(canda)

Coral decline, causes and effects: local variables, regional issues

What can be done

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In a recent dissertation (Vermeij, 2002) one of the so called "stellingen" states that "if the government does nothing the (local) coral reef will be gone in 30 years time". So, the government should do something. What exactly should we do and will it help? How long will the coral reef last if we do or don't. Can it be saved, or will it be gone in 30 years time anyway, whatever we do. Or will it last 30 years and one month, 30 years and two months or may be fifty or a hundred years. This reasoning brings us right away to a discussion of the causes of coral reef decline. There are of course many causes. A recent handbook called Coral reefs, Mangroves and sea grass: a source book for managers (Talbot, F., Wilkinson, C., 2001) gives the following:

1. rise in CO_2 levels and related climate change
2. destructive fishing (dynamite, cyanide)
3. coral mining
4. sediment
5. inorganic and organic pollution
6. overfishing
7. oil pollution
8. heavy metals and pesticides
9. physical damage from boat anchors
10. uncontrolled tourism

To these we can add the introduction of exotic organisms and diseases from other areas, such as the *Diadema antillarum* sea urchin disease.

In the handbook several case studies are given. One of the things we note when studying these case studies is that while there is almost complete agreement on the diverse factors which cause the decline of coral reefs, this agreement does not extend to the question of the relative importance of these factors. Each case study in itself seems perfectly logical but when we compare them with each other they sometimes seem to contradict each other. While causes can of course differ from area to area, some of the explanations seem a bit odd when compared to each other. We find that the decline of reefs in Kenya is attributed to overgrazing by the sea urchin *Echinometra mathaei.* This overgrazing being caused by overfishing of their predators. In the case of Jamaica an important factor in the collapse of the coral reef mentioned is the 1983 disease of the black spined sea urchins. Without grazing fish (due to overfishing) and grazing sea urchins (99% eliminated by the disease) there was spectacular growth of large algae (*Sargassum, Lobophora* and *Dictyota*), this prevented settlement of young corals. In the same case study it is stated that (before the 1983 sea urchin disease) the coral reef was affected by too much grazing by too many sea urchins. Their main predators having been reduced through overfishing. In the case of San Blas Panama it is stated that there is some fishing, but no overfishing. Much damage was done by the 1983 sea urchin disease, fishing had little to do with it. All of the above could very well be perfectly true and is not necessarily contradictory, since we are dealing with complex ecosystems. Nevertheless the above illustrates that our understanding of these matters is still incomplete. In the case of Jamaica there has been discussion on the role of overfishing. Some authors maintain that the Jamaican reefs were already being overfished long before their rapid decline set in and that the root cause of the decline has to do with nutrient levels in the water (Lapointe *et al,* 1997), especially nitrogen cycle products such as nitrates. In their view overfishing probably is a contributing factor, but certainly not the main cause.

Rise in CO_2 levels is a problem in itself and is a root cause of, global warming, rising seawater temperature and seawater level rise and more frequent occurrence of strong hurricanes which damage the reefs. There is agreement that climate change is having a significant impact on the world's coral reefs and that in any case it is one of the main causes of coral decline. Some hold the view that coral reefs will disappear from most tropical areas and will shift towards the poles. In the northern hemisphere they would shift northward and maintain themselves only in more northerly cooler areas such as the northern parts of the Golfo the California (Mar de Cortez) and the Suez area, which are nowadays at the edge of their area of distribution, as has happened during some past interglacials. In this view our current tropical reefs will be gone in 30 years, whatever we do. An opposite view holds that higher CO_2 concentrations reduce the pH of the seawater, which increases the dissolving of the reef structure. At higher latitudes coral growth is slower and presumably cannot compensate for this effect. Others feel that presumably increases in air and sea temperatures and the related coral bleaching must also have happened before, in the geological past and yet coral reefs managed to recover. Often it is felt that we should not concentrate on this topic too much since there is little we can do about it anyway and it would be better to try to influence those factors that we can do something about.

In the case of Curaçao it is clear that we have been affected by these global trends and by the regional sea urchin disease as well. We have experienced many coral diseases, severe coral bleaching in 1985. tropical storm Joan in 1988, and the rough seas caused by hurricane Lenny in 1999. The destructive causes of coral mining, destructive fishing (dynamite, cyanide) do not apply. This leaves us with the following causes which we could influence:

4. sediment
5. inorganic and organic pollution
6. overfishing
7. oil pollution
8. heavy metals and pesticides
9. physical damage from boat anchors
10. uncontrolled tourism

In this article we will mainly concentrate on points 4, 5 and 6.

4. Problem: Sediment

- entrance to the Piscaderabaai
- entrance Sta. Cruz lagoon/saliña
- newly constructed artificial beaches - Seaquarium, Princess Beach, Avila, Sonesta
- adding sand to existing beaches Caracasbaai, Daaibooi, Cas Abou, Playa Kalki and others
- increased run-off in general from inhabited areas, carrying more sediments

Remedy: Do not open entrances to inner bays. Reduce amounts of sand applied to beaches. Try to keep existing vegetational cover intact.

5. Problem: 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 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 the global causes mentioned earlier, to a nutrient problem or possibly a synergistic effect between the two.

- In many areas, nutrients on the coral reef are derived from excess fertiliser used in agriculture, which is washed out to the sea. In Curaçao there is no large-scale agriculture; some small-scale horticulture exists. In addition in these operations one of the problems is usually that the operators use insufficient fertiliser. Nutrients in Curaçao waters and groundwaters are thus almost exclusively derived from household wastewater. Use of pesticides is also very limited. Most pesticides are used in households.

- 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. Recently at a beach in the San Juan area (Playa Mansaliña) I saw a few *Ulva latuca* green algae growing on a rock which is standing separately in the water, some 10 meters from the coast and I was asking myself what is *Ulva* doing here? Could it be related to the upstream housing development at Cas Abau? Or may be too many visitors urinating in the water during the weekends? Or could it have been caused by dung of a herd of goats (washed into the water by rains), which were using a tree nearby as a resting place?

- still some direct discharge of household wastewater (Punda area)

- 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 72 ppm) a few nitrites and nitrates and some other N products. Total N load is about 83 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 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 Curaçao, total production for Klein Hofje is about 2800 - 3100 m^3/day and the plant at Klein Kwartier 1000 m^3/day. 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, which is infiltrated into the soil at Soltuna. At Klein Kwartier about 200-300 m3 a day is being used for landscaping around the plant and by an agricultural project nearby, a large part of the effluent is infiltrated into the soil. Some of this will probably eventually end up in the Schottegat inner bay and from there may be even reach the sea. It would be better to use all the water for agriculture. At present only the overflow goes to the Sorghum ponds at LVV. These can absorb about 300- 400 m^3 per day. There is a small plant at Tera Cora which produces about 60 m^3/day. Total effluent treated by these 3 plants is roughly 4000 m^3 a day. The N load of this effluent is already much lower than the N load of untreated wastewater. One of the problems is that in several areas where wastewater is collected there is considerable leakage. The volumes of water given are only for those waters that actually reach the treatment plants. At Klein Hofje the waters used for irrigation are pumped to a large steel tank. In this tank conditions become anaerobic again, when the water finally comes out of the lines some of the nitrates have probably been reduced to N^2 . When the water comes out of the dripper or sprayer it is aerated again and NH^4+ and NO^{2-} which may be present will reoxidize to nitrate and N^2 will escape. Thus the total N load is further reduced. From the tank the waters are pumped to the Soltuna agricultural project, where they are used in horticulture, to the Blauw golffield and landscaping, to several hotels, where the water is used for landscaping and to the *Washingtonia* palms along the E.C. road and Pater Euwensweg.

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 11.000 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. As explained earlier, 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. There has been pressure to open up the old connection from Spaanse water to the Caracasbay, which would benefit the waters in the inner bay, but which would simply transfer the problem to the outside bay instead of solving it and which would dump the said nutrients directly onto the coral reef. Already there is quite some algal growth at the public beach at Caracasbay, which I think has to do with nutrients leaching out from the inner bay, through the fairly narrow land ridge between the two.

We have to know the extent of the nutrient problem and whether this is really a major problem as we assume it is, or whether it may be a contributing factor but not really the major problem.
It is very important that we achieve a better understanding of these basic problems. Even though our assumptions may seem very reasonable there are not enough data to back them up and often when the data are available the situation turns out to be somewhat different again. We should track concentrations of nitrates and other N cycle products in groundwater, 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. Some of this work has already been done (Gast, 1998, Gast *et al* 1999). 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. In order to sell such programs to the public the problem has to be better documented. 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.

6. Overfishing

The Curaçao fisheries are mostly pelagic fisheries. In the period 1977-1980 estimates of total fish landings were made and landings of reef fishes were estimated to constitute about 10-15% of total landings (all percentages are given on a weigth basis). On a total catch of approximately 900 tons this would have been 90-135 tons of reef fish/year. This was roughly in agreement with FAO figures which held that a sustainable yield from areas with coral reefs would be 2-4 tons square km per year. Since last year a much more detailed sampling system has been set up and preliminary data indicate that landings of reef fish now make up about 13,9 % of catches, which is in the same range as the 1977-1980 estimates. From the new data it seems that landings of both pelagic and demersal fish have declined markedly. However since the fluctuations in the landings of pelagic fish are quite considerable from season to season and from year to year, the data collected should cover at least a three year period to be able to draw more definite conclusions. In the 1977-1980 data it can be noted that landings of rainbow runner (*Elagatis bipinnulata*) constituted about 10-15% of the total catch, in the new 2000-2001 data the rainbow runner is almost completely absent. This species has simply disappeared. Wahoo (*Acantocybium solandri*), which is called mulá in Curaçao is now the most important species with 38% of landings (up from 25% in 1977-1980). This increase in percentage of total catch is not due to an increase in landings but to the decline of landings of other species. Catches of all tunas (called Buni in Papiamentu) have also declined. This is probably due to overfishing on the Atlantic ocean, but may also be influenced by oceanographic changes. The landings of demersals are

Demersals...

less influenced by the seasons and are not expected to fluctuate strongly from year to year. On the basis of the sampling which has been done up to now, the yearly estimate for landings of demersals by Curaçao fishermen is only 37,7 tons. The sample we now have is sufficiently large, this figure is thus more definite than the estimates for the pelagics. This figure does not include landings by sport fishermen, but these were not included in the previous estimates either. Fishing for demersals has declined. Line fishing for demersals at night has become very dangerous, one is likely to get shot at by drug smugglers. 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. On the other hand some gill-nets are nowadays being used catching a variety of demersal fishes (at Westpunt). 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. It is thus difficult to judge from these data whether there is overfishing. 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.

7. Oil pollution

Oil pollution in Curaçao started in 1916 when the Shell oil refinery established itself on the island. Visitors in the 1920's and 1930's remark that the whole harbour was always smelling of oil. I myself remember this smell very clearly from the 1950's and early 1960's. In 1926 there was a large fire and oil floating on the water in the Schottegat burned for days. On pictures taken from the air in the 1950's we can usually see an oil slick coming out of the harbour entrance. Nowadays the harbour is much much cleaner. The same holds true for the Caracasbay and Bullenbaai area. Suffice to say that oil pollution can have effects on corals and coral reefs, but is very unlikely to have caused, or significantly contributed to the decline of coral cover observed in Curaçao since the 1960's (except near the harbour entrance).

8. Heavy metals and pesticides

Plastics contain significant ammounts 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. At the North coast all sorts of materials have been dumped into the water for years, this includes items like batteries, transformers and empty or half-empty containers of pesticides. In the past the safest way of disposing of such items was thought to dump them into the sea. Although this practice ended in 1986 it is not unlikely that there are still effects. In some areas high concentrations of heavy metals, which were probably dumped by the refinery were found and in areas where ships are painted (Curaçao) TBT is found. 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 in Curaçao since the 1960's.

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