FastTrack publication

Bull Mar Sci. 94(2):149–169. 2018
https://doi.org/10.5343/bms.2017.1164

introduction

The ecology and conservation of Cuba's coastal and marine ecosystems

Joe Roman

Gund Institute for Environment and Rubenstein School of Environment and Natural Resources, University of Vermont, Burlington, Vermont 05405. Email: <romanjoe@gmail.com>.

Marine Ecology and Conservation in Cuba

Guest Editors:
Joe Roman, Patricia González-Díaz
Section Editor:
Joseph E Serafy

Date Submitted: 3 November, 2017.
Date Accepted: 1 March, 2018.
Available Online: 29 March, 2018.

ABSTRACT.—Cuba has some of the most well-protected coastal ecosystems in the Caribbean Sea, with strong marine policies and legislation, including a system of marine protected areas intended to cover 25% of its insular shelf. The crown jewel of the system, Jardines de la Reina National Park, has near pristine levels of apex predators and well-preserved coral reefs. Yet overfishing, illegal fishing, land-based pollution, and global changes, including increased bleaching events and more intense hurricanes, are widespread stressors and major threats to marine ecosystems. Limited resources have hindered Cuba's ability to address these threats. Despite having numerous shared species and resources with the United States, the political division between the two governments has resulted in limited transfer of scientific information. At the end of 2014, the Obama and Castro administrations announced that they would begin improving relations after an approximately 50-yr gap that followed the US embargo of 1962, presenting an opportunity for more scientific exchange and collaboration in environmental management. This special issue of the *Bulletin of Marine Science* celebrates Cuban marine science and conservation efforts, while recognizing that improved relations and increased tourism and trade could put some natural areas at risk. Joint research shows promise that Cuba, the US, and other countries can work together on regional conservation efforts.

The science of two nations may be at peace while their politics are at war.
Joseph Banks, 1796

Luces Largas

In 2014, I had the good fortune to teach a class in Cuba with Patricia González-Díaz, one of Cuba's leading coral biologists. It was still a heavy lift for Americans to work in Cuba. University officials were concerned about bringing students to a country that was sanctioned by the US government. All transactions had to be done in cash (mostly still true), and there were no commercial flights between the US and Cuba (no longer true). But there were benefits to being early adopters. We were working fertile ground that had gone fallow for too long. Although a few organizations were active in marine conservation in Cuba, such as the Environmental Defense Fund, the Cuba Marine Conservation Program at the Ocean Foundation, and Ocean Doctor, we felt like trailblazers, joining forces with some of the country's leading researchers and policymakers, such as Jorge Angulo Valdés (University of Havana) and Fabián Pina-Amargós (Sucursal Marlin Jardines de la Reina).

One day, after I was caught in a torrential rainstorm in Havana, Patricia offered to drive me across town to my hotel in her 1980s Russian Lada. The roads leading up to Rio Almendares were flooded, and many drivers opted to retreat to higher ground. I told Patricia I could wait until the water subsided. Characteristically, she told me *"De los cobardes, no se ha escrito nada"* (nobody writes about cowards). She crossed the river and drove me home. González-Díaz, who now leads the Centro de Investigáciones Marinas (Center for Marine Research) at the University of Havana, has been fearless in her dedication to US-Cuba collaboration, driving policy with her *luces largas*, or high beams. (In Cuba, where old American and Soviet cars are still commonplace, one could be forgiven for using an automotive metaphor.)

With our first class of graduate students from the University of Vermont, Duke University, and University of Havana, we traveled to the Bahía de Cochinos, or Bay of Pigs, the site of a failed US-backed military invasion after the Cuban Revolution. Along the way, we passed retired *ingenios*, sugar mills—the brick stacks long gone cold—and billboards marking Castro's headquarters during the invasion, and the last steps of the insurgents before they were captured, killed, or reversed course. On the bus, Patricia told me that the first chapter of her dissertation had been rejected from the *Bulletin of Marine Science* without review. I was shocked to learn that Cubans had not been able to publish in the *Bulletin,* a leading publication on Caribbean marine science, and other US journals, for decades—but was not sure what I could do about it. This special issue provides the answer.

Cuba and the United States have had a complex relationship, dating back at least to the 1890s. The US allied with Cuba (or intervened) in its war for independence against Spain. The US military then ruled Cuba between 1898 and 1902, when the country was granted formal independence. In 1961, soon after Fidel Castro became prime minister of Cuba, the US broke off diplomatic relations with Havana, increased sanctions, and established a trade embargo in 1962 that is still in place. The tensions between the two countries remained heightened during the Cold War and have continued after the collapse of the Soviet Union. The embargo and restrictions on travel have shaped the scientific relationship between the two countries since the 1960s.

The United States and Cuba have a long, rich history of conducting joint research—collaboration that slowed, but did not end, during the Cold War and following decades. After a 25-yr hiatus, the American Museum of Natural History, for example, conducted an ornithology expedition in Cuba to search for the ivory billed woodpecker in 1985, followed by numerous expeditions and research papers, including one in this issue on Cuban crocodiles (Milián-García et al. 2018). The productive collaboration between Rodolfo Claro (Instituto de Oceanología in Cuba) and Kenyon Lindeman (Florida Institute of Technology) resulted in definitive publications that helped inform management and the platting of marine parks (Claro et al. 2001, Claro and Lindeman 2003, Paris et al. 2005).

In a letter to President-elect Barack Obama in December 2008, scientists and conservationists called upon the new administration to remove impediments to scientific exchange and expand environmental cooperation with Cuba. "Greater communication and collaboration among scientists and conservation professionals in the two countries will benefit both the American and Cuban people, and the shared ecosystems to which both nations are so intimately linked," they wrote (F Krupp, Environmental Defense Fund, pers comm). In his first term, President Obama made changes in visa and licensing policies that increased collaborations between Cuban and US nongovernmental organizations and researchers, resource managers, and conservation organizations. These included a partnership between the Environmental Defense Fund (EDF) and the Cuban Center for Marine Research on the status of migratory shark populations in the Gulf of Mexico, joint research between Sea to Shore Alliance and the University of Havana on endangered manatees, work by the Wildlife Conservation Society and Cuban park officials on wetlands and endangered species, and efforts by the Ocean Foundation and Cuban experts to study and protect endangered sea turtles. Following the Deepwater Horizon oil spill in 2010, the White House also authorized unprecedented discussions between the US Coast Guard and Cuban counterparts to prevent and respond to oil spills in the Gulf of Mexico (Peterson et al. 2012). These early dialogues and collaborations would be critical to improving relations between the two countries during the Obama administration.

Collaboration picked up after the US and Cuba began the process of reestablishing diplomatic relations in December 2014. In October 2015, the Cuban government adopted its first National Plan of Action for Sharks and Rays, with the help of US scientists and conservationists (https://www.edf.org/sites/default/files/content/npoa-english.pdf). The following month, the US and Cuba signed a memorandum of understanding (MOU) to establish sister marine sanctuaries, including the Florida Keys National Marine Sanctuary and Guanahacabibes National Park on the west coast of Cuba, the first MOU between the two governments since diplomatic relations were restored (https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/about/us-cuba-mou-english.pdf). The two countries also released a joint statement to facilitate the exchange of scientific information and increase cooperation to protect marine and coastal ecosystems, reduce disaster risk, and prevent oil spills (US State Department, Republic of Cuba 2015). In January 2017, just a week before Obama left office, the two countries signed a Twinning Agreement, pairing the Ciénaga de Zapata National Park, adjacent to the Bay of Pigs, with the Everglades National Park in the US and agreeing to better manage both parks, which share similar ecosystems (Ministry of Foreign Affairs of Cuba 2017).

After she was rejected from the *Bulletin,* Patricia told me that she was depressed, but her academic advisor convinced her to resubmit. The work would eventually appear in *Revista de Biología Tropical*, published in Costa Rica (González Díaz et al. 2010). I considered writing an op-ed criticizing the US Sanctions Program and journals that had rejected Cuban scientists. But Daniel Whittle, senior attorney and head of the Cuba program at the Environmental Defense Fund, convinced me that a soft approach, contacting the *Bulletin* directly, might be more effective. Cubans, after all, had been publishing in other US journals for years: some publishers used the presence of international offices, where US laws did not apply, to insulate themselves from the embargo. Others, such as Columbia University, Harvard University, and the University of Pittsburgh presses—the last of which publishes the multidisciplinary journal *Cuban Studies*—published peer-reviewed articles by Cubans and not through any foreign subsidiary.

Whittle and colleagues (including myself) did a close read of the guidance from the Department of Treasury's Office of Foreign Assets Control (OFAC), uncovering an exemption to the ban for Cuban authors in academic and research institutions, which was later clarified in a letter to Elsevier (Seeley 2015). As long as an author or collaborator is not acting on behalf of the Cuban government, editorial transactions are generally licensed under OFAC 31 C.F.R. 515.577, including "collaborating on the creation and enhancement of written publications" and "substantive editing of written publications" (OFAC 2011). The rule noted that academic and research institutions and their personnel were not to be included in the definition of "government of Cuba." Authors from the University of Havana and other Cuban institutions could publish in US journals, and these journals could peer review and edit manuscripts from Cuban authors. (Some restrictions remain on scientists from nations sanctioned under OFAC. These regulations on peer-reviewed science should be overturned as well.)

We wrote the *Bulletin* alerting them of this policy in late 2015, and then sent a follow-up message in January 2016. I soon received an email from the editor, Joe Serafy, that got me up out of my seat. Serafy told me that he had forwarded our email to the University of Miami's general counsel. After review of the OFAC policy and new guidance letter, the University of Miami general counsel gave clearance for the *Bulletin* to review, edit, and publish manuscripts from Cuba. "Many thanks for bringing all of this to our attention," Serafy concluded.

And it all could have ended there, except when I mentioned the news to Taylor Ricketts, director of the Gund Institute for Environment at University of Vermont, he asked, "Why don't you celebrate the change and suggest a special issue?" Cuba, after all, was at a crossroads. The improved relations that helped foster scientific cooperation were also expected to increase tourism, foreign direct investments, and development pressures, with potentially large impacts on coastal and marine ecosystems. Cuba could follow the pathway of many Caribbean nations, with widespread development along the coast, or continue on a more sustainable path, protecting its wildlife and natural resources, and embracing ecotourism as its ethos and brand, much as Costa Rica has done. A special issue focused on marine ecology and conservation could help inform these decisions.

The editors, when approached, wholeheartedly agreed. "We are very excited about the prospect of an issue devoted to Cuba, given our pre-embargo history," wrote Serafy. "In fact, a faculty member from the University of Havana, Luis Howell Rivero, was on our first editorial board in 1951." We asked Patricia González-Díaz, who had become director of the Center for Marine Research at the University of Havana, to serve as a guest editor and help solicit manuscripts from scientists in Cuba. This issue is the result of our collaboration.

Introduction to the Special Issue

Cuba is considered by many to be the ecological crown jewel of the Caribbean Sea (Whittle and Rey Santos 2006). But what is the state of the country's marine ecosystems? How have Cuban policies supported or thwarted its status? What are the

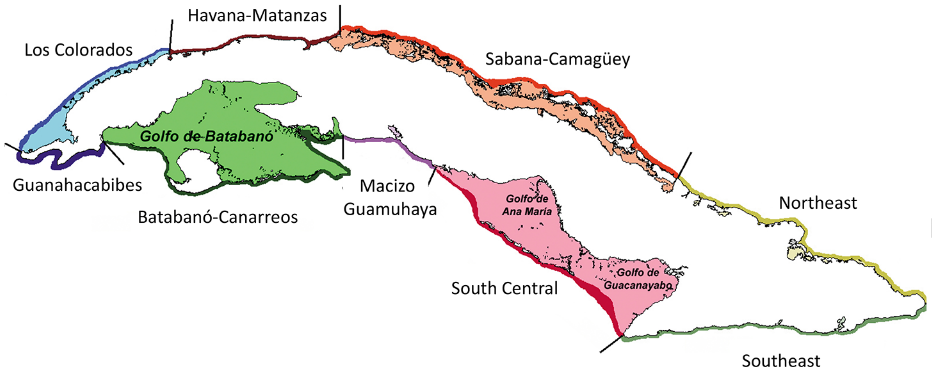

Figure 1. The nine coastal zones of Cuba, established during a workshop in 2001 (adapted from Areces 2002).

likely consequences of changing relations between the US and Cuba to coastal and marine systems? We realized that there was a need to address these questions, and the clarification of policy created an ideal platform and opportunity to do so in the *Bulletin of Marine Science*. The 17 studies gathered here reflect the work of some of Cuba's preeminent and emerging scientists and managers, along with the research of international scientists and policy makers working in the Caribbean nation. To our knowledge, it is the most extensive collection of Cuban marine science and conservation in a single English-language issue.

Cuba's Coastal and Marine Ecosystems.—Cuba is the largest archipelago in the Caribbean Sea, comprised of about 4000 islands and cays, with the highest marine biodiversity in the region (Miloslavich et al. 2010). The country's nine ecoregions, or ecozones, are shown in Figure 1. The country's primary coastal marine ecosystems include coral reefs, hard nonreef bottoms, sandy and muddy bottom habitats, seagrass beds, mangroves, coastal lagoons and estuaries, and beaches. The first group of papers relates to terrestrial and marine connections, including mangroves, coral reefs, seagrass beds, and mud bottoms (Galford et al. 2018, González-Díaz et al. 2018, Martínez-Daranas and Suárez 2018, Armenteros et al. 2018). These ecosystems support unique species assemblages and provide connectivity for many marine organisms in the Caribbean Sea and Gulf of Mexico.

Coral reefs surround >95% of Cuba's insular shelf, extending approximately 3966 km (Wilkinson 2008a). Although these reefs are often admired for their pristine state and abundance of apex predators, González-Díaz et al. (2018) show that there is considerable variability across the country. Part of this is likely the result of the natural abiotic and biotic differences between Cuba's northern and southern coasts, as reflected in the population structure observed for several marine species in the country (García-Machado et al. 2018), but there are also regional differences in human population size and activities. Cuba's most renowned reefs—such as Jardines de la Reina off the south-central coast—are among the most pristine in the Caribbean region, largely due to strong enforcement and distance from major cities (Pina-Amargós et al. 2014, *see* fig. 3 in Perera Valderrama et al. 2018). Areas exposed to intensive fishing and pollution, such as those along the northwest coast, exhibit reduced coral density and diversity (Duran et al. 2018).

In the 1990s, many reefs close to Havana had low coral cover of <10%, but others, more distant from the capital, were relatively healthy, with around 30% cover. Recent surveys show a drastic decline of coral cover in all sites, putting them near the Caribbean-wide average. Of particular concern is the loss of reef-building species, such as *Orbicella annularis* (Ellis and Solander, 1786) and *Montastraea cavernosa* (Linnaeus, 1767), though a few more resilient species, such as *Siderastrea siderea* (Ellis and Solander, 1768), persist in many areas (González-Díaz et al. 2018). The causes for this decrease are uncertain, but there may be local and global stressors at work. Large individuals of midnight parrotfish, *Scarus coelestinus* Valenciennes, 1840, and rainbow parrotfish, *Scarus guacamaia* Cuvier, 1829, important grazers of macoralgae, were present in northwest Cuba up until the 1970s (Aguilar and Gonzalez-Sanson 2007), but they have been targeted by fishers around Havana in recent decades. Their current scarcity has put the region at risk of remaining in a coral-depleted alternative stable state (Steneck et al. 2014).

Of perhaps greater concern, the changes could be a sign that local protection of coral reefs can be overwhelmed by global stresses, such as increased temperatures, bleaching events, greater intensity of hurricanes, and invasive species. Although reefs with few anthropogenic impacts tend to show signs of recovery in 3–5 yrs after a hurricane (Great Barrier Reef Marine Park Authority 2011), the rise of extremely intense hurricanes coupled with increased human impacts, could result in more shifts from coral- to algal-dominated communities (Hughes et al. 2010). Widespread changes have been observed at Isla de la Juventud (J Roman, pers obs) and the Guantánamo Naval Base, which has shown increases of disease and a decline in biodiversity (Cooke and Marx 2015). According to Risk et al. (2014), the changes at the US naval station stem from upstream land-based sources of pollution under Cuban jurisdiction, making management of the reef systems a challenge. Coral reef decline is especially worrisome given the high biological diversity of these systems and their role in providing ecosystem services, such as protecting coastlines and communities. It also serves as a warning to the nation as it considers increased coastal development.

Mangroves cover about 450,000 ha, or 5% of Cuba, and represent 11% of the forested area. In Cuba, there are four species: red mangrove, *Rhizophora mangle* L.; black mangrove, *Avicennia germinans* (L.) L.; white mangrove, *Laguncularia racemosa* (L.) C.F. Gaertn.; and button mangrove, *Conocarpus erectus* L. They occupy 77% of their potential ecozone, which suggests a high degree of preservation, whether because of strict protection or their remote or challenging nature (Galford et al. 2018). In a Caribbean-wide study conducted by Serafy et al. (2015), only Cuba and Puerto Rico showed increases in mangrove forest between 1993 and 2012; during the same period, Barbados lost 87% of its mangroves. Preserving this ecosystem is a matter of Cuban pride and perhaps military history: the vast and dense mangroves around the Bay of Pigs are widely regarded as having constrained the progress of insurgents during the US-backed invasion of the island (Galford et al. 2018). Nowadays, Cuban mangroves are more likely to be recognized for their role in trapping terrestrial sediments, protecting coastal communities from intense waves, and storing carbon.

Approximately half of the Cuban shelf is occupied by seagrass meadows, covering >23,000 km^2 (Martínez-Daranas and Suárez 2018). The dominant species are turtle grass, *Thalassia testudinum* K.D. Koenig, manatee grass, *Syringodium filiforme* Kütz., and shoal grass, *Halodule wrightii* Asch. These vast areas are so productive that they could sequester about 33% of the carbon emitted by Cuba (Martínez-Daranas 2010).

Despite their size, seagrass meadows are under threat from eutrophication and erosion, which can result in low water transparency (Martínez-Daranas and Suárez 2018). Mangroves and seagrasses serve as important nursery areas for juveniles of many species of coral reef fishes (Mumby et al. 2004, Serafy et al. 2015). Mudflats are often overlooked in discussions of key coastal ecosystems, yet in Cuba, healthy silt and mud areas are highly productive and considered important for shrimp, mollusks, and fisheries (Armenteros et al. 2018). They represent important areas for the decomposition and export of organic matter to other marine ecosystems (Claro 2006).

Less well studied groups are the macrobenthic polychaetes, nematodes, crustaceans, and mollusks that inhabit mudflats. These organisms play important roles in soft sediments, including bioturbation, with its significant positive influence on biological diversity, energy and matter transfer to higher trophic levels, and oxidation of organic matter (e.g., Thrush et al. 2006). Armenteros et al. (2018) examined infaunal communities in the Cuban gulfs of Ana Maria, Batabano, and Guanahacabibes. They found that seagrass beds had the highest species diversity. Infaunal mollusks dominated the muddy bottoms of these areas, with carnivorous molluscs abundant in mangroves. The considerable variation in species assemblages among the bays indicates that there may be limited connectivity between them.

These coastal and marine areas do not exist in isolation. Rather, they are directly affected by and inextricably linked to activities conducted on land (Galford et al. 2018). Forty-five percent of Cuba's land is devoted to agriculture, including pasturage and crop production. Much of this area (78%) falls within the dry forest ecoregion, with vast expanses of agriculture surrounding the island's many watersheds. Current landscape configurations allow agricultural runoff into wetlands and mangroves; coupled with reduced freshwater flow resulting from the extensive number of dams in Cuba, these changes have increased the negative effects of runoff and reduced the ability of these ecosystems to retain sediments and filter nutrients (Galford et al. 2018). If Cuba switches from relatively low-impact, low-intensity agriculture—in place since the collapse of the Soviet Union—to industrial agriculture, it could further imperil an already fragile coastal system. Agricultural intensification can have widespread negative effects on biodiversity, as it did on Europe's farmland birds (Donald et al. 2001) and marine fishes and shellfish populations in the Gulf of Mexico as a result of hypoxia (Rabalais et al. 2002). It should be approached with caution in Cuba, with careful consideration of the tradeoffs between high-yielding agriculture and maintaining the diversity that sets Cuba apart from other Caribbean nations.

Not surprisingly, sampling efforts in Cuba have been greatest in shallow, nearshore waters, where there are good species records, whereas offshore and deep environments are not as well studied (Miloslavich et al. 2010). One exception in this issue is an examination of the pico- and nanoplankton (<20 μm) of Cuba's deep oceanic waters. Lugioyo Gallardo and Loza Álvarez (2018) found that the biomass per cubic meter of heterotrophic nanoplankton and microzooplanton was much higher than that of the autotrophs they fed on. This inverted trophic pyramid indicates that small heterotrophic organisms play an important role in nutrient cycling off Cuba.

As with several other systems examined in this issue, there is considerable spatial variability in the bacterioplankton in Cuban waters. In their review of the population connectivity of marine organisms, which included shrimps, fishes, turtles, and dolphins, García-Machado et al. (2018) show that there are three general patterns of population structure across the Cuban coast: a north-south break, an east-west split in the south, and local genetic differentiation. Shaped by the geography of the island, current patterns, larval recruitment, and foraging behavior, these genetic partitions can help guide the management of particular species and the design of marine protected areas.

Cuba's Threatened Marine Species.—Despite Cuba's good fortune in having a diverse array of terrestrial and marine species, many of the nation's coastal ecosystems are at risk. Cuban marine biodiversity is seriously threatened by human activities, including pollution from land-based sources, reduction of freshwater flow and watershed deforestation, clearing of mangroves, unsustainable fishing, invasive species, poaching of endangered species, unsustainable coastal and marine tourism, pollution from marine-based sources, and climate change (Gerhartz-Muro et al. 2018).

Many individual species are also at risk. Cuba's unregulated and unsustainable fishing of marine turtles ended in 1995, with an exemption for two communities that relied on the turtles for subsistence. Attempts to maintain a sustainable harvest failed, and all turtle fisheries closed in 2008. Unfortunately, illegal harvests in nesting areas continue, with uneven management and enforcement in protected areas (Azanza-Ricardo et al. 2018). Isla de la Juventud appears to be especially vulnerable to illegal harvest, with 142 known captures of sea turtles in five seasons. Climate change might also be affecting these marine reptiles. Loggerhead turtles, *Caretta caretta* (Linnaeus, 1758), are highly sensitive to temperature variation; warmer sea-surface temperatures can result in shorter nesting seasons (Pike et al. 2006). During an 18-yr study of loggerhead turtles on Guanahacabibes Peninsula, Azanza-Ricardo et al. (2017) found a reduction in clutch size, incubation period, and hatchling size; the high incubation temperatures recorded in monitored nests and shorter incubation periods indicate a potential feminization of hatchling production.

Álvarez Alemán et al. (2018) show that human activities have slowed the recovery of the Antillean manatee, *Trichechus manatus manatus* Linnaeus, 1758, in Cuba, despite the existence of some exemplary habitat and laws to protect the species. Poaching and entanglements are two of the most common causes of mortality. An exception is the area around the Zapata Peninsula, which remains one of the most important areas for manatees in Cuba. It could be an important source population for the rest of the country in the future.

One of the most charismatic and rare species in the mangroves is the critically endangered Cuban crocodile, *Crocodylus rhombifer* Cuvier, 1807. Endemic to Cuba, the species is absent from most of its historical range and is now found in two populations: 3000–5000 individuals in Zapata Swamp and a much smaller population in Lanier Swamp on the Isla de la Juventud (Targarona et al. 2008). Conservation efforts include captive breeding, reintroductions, and protected areas, though illegal hunting continues in the country. The American crocodile, *Crocodylus acutus* Cuvier, 1807, with a range that extends from Florida to Venezuela in the Atlantic Ocean, and Mexico to Ecuador in the Pacific Ocean, also exists in Cuba, where populations remain healthy. Milián-García et al. (2018) reveal that the Cuban populations of the American crocodile are distinct from the continental lineages, forming a sister-species relationship instead with the Cuban crocodile. This finding, that there could be two endemic crocodiles in Cuba, has important ecological, evolutionary, and management implications. The Cuban *C. acutus* is in need of an update in its conservation status in light of its deep divergence from the continental form.

Cuba is known for its abundant shark populations, at least in the well-protected area of Jardines de la Reina National Park. Yet relatively little is known about shark movement patterns in the region. Using pop-up satellite tags, Hueter et al. (2018) examined the movement of silky sharks, *Carcharhinus falciformis* (Müller and Henle, 1839), in the park. They found that sharks spent more time in deeper water during the day (up to 640 m, the deepest recorded dive for this species), with intermittent trips to the surface in the morning, possibly in response to bait released by shark-diving boats. Whether the conservation benefits of shark-diving tourism, especially when it relies on bait to attract sharks as in Cuba, outweigh the possible costs to behavior is debated (e.g., Fitzpatrick et al. 2011, Maljković and Côté 2011). Silky sharks are hunted for the shark-fin trade outside of Cuba, and they are an important part of the Cuban longline fishery, where they are targeted for meat (Aguilar et al. 2014). A sustainable and properly managed shark-watching industry could help improve populations in the country.

The movement of manatees, sea turtles, sharks, and teleost fish through the Caribbean Sea, Gulf of Mexico, and western Atlantic Ocean provides scientific backing for an obvious need: effective marine conservation relies on improving local efforts and building stronger international agreements among countries in the region. Cuba is party to the Convention on Biological Diversity and the Cartagena Convention, a regional legal agreement for the Caribbean Sea. These agreements are essential to the country's conservation commitments, though enforcement and funding often fall short.

Cuba's Marine Fisheries.—Coral reef fish populations are particularly prone to overfishing: more than half of 49 island countries examined in one study were shown to be exploiting reef fisheries in an unsustainable way (Newton et al. 2007). Many of Cuba's fisheries are considered fully or overexploited, suffering from the ailments of other countries in the Caribbean Sea and across the globe: overfishing, illegal fishing, and habitat degradation. Such practices have changed the structure of fish communities of Caribbean coral reefs, reducing the abundance and size of large predatory fishes. But there is hope: these systems have a high recovery potential for predatory fish biomass (Valdivia et al. 2017).

The fishing industry in Cuba is organized into 14 state enterprises operating more than 700 boats, with 385 targeting finfishes; all invertebrate fisheries and 90% of fin fisheries are state run (Puga et al. 2018). There are also more than 3600 smaller private boats that operate under a strict contract regime with the state. Finfishes comprise the majority of the catch, though total catch and effort have declined considerably since peaking in the 1980s (Claro et al. 2009, Puga et al. 2018). The state and prospects of Cuba's marine fisheries are addressed in four papers in this issue. Baisre (2018) estimates that about 74% of Cuban fisheries are overexploited, 20% are fully exploited, and 5% have collapsed. Groupers and snappers, which aggregate on a few, predictable spawning sites, are especially prone to uncontrolled fishing (Claro et al. 2009). Commercial catches of the Nassau grouper, *Epinephelus striatus* (Bloch, 1792), for example, have declined by 98% since 1963, with much of the annual catch taken from spawning aggregations (Jones et al. 2004, Baisre 2018). Lane snapper, *Lutjanus synagris* (Linnaeus, 1758), has been subject to intense fishing, with set nets and bottom trawls used during spawning migrations (methods that have been closed since 2008 and 2012, respectively); snapper populations have continued to decline despite new regulations, perhaps because of spawning-season fishing and increased salinity of inner lagoons as a result of damming (Claro et al. 2009). The observed declines of so many finfish often have dire effects on marine ecosystems. The removal of top predators and herbivores can prompt trophic cascades, with impacts on coral reef structure and function, further reducing fisheries productivity (Dulvy et al. 2004, Newton et al. 2007).

Puga et al. (2018) employed a productivity-susceptibility analysis for 34 finfish species in Cuba. Many species have similar vulnerabilities across the country's four management zones, despite their ecological and economic differences, perhaps indicating that policy and management can be conducted on a national scale. But the differences among the zones also call for more fine-scaled approaches. Catch and effort are highest in the southeast, which is dominated by abundant herrings, e.g., *Opisthonema oglinum* (Lesueur, 1818). Whether this dominance is a result of natural abundances, fishing down marine food webs (Pauly et al. 1998), or a trophic cascade after intensive exploitation of top-level predators (Szuwalski et al. 2017) deserves further study in Cuba. Catch per unit effort is lowest in the northeast, which has a relatively diverse fishing profile, with no species making up more than 10% of the harvest. The generally low catches in Cuba likely reflect overfishing and habitat degradation on the coast, including extensive damming. The species examined by Puga et al. (2018) represent just a portion of the total catch. An expanded analysis could help Cuba prioritize research, monitoring, stock assessments, and management actions that include new fisheries policies.

Protections can work in Cuba. Set nets were banned in 2008, and fish trawling has been banned throughout the Cuban shelf since 2012, with benefits to seagrasses and other benthic systems. The total predatory fish biomass in the Jardines de la Reina National Park is within the range that would be expected in the absence of human activities (Valdivia et al. 2017). This protected area had the highest level of apex-predator biomass in a five-nation study of Caribbean coral reef communities (Newman et al. 2006), and relatively low levels of fleshy algae biomass, which are among the strongest competitors of corals for space and can have indirect impacts on coral health (Knowlton 2001, Smith et al. 2006). The region around the park produces about 40% of Cuba's finfish catch, is home to highly valuable shrimp and lobster fisheries, and encompasses some of the best-preserved coral reef ecosystems in the Caribbean region, attracting international tourism (Gerhartz-Muro et al. 2018).

Support for the park and regional management did not happen overnight. At the regional scale, problems included illegal fishing in protected areas, no catch limits for fish, poor communication between communities, and low community support for marine protected areas (MPAs). Some of the success for regional management is thanks to the SOS Pesca project, a 4-yr initiative that brought together stakeholders, conservationists, and managers to improve fisheries sustainability, environmental conservation, and quality of life in the neighboring communities of Playa Florida and Guayabal (Gerhartz-Muro et al. 2018). The initiative helped win support for new MPAs and end overfishing practices, resulting in total fish biomass and trophic structure that resemble the relatively healthy reef fish populations in parts of the Pacific Ocean (Friedlander and DeMartini 2002, Newman et al. 2006).

Invertebrate fisheries in Cuba are managed according to scientific assessments, and they appear to be better regulated than those for finfish, although they are not immune to overfishing and illegal fishing. Hernandez-Betancourt et al. (2018)

examined the sea cucumber fishery in Cuba which has been under a quota system since its inception in 1999. The first 2 yrs of the fishery had heavy harvests, with more than 3 million chocolate-chip cucumbers, *Isostichopus badionotus* (Selenka, 1867), captured. As a result of these large extractions, catches and production decreased from 1153 sea cucumbers per boat per day in 1999 to 350 sea cucumbers per boat per day in 2002 (Alfonso et al. 2003). Regulations, including closures of overfished regions, a fishing ban during the peak months of reproduction, and minimum-size requirements, have helped this species recover. Although Hernandez-Betancourt et al. (2018) have found the fishery to be relatively healthy, there has been a decline in biomass of *I. badionotus* since 2003, and catch rates are above those needed to attain the maximum sustainable yield. As with many of the papers examined, reduced take is suggested, and the authors recommend significant quota reductions for this species.

Catches of Caribbean spiny lobster, *Panulirus argus* (Latreille, 1804), the most valuable fishery resource in Cuba, declined after peaking in the 1980s. Landings have leveled off since the early 2000s, following reductions in fishing effort, and a new focus on ecosystem-based fishery management actions and the adoption of an adaptive management approach. The main regulatory measures for spiny lobster include limited entry for state fleets, minimum legal size, territorial use rights for fishing (TURFs), gear restrictions, closed seasons, and permanently closed areas to protect juveniles and spawners. An assessment of the impact of tropical cyclones and coastal habitat degradation on spawning stock was critical in enacting new management actions; the total allowable catch is set annually and based on updated stock assessments that takes hurricanes and habitat degradation into account (Ehrhardt et al. 2011, Puga et al. 2013). Unfortunately, successes in reducing fishing effort are now at risk from poaching; Alzugaray et al. (2018) found that >18% of the total annual catch of spiny lobsters is from illegal, unreported, and unregulated fishing. This rise in illegal fishing likely coincides with the increase in tourism and opening of private restaurants (*paladares*) in Cuba. Alzugaray et al. (2018) assume that illegal fishing did not occur before 1996. Confiscations since 1996 indicate that nearly a fifth of all lobsters captured in Cuba is illegally caught.

Cuba has acknowledged the seriousness of illegal fishing, signing the Food and Agricultural Organization's Agreement on Port State Measures to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing in 2016, but much work remains to be done. Critical to the future of the nation's fisheries will be the promotion of sustainable and ecologically friendly practices that include strong enforcement, ecosystem-based fishery management, and the adoption of a precautionary approach.

Conservation Initiatives.—Cuba has a long history of deforestation, with direct impacts on terrestrial ecosystems and indirect effects on marine systems. During the first 300 yrs of Spanish settlement, roughly from 1500 to 1800, forests were cleared by the Spanish Royal Navy for its shipbuilding industry. During the nineteenth century, vast areas were cleared for cane fields and to fuel sugar production (Funes Manzote 2009). After centuries of deforestation, Cuba's reforestation efforts began during the Cuban revolution, with an 18% increase of forests between 1959 and 1992 (Díaz-Briquets 1996). Interior and mangrove forests appear to have stabilized in the country. With >90% of its intact forested landscape protected, Cuba was one of only two countries (the other being Nepal) to show a zero loss between the years 2000 and 2013 (Potapov et al. 2017).

Cuba passed its first environmental law in 1981, promoting environmental protection and the rational use of natural resources. But implementation lagged until after the 1992 United Nations Conference on Environment and Development, often referred to as the Rio Earth Summit, when the Cuban government began to strengthen its environmental policy. In 1994, the new Ministry of Science, Technology and the Environment (CITMA) took over the reins of environmental management in the country (Houck 2000). In charge of environmental regulations and natural areas, CITMA has identified and protected sensitive ecosystems, and several expansive protected areas have been essential to the maintenance of the country's biodiversity. Ciénaga de Zapata National Park contains the largest wetlands in Cuba, as well as coral reefs, seagrass beds, keys, mangrove forests, and an underwater canyon. Declared a UNESCO Biosphere reserve in 2001, it is home to many rare and endemic species including the Zapata Rail, *Cyanolimnas cerverai* Barbour and J. L. Peters, 1927, the Cuban crocodile, and the Cuban gar, *Atractosteus tristoechus* (Bloch and Schneider, 1801). Other important protected areas include the Sierra del Rosario (the island's first biosphere reserve established in 1985), the Guanahacabibes Peninsula National Park in the northwest, and the Alejandro de Humboldt National Park in the southeast.

Two papers in this issue examine government policy and marine protection: Gerhartz-Muro et al. (2018) evaluate the major policy instruments for marine conservation in Cuba and Perera Valderrama et al. (2018) examine marine protected areas specifically. While acknowledging that there is a much stronger policy focus on terrestrial than marine systems in Cuba, Gerhartz Muro et al. (2018) conclude that the country's marine-environmental policy framework is relatively strong, scoring high marks for operating on multiple spatial scales and establishing a sound scientific basis for management. Resource limitations, however, hinder truly effective marine conservation at a national scale and too little attention is paid to precautionary and adaptive approaches.

MPAs cover 25% of the Cuban shelf, creating a network of important habitats that include 30% of coral reefs, 24% of seagrass beds, and 35% of mangroves (Perera Valderrama et al. 2018). These areas span all nine of the nation's coastal ecoregions, from the Southwest (Costa de Sur de Oriente), to the Southeast (Península de Guanahacabibes), North Central (Archipelago Sabana Camagüey), and Northwest (Costa Norte de Oriente). These ecoregions, shown in Figure 1, were established during a 2001 workshop (Areces 2002). They have helped form many of the management decisions later made by the National Center of Protected Areas (CNAP, for the Spanish Centro Nacional de Áreas Protegidas) and the Ministry for the Fishing Industry (Areces 2002). The 2014 National System of Protected Areas, or SNAP (Sistema Nacional de Áreas Protegidas de Cuba), provides guidelines for the creation of new protected areas within the network and for the management of the 120 protected areas, including 62 MPAs, currently in place (Gerhartz-Muro et al. 2018). The conservation goals of the system include contributing to the sustainability of fisheries, protecting marine and coastal biodiversity, protecting unique marine landscapes and dive sites, educating visitors, and developing nature tourism (Areces et al. 2012).

Cuba's protected areas of national significance range from nature reserves (IUCN category 2, such as Jardines de la Reina National Park) to special regions of sustainable

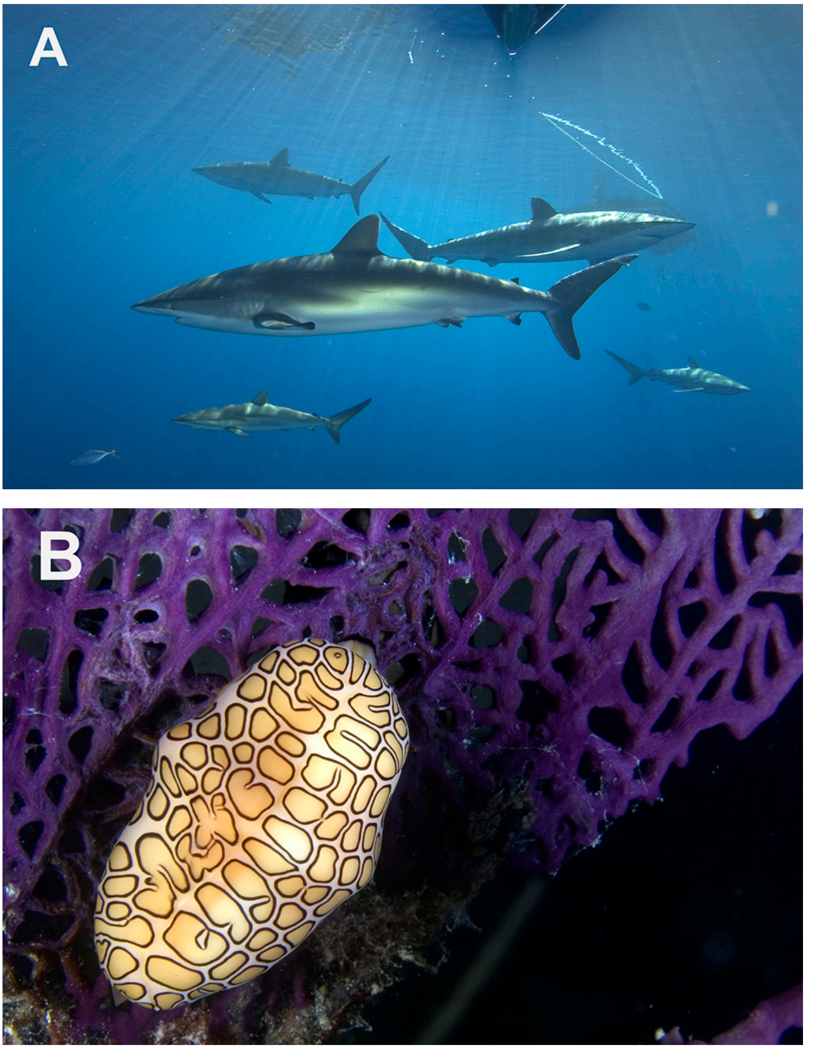

Figure 2. Jardines de la Reina National Park has high levels of (A) apex predators, such as the silky shark (*Carcharhinus falciformis*) and a diversity of (B) benthic species, such as the flamingo tongue snail (*Cyphoma gibbosum)*. Photographs reproduced with permission from N López Fernandez.

development (IUCN category 6, such as Ciénaga de Zapata Biosphere Reserve, including the largest wetland in the insular Caribbean). Jardines de la Reina is one of the premier protected areas of the Caribbean region, showing evidence of good management, restoration of highly valued fish species such as sharks, and economic benefits (Pina-Amargós et al. 2014; Fig. 2). The effective management of the park is conducted by a public-private partnership between the Italian ecotourism company, Avalon, and the Cuban agency Marlin Náuticas y Marinas, which has been essential in enforcing park restrictions. These protections help fish species and coral reefs; marine reserves have been show to alleviate the impacts of marine diseases. After severe cyclones, corals inside reserves show much lower levels of disease than those outside (Lamb et al. 2016). Coral accretion rates are also higher in protected areas, especially if parrotfish populations are maintained or restored (Cramer et al. 2017).

Other areas have not shown such success. Established in 2012, Punta Francés National Marine Park, on the Isla de la Juventud, has high algal cover and reduced fish populations. Industrial and subsistence fishing takes place along the boundaries of the reserve and even within it (Angulo-Valdés and Hatcher 2013). The surprising results from a recent master's thesis revealed greater species richness and abundance of reef fishes outside the no-take area than within the reserve, even though it is relatively remote, with no easy access except by boat (Navarro Martínez 2015). Lack of financing and staff could be reasons for this surprising finding, shortfalls that have been found to restrict the conservation performance of other MPAs (Gill et al. 2017), though source-sink dynamics could also be at play. Building capacity for MPA management in Cuba and strengthening fisheries governance through local participation will be essential in delivering on the promise of this extensive network of conserved areas.

Collaboration between Cuba and the US continues to reap rewards for both countries and the broader region. Following the Deepwater Horizon spill, opportunities for coordination between the US and Cuba increased. The Trinational Initiative for Marine Science and Conservation in the Gulf of Mexico and Western Caribbean is aimed at restoring coastal and marine resources shared by Cuba, Mexico, and the US. It is a step in the right direction, but a truly integrated strategy for managing the Gulf of Mexico and surrounding waters, with strong international projects, has yet to be achieved. The countries might look to the governing structure of the European Union for guidance (Cruz and McLaughlin 2008). Though the political hurdles can be substantial, the conservation benefits make the effort worth pursuing.

The fate of Cuba's coastal and marine systems is up to the Cubans, of course, but there is one place where US citizens have a direct say on the island: the Naval Station Guantánamo Bay. The area has been used as a military base and later a prison since it was first opened in 1903 under lease from the Cuban government. Since the revolution, the Cuban government has considered the US presence in Guantánamo illegal, refusing to cash the annual rent check of $4085 (Strauss 2009). Many in the US consider an unconditional withdrawal from the base a nonstarter (Roman and Kraska 2016). So why not transform the base, now associated with terrorism and torture (*see* e.g., Fallon 2017), into a research center and international peace park? It would be a place where researchers, policy makers, and managers in Cuba, the US, and throughout the Caribbean—many of them represented in this issue—could gather to study and address some of the greatest challenges of the twenty-first century, including biodiversity loss and climate change (Roman and Kraska 2016). A first step in returning the land to Cuba, the new Guantánamo would be a place to celebrate the hard-earned scientific diplomacy between the two nations.

The Way Forward.—The ecologist Jeremy Jackson, scientific director of the Global Coral Reef Monitoring Network, once said, "The way that Cuba goes will determine the future of the Caribbean." The comment was intended, I think, to inspire young Cuban researchers and policymakers to make the right decisions in managing their coastline in the face of imminent change. Tourism, the second largest sector of the Cuban economy, continues to grow rapidly, contributing approximately $8.9 billion to the country's gross domestic product and supporting 462,000 jobs (WTTC 2017). It is not as easy to be sanguine about the potential impacts of this growth to coastal and marine ecosystems. Natural resource agencies often fail to understand coastal tourism, and agencies in charge of tourism development are rarely involved with the evaluation of its effects on the environment (Hall 2001). Yet some argue that the centralized state in Cuba will ensure that the benefits will outweigh the problems created by tourism (Wilkinson 2008b).

In one sense, Cuba may be at an advantage: in much of the world, the interaction of human population growth and increasing need for food production tends to undermine protection of the natural world (Crist et al. 2017). Unlike most countries, Cuba's human population is expected to decline in the coming years (United Nations 2017). A stable human population, and a relatively small per-capita carbon footprint (approximately 3.0 t CO_2 yr^{-1}; World Bank 2018), could help Cubans protect their well-being while sustaining the nation's rich biodiversity.

Preserving living Cuba will take more than a stable human population. More than half of the papers (9/17) in the present issue point to illegal fishing, poaching, and illegal clearing of native habitats as a concern. The annual illegal catch of spiny lobsters, for example, represents >18% of the total harvest (Alzugaray et al. 2018). Illegal hunting of manatees persists, and poaching is a primary source of mortality in Isla de la Juventud and western Cuba (Álvarez Alemán et al. 2018). Illegal fishing of sea turtles and poaching in nesting areas is a critical conservation threat (Azanza-Ricardo et al. 2018). Essential in preserving Cuba's marine life will be continued enforcement in areas such as the Jardines de la Reina and enhanced protection efforts in reserves that show signs of damage, such as Punta Francés National Park.

Increased enforcement, funding for protection measures, and community engagement will be critical in fulfilling the country's conservation goals. Many of the island's fisheries are depleted, and its watersheds are in peril. Restoring the country's fish populations is an essential step forward, requiring enhanced management, enforcement, and science. A recent study of spawning aggregations of Cuban snappers (Lutjanidae) showed that the majority of larvae produced from snapper spawning aggregations are retained on-island, often within the region where they were spawned (Kough et al. 2016). Understanding larval connectivity for snappers and other fishes should help inform the placement of spawning reserves. Artisanal fishing also needs attention, as shown by the low biomass on the reefs of northern Cuba. Restoring the nation's parrotfish populations will be necessary to enable coral recovery and persistence (Cramer et al. 2017). New laws to protect these fish are expected to go into effect in Cuba in late 2018.

Cuba embraced integrated coastal zone management (ICZM) after the Earth Summit in 1992, and the development of marine protected areas and zoning systems is at the heart of its efforts to manage the country's rich ecological diversity (Kritzer et al. 2014, Gerhartz-Muro et al. 2018). The Coastal Zone Management Decree Law, passed in 2000, established the general principles for the conservation and improvement of the coastal zone, with a focus on coastal wetland ecosystems and mangroves in particular (CITMA 2000). The inclusion of the marine component of the coastal zone in national policies and legislation has been limited (Gerhartz-Abraham et al. 2016). A stronger national policy will be necessary for local ICZM initiatives to succeed fully. International collaborations, as exemplified in this issue, will help Cuba and all the countries of the Caribbean improve marine spatial planning and the management of coastal ecosystems.

Acknowledgments

Patricia González-Díaz and I thank *Bulletin of Marine Science* editors JE Serafy and RJ Araújo for their guidance and encouragement in producing this issue. A chance meeting with GS Shideler on a charter plane from Cuba prompted one of my first emails to the journal. He has been essential in every step of the issue. D Whittle of the Environmental Defense Fund was crucial in researching US policy and developing the special issue from start to finish. T Ricketts first suggested the idea of a special issue after the thaw of embargo restrictions on Cuba. D Greger employed her literary and editorial skills to improve many of the submitted manuscripts. L Kaufman helped develop the themes for the issue, A Puritz provided editorial assistance, and two anonymous reviewers helped improve this introduction. J Erickson, then Dean of the Rubenstein School of Environment and Natural Resources, coaxed me into teaching my first course in Cuba, starting me on this path. Financial support has been provided by the Environmental Defense Fund, Gund Institute for Environment and Rubenstein School of Environment and Natural Resources at the University of Vermont, Sarah and Daniel Hrdy Visiting Fellowship in Conservation Biology at Harvard University, Paul Lattanzio, and Winthrop and Allison Pescosolido.

Literature Cited

Aguilar C, Gonzalez-Sanson G. 2007. Composición de la ictifauna costera de Ciudad de la Habana y evaluación de los factores que la determinan. Rev Investig Mar. 28:43–56.

Aguilar C, González-Sansón G, Hueter R, Rojas E, Cabrera Y, Briones A, Borroto R, Hernández A, Baker P. 2014. Shark catches in the northwest region of Cuba. Lat Am J Aquat Res. 42(3):477–487. https://doi.org/10.3856/vol42-issue3-fulltext-8

Alfonso I, Frías MP, Aleaga L, Alonso C. 2003. Análisis de la pesquería del pepino de mar *Isostichopus badionotus* en la región sur oriental de Cuba. 6th Congreso de Ciencias del Mar, La Habana.

Álvarez Alemán A, Alfonso EG, Martin-Vianna YF, Hernández Gonzalez Z, Escalona Domenech R, Hurtado A, Powell J, Jacoby CA, Frazer TK. 2018. Status and conservation of manatees in Cuba: historical observations and recent insights. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2016.1132

Alzugaray R, Puga R, Piñeiro R, de León ME, Cobas LS, Morales O. 2018. Caribbean spiny lobster (*Panulirus argus*) fishery in Cuba: review and current status recognizing impacts of illegal fishing and environmental variability. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2016.1126

Angulo-Valdés J, Hatcher B. 2013. A new methodology for assessing the effectiveness of marine protected areas. Rev Investig Mar. 33:55–70.

Areces AJ. 2002. Ecoregionalización y clasificación de hábitats marinos en la plataforma cubana: resultados. Havana: Instituto oceanología, WWF-Canada, Environmental Defense, Centro Nacional de Áreas Protegidas.

Areces AJ, Gerhartz J, Duttit R, Martinez C. 2012. Assessing Representativeness of the Cuban Subsystem of Marine Protected Areas (SMPA). I. An overview. Wider Caribbean and Western Mid-Atlantic Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas. Recife, Brazil: UNEP Convention on Biological Diversity.

Armenteros M, Saladrigas D, González-Casuso L, Estevez ED, Kowaleski M. 2018. The role of habitat type in controlling diversity of macrobenthic communities in three gulfs of the Cuban Archipelago. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2017.1013

Azanza Ricardo J, Gernartz Muro JL, Martín-Viaña YF, Moncado G, Bretos F, Medina Cruz Y, Nodarse Andreu G, Pérez-Martín R, García Alfonso E. 2018. Marine turtle conservation in Cuba: achievements and challenges facing persistent and emergent threats. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2016.1123

Azanza-Ricardo J, Ibarra Martín ME, González-Sanson G, Harrison E, Medina Cruz Y, Bretos F. 2017. Possible effect of global climate change on *Caretta caretta* (Testudines, Cheloniidae) nesting ecology at Guanahacabibes Peninsula, Cuba. Chelonian Conserv Biol. 16:12–19. https://doi.org/10.2744/CCB-1241.1

Baisre JA. 2018. An overview of Cuban commercial marine fisheries: the last 80 years. Bull Mar Sci. This issue.

CITMA (Ministry of Science, Technology and Environment). 2000. Coastal zone management, Decree Law 212-2000. August 8, 2000. https://www.edf.org/sites/default/files/9621_Cuba_Decree-Law_212.pdf

Claro R. 2006. Diversidad ecólogica: El archipiélago y la plataforma marina de Cuba. *In:* Claro R, editor. La Biodiversidad Marina de Cuba. Havana: Instituto de Oceanología.

Claro R, Lindeman KC. 2003. Spawning aggregation sites of snapper and grouper species (Lutjanidae and Serranidae) on the insular shelf of Cuba. Gulf Caribb Res. 14:91–106. https://doi.org/10.18785/gcr.1402.07

Claro R, Lindeman KC, Parenti LR, editors. 2001. Ecology of the marine fishes of Cuba. Washington, DC: Smithsonian Institution Press.

Claro R, Sadovy de Mitcheson Y, Lindeman KC, García-Cagide AR. 2009. Historical analysis of Cuban commercial fishing effort and the effects of management interventions on important reef fishes from 1960–2005. Fish Res. 99:7–16. https://doi.org/10.1016/j.fishres.2009.04.004

Cooke CA, Marx DE Jr. 2015. Assessment of the impact of Super Storm Sandy on coral reefs of Guantánamo Bay, Cuba. SSC Pacific. Techninal Report 2065. Available from: http://www.dtic.mil/get-tr-doc/pdf?AD=ADA616410

Cramer KL, O'Dea A, Clark TR, Zhao J, Norris RD. 2017. Prehistorical and historical declines in Caribbean coral reef accretion rates driven by loss of parrotfish. Nat Commun. 8:14160. https://doi.org/10.1038/ncomms14160

Crist E, Mora C, Engelman R. 2017. The interaction of human population, food production, and biodiversity protection. Science. 356:260–264. https://doi.org/10.1126/science.aal2011

Cruz I, McLaughlin RJ. 2008. Contrasting marine policies in the United States, Mexico, Cuba and the European Union: Searching for an integrated strategy for the Gulf of Mexico region. Ocean Coast Manage. 51:826–838. https://doi.org/10.1016/j.ocecoaman.2008.08.004

Díaz-Briquets S. 1996. Forestry policies of Cuba's socialist government: an appraisal. Cuba in Transition. Association for the Study of the Cuban Economy. p. 425–437.

Donald PF, Green RE, Heath MF. 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proc Biol Sci. 268:25–29. https://doi.org/10.1098/rspb.2000.1325

Dulvy NK, Freckleton RP, Polunin NVC. 2004. Coral reef cascades and the indirect effects of predator removal by exploitation. Ecol Lett. 7:410–416. https://doi.org/10.1111/j.1461-0248.2004.00593.x

Duran A, Shantz AA, Burkepile DE, Collado-Vides L, Ferrer VM, Palma L, Ramos A, González Díaz P. 2018. Fishing, pollution, and climate change drive changes in coral reefs of Havana, Cuba. Bull Mar Sci. This issue.

Ehrhardt NM, Puga R, Butler MJ IV. 2011. Implications of the ecosystem approach to fisheries management in large ecosystems. The case of the Caribbean spiny lobster. *In:* Fanning L, Mahon R, McConney P, editors. Towards marine ecosystem-based management in the wider Caribbean. Amsterdam: Amsterdam University Press. p. 157–175.

Fallon M. 2017. Unjustifiable means: the inside story of how the CIA, Pentagon, and US Government conspired to torture. Simon & Schuster. 240 p.

Fitzpatrick R, Abrantes KG, Seymour J, Barnett A. 2011. Variation in depth of whitetip reef sharks: does provisioning ecotourism change their behaviour? Coral Reefs. 30(3):569–577. https://doi.org/10.1007/s00338-011-0769-8

Friedlander AM, DeMartini EE. 2002. Contrasts in density size and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators. Mar Ecol Prog Ser. 230:253–264. https://doi.org/10.3354/meps230253

Funes Manzote R. 2009. From rainforest to cane field in Cuba: an environmental history since 1492. University of North Carolina Press.

Galford GL, Fernandez MR, Roman J, Monasterolo I, Ahmed S, Fiske G, González-Díaz P, Kaufman L. 2018. Rainforest to reef: Cuba's ecosystems. Bull Mar Sci. This issue.

García-Machado E, Ulmo-Díaz G, Castellanos-Gell J, Casane D. 2018. Patterns of population connectivity in marine organisms around Cuba. Bull Mar Sci. This issue.

Gerhartz-Abraham A, Fanning LM, Angulo-Valdes J. 2016. ICZM in Cuba: challenges and opportunities in a changing economic context. Mar Policy. 73:69–76. https://doi.org/10.1016/j.marpol.2016.07.009

Gerhartz-Muro JL, Kritzer JP, Gerhartz-Abraham A, Miller V, Pina-Amargós F, Whittle D. 2018. An evaluation of the framework for national marine environmental policies in Cuba. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2017.1058

Gill DA, Mascia MB, Ahmadia GN, Glew L, Lester SE, Barnes M, Craigie I, Darling ES, Free CM, Gelmann J, et al. 2017. Capacity shortfalls hinder the performance of marine protected areas globally. Nature. 543:665–669. https://doi.org/10.1038/nature21708

González Díaz P, González-Sansón G, Álvarez Fernández S, Perera Pérez O. 2010. High spatial variability of coral, sponges and gorgonian assemblages in a well preserved reef. Rev Biol Trop. 58:621–634.

González-Díaz P, González-Sansón G, Aguilar Betancourt C, Álvarez Fernández S, Perera Pérez O, Hernández Fernández L, Ferrer Rodríguez VM, Cabrales Caballero Y, Armenteros M, de la Guardia Llanso E. 2018. Crown jewels of the Caribbean? Status of coral reefs in Cuba. Bull Mar Sci. This issue.

Great Barrier Reef Marine Park Authority. 2011. Impacts of Tropical Cyclone Yasi on the Great Barrier Reef: a report on the findings of a rapid ecological impact assessment: July 2011. GBRMPA, Townsville, Australia.

Hall CM. 2001. Trends in ocean and coastal tourism: the end of the last frontier? Ocean Coast Manage. 44:601–618. https://doi.org/10.1016/S0964-5691(01)00071-0

Hernandez-Betancourt A, Puga Millán R, Borroto Vejerano R. 2018. Conservation strategy for the Cuban sea cucumber (*Isostichopus badionotus*) fishery. Bull Mar Sci. 94(2). This issue. http://dx.doi.org/10.5343/bms.2017.1005

Houck OA. 2000. Environmental law in Cuba. J Land Use Environ Law. 16:1–81.

Hueter RE, Tyminski JP, Pina Amargós F, Morris JJ, Ruiz Abierno A, Angulo Valdés JA, Lopez Fernandez N. 2018. Movements of the silky shark (*Carcharhinus falciformis*) as tracked by four satellite-linked tags off the Caribbean coast of Cuba. Bull Mar Sci. This issue.

Hughes TP, Graham NAJ, Jackson JBC, Mumby PJ, Steneck RS. 2010. Rising to the challenge of sustaining coral reef resilience. Trends Ecol Evol. 25:633–642. https://doi.org/10.1016/j.tree.2010.07.011

Jones L, Warner G, Linton D, Alcolado P, Claro-Madrua R, Clerveaux W, Estrada R, Fisher T, Lockhart K, Pardee M, et al. 2004. Status of coral reefs in the Northern Caribbean and Western Atlantic node of the GCRMN. *In:* Wilkinson CR, editor. Status of coral reefs of the world. Townsville, Austrailia: Global Coral Reef Monitoring Network and Australian Institute of Marine Science. p. 451–472.

Knowlton AR. 2001. The future of coral reefs. Proc Natl Acad Sci USA. 98:5419–5425. https://doi.org/10.1073/pnas.091092998

Kough AS, Claro R, Lindeman KC, Paris CB. 2016. Decadal analysis of larval connectivity from Cuban snapper (Lutjanidae) spawning aggregations based on biophysical modeling. Mar Ecol Prog Ser. 550:175–190. https://doi.org/10.3354/meps11714

Kritzer JP, Hicks CC, Mapstone BD, Pina-Amargós F, Sale PF. 2014. Ecosystem-based management of coral reefs and interconnected nearshore tropical habitats. In: Fogarty MJ, McCarthy JJ, editors. The Sea, Volume 16. Cambridge, MA: Harvard University Press. p. 369–419.

Lamb JB, Wenger AS, Deviln MJ, Ceccarelli DM, Willimason DH, Willia BL. 2016. Reserves as tools for alleviating impacts of marine disease. Phil Trans Roy Soc B. 371:20150210. https://doi.org/10.1098/rstb.2015.0210

Lugioyo Gallardo GM, Loza Álvarez SL. 2018. Spatial temporal variability of bacterioplankton and phytoplankton in Cuban oceanic water and their trophic relations. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2016.1121

Maljković A, Côté IM. 2011. Effects of tourism-related provisioning on the trophic signatures and movement patterns of an apex predator, the Caribbean reef shark. Biol Conserv. 144(2):859–865. https://doi.org/10.1016/j.biocon.2010.11.019

Martínez-Daranas B. 2010. Los pastos marinos de Cuba y el cambio climático. *In:* Hernández Zanuy A, Alcolado PM, editors. La biodiversidad en ecosistemas marinos y costeros del litoral de Iberoamérica y el cambio climático I: Memorias del Primer Taller de la Red CYTED BIODIVMAR. La Habana, Cuba: Instituto de Oceanología. p. 43–60.

Martínez-Daranas B, Suárez AM. 2018. An overview of Cuban seagrasses. Bull Mar Sci. This issue.

Ministry of Foreign Affairs of Cuba. 2017. Press release [Online]. Cuba and the United States signed twinning agreement between Ciénaga de Zapata and Everglades National Parks. January 18, 2017. Available from: http://www.minrex.gob.cu/en/cuba-and-united-states-signed-twinning-agreement-between-cienaga-de-zapata-and-everglades-national

Milián García Y, Castellanos Labarcena J, Russello MA, Amato G. 2018. Mitogenomic investigation reveals a cryptic lineage of *Crocodylus* in Cuba. Bull Mar Sci. This issue. http://dx.doi.org/10.5343/bms.2016.1134

Miloslavich P, Díaz JM, Klein E, Alvarado JJ, Díaz C, Gobin J, et al. 2010. Marine biodiversity in the Caribbean: Regional estimates and distribution patterns. PLoS One. 5(8):e11916. https://doi.org/10.1371/journal.pone.0011916

Mumby PJ, Edwards AJ, Arias-Gonzalez JE, Lindeman KC, BLackwell PG, Gall A, Gorczysnka MI, Harborne AR, Pescod CL, Renken H, et al. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature. 427:533–536. https://doi.org/10.1038/nature02286

Navarro Martínez ZM. 2015. Ictiofauna arrecifal de Punta Francés, Cuba: Estructura y estado de conservación en el periodo 2011–2014. Masters. University of Habana.

Newman MJH, Paredes G, Sala E, Jackson JBC. 2006. Structure of Caribbean coral reef communities across a large gradient of fish biomass. Ecol Lett. 9:1216–1227. https://doi.org/10.1111/j.1461-0248.2006.00976.x

Newton KM, Côté IM, Pilling GM, Jennings S, Dulvy NK. 2007. Current and future sustainability of island coral reef fisheries. Curr Biol. 17:655–658. https://doi.org/10.1016/j.cub.2007.02.054

OFAC (Office of Foreign Assets Control). 2011. Cuban assets control regulations. Accessed 20 November, 2017. Available from: https://www.ecfr.gov/cgi-bin/text-idx?SID=5ebb49c137af87e5cd7c75fcc1b29b4f&mc=true&node=pt31.3.515&rgn=div5#se31.3.515_1557

Paris CB, Cowen RK, Claro R, Lindeman KC. 2005. Larvae transport pathways from Cuban snapper (Lutjanidae) spawning aggregations based on biophysical modeling. Mar Ecol Prog Ser. 296:93–106. https://doi.org/10.3354/meps296093

Pauly D, Christensen V, Dalsgaard J, Froese R, Torres F Jr. 1998. Fishing down marine food webs. Science. 279:860–863. https://doi.org/10.1126/science.279.5352.860

Perera Valderrama S, Hernández Ávila A, González Méndez J, et al. 2018. Marine protected areas in Cuba. Bull Mar Sci. 94. This issue. http://dx.doi.org/10.5343/bms.2016.1129

Peterson EA, Whittle DJ, Rader DN. 2012. Bridging the gulf: finding common ground on environmental and safety preparedness for offshore oil and gas in Cuba. Environmental Defense Fund. Available from: https://www.edf.org/sites/default/files/EDF-Bridging_the_Gulf-2012.pdf

Pike DA, Antworth RL, Stiner JC. 2006. Earlier nesting contributes to shorter nesting seasons for the loggerhead turtle, *Caretta caretta.* J Herpetol. 40:91–94. https://doi.org/10.1670/100-05N.1

Pina-Amargós F, González-Sansón G, Martín-Blanco F, Valdivia A. 2014. Evidence for protection of targeted reef fish on the largest marine reserve in the Caribbean. PeerJ. https://doi.org/10.7717/peerj.274

Potapov P, Hansen MC, Laestadius L, Turubanova S, Yaroshenko A, Thies C, Smith W, Zhuravleva I, Komarova A, Minnemeyer S, et al. 2017. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. Sci Adv. 3(1):e1600821. https://doi.org/10.1126/sciadv.1600821

Puga R, Piñeiro R, Alzugaray R, Cobas LS, de Leon ME, Morales O. 2013. Integrating anthropogenic and climatic factors in the assessment of the Caribbean spiny lobster (*Panulirus argus*) in Cuba: implications for fishery management. Int J Mar Sci. 3:36–45.

Puga R, Valle S, Kritzer JP, Delgado G, de Leon ME, Giménez E, Ramos I, Moreno O, Karr KA. 2018. Vulnerability of nearshore tropical finfish in Cuba: implications for scientific and management planning. Bull Mar Sci. This issue. https://doi.org/10.5343/bms.2016.1127

Rabalais NN, Turner RE, Scavia D. 2002. Beyond science into policy: Gulf of Mexico hypoxia and the Mississippi River: nutrient policy development for the Mississippi River watershed reflects the accumulated scientific evidence that the increase in nitrogen loading is the primary factor in the worsening of hypoxia in the northern Gulf of Mexico. Bioscience. 52:129–142. https://doi.org/10.1641/0006-3568(2002)052[0129:BSIPGO]2.0.CO;2

Risk MJ, Burchell M, Brunton DA, McCord MR. 2014. Health of the coral reefs at the US Navy Base, Guantánamo Bay, Cuba: a preliminary report based on isotopic records from gorgonians. Mar Pollut Bull. 83:282–289. https://doi.org/10.1016/j.marpolbul.2014.03.026

Roman J, Kraska J. 2016. Reboot Gitmo for US-Cuba research diplomacy. Science. 351:1258–1260. https://doi.org/10.1126/science.aad4247

Seeley M. 2015. How sanctions laws affect publishing: OFAC provides new guidance [Online]. Elsevier Connect. 8 December, 2015. Available from: https://www.elsevier.com/connect/how-sanctions-laws-affect-publishing-ofac-provides-new-guidance

Serafy JE, Shideler GS, Araújo RJ, Nagelkerken I. 2015. Mangroves enhance reef fish abundance at the Caribbean regional scale. PLoS One. 10:e0142022. https://doi.org/10.1371/journal.pone.0142022

Smith JE, Shaw M, Edwards RA, Obura D, Pantos O, Sala E, Sandin SA, Smriga S, Hatay M, Rohwer FL. 2006. Indirect effects of algae on coral: Algae-mediated, microbe-induced coral mortality. Ecol Lett. 9:835–845. https://doi.org/10.1111/j.1461-0248.2006.00937.x

Steneck RS, Arnold SN, Mumby PJ. 2014. Experiment mimics fishing on parrotfish: insights on coral reef recovery and alternative attractors. Mar Ecol Prog Ser. 506:115–127. https://doi.org/10.3354/meps10764

Strauss M. 2009. The leasing of Guantanamo Bay. Praeger Security International.

Szuwalski CS, Burgess MG, Costello C, Gaines SD. 2017. High fishery catches through trophic cascades in China. Proc Natl Acad Sci USA. 114:717–721. https://doi.org/10.1073/pnas.1612722114

Targarona RR, Soberón RR, Cotayo L, Tabet MA, Thorbjarnarson J. 2008. *Crocodylus rhombifer*. The IUCN Red List of Threatened Species 2008: e.T5670A112902585.

Thrush SF, Hewitt JE, Gibbs M, Lundquist C, Norkko A. 2006. Functional role of large organisms in intertidal communities: community effects and ecosystem function. Ecosystems. 9:1029–1040. https://doi.org/10.1007/s10021-005-0068-8

US State Department, Republic of Cuba. 2015. Joint Statement between the United States of America and the Republic of Cuba on Cooperation on Environmental Protection. Available from: https://2009-2017.state.gov/e/oes/rls/pr/249946.htm

United Nations. 2017. World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. United Nations Department of Economic and Social Affairs, Population

Division. Available from: https://esa.un.org/unpd/wpp/publications/Files/WPP2017_KeyFindings.pdf

Valdivia A, Cox CE, Bruno JF. 2017. Predatory fish depletion and recovery potential on Caribbean reefs. Sci Adv. 3:e1601303. https://doi.org/10.1126/sciadv.1601303

Whittle DJ, Rey Santos O. 2006. Protecting Cuba's environment: efforts to design and implement effective environmental laws and policies in Cuba. Cuban Stud. 37:73–103. https://doi.org/10.1353/cub.2007.0018

Wilkinson C. 2008a. Status of coral reefs of the world: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre.

Wilkinson S. 2008b. Cuba's tourism "boom": a curse or a blessing? Third World Q. 29:979–993. https://doi.org/10.1080/01436590802106189

World Bank. 2018. CO_2 emissions (metric tons per capita). Available from: https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?view=map

WTTC (World Travel and Tourism Council). 2017. Travel and tourism: economic impact 2017, Cuba. London. Available from: https://www.wttc.org/-/media/files/reports/economic-impact-research/countries-2017/cuba2017.pdf