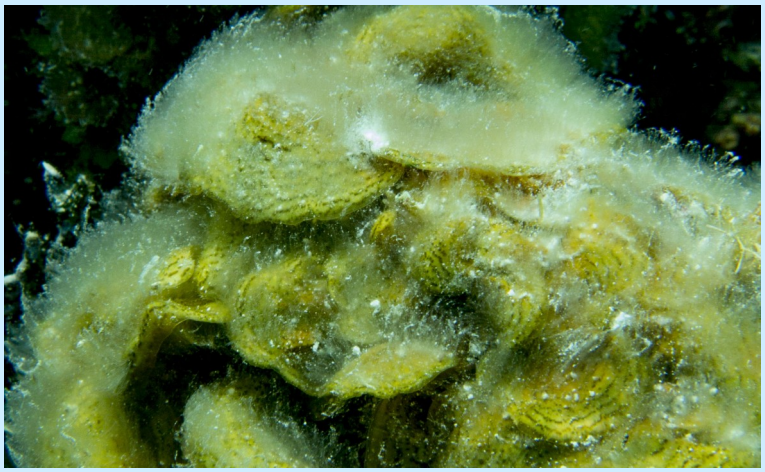
FORCE Management Brief #5 for Caribbean Reef Management

Reducing nutrients to restore the coral-algal balance

The issue

On coral reefs, there is constant competition for space among organisms such as corals, algae and cyanobacteria. Macroalgae are seaweeds that can overgrow neighbouring corals. Turf algae are mixed algal communities composed of small macroalgae and cyanobacteria. Turf algae tends to reduce the recruitment of new corals and can also overgrow existing corals. Cyanobacterial mats can overgrow both macroalgae and corals. Recent human activities (e.g. coastal development and agricultural fertilizer) have caused an unnaturally high flow of nutrients such as nitrogen and phosphorus onto many reefs. This causes macroalgae, turf algae and cyanobacteria to grow faster and overgrow corals. If nutrient influxes persist, coral reefs could turn into ecosystems dominated by algae and cyanobacteria, decreasing the reef's' ecological, economic and aesthetic value.



The approach

On Curacao we studied which benthic organisms profit most from temporary nutrient enrichment events. Whether a organism 'profits' is determined by (1) its ability to quickly acquire available nutrients, and (2) its ability to utilize these nutrients for potential growth.

First, we identified which nutrients (i.e. nitrate, ammonium, or phosphate) are limiting the growth of the abundant brown macroalga *Lobophora variegata* using a newly developed method. *L. variegata* is one of the ecologically relevant algae on reefs in the Caribbean, as it is able to quickly overgrow large parts of live coral.

Second, we identified which benthic group (i.e. coral, macroalgae, turfalgae, or cyanobacteria) can outcompete the other groups in terms of rapid nutrient uptake and whether the uptake of these nutrients causes such organisms to grow faster, thus determining (to some degree) their competitiveness for space among other organisms within reef communities.

Lastly, we worked out to what extent turfalgae – an increasingly abundant group of small macroalgae and benthic cyanobacteria with a height up to 1 cm - can fix nitrogen on a reef. Turfalgae are currently one of the most dominant benthic components on many reefs in the Caribbean, that offset part of their nitrogen limitation by fixing nitrogen themselves. Because nitrogen is one of the most important nutrients limiting growth on the reef, this capacity provides turf algae with a competitive advantage over other benthic organisms on the reef that cannot fix nitrogen themselves.

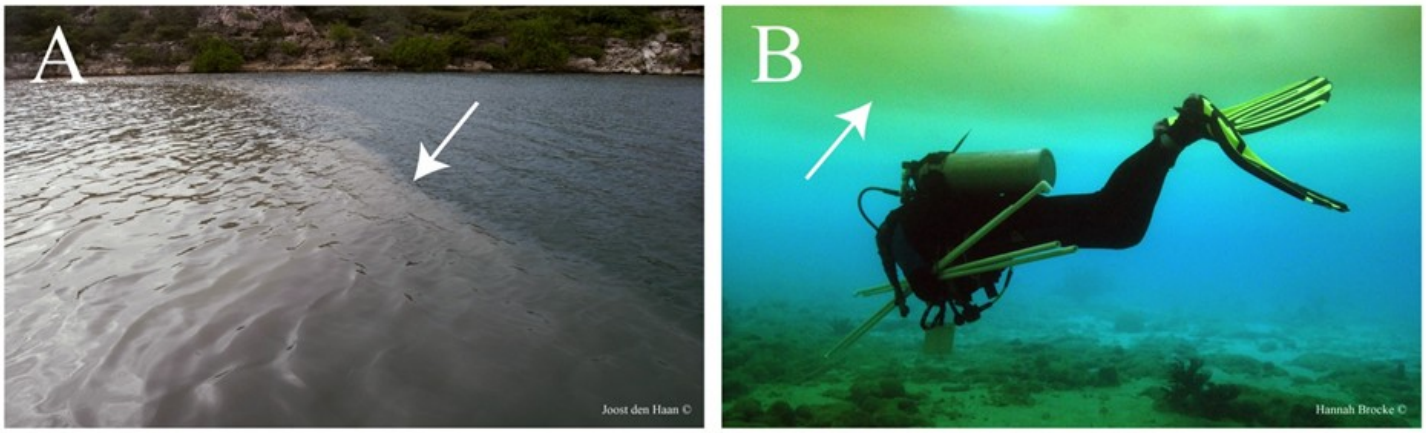


Figure 1: Temporary nutrient enrichment events entering coral reefs from land as seen from the surface (A) and under water (B)

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The evidence:

Using a new technique developed by FORCE researchers, we discovered the most abundant, and the most damaging to coral, macroalgal species *(Lobophora variegata)* was found to be limited by the availability of nitrogen and phosphorus. To examine which benthic organisms profit most from higher levels of nitrogen and phosphorus, coral, macroalgae, cyanobacteria and turf algae were exposed to nutrient pulses (raised levels of nutrients). Nutrients were delivered in the form of ammonium (NH4) and phosphate (PO4), both of which can be found in fertilizer and sewage.

Macroalgae, cyanobacteria and turf algae were all able to take up nutrients much faster than corals. Turf algae took up nutrients faster than most macroalgal species. Studies on turf algae and cyanobacteria showed that they can fix considerable amounts of molecular nitrogen (N2) under natural conditions and thus are less dependent upon external sources of nitrogen entering the reef. However, increases in external sources of both nitrogen and phosphorus can increase their growth rate as these nutrients often limit their growth under normal, low nutrient conditions

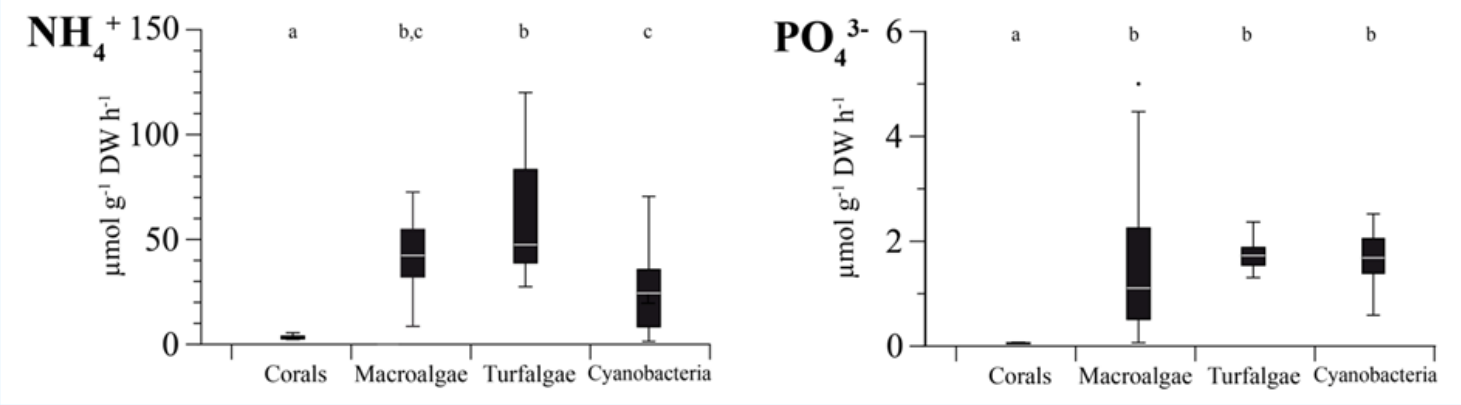

Figure 2. Uptake of NH_4^+ (left) and PO_4^{3-} (right) by corals, macroalgae, turfalgae and benthic cyanobacteria. Letters above indicate whether they are significantly different from one another ($P<0.05$, Mann Whitney U Test)

Management use

Reduce nutrient input to reefs, focusing on sources of phosphate.

Since macroalgae, turf algae and cyanobacteria all take up nutrients, reductions in nutrient flows onto reefs will help reduce the growth potential of these algae and cyanobacteria. Reducing the phosphate inflow will specifically decrease the growth of turf algae and cyanobacteria since they are less dependent on external nitrogen as they can fix otherwise unavailable nitrogen. In particular, sources of phosphate, such as raw sewage outfalls, should be reduced.

Nutrient flows can vary both in time (e.g. seasonal upwelling) and space (reefs near the mouth of a river are likely to have higher nutrient levels). However if nutrient levels are continuously measured, efforts could be made to find and eliminate the source of the nutrients.

Reducing nutrient flow onto reefs will ultimately benefit corals as they compete for space with algae and cyanobacteria.

Further information

den Haan J, Huisman J, Dekker F, ten Brinke JL, Ford AK, van Ooijen J, van Duyl FC, Vermeij MJA, Visser PM (2013) Fast detection of nutrient limitation in macroalgae and seagrass with nutrient-induced fluorescence. PLoS ONE 8(7):e68834. Available free online: www.plosone.org/

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