazil, upstream into the Andean Amazon piedmont regions of Peru and Bolivia for spawning. This fish's journey of more than 7000 miles along river corridors represents the longest freshwater migration of any species on Earth.

The Latin America and Caribbean region is also renowned for its cultural diversity. Again, much of this diversity is closely linked to rivers. Rivers have influenced where human settlements occur, how they spread, and how they are accessed today. For example, Lima, Peru, located in the country's arid coastal region, grew from indigenous settlements along the Rimaq River. Many areas of

The Cachiyacu River drains part of the Andean Amazon region of Peru. This and other rivers of the region harbor extraordinary biological diversity and support the lives and livelihoods of riparian human populations. Photo by Alvaro del Campo, The Field Museum.

Latin America are still only or most easily accessed by river. For example, Tawaka and Miskito communities in the lowland wilderness of eastern Honduras communicate primarily via the Patuca River and its tributaries. Even some large cities, such as Iquitos, Peru, at the confluence of the Nanay and Amazon rivers, are only accessible by river or air. Rivers have shaped culture and identity for numerous indigenous groups and form an important part of the cosmovision, identity and daily life of many Amazonian inhabitants.

Beyond biological and cultural richness, rivers provide numerous ecosystem services for people throughout the region: water for domestic, agricultural and industrial purposes; hydropower for electricity generation; fiber and materials for building; and food from fish and other organisms. Freshwater fisheries are a primary source of food and income for millions of people across Latin America and the Caribbean, particularly along large river systems like the Magdalena-Cauca, Orinoco, Amazon and Paraná. In addition, rivers provide supporting ecosystem services, such as transportation corridors for movement of goods and people, and regulating ecosystem services, including waste assimilation and climate regulation. Many recreational activities, especially those related to nature-based tourism, are also tightly linked to rivers.

Increasingly, however, these traditional uses and services are under threat from climate change, with the potential to irreversibly disrupt critical connections between rivers, people and nature. Melting glaciers in the Andes, a direct impact of climatic warming, alter the flows of glacier-fed river systems, first causing increased flows and then severe reductions once the glaciers are gone. Many Andean cities—La Paz, Bolivia, or Quito, Ecuador—that depend on glacier-fed rivers for water for domestic, agricultural and industrial needs are being forced to rethink the sources of their supply. Furthermore, climate change has already been linked to an increase in extreme events, such as storms, floods and droughts. The intense 2017 hurricane season, which brought several destructive, record-breaking storms, including Irma and Maria, can be explained in part by warming ocean temperatures. In Caribbean islands like Puerto Rico, heavier rainfall increased the volume of rivers, causing floods that destroyed or damaged human settlements. The survival of aquatic organisms can also be compromised during these extreme events. Changes in rainfall patterns across parts of South America have led to flooding and mudslides that have affected human settlements and plant and animal species. For example, hundreds of people were injured, swept away or buried when heavy rains caused landslides and flooding around the city of Mocoa, Colombia, in 2017. Conversely, extreme droughts in the Amazon, such as the one that occurred in 2005, led to decreased river flows across the basin, stressed Amazonian forests, and reduced quality and availability of ecosystem services. Droughts of similar magnitude and impact in 2010 and 2015 suggest that these kinds of events, attributed to climate change, may now be part of regular climatic cycles. This could have severe consequences for the Amazon and its ability to regulate global climate.

Despite the evidence, the power of climate change to alter rivers often goes overlooked. Current conversations about river conservation and management challenges in many Latin American and Caribbean countries more frequently center on immediate threats, such as new dams, excessive water withdrawals or water pollution. While these are all important issues to address, the solutions must include the potential effects of climate change. Countries need to consider options for size, placement and operation of new hydropower dams and develop mitigation strategies for compensation of river flows downstream. The river flow data typically used for modeling generation potential and developing mitigation strategies are based on historical flow records from the past 50-100 years. In many rivers, climate change has already led to a departure from historical river flow trends as a consequence of melting glaciers or altered rainfall patterns. Therefore, both expected electricity generation—the benefit of hydropower—and the ability of mitigation plans to reduce environmental impacts—the cost of hydropower—may be inaccurate if they do not contemplate climate change scenarios. Similarly, water allocation or wastewater discharge permits for rivers rely on the availability of water according to historical trends. Because of the potential for climate change to alter river flows, existing and future permits need to include room for adjustments and revisions under new climate scenarios.

The past, present and future of Latin American and Caribbean peoples and ecosystems are intimately tied to rivers and their naturally dynamic character. Protecting them in the face of climate change presents one of the most important tasks of our generation. In closing, I offer three suggestions for this challenge. First, building on the success of protected areas as a model for conservation, policymakers should envision new kinds of protected areas or designations specific to rivers. An early pioneer of this idea is Colombia, which introduced a "protected river" designation that recognizes and protects the dynamic nature of waterways. Second, climate change assessments should increase their consideration of riverscapes and river corridors. Instead of stopping discussions of glacier melt at the glacier, its path must be followed along rivers to measure the impact on human populations and ecosystems downstream. Finally, any new plans or policies should draw upon the strengths and assets of riverside human populations to protect rivers now and into the future. Examples of local river management and conservation strategies during changing times abound, and they may hold part of the solution for protecting rivers under future climate scenarios.

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Mexican Community Forests: A Global Model for Mitigating and Adapting to Climate Change

by David Barton Bray

The 2018 report of the Intergovernmental Panel on Climate Change (IPCC) could not have been clearer. The Paris Accords of 2015 set an ambitious target for the world to stop global warming from exceeding 2.7 degrees Fahrenheit (1.5 degrees Celsius) by 2050, from a baseline of the beginning of the Industrial Revolution. According to the IPCC, however, the impacts and costs of even that goal will be much greater than expected. We are currently at just 1.8 degrees Fahrenheit (1.0 degrees Celsius) of global warming, and even at that the past decade has brought a deeply disturbing series of mega-storms, mega-fires, mega-droughts and mega-floods around the world. All of this will only get much worse at 2.7 degrees Fahrenheit of warming, and far worse at the 3.6 degrees Fahrenheit (2 degrees Celsius) that is the Paris Accords' fallback goal.

The carbon emissions that are driving global warming come from both the burning of fossil fuels and deforestation. The world's forests serve as massive carbon reservoirs, and their conservation and restoration is a key strategy for cooling the planet. As the University of Virginia's Deborah Lawrence noted recently in *National Geographic*, "Forests provide a super-important service to humanity by currently removing about 25 percent of our CO_2."

The forests of Latin America and the Caribbean have a key role to play in both mitigating climate change and adapting to it. The region's largest source of greenhouse gas emissions, the United Nations Food and Agriculture Organization (FAO) has noted, is deforestation. Yet despite the rapid rate at which forests are being converted to other land uses, mostly agriculture and livestock, the region still leads the world in conserved forests and biodiversity. South America is home to the Amazon Basin, the world's largest carbon sink, and the indigenous territories of Latin America and the Caribbean store more carbon than the forests of the Democratic Republic of the Congo, the world's second largest remaining tropical forest.

Worker measuring logs harvested from community forests in Vencedores, Durango, Mexico.

Rivers, Forests and Soils

The community forests of Mexico provide one of the most promising global models for stopping deforestation and generating incomes for local communities while conserving biodiversity. Mexico is globally recognized for its advances in achieving sustainable forest management while generating local income. Some 60% of its national forests are directly owned by communities, the second highest rate of community ownership in the world. In contrast, 97% of the forests in India are owned by the government. In Mexico, communities are managing their forests for the commercial production of timber in forest management programs approved by the country's environmental secretary, making it the global leader in community forest management. In any given year, around 1,600 community forest enterprises operate in Mexico. Dozens of these are highly sophisticated, vertically integrated timber enterprises featuring sawmills and even furniture factories. They employ hundreds of workers from the surrounding villages, providing good wages, health insurance and modest pension plans, unheard of in most of rural Mexico.

Like the rest of the world, however, Mexican forests are experiencing climate change from increased precipitation, higher temperatures and extreme storm events, threatening rural livelihoods and biodiversity. Climate change models for the forests of Mexico suggest an expansion of arid ecosystems, such as tropical dry deciduous forests and Sonoran Desert scrub, that will progressively replace the conifer forests, semi-deciduous forests and cloud forests where most Mexican community enterprises operate.

Globally, these emerging climate stressors have driven widespread concern over the possibility of catastrophic shifts in forest ecosystems. In the Amazon basin, interactions between deforestation, fire and climate-driven drought are feared to be leading to a "tipping point" of rapid degradation of the Amazon forest. In Mexico, in contrast, solid evidence suggests that community forest enterprises are resilient to catastrophic tipping points and both mitigate and are adapting to climate change. Many community forest regions of Mexico are characterized by stabilizing positive feedback loops from strong community governance, supportive public policy and market incentives for collective action around timber management. This provides an important model for global forests, and one that has recently emerged onto the world stage in the context of REDD+ (Reduction of Deforestation and Degradation, plus conservation, sustainable forest management and enhancement of carbon stocks). This international framework incorporates forests into efforts to reduce carbon emissions. Negotiated under the UN Framework Convention on Climate Change (UNFCCC) beginning in 2005 and endorsed as part of the Paris Accords in 2015, REDD+ calls for industrialized countries to provide results-based financial incentives to developing countries that reduce emissions from forest loss and degradation.

For many years, climate negotiations did not include discussion of forests for a variety of political reasons, including concerns about "permanence" (carbon stored in forests can easily go up in smoke) and "leakage" (forests conserved in one place could result in others being cut down nearby). Forests finally began to emerge from the international political wilderness at the Conference of Parties (COP) negotiations in Montreal in 2005 with a proposal from Papua New Guinea and Costa Rica. At the 2007 COP in Bali, thanks to further efforts by these two countries, forests were formally included in what was called the Bali Action Plan. It mentioned financial compensation for reduced forest carbon emissions and called for the development of technological capacity to monitor deforestation. It had been hoped that the COP meeting in Copenhagen in 2009 would achieve a comprehensive climate agreement and ambitious emissions reduction targets, and that large-scale financing for forests would be part of the agreement. The collapse of the negotiations and a fig leaf of an agreement did, however, include REDD+ as a component of future negotiations and called for the establishment of national forest monitoring systems.

It was in this context that Mexican forests officially entered the realm of the international politics on climate change in 2010 with the COP 16 meetings in Cancún. In late 2010, the Mexican government laid the groundwork for a national program in the document *Mexico's Vision on REDD+ and the National REDD+ Strategy*, which declared "sustainable rural development" as the central animating REDD+ strategy. The Cancún meetings highlighted Mexico's community forest program, particularly its payment for hydrological services. The carbon generated by travel to the conference was offset by purchasing forest carbon credits from the Oaxaca-based NGO *Servicios Ambientales de Oaxaca*. With funds from the World Bank's Forest and Climate Change (FCC) initiative and Forest Investment Program (FIP), Mexico established the goal of administering its forests sustainably, creating social capital around their protection and sustainable use, and generating additional income from forest products and services, including REDD+.

This policy focus was based on the fact that Mexican community forests already were well known as a model of sustainable rural development. Indeed, current outcomes in many, but not all, regions of Mexico could be termed post-REDD+ landscapes, models of what areas elsewhere in the world will look like if REDD+ strategies to reduce deforestation and achieve the co-benefits of sustainable livelihoods and biodiversity succeed.

A number of studies have found that community forests can make substantial contributions to carbon capture, offsetting emissions created by burning fossil fuels. As early as the mid-1990s, conservative estimates placed the total economic value of Mexico's forests at around US$4 billion, with nearly 95% of the value coming from carbon storage. Other research projected a policy scenario where the forests of Mexico could become a carbon sink by 2025, and this has actually happened in the temperate forests, where deforestation is now virtually non-existent. More recently, a 2018 study of carbon storage in above- and belowground dry woody mass and soil organic matter in 64 countries in all four major biomes (tropical, subtropical, temperate and boreal) found that Mexico ranked fifth in carbon storage globally. Mexico also has some of the best-documented projects in the voluntary carbon market, including a community in the Sierra Sur of Oaxaca that has an agreement to offset the carbon of Palo Alto, California.

Beyond Mexico, it has been calculated that natural climate solutions such as improved forest management can provide 37% of the cost-effective CO_2 mitigation needed by 2030 to have a >66% chance of holding global warming below 2°C. Managing forests for the sustainable production of timber actually gives them an enhanced value for carbon storage. Logging of forests creates a cyclical pattern of carbon release and capture, with intensively managed stands storing less carbon than unmanaged forests, although this also depends on the extent of the forest under study.

However, the amount of carbon released and captured and the time period over which it occurs can vary greatly between and within different silvicultural treatments. The final destination of harvested trees needs to be taken into account, as well. "Fast-pool" carbon biomass includes smaller roots, bark, foliage and branches that decompose quickly, and tree products that are converted into short-lived paper products. "Slow-pool" carbon biomass includes stumps or larger pieces of the trunk that may be left behind, and timber that goes into long-term storage in furniture and buildings. In the Mexican case, most of the harvest goes into the slow pool in long-lived forest products.

Delaying annual timber harvests to increase carbon storage is a common practice among Mexican community forest enterprises. A study in Oaxaca and Chihuahua documented that these enterprises often fail to meet their complete authorized volume for a logging year due to such factors as permits that are late to arrive, rain, planning problems or conservation-oriented decisions. When this happens, government regulations prohibit the unlogged volume from carrying over to the next logging year, lengthening the harvest cycle.

As of the late 2010s, climate change does not appear to have had any clearly discernible impacts on Mexican forests, but serious ones are projected. Climate change models show that the current geographic distribution of pines could decline anywhere from 0.2-64% depending on the species, with major reductions for some important commercial species. Models also predict a rise in temperatures and reduced precipitation, which would drive vegetation towards higher elevations and likely affect the growth of pines by 2030. Species at especially low elevations, such as *Pinus oocarpa*, or higher ones, such as *Pinus harwegii,* are particularly vulnerable. The altitudinal requirements for *Pinus oocarpa*, important for resin, could be as much as 300 meters higher in 2030 than they are currently.

Beyond the specific adaptations that can be pursued by Mexican community forests, the entire model can be considered a pre-adaptation to the impacts of climate change. The political, economic, social and ecological features of these forests make them resilient to climate change, and their support seems firmly entrenched in Mexican forest policy for the foreseeable future. Recessions may drive down the sale of timber, but demand for this product will always remain high, maintaining incentives for collective action. Many forest communities have such high forest cover that they could easily increase food production if necessary without harming commercial timber harvest. Around the world, community collective action is posited as a frontline adaptation to modifying the rate and direction of ecosystem response to climate change. The Mexican model, therefore, can provide important lessons for other forest-rich developing countries working to increase their resilience to this challenge.

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Santos Ernesto Casco, 54, a small farmer from the San Antonio community of Madriz, Nicaragua, has implemented various techniques of conservation agriculture including the use of stubble as organic soil-cover to conserve water and add organic matter. OSCAR LEIVA/Programa de Agricultura, Suelo y Agua en Mesoamérica.

A New Opportunity for Slowing Climate Change: Soil Management in Agriculture in the Americas

by Deborah Barry

The thrust of combined global efforts to address climate change appears to be focused more on adapting to its impacts rather than forging collective commitments for its mitigation by decreasing net greenhouse emissions. Recently, however, breakthroughs in both the science and global politics of the management of soil carbon have offered a new window for tackling emissions while ensuring the world's needed food production.

In the Americas, we have an opportunity to implement these management policies soon, and at a scale that is relevant globally. Until recently, soil scientists taught us that soil was formed slowly over time, honed from parent materials by weathering. But over the last several decades, scientists and farmers have discovered that we don't have to wait a hundred years for new soils to form, or at least to become "reactivated" as a living organism that can provide the sustenance we need for growing food and fiber. This could move the needle much faster on decreasing greenhouse gas emissions that are accelerating climate change.

The predominant disciplinary bases for the assumption that soil creation was a slow process were geology, pedology, physics and chemistry. In the late 1960s, concern over global hunger led to what is known as the Green Revolution, giving a major impetus to recommendations for agricultural production based on these purely physical assumptions. Soil structure

Approaches to Soil Knowledge and Management

TRADITIONAL APPROACH	NEW APPROACH
Soil fertility	Soil health
Physical restoration of soil	Biological restoration of soil
Soil forms from below to above	Soil forms from above to below
Reduce erosion	Increase soil porosity
Reduce runoff	Increase water infiltration
Soil and water conservation	Water and soil conservation
Physical works to control runoff	Vegetative cover
Monocrops	Crop rotation or multi-cropping

Source: José R. Benites Jump, Food and Agricultural Organization (FAO) of the United Nations.

as seen as a given, immutable. When soil needed enriching, scientists prescribed chemical inputs to bring its fertility to the level needed for new, improved seeds. Together, the thinking went, these efforts would increase productivity and production, enough to feed the world. For more than 50 years, these predominant prescriptions for managing soils emanated from the world's most important scientific research centers. They fostered global investments —both public and private—to roll out this approach in both large- and small-scale production units across the globe. The results in yields over the medium term were significant.

With time, however, two important trends emerged. One was the recognition that the tradeoffs for gaining increased productivity were soil degradation and loss. Decades of high tillage, mono-cropping and chemical inputs were leading to a decrease in yields and eventual soil "death" in many places. In the 1990s, biology entered the realm of soil science, bringing a radical new interpretation. The result was the recognition that soils house some of the liveliest ecosystems on Earth. The existence of *billions* of bacteria, nematodes, fungi and other microorganisms in the soil could actually transform its physical and chemical conditions. The role of organic material—often removed from the soil surface under the Green Revolution agricultural paradigm—is now seen as vital to keeping soils "alive" and for reactivating productive capacity. This shift in understanding and managing soils is synthesized in the chart above.

Today, we know that when soil organic material is generated through improved agricultural and livestock management practices, productivity increases without destroying the soil over time. This process captures and stores more CO_2 from the atmosphere. The most effective practices include minimal or no tillage, the use of mulch or cover crops (according to rainfall regimes), and crop rotation. Together, these practices are known as conservation agriculture. Also crucial is adding crop residues such as mulch, straw or compost to the soil, and keeping it covered year round. The introduction of agroforestry crop systems, such as coffee, cacao and/or fruit trees, is ideal. The solution will vary according to soil types and climate, as well as the needs of farmers. Local experimentation is crucial for success. In this system, there is no "one size fits all" recipe.

For farmers and ranchers facing the two principal impacts of climate change—drought and flooding—this is very good news. The adoption of proper management practices translates into increased soil fertility and plant nutrition. It also enhances the soil's capacity to store more water, keeping plants alive longer during drought, and provides constant soil cover to protect from erosion during heavy rains. These same practices simultaneously lower CO_2 emissions and increase its storage in the soil, turning soils into a potent tool for combating climate change.

Policy acceptance of soils in mitigating climate change

The potential of soils to mitigate greenhouse gas emissions has been overlooked until very recently, and has thus been absent from the global framework for climate negotiations. This was a major oversight, given that soils contain two to three times more CO_2 than the atmosphere. In 2015, soils were finally recognized as the "new" most important natural resource for both decreasing CO_2 emissions and storing more of them. At the 21st Climate Summit in Paris, the French Minister of Agriculture introduced soils into the global framework for greenhouse gas emissions in what he called the "4 per 1,000" program:

> ***"The idea is simple: it is to increase the amount of CO captured by the soil by four grams per kilo of soil. Hence the concept of '4 per 1,000.' If the whole planet managed to do this, the world's carbon dioxide emissions would be cancelled out in one year. This is still a long way off, but with changes to farming practices, agricultural soils could absorb up to 10% of our current CO_2 emissions by 2030."***

Juan Hurtado, 65, showing the association (crops sown or interplanted with other temporary or permanent crops) of leguminous Canavalia with coffee on his farm in Las Delicias of San Ramón in Matagalpa, Nicaragua. The roots of Canavalia replenish nitrogen in the soil and when pruned, the cuttings are used as mulch to conserve soil moisture. OSCAR LEIVA/Programa de Agricultura, Suelo y Agua en Mesoamérica.

A 4/1000 annual growth rate of the soil carbon stock intends to show that even a small increase (from agriculture, grasslands, pastures and forests) is crucial to improving soil fertility and agricultural production and achieving the objective of limiting the planet's temperature increase to 1.5°C.

The program will champion the use of agricultural soils to act as a major carbon sink while improving global food security by enhancing soil fertility and combating land degradation. It will help farmers adapt agriculture to climate change on the world's 570 million farms. The focus is on decreasing deforestation while improving agricultural practices and livestock management regimes that will now count as measurable contributions to each country's targets for climate mitigation. Proposals have emerged since the Paris accords, and a recent article in the prestigious scientific journal *Nature* laid out an 8-step process in this direction.

Opportunities in the Americas

The scale of agricultural and livestock-producing land in the Americas is relevant globally. Together, North, Central and South America have to support agricultural and particularly livestock production. This is also the part of the world where the adoption of environmentally friendly agriculture practices is occurring most rapidly. According to a recent study, the area under these alternative practices has grown significantly in South America, with Argentina, Brazil, Paraguay and Uruguay using conservation agriculture on more than 70% of their total arable cropland. Together, North and South American cropland under conservation agriculture makes up nearly 74% of the global total, with high rates of increase in adoption.

At the smallholder level, state-supported programs are urgently needed to promote change in practices. Here the challenge lies more in teaching methods and outreach or extension mechanisms, but Latin America has pre-existing experiences to draw on, such as *Campesino a Campesino*, a grassroots movement in which peasant farmers teach one another how to protect their environment while still earning a living. Technically, it requires the adaptation of soil management practices to hillsides and poorer soil conditions, and has proven successful in Central America.

Learning via research and farmer experimentation has been occurring across the Americas for decades. Literature abounds, and the scientific knowledge is considerable. A critical mass of farmers, practitioners and scientific leaders have led the way, some focusing on the more technical aspects of changing approaches to soil management. Latin America is flourishing with potentially transformative initiatives, including the agroecology movement, the Brown Revolution, Regenerative Agriculture-Carbon initiative, Savory Institute, USDA Natural Resources Conservation Services, Conservation Technology Information Center, and the FAO/LA-Conservation Agriculture Network. Other incentives from the market and policy spheres include Solidaridad, Slow Food-USA and Slow Meat, and the Agroecology Fund, to mention a few. Even with all the known hurdles to overcome, Latin America could become a global leader in showing how better soil management in agricultural and livestock can be a crucial tool in reducing emissions and enabling a more sustainable future.

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Disaster Risk Reduction and Climate Adaptation in Latin America's Informal Urban Settlements: An Ecological Approach

by Juan Pablo Sarmiento & Meenakshi Jerath

In 2015, the Peruvian Center for Disaster Studies and Prevention (PREDES) began an afforestation activity on the slopes of Independencia, one of 43 districts in Lima. The activity was conceived as part of an urban disaster risk reduction (DRR) project in informal settlements called the Neighborhood Approach, with support from the United States Agency for International Development's Office of Foreign Disaster Assistance (USAID/OFDA). The concept has evolved as an integrated, multi-sectoral analytical framework centered on the geographic confines of neighborhoods to address disaster risks in urban settings through community planning. The participatory process and framework flexibility of the Neighborhood Approach for DRR ensures adaptation to local contexts and incorporation of the priority sectors relevant to community needs.

Urban areas of developing countries face enormous challenges from uncontrolled and unplanned growth. Increasing numbers of urban residents live in slums and informal settlements, presenting governments with the challenge of providing urban services for all. The available urban demographic data show that there is still a long way to go to reduce the wide gap between slum dwellers and urban residents who live in adequate housing with access to basic services, making informal settlements a persistent issue that requires close attention.

The PREDES project in Independencia

The city of Lima, with approximately 10 million inhabitants, has experienced an alarming expansion of its urban limits toward the eroded hillsides of the city's periphery. There, approximately one million people live in precarious dwellings exposed to hazards such as rock falls, landslides and earthquakes. Half of Independencia (1456 hectares) is located on those hillsides, where a population of 100,000 lives in about 18,000 vulnerable structures.

The PREDES project aimed to strengthen the capacity of community, regional and national stakeholders in disaster risk management in the vulnerable peripheral settlements of Independencia. It was based on multiple actions, including the establishment of afforestation areas equipped with water tanks and irrigation systems. It also involved technical assistance for preparing disaster risk management plans at the municipal and community levels.

The initiative began by planting 300 native trees resistant to pests and water scarcity on the arid and rugged hills, where no vegetation grew before. The initial objective was multipurpose: to stabilize the soil against frequent rock falls and integrate native species associated with different use values, such as natural medicine and construction materials. The activity was well received by community members, who participated actively in the planting and maintenance.

Scaling the afforestation project

A few months after its inception, the pilot afforestation project took an unexpected turn. The community and PREDES staffers began to note that the growing belt of plants generated a protective area around the neighborhood, preventing the otherwise spontaneous growth of settlements up the mountain. The proliferation of settlements uphill exposes more and more people to disaster risk every year, increasing the vulnerability of the community multifold. Local authorities recognized the contribution of the

Youth volunteers from the Independencia district of Lima planting native species on the surrounding mountainside to mitigate disaster risk and improve environmental conditions, 2017. The urban neighborhood project is part of a USAID/OFDA-funded initiative spearheaded by the NGO, PREDES. Photo courtesy of PREDES.

afforestation area toward keeping this risk at bay for Independencia, triggering a proposal to not only seek legal protection for the afforestation effort but also extend it to informal settlements in the surrounding hills. PREDES rose to the occasion, developing a broad strategy involving stakeholders at national, subnational and local institutions.

The community, under the stewardship of PREDES, went on to create a 14-hectare urban forest on the steep slopes of the Independencia mountains, planting more than 3,500 native trees (molle, tara, palo verde, mimosa, tecoma, huaranguillo, and tuna) and building trails, scenic outlooks and family recreation spaces. These efforts included an innovative irrigation system necessitated by the difficult conditions of the terrain—high slopes, absence of water and thin topsoil. Gray water from the community was treated locally and pumped to higher altitude tanks to operate a gravity-based irrigation system, supplemented by the use of hydrogel, a colloid to retain water close to plant roots. These measures sought to ensure high rates of seedling survival and growth in the harsh environment. By 2016, mayoral decree No. 005-2016-MDI had designated the urban forest as the Sustainable Ecotourism Forest Park "Boca de Sapo," an urban control measure for disaster risk prevention and climate change adaptation and mitigation.

Based on the Boca de Sapo experience, the municipality of Independencia's Office of Environmental Management is planning to create seven other forest parks, benefiting 86 precarious and crowded settlements. The National Superintendence of State Property, the Province of Lima and district governments are working on the necessary legal arrangements.

Greener, happier cities

Unplanned and uncontrolled growth in the developing urban world has exposed a burgeoning number of people living in slums and precarious conditions to a variety of socio-natural hazards. The PREDES afforestation project in Independencia demonstrates the importance of community participation and an enterprising flexibility in the design and implementation of DRR interventions adapted to local contexts and needs. The initial purpose, to stabilize the soil against frequent rock falls, grew to become an effective measure to control urban sprawl and enrich urban ecology, leading to the development of conservation measures such as the ecotourism park. Besides reducing the clear and present disaster risk, the urban forest, full of native species with different use values, has the potential to provide a wide array of ecological services, including carbon sequestration and storage. These in turn contribute to climate change mitigation, air pollution removal and storm water runoff reduction. In reporting about this project, the Food and Agriculture Organization of the United Nations (FAO) referred to urban forests as having "… the power to transform cities into greener, healthier and happier places in which to live."

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