40-year study: Changes on the Coral Reefs of Bonaire and Curaçao

Although it's now becoming widely accepted that coral reefs are degrading quickly on a global scale, there have been very few long-term studies where this is measured. Humans can have drastic impacts on the environment, prompting changes in coral reefs through acts such as overfishing, pollution and coastal development (de Bakker et al, 2016). Shifts in water quality have led to a change in reef dynamics, with many areas experiencing a loss of corals and an increase in species which benefit from these nutrient rich environments, such as algae and cyanobacteria (Broche et al, 2015).

Last month, Didier de Bakker from Wageningen University defended his thesis, in which he documented and studied the ecological degradation of coral reefs around Curaçao and Bonaire. This project continued upon research which started in the 1970s. The findings of this study were previously published in a 2017 paper titled "40 Years of benthic community change on the Caribbean reefs of Curaçao and Bonaire: the rise of slimy cyanobacterial mats", which earned de Bakker's the 'Best Paper Award 2017' from Coral Reef magazine.

This 40-year study worked to link changes in the coral reefs to human population growth on both islands. This research highlighted the shift from large reef-building coral species to an increase in benthic cyanobacteria and macroalgae. There was also a shift from large reef-building coral that form complex structures to more weedy corals that form smaller colonies which do not facilitate the same structural complexity needed for proper reef functioning and coastal protection, such as protection against flooding and erosion. This research also showed that areas of the reef where entry by people is prohibited exhibited the least amount of degradation, illustrating the importance of actively managing and preserving these ecosystems (de Bakker et al, 2017).

Benthic Cyanobacterial Mats

Although cyanobacteria have always played a small part within reef ecosystems, there is new evidence to support that it is becoming much more prevalent (Ford et al, 2018; de Bakker et al, 2017). Some species of cyanobacteria will group together to form benthic cyanobacterial mats (BCM). These BCMs lay along the bottom of the ocean and flourish in nutrient rich water. BCMs were first noticed in the early 1990s on reefs worldwide. Many human driven factors can lead to algal blooms, creating direct competition between BCMs and corals (Ford et al, 2018). In fact, a study conducted off the coast of Curaçao found a higher occurrence of BCMs in sheltered reefs near areas of high coastal development, strongly supporting a link between shifts in water quality and blooms of BCMs (Broche et al, 2015). This same study also noted that areas with higher BCM populations also hosted higher benthic macroalgae and significantly less corals. This is most likely due to the BCMs' ability to fix nitrogen, and an increase of nitrogen in a system may promote the growth of these macroalgae (Broche et al, 2015).

Cyanobacteria are not only a competitor for coral reefs, but one particular species has also been directly linked to coral's black band disease (Frias-Lopez, 2003). Black band disease was first spotted in the Caribbean off the coast of Belize in 1973 (Antonius, 1973). Since then, it's been documented in coral reefs all around the world. This disease comes from BCMs and can infect coral at a rate of 1 cm/day. This disease spreads from the top to the bottom, destroying healthy tissue and leaving behind dead skeletal remains (Antonius, 1973). Furthermore, with over 60 different cyanobacterial toxins documented, BCMs can cause a range of issues for humans and other animals living within these waters. Cases of fatal poisonings of domestic and wild animals have been linked to cyanobacteria, and highlight the importance of monitoring BCMs (Bell and Codd, 1994).

Curaçao and Bonaire

A team of researchers conducted a 40-year study off the coasts of Curaçao and Bonaire, documenting shifts in local reef populations, specifically: corals, algal turfs, benthic cyanobacterial mats, macroalgae, sponges and crustose coralline algae. To do this, permanent quadrats were placed at varying depths (10, 20, 30, 40 m) and photographed in 3- and 6-year intervals starting in 1973, and annually since the early 1990s. Three sites were selected off Curaçao (CARMABI Buoy One [I and II] and CARMABI Buoy Two [III]) and 1 site off Bonaire (Karpata) (de Bakker et al, 2017).

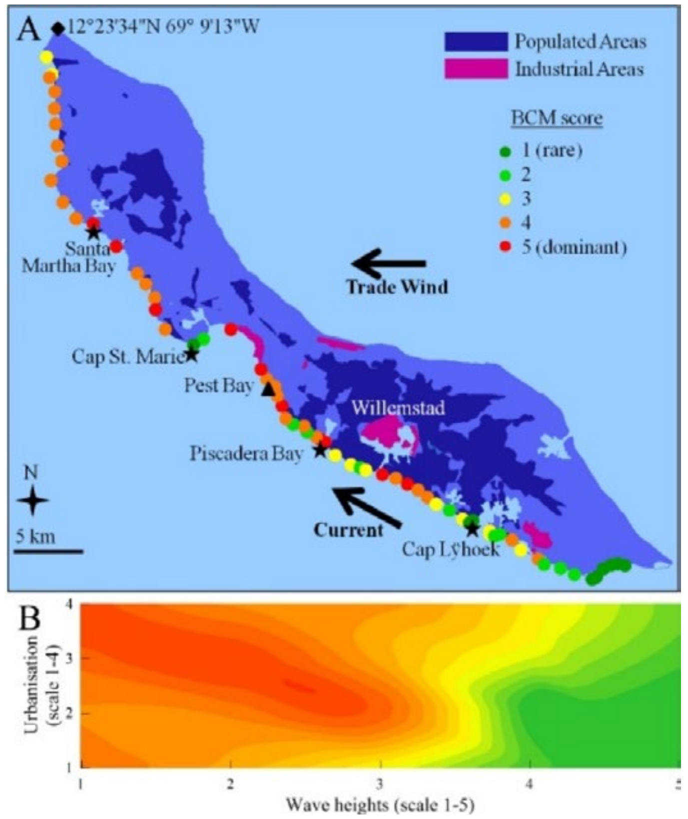
The results of this study found that in 40 years the following shifts occurred. Overall, there was a decrease in the cover of calcifying organisms from 32.6% to 9.2% for corals and 6.4% to 1% of crustose coralline algae. At first, coral cover was replaced with algal turfs and macroalgae, with a growth from 24.5% to 38% in the early 1990s. Their reign shifted once again as a decline in algae turfs from 11% in 2002 to 2% in 2013 gave way to the rise in benthic cyanobacterial mats. BCMs increased from 7% in 2002 to 22% in 2013. There was also a slight increase in sponges over these 40 years, from 0.5% to 2.3%. This breakdown can be seen in table below. It is important to note that there was not always a clear direct connection between the decrease in coral and an increase in a competitive species, however, it is believed that coral's slow growing nature puts it at a disadvantage when up against faster growing organisms when battling invasion or recovery after damage (McCook et al., 2001).

It's very likely that decreased water quality paired with an increase in water temperature are the main catalysts for the increase of BCMs (Brocke et al, 2015a). Each of the four locations studied in the 40-year project were contaminated with untreated sewage water through both direct discharge and groundwater (Buth and Ras, 1992; Lapointe and Mallin, 2001). Without waste water being properly treated and managed, this is a problem that will continue to grow as these islands further develop. Increased impact of pressures related to the increase in local populations and tourists, such as increased coastal development, increased physical damage due to humans interacting with the reef and an increase of land-based pollution will only further stress these environments. If the coral reefs are to be protected, these issues will require a complex, interdisciplinary approach to carefully manage the growth and development of both islands.

Future of Coral Reefs

If current trends continue, these reefs will continue to experience a decrease in calcifying corals, which could lead to a decrease in the structural complexity of the entire reef system (Alverez-Filip et al., 2011). Furthermore, once BCMs dominate reef areas, they will impair coral recruitment and their contribution to the release of dissolved organic compounds will further exacerbate the degradation of the entire reef (Brocke et al, 2015b). Understanding the underlying causes of these BCM blooms may be the key to reversing this trend.

Long term studies, such as these, highlight the importance of understanding the entire reef benthic system, as small population shifts can be indicators of much larger issues. If human factors are the driving force behind these changes, this means that humans can also be driving force for correction. As climate change continues to demonstrate the fragility of these systems, it will become increasingly important to understand our role in the environment.

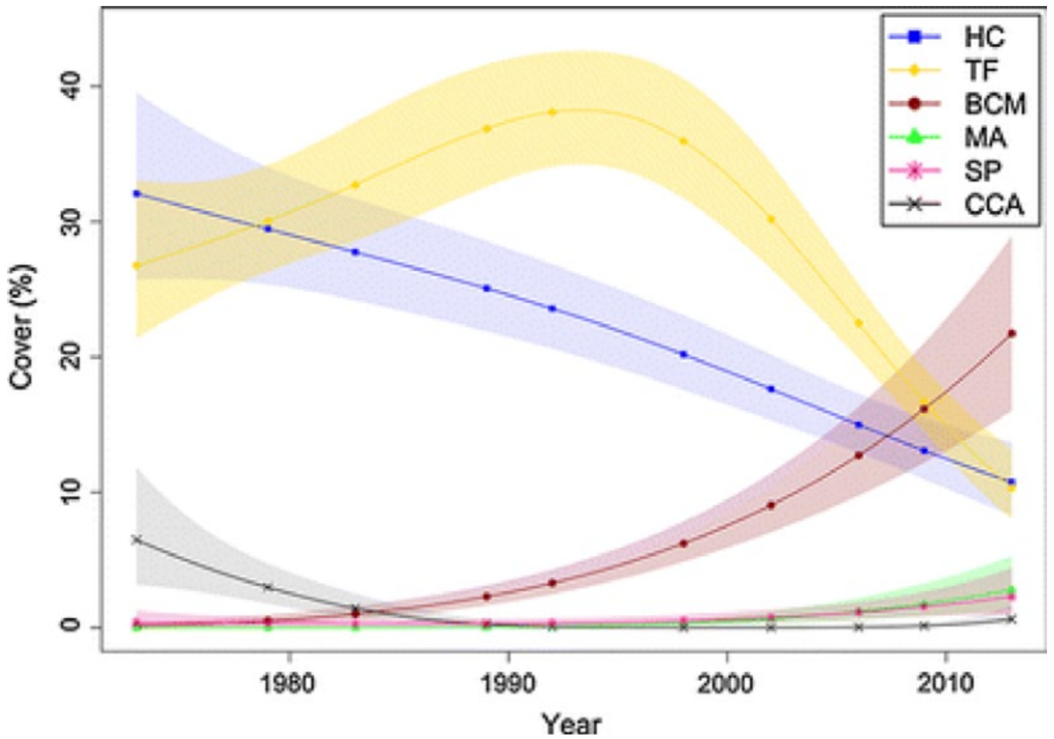


Top left figure:
2015 Map of BCM on Curaçao (Brocke et al, 2015)

Top right figure:
Mean percentage cover and 95% confidence interval of the 4 study sites (de Bakker at al., 2017)

Bottom right figure:
Trajectories of change for six benthic groups (1973-2013): hard coral (HC, blue), algal turfs (TF, yellow), benthic cyanobacterial mats (BCM, brown), macroalgae (MA, green), sponges (SP, pink), and crustose coralline algae (CCA, black). Lines represent estimated models (with 95% confidence bands) of the change in mean percentage cover over 4 sites and depths (10, 20, 30, 40 m) at Bonaire and Curacao (de Bakker et al., 2017)

Group	1973/1974		2013	
	Mean	95% CI	Mean	95% CI
Hard coral	32.6	24.7–42.9	9.2	5.3–14.5
Algal turfs	24.7	18.4–32.1	10.7	8.6–13.6
Benthic cyanobacterial mats	0.1	0.0–0.1	22.2	16.0–29.5
Macroalgae	0.0	0.0–0.0	2.0	0.4–6.6
Crustose coralline algae	6.4	4.4–9.0	1.0	0.2–3.0
Sponges	0.5	0.1–1.5	2.3	0.8–5.5
Other	1.3	0.2–4.3	2.3	1.0–4.8
Bare substrate	4.4	2.9–6.4	0.6	0.1–2.1
Sand	13.8	9.4–19.8	13.1	9.2–18.0



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