Nutrients on Coral Reefs

Concentrations of nutrients, especially nitrates. In recent years it has become increasingly clear that high concentrations of nutrients, especially nitrogen cycle products such as ammonia, nitrites and nitrates can be a serious problem for coral reefs. While the nitrate norm for drinking water for human beings is 20 ppm, corals in a sea- water aquarium will die at 2 ppm and corals on a coral reef are seriously stressed at much lower levels. The problem is that corals are naturally adapted to a low-nutrient environment and are thus extremely sensitive to quite low levels of nutrient pollution. The threshold for dissolved inorganic nitrogen is only 1.0 um (Lapointe *et al*, 1997). In the sea there is usually enough oxygen present to fully oxidize ammonia and nitrites to nitrates. Nevertheless ammonia and nitrites to which corals are even more sensitive can be present near outflows or in inner waters. Indications are that sewage waters are probably a major problem. A study by Bak & Nieuwland (Bak R.P.M., Nieuwland, G., 1995). indicates that coral cover at three transects in Curaçao and one at Karpata in Bonaire has declined considerably during a period of twenty years. The Karpata area is a fully protected area, there is no fishing, or anchoring in this area. This decline can thus be related to global causes, to a nutrient problem or possibly a synergistic effect between the two.
In many countries, nutrients on the coral reef are derived from excess fertiliser used in agriculture, which is washed out to the sea. In Aruba, Curaçao and Bonaire there is no large-scale agriculture. Nutrients in Aruba waters and are thus probably almost exclusively derived from household wastewater. Use of pesticides is also very limited. Most pesticides are used in households. The calcareous zones are very porous and sewage nutrients will seep out to the sea almost unimpeded. In areas with impermeable volcanic soils or clays, this is much less of a problem, since the nutrients are unlikely to reach the sea.
In the calcareous coastal zone in Curaçao there has been quite some housing development in recent years (Jan Thiel, Blauwbaai, Boca St Michiel, Rif area, Cas Abou, Coral Cliff, Lagun, Westpunt-Playa Kalki). This is likely to have caused quite some seepage of sewage waters directly to the sea via cracks in the porous limestone. Phosphates will tend to get bound by the limestone but the nitrates will reach the sea. (coastal development in Bonaire has taken place in calcareous limestone areas, this may be a mayor problem). Wastewater collected at the sewage treatment plant Klein Hofje in Curaçao typically contains about 83 ppm of N products, this value is probably indicative for other local wastewater as well. In Aruba most waste water is treated at the Bubali sewage treatment plant, there is a tertiary pond with reeds which absorb a lot of N products and water is used for irrigation of a golf field. Nevertheless new housing or hotel development, not connected to the sewage system, in calcareous areas can cause problems.

In Curacao there is some seepage of sewage water via inner bays (Spanish water, Schottegat, Piscaderabay) and directly into the sea via groundwater (Gast, 1998). In some wells nitrate concentrations as high as 100 ppm have been found. Curaçao had a large population since the oil industry established itself, in any case there must have been considerable seepage of N cycle products, especially via the Schottegat and this could very well have been a factor in the decline of corals near the harbour entrance. This however did not affect areas further downstream, where the decline of coral cover set in much later. The main difference with the situation nowadays would be that there were few developed areas along the coast, in limestone areas. Still it is quite possible that the nutrients that reach the sea via groundwater seepage are an important contributing factor which in many areas, may not have been critical in the past, but which can now in some cases raise concentrations above a certain critical threshold level.

- some nutrients are present in the ocean and belong to a “general Caribbean background level”, which has increased during the last decennia.

Remedy: The nutrient problem can be solved to a large extent by treating the effluent and subsequently using the water for irrigation of landscaping, ornamental plants, golf fields (grass absorbs a lot of nitrogen), fodder for animals (such as Sudan grass, buffalo grass or Sorghum) or horticulture. Fodder with an excellent C/N ratio has been obtained using these waters.
A central sewage system can be used and/or smaller treatment system. Depending on the volumes of water available, the distance to a central treatment facility and the area where the wastewater can be used, a choice can be made. Local water prices are very high, consequently people use little water and sewage water tends to be highly concentrated.

Central wastewater treatment facility: the incoming wastewater at the sewage treatment plant typically contains high loads of ammonia (about 70 ppm) a few nitrites and nitrates and some other N products. Total N load is about 80 ppm. In the anaerobic parts of the treatment process a lot of N^2 is produced which is flushed out and escapes to the air during the following aerobic stage of the treatment process. In the aerobic parts of the sewage system the remaining N products are

fully oxidized to nitrates. In the central wastewater treatment system in Curaçao the waters in the tertiary finishing pond typically hold concentrations of 20-25 ppm of nitrates and no ammonia and/or nitrite (when the plant operates properly. In the rainy season these volumes increase since some rainwater enters the sewage system. At Klein Hofje the tertiary pond has been lined with plastics, there is some leakage due to holes made in the plastic by crabs. The remaining available water is fully used for landscaping and agriculture (see below). In the rainy season there can be some overflow. One of the problems is that in several areas where wastewater is collected there is considerable leakage.
The smaller treatment systems: nowadays these are made of GRP tanks with different chambers, in one of the tanks the water is aerated. The tanks are installed below ground. One of the advantages is that the collecting lines are relatively short, reducing the chances of leakage. One of the main problems with these smaller systems is that they are sensitive to abrupt changes in loading (this can affect larger systems too, but usually these have more buffering possibilities). Another problem is that they are usually operated by the gardener, who often does not have the necessary level of knowledge to detect and/or correct malfunctioning. When the water is used for landscaping around the hotel, apartments or houses that share such a system, the nutrients will be absorbed by the vegetation.

If we tentatively compare the situation in Curaçao and Bonaire we see that Curaçao has a much larger population of about 130.000 compared to about somewhat less than 14.000 on Bonaire (not counting the fluctuating tourist population) Thus one would expect the nutrient problem to be much worse in Curaçao. However several other factors are probably also of importance. Curaçao is substantially larger, the coastal currents are much stronger than in the enclosed bay of Kralendijk, most housing in Curaçao is situated in the Curaçao lava formation, while Kralendijk has been built in a porous calcareous area. In Curaçao at least 4000 m^3 of water is treated (which roughly represents wastewater produced by 70.000 inhabitants) and the effluent containing high concentrations of nitrates is used for irrigation and not reaching the sea which probably also makes for some difference. In Curaçao several large inner bays buffer the nutrient loads before reaching the sea. This however can be a problem in itself. In the Piscadera inner bay several algae which are characteristic for high nutrient situations can be found. At the Spanish water blooms of blue-green algae have started to occur quite regularly, especially during periods when the waters are very warm and when there is not much wind. These blooms are undoubtedly related to nutrients.
We should track concentrations of nitrates and other N cycle products in the sea, by measuring it in wells in both calcareous and other areas, in the inner bays, the outer bays and along the reef in both Curaçao and Bonaire. It is possible to treat waste waters and use the effluent to eliminate nutrients. As has been discussed above this is already being done but it could be extended by enacting legislation to control this problem especially in the porous limestone areas. Treated wastewaters which are now infiltrated into the soil should be used for agriculture and landscaping whenever possible. Inner bays can act as buffers by preserving mangrove areas.

The use of kanastas (fish pots) has declined, very few are nowadays used. Thus the fishing pressure on the smallest grazing reef fish which are caught with kanastas is probably less. While fishing probably has had some influence on coral cover, the reverse is probably also true. The decline in coral cover has probably influenced landings of demersal fish. Thus it would seem that while fishing for demersals has declined, the carrying capacity may also have declined. However it seems unlikely that fishing has been a major cause of the decline of coral cover in Curaçao. Available data from Boeke (1907) and Zaneveld (1961) indicate that there has been a considerable fishery for demersals long before the decline of coral reef cover started. Fish traps for instance were much more widely used in the past and these are the ones most likely to catch the smaller herbivorous fish which graze on the coral reef. It is however difficult to directly compare these older data directly with the data we have collected now. In Bonaire a marked decline in coral cover has been observed at Karpata in an area in which there is no fishing (Bak & Nieuwland) .

Spear fishing is prohibited. In those cases where catches of illegal spear fishermen have been recorded by the data collector, the catch per unit of effort was much higher than the CPUE of fishermen fishing for demersals with lines from small boats. Also the investment needed and the operating costs are much lower. For these reasons illegal spear fishing remains attractive.

What to do: Island fisheries legislation regulating amongst others, maze width for fishpots and gillnets and self-destructing panels and escape slits for fish pots.

Plastics contain significant amounts of heavy metals (especially cadmium and mercury). Especially on our North coast a lot of floating plastic debris is found. The UV radiation of the sunlight will break these plastics down and heavy metals will be released. Very little is known about the extent of pollution by heavy metals and whether these are firmly bound to the sediments, have washed away or have been able to enter the food chain. Pollution by heavy metals and pesticides can

have effects on corals and coral reefs, but is unlikely to have caused, or significantly contributed to the decline of coral cover observed

Literature

Bak, R.P.M., Nieuwland, G.- 1995 - Long-term change in coral communities along depth gradients over leeward reefs in the Netherlands Antilles. Bulletin of Marine Science, 56(2): 609-619.

Lapointe, B.E., Littler, M.M., Littler, D.S. - 1997 - Macro algal overgrowth of fringing coral reefs at Discovery, Jamaica: bottom-up versus top-down control. Proc 8th Int Coral Reef Sym 1:927-932