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.

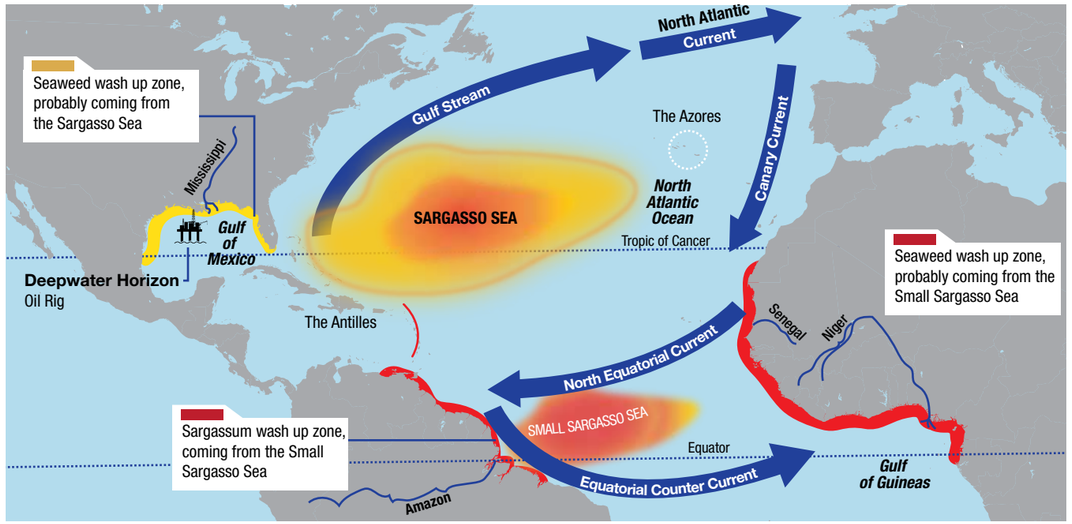
Around the world, we are also witnessing a large increase in blooms of macroalgae (seaweed), again associated with increasing temperatures and ocean enrichment. A good example is the "green tide" formed by the seaweed *Ulva prolifera*, which cost China approximately US$100 million in damages in 2008. 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.