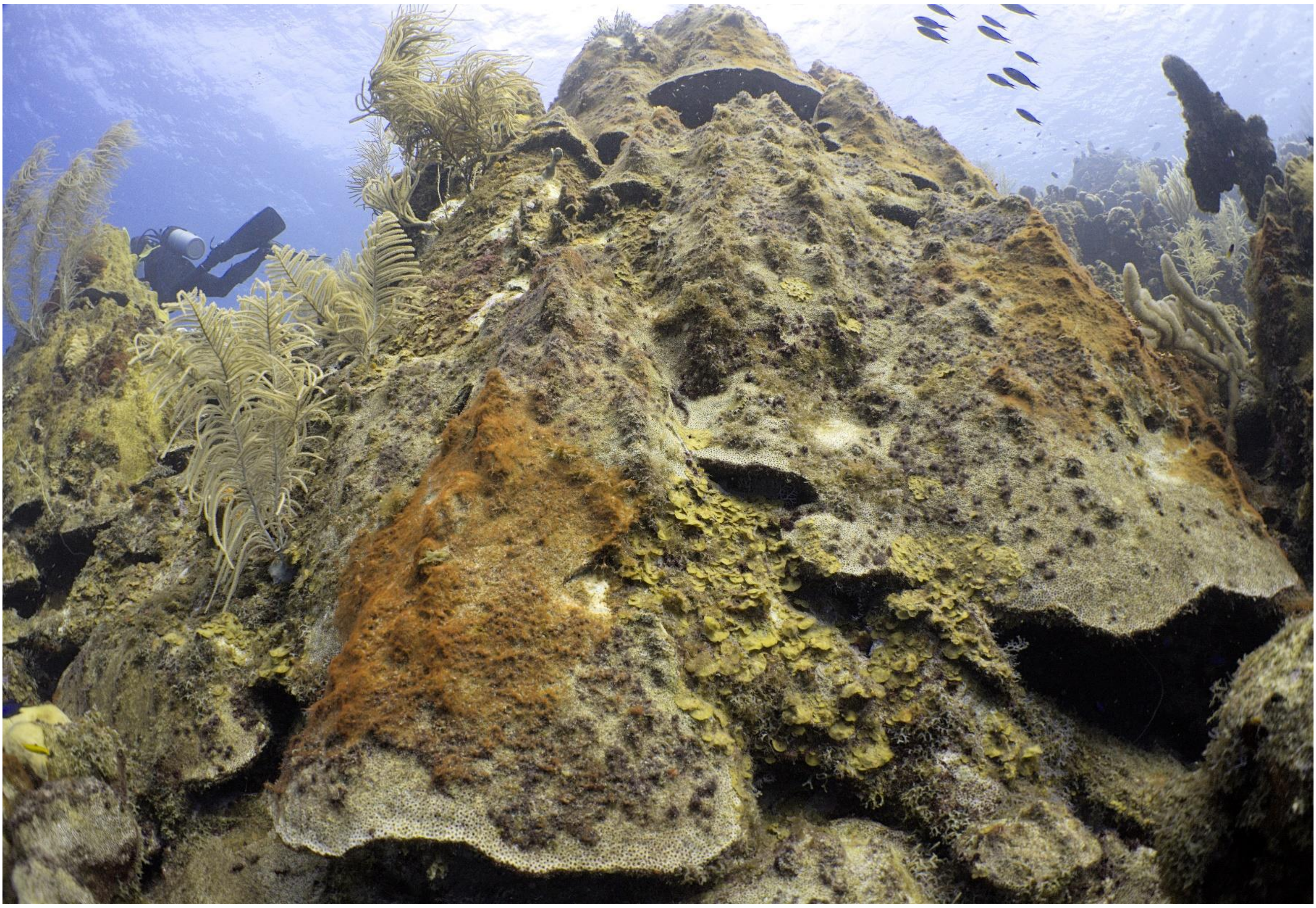

Conservation State of Coral Reefs and Communities of the Caribbean Netherlands

Author(s): E.H. Meesters[1], M. van der Geest[1], T. Kemenes van Uden[1], E. Boman[2], E. Butler[2], A. Hylkema[3/4], M. Lehwald[3], K. Wulf[5], C. Eckrich[6]. and R. Francisca[6]

1 Wageningen Marine Research

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Photo cover: Erik Meesters
The photograph shows the devastating impacts that climate change has had on one of the largest coral colonies on the island. This coral which is more than 5 meters high and most likely more than 500 years old is now completely dead.

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Summary

This report give a summary of the status of the coral reefs and coral communities of the Caribbean Netherlands. It includes the islands Bonaire, Saba, St. Eustatius and the Saba bank. Since the previous State of Nature report, the state of the corals and coral communities has worsened and should now be seen as extremely unfavorable. Coral cover on Bonaire is now on average less than 10% (mean of 5 and 10m depth), less than 3% on Saba and St. Eustatius. Algae are now the dominating group on the reefs of the Caribbean Netherlands. There are still individual sites that have a reasonable amount of coral cover, but these are disappearing rapidly. For Bonaire population growth and non-effective sewage treatment are the main local impacts. Together with rising sea levels, increasing sea water temperature and acidification, water quality is likely to seal the fate of Bonaire’s reef. Climate change effects are accumulating and measures to decrease local impacts and increase resilience are more urgent than ever. Only a policy directed at improving water quality and limiting terrestrial runoff together with strict enforcement and combined with active restoration of corals and herbivores may be able to improve the condition of Bonaire’s reef. But even then, the outcome is unsure in the face of failing international attempts to halt climate change. However, not to act should not be an option, given our responsibility towards future generations.

1 Status

The coral habitats in the Caribbean Netherlands can be found in the marine environments of Bonaire, Saba, and St. Eustatius, and the Saba Bank. When viewed from a historical perspective the current status of all these areas should generally be viewed as extremely unfavorable, though there are local areas that present hopeful exceptions. Caribbean wide coral cover has decreased steadily over the last 50 years (Jackson et al. 2014), caused by anthropogenic pressures such as overfishing, pollution, diseases, and, more recently, by climate change induced events like bleaching.
Conservation and protection of corals is a goal of many international treaties, such as the Convention of Biological Diversity (CBD, entered into force 1993), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 1975), the Ramsar Convention on Wetlands (1975), the United Nations Convention on the Law of the Sea (UNCLOS, 1994), and UNESCO's World Heritage Convention (WHC, 1975). Important for the Caribbean are also regional agreements such as The Protocol Concerning Specially Protected Areas and Wildlife (SPAW), as part of the Cartagena Convention (1986). Notwithstanding these agreements, little progress has been made in turning the tide for coral reefs.
Organizations that play an important role in the protection of coral reefs are the United Nations Environment Programme (UNEP), the International Coral Reef Initiative (ICRI), the Global Coral Reef Monitoring Network (GCRMN), the World Wildlife Fund (WWF), and The Nature Conservancy (TNC).
Within the Kingdom of the Netherlands the Caribbean Netherlands' coral reefs are protected through established Nature Parks, national laws, and local regulations.
Management and protection of the marine resources of the Caribbean Netherlands is carried out under supervision of the Ministry of Agriculture, Fisheries, Food Security and Nature (LVVN), the Ministry of the Interior and Kingdom Relations (BZK), and the Ministry of Infrastructure and Water Management (I&W), with delegated responsibilities to the island governments of the public entities Saba, St. Eustatius, and Bonaire. Day to day management of the marine parks is carried out by mandated non-governmental organizations, being Stichting Nationale Parken (STINAPA) on Bonaire, St. Eustatius National Parks (STENAPA) on St. Eustatius, and Saba Conservation Foundation (SCF) on Saba. Monitoring of the status of the coral communities of the Caribbean Netherlands is carried out in collaboration with the local NGOs.

2 Characteristics

2.1.1 Description

An evaluation of the Conservation State of corals in the Caribbean Netherlands requires a separation between the southern and the northern part. These two areas are more than 600km apart and climatologically very different. In the south the environment is characterized by semi-arid conditions receiving much less rain than the northern area. A very important consideration for reef development is the difference in hurricane return times between the northern and the southern Caribbean. Historical patterns show that around Aruba, Curacao, and Bonaire hurricane frequency is much less than around Saba, St. Eustatius, and St. Maarten. This is most likely the reason why reef development on the Saba bank occurs deeper than on Bonaire and fringing reefs have not developed around Saba, St. Maarten, and St. Eustatius. Local threats vary between the relatively small and sparsely populated Saba and St. Eustatius, and densely populated Bonaire. The main local threats are overfishing (often artisanal), eutrophication, pollution, and erosion. More regional threats include diseases and the consequences of climate change. Diseases spread through the whole Caribbean without much distinction between islands and appear to occur more frequently in recent years. In 2023 the Stony Coral Tissue Loss Disease (SCTLD) has wreaked havoc on Bonaire and on Saba, and a (possibly recurring) disease among black sea urchins has decimated these important herbivores once again (Hylkema et al. 2023). Bleaching of corals through extensive periods of increased sea surface temperatures also occurs almost yearly now and has been extreme in 2023 (***Figure 1***) and 2024 is currently developing into one of the warmest years on record with bleaching likely causing severe stress again later in the year (***Figure 2***). Observations in October 2024 suggest that the combination of bleaching and disease have had a devastating effect on the reef, where certain coral species having been removed completely and coral cover decreased generally everywhere.

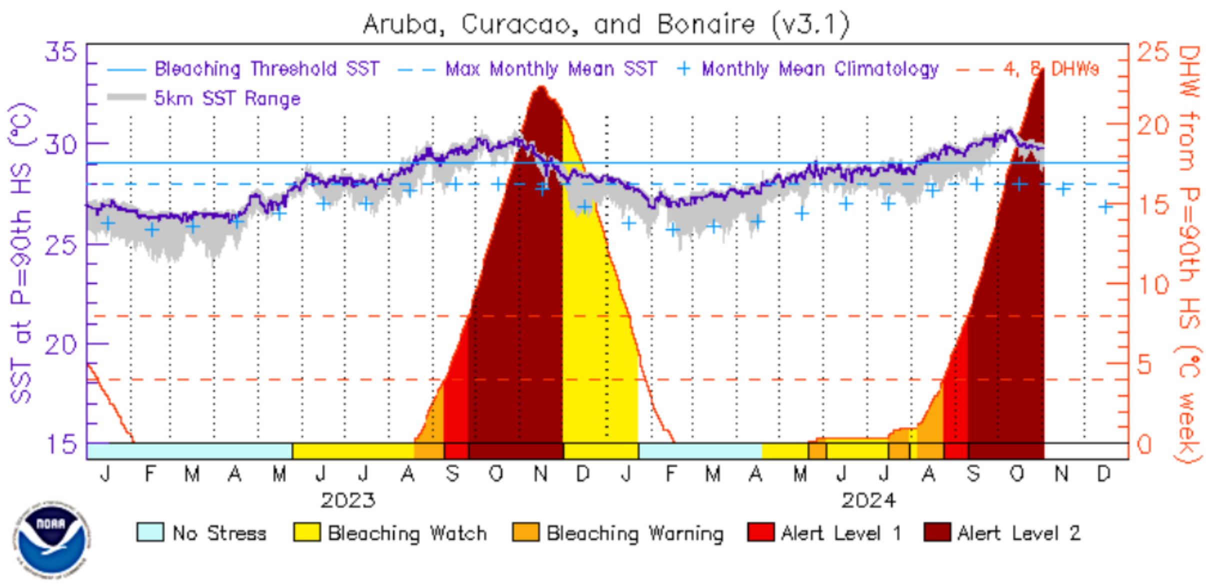

Figure 1. *Sea surface water temperature around the A, B, C islands in 2023 and 2024. The dark blue line depicts the temperature (left y-axis), the grey area indicates temperature values during previous years till 1985. The coloured area displays the Degree Heating Weeks (right y-axis), a measure for the amount of stress corals are exposed to as a consequence of heating. Data courtesy of NOAA.*

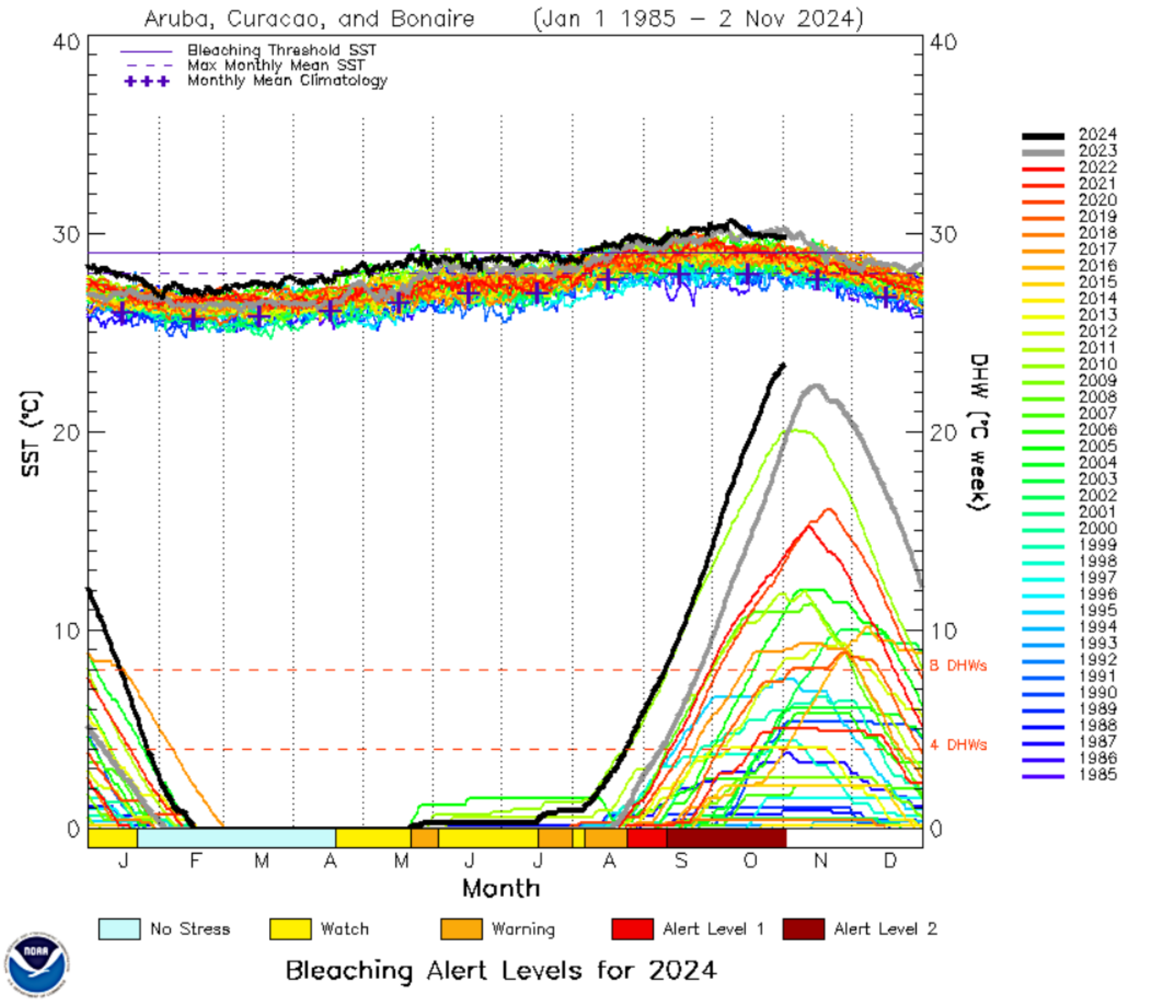

Figure 2. *Multiple years graph of temperature and Degree Heating Weeks (DHW) for A, B, C islands. Courtesy NOAA. DHW is a metric for the amount of stress corals experience due to warmer sea surface temperatures.*

3 Relative Importance within the Caribbean

Coral reefs are the most diverse ecosystem in the world. They are biodiversity hotspots, providing food and protection to numerous species, and a plethora of ecosystem services to human societies. For the islands of the Caribbean Netherlands, underwater nature has always been one of the pillars of the local economy which depends heavily on tourism. The reef of Bonaire reportedly is one of the best reefs in the Caribbean (Jackson et al. 2014), however since the start of monitoring in the Dutch Caribbean this reef has suffered under many different pressures (Bak and Luckhurst 1980, De Bakker et al. 2016, de Bakker et al. 2017, de Bakker et al. 2019).

4 Ecological aspects

4.1.1 Habitat

There is a very clear distinction between the reefs in the south, the so-called leeward islands, and the reefs in the north, also called the windward islands (Bak 1975). Reef development is much higher in the south along the leeward sides of the islands of Bonaire, Curacao and Aruba. The reefs in the south are quite similar with a gradually sloping terrace to a drop-off at 7-12m depth after which the slope increased to 45 degrees to vertical (Bak 1977, Duyl 1985). A second terrace at 50-60m may be present locally and a second drop-off beyond that. Depending on depth, different coral species can be found at any locality, for example, *Acropora palmata*, or elkhorn coral, generally occurs between 1-4m depth in a zone with strong water movement. *A. cervicornis*, or staghorn coral, generally occurs somewhat deeper, between 4 and 8m depth. Around 10-12m is generally the area with the highest coral growth and diversity. Over the drop-off, coral cover and diversity remain high to approximately 35-40m after which they rapidly decline. As light decreases exponentially with depth, coral colonies become flatter and coral growth decreases.
In the northern area of the Caribbean Netherlands, a large reef complex occurs along the eastern and southern rim of the Saba Bank. Around Saba and Statia corals can be found in varying densities on mostly volcanic underground.

4.1.2 Survival

Corals, having evolved in nutrient-poor waters, depend for their survival on clear and clean water. Living in symbiosis with zooxanthellae, unicellular algae, they are to a large degree dependent on sunlight for their energy. Main threats are therefore often related to water clarity, such as eutrophication and sediment run-off. Other important factors for coral survival are temperature and diseases. Diseases that have had a large impact on coral reefs can be diseases that target corals directly, such as the White Band Disease (Bak and Criens 1981, Gladfelter 1982, Duyl 1985) or the Stony Coral Tissue Loss Disease (Alvarez-Filip et al. 2019), but also diseases that targeted important functional species such as the black sea urchin *Diadema antillarum (Lessios et al. 1984)* which is a crucial grazers of turf and macro-algae. Marine heat waves cause coral bleaching, can have devastating impacts, and are increasing in frequency and severity (Bove et al. 2022). Climate change induced sea level rise is also a threat as reefs may not be able to keep up with rising waters (Perry et al. 2013, de Bakker et al. 2019) and corals end up in deeper water where their growth is even slower.
Coral reefs perform many functions for resident flora and fauna, but also to human societies, where they are called ecosystem services such as the provisioning of food in the form of fish and shellfish, shoreline protection, and opportunities for tourism and recreation. With the degradation of coral reefs, these services are also under threat.

4.1.3 Minimum viable population size

Globally, and even more so in the Caribbean, the survival of coral reefs is in grave peril (Hoegh-Guldberg et al. 2023) and the warming of the oceans appears to be speeding up. Crossing the 1.5 degrees threshold will have devasting effects on ecosystems all around the globe, but particularly for shallow water tropical coral reefs that have evolved in waters with very limited variation in temperature. The IPCC Climate Change 2023 report predicts 70-90% loss of warm water coral reefs at 1.5 degrees heating and more than 99% at 2 degrees heating with high confidence (Core Writing Team 2023).

5 Present distribution and reference values

Of the 65 coral species in the IUCN red list database 19 are critically endangered (***Table 1***), 11 near threatened, 44 least concern, and 2 data deficient (IUCN database accessed 27/06/2024).

Table 1. *Critically endangered coral species according to IUCN.*

Common name	*Species name*
Staghorn Coral	*Acropora cervicornis*
Pillar Coral	*Dendrogyra cylindrus*
Smooth Flower Coral	*Eusmilia fastigiata*
Lowridge Cactus Coral	*Mycetophyllia danaana*
Atlantic Mushroom Coral	*Scolymia lacera*
Maze Coral	*Meandrina meandrites*
Rough Cactus Coral	*Mycetophyllia ferox*
Grooved Brain Coral	*Diploria labyrinthiformis*
Ten-ray Star Coral	*Madracis decactis*
Closed-valley Brain Coral	*Colpophyllia breviserialis*
Elkhorn Coral	*Acropora palmata*
Lamarck's Sheet Coral	*Agaricia lamarcki*
Lowrelief Lettuce Coral	*Agaricia humilis*
Jackson maze coral	*Meandrina jacksoni*
Artichoke Coral	*Scolymia cubensis*
Symmetrical Brain Coral	*Pseudodiploria strigosa*
Massive Starlet Coral	*Siderastrea siderea*
Thin Leaf Lettuce Coral	*Agaricia tenuifolia*
Sunray Lettuce Coral	*Helioseris cucullata*

Next to the Critically Endangered species according to the IUCN, in 2023 the Stony Coral Tissue Loss Disease (SCTLD) has severely impacted the following species: Maze coral (*Meandrina meandrites*), flower coral (*Eusmilia Fastigiata*), great star coral (*Montastraea cavernosa*) and the brain corals (*Pseudodiploria strigosa*, *Diploria labyrinthiformis* and *Colpophyllia natans*) as well as pillar coral (*Dendrogyra cylindrus*) and star coral (*Dichocoenia stokesi*) on Bonaire. It must be feared that all these species are now as well critically endangered and close to extinction (Pepe et al. 2025).
Description of the distribution and community composition of the coral reefs of the Dutch Caribbean (all 6 islands) go back to the early seventies of the previous century (Roos 1971, Bak 1975, Bak 1977, Van der Land 1977, Duyl 1985). Only the islands in the southern Caribbean and the Saba bank harbour fringing coral reefs in the sense that the areas around the islands consist of calcium carbonate bottoms built by corals over thousands of years. The islands of St. Maarten, Saba, and St. Eustatius are characterized by the presence of coral communities that grow on lava outcrops and where calcium carbonate bottom formation is either absent or at best very rudimentary.

6 Assessment of National Conservation State

The status of the coral reefs of the Caribbean Netherlands should be described as extremely unfavorable.

6.1 Trends in the Caribbean Netherlands

Trends of varying length can be constructed with data from different sources for coral cover for each of the three islands. Historical data for coral reefs are generally limited in duration, but for Bonaire (and Curacao) we have access to data that form the longest time-series in the world. The data collection was initiated by Prof. Dr. R.P.M. Bak from the Netherlands Institute of Sea Research and the University of Amsterdam in 1973 (1974 for Bonaire) and is nowadays continued by researchers from Wageningen Marine Research with support from the Ministry of Agriculture, Fisheries, Food Security and Nature. The data are based on images of approximately 9 square meters of reef at 10, 20, 30, and 40m depth at multiple locations on Bonaire and Curacao. On Bonaire the data are mainly from Karpata, one of the oldest diving locations in Bonaire, and by many divers still considered as one of the best locations on the leeward side of Bonaire.

6.1.1 Bonaire: long-term prospects

The four long-term trends in ***Figure 3*** indicate that the reef used to have much higher coral cover in the nineteen seventies. From 30m upward cover by corals was higher than 60%. At 10 and 20m depths, coral degradation started already during the eighties with some recovery at 10m depth during the late nineties but then continued further downward from 2000 to 2010. At 10m some recovery occurred between 2015 and 2022, but in 2023 coral cover again appears to decrease. At 20m depth coral cover decreased more rapidly, bottoming around the end of the previous century, not showing any signs of recovery till this day. At 30 and 40m depth coral cover decreased almost continuously during the last 50 years.

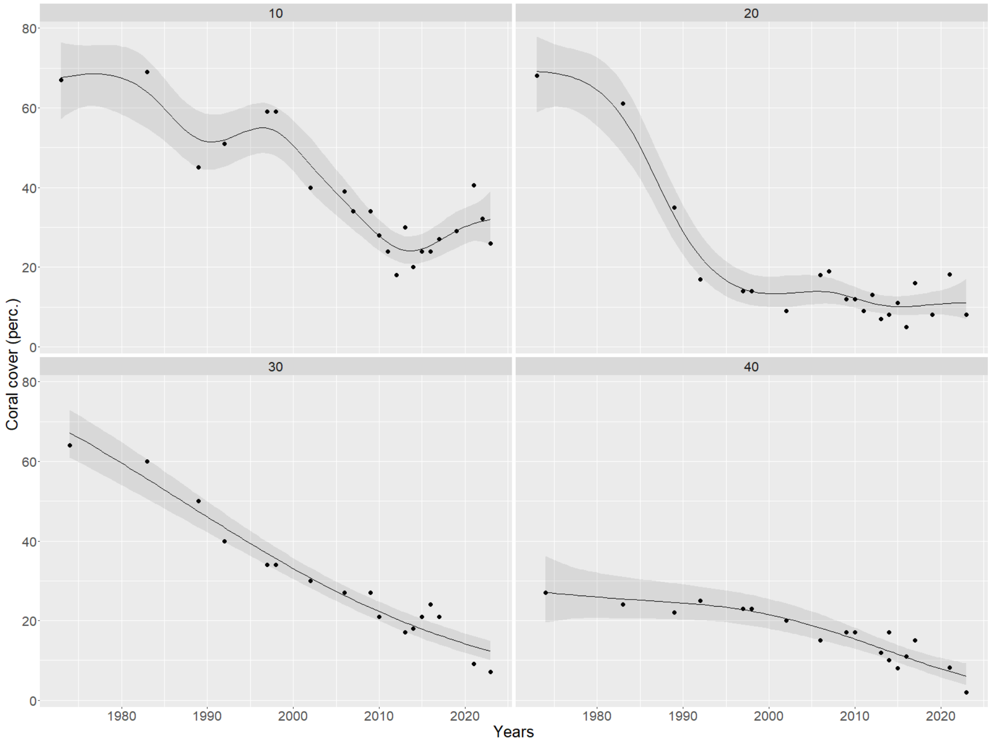

Figure 3. *Long-term trend for Karpata, Bonaire, at 10, 20, 30, and 40m depth. The black line denotes the estimated mean value and the shaded area indicates the 95% confidence interval. Note that the trends do not yet include the effects of 2024.*

6.1.2 Bonaire: area wide prospects

In 2014, the first reef inventory of the entire leeward coast of Bonaire was conducted. Fish and coral communities were assessed at 115 sites at 5 and 10m depth. This survey has now been repeated in 2017, 2020, and 2023 and for 10m depth the data are used to calculate the so-called Reef Health Index (RHI[1]). This index uses 4 important variables and is being consistently used in the meso-American reef area. For each location, a score from 1 to 5 (***Table 2***) is calculated for the amount of coral cover, cover by macro-algae, biomass of herbivorous fish (mainly parrotfish), and the biomass of commercial fish (mainly groupers and snappers) based on pre-set criteria (***Table 2***). Next, the average value per location is calculated to arrive at the RHI value. The average value is assessed as follows: critical, 1-1.8; poor, >1.8-2.6; fair/ok, >2.6-3.4; good, >3.4-4.2; very good >4.2-5. Thus, an RHI value is obtained for each of the 115 locations and an overall mean index is calculated for the leeward reef as a whole (***Figure 4***). ***Figure 4*** shows the mean RHI value based on 115 sites for the years 2014, 2017, 2020, and 2023 only for sites at 10m depth. This is depth that this index is generally meant for as it is the zone where most research in the past has concentrated upon. Overall, the reef of Bonaire at 10m depth appears relatively stable and is judged as still doing ok, but the 2023 value is significantly lower than 2020 and close to becoming bad at the next survey round. The data from 2023 also do not yet include the consequences of the bleaching and disease which were both most pronounced at the end of 2024.

[1] www.healthyreefs.org

Table 2. *Reef Health Index categories. Very good scores get 5 points, good 4 points, fair 3, etc. The final RHI value is calculated by averaging the values of the 4 variables.*

RHI variables	**Very good (5)**	**Good (4)**	**OK/Fair (3)**	**Bad/Poor (2)**	**Critical (1)**
Coral cover (%)	≥ 40	20.0-39.9	10.0-19.9	5.0-9.9	<5
Macro-algal cover (%)	0-0.9	1.0-5.0	5.1-12.0	12.1-25	>25
Biomass herbivorous fish (g/100m2)	≥3480	2880-3479	1920-2879	960-1919	<960
Biomass commercial fish (g/100m2)	≥1680	1260-1679	840-1259	420-839	<420

Table 3. *Mean values (between brackets the limits of the 95% confidence interval) for fish biomass of herbivorous and commercial fish, and cover of corals and macro-algae from 2014 to 2023 for the whole leeward side of Bonaire at two depths. RHI categories for 10m as in* ***Table 2****.*

	2014	**2017**	**2020**	**2023**	**Depth (m)**
Mean biomass commercial fish (g/100m^2)	54 (34; 83)	65 (41; 100)	137 (95; 192)	45 (27; 70)	5
	325 (238; 434)	466 (400; 539)	832 (714; 964)	422 (338; 521)	10
Mean biomass herbivorous fish (g/100m^2)	1547 (1282; 1852)	1448 (1204; 1726)	1492 (1189; 1849)	775 (592; 997)	5
	1769 (1553; 2008)	2332 (2156; 2520)	2712 (2428; 3021)	1841 (1648; 2051)	10
Mean coral cover (percentage)	6.2 (4.6; 8.2)	3.6 (2.4; 5.1)	5.2 (3.8; 6.9)	4.4 (3.1;6.0)	5
	18.7 (16.9; 20.7)	17.3 (14.6; 20.4)	19.6 (16.8; 22.7)	15.4 (13.2;17.9)	10
Mean cover macro-algae (percentage)	0.1 (0.1; 0.3)	1.1 (0.5; 2.0)	0.9 (0.5; 1.6)	0.6 (0.3; 1.1)	5
	1.7 (1.1; 2.5)	4.8 (3.4; 6.6)	4.2 (3.1; 5.5)	4.6 (3.2; 6.4)	10

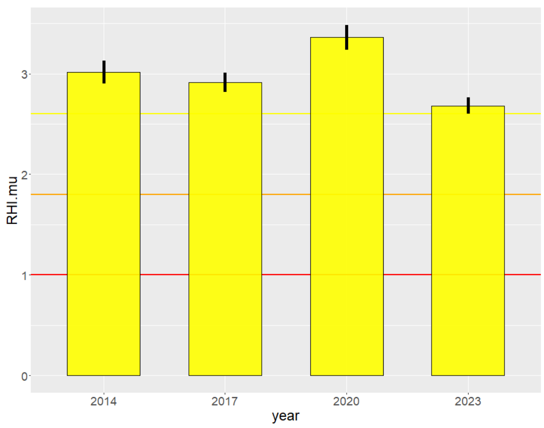

Figure 4. *The average RHI index from 2014 till 2023 for Bonaire at 10m depth. Horizontal lines present the thresholds below which a coral reef is judged as ok, bad, or critical. Each bar is based on measurements from 115 sites on the leeward side of the island.*

Looking at the individual variables for 5 and 10m (***Table 3***) coral cover has decreased from 18.7 to 15.4 over the course of 10 years. At 5m depth coral cover also decreased, from 6.2 to 4.4 percent. Cover by macro-algae is relatively low, but fish biomass is generally in a bad condition. For the commercial fish especially, the values are almost critical. This seems to indicate that the larger predatory fish, groupers and snappers, are under too much pressure, most likely from illegal fishing. Also, all values at 5m are lower than at 10m. This is a common feature for the reef, but this means that on average, values for the whole reef terrace are lower than those found at 10m. Around 10m depth coral cover is generally highest but a value of 15.4% is, from an historical perspective (***Figure 3***), very low and based on scientific research not enough to keep up with sea level rise (de Bakker et al. 2019).

 shows the average index and the distribution of the 115 sites over the different reef health categories from critical to very good. The overall index has decreased in 2023 after being relatively stable from 2014 to 2020 and the number of good and very good sites is decreasing, while the number of sites that qualify as bad and critical has increased.

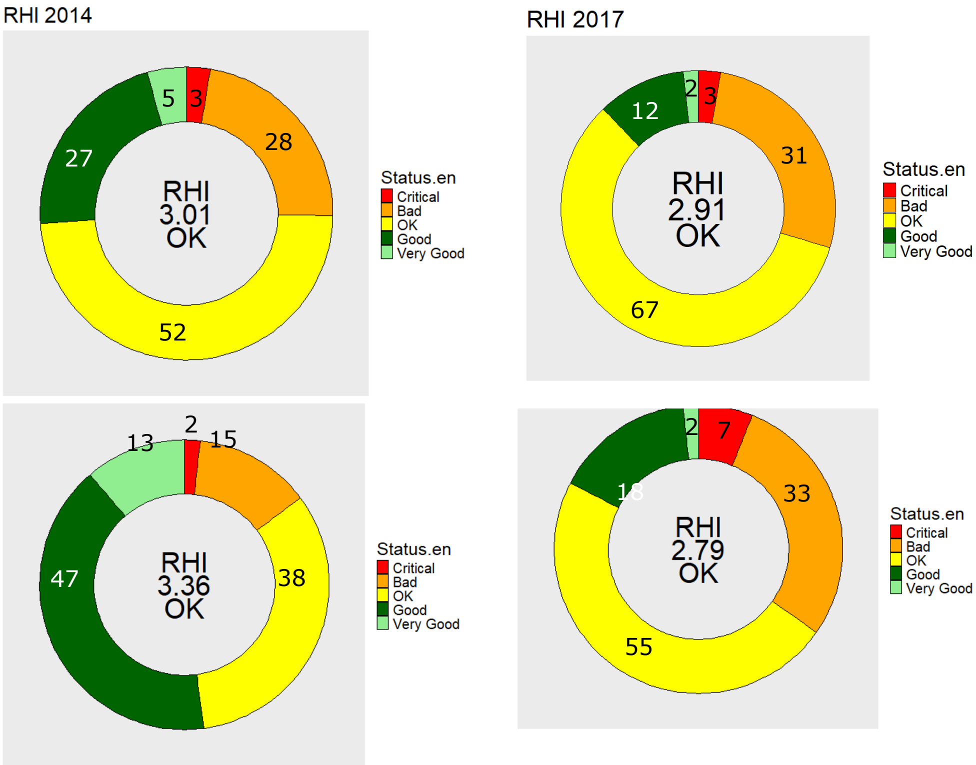

Figure 5. *The data of* ***Table 3*** *at 10m depth visualized. Numbers in the ring refer to the number of sites in the corresponding category.*

6.1.3 Saba

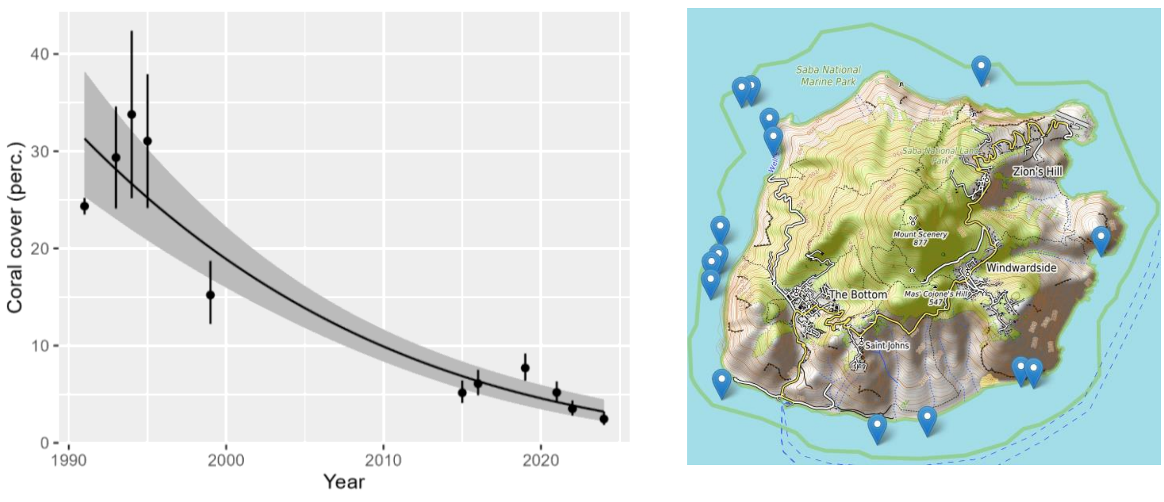

Figure 6. *Average coral cover around the island Saba (left) and a map (©OpenStreetMap) of the different monitoring locations around Saba (right).*

Around Saba coral cover has decreased since the early nineties (***Figure 6***). The amount of cover by algae (turf and macro-algae, see ***Table 4***) is now more than 60%. The most likely causes for this degradation are increased run-off through erosion, bleaching mortality caused by climate change, coral diseases, and eutrophication of the coastal zone potentially aggravated by incidental sewage dumps by passing cruise ships. Passing cruise ships can have 4 times as many passengers as Saba has inhabitants. Under the MARPOL treaty cruise ships allowed to dump organic waste like food and sewage (lightly treated) already 3 nautical miles from land. This may create clouds of nutrient-rich water large enough to bath the whole island.

Table 4. *Cover of main benthic categories on Saba in 2024.*

Benthic category (>1%)	Mean percentage cover (95% confidence limits)
Corals	2.15 (1.63,2.79)
Crustose coralline algae	4.82 (3.31,6.79)
Cyanobacteria	1.01 (0.61,1.6)
Macro algae	33.65 (26.64,41.96)
Sponges	6 (3.94,8.77)
Turf algae	27.94 (22.48,34.33)

The status of the coral communities around Saba should be evaluated as extremely unfavourable.

6.1.4 St. Eustatius

Since the previous State of Nature coral cover in St. Eustatius has not improved. If anything, it has further deteriorated (***Figure 7***). The number of monitoring locations has increased, and monitoring is now yearly conducted by St. Eustatius National Parks (STENAPA). Average coral cover in 2023 is less than 1%, and with 1.5%, somewhat higher in the reserves. Estimated cover for the other important benthic categories is given in the table below. This indicates that more than 50% of the living bottom cover nowadays consists of algae. A notable difference between St. Eustatius and Saba is the cover by turf algae and cyanobacteria which is much higher than on Saba. Cover by macro-algae on the other hand appear to be much lower. Possibly, this is an effect caused by difference in the time of sampling, as cyanobacteria are most abundant in the warmer periods.

Table 5. *Cover of main benthic categories on St. Eustatius in 2023.*

Benthic category (>1%)	Mean percentage cover (95% confidence limits)
Corals	0.89 (0.5, 1.4)
Crustose coralline algae	0.04 (0.01,0.15)
Cyanobacteria	14.2 (8.8, 21.6)
Macro-algae	16.4 (12.1, 21.7)
Sponges	7.5 (5.58, 9.86)
Turf algae	39.3 (32.1, 47.6)

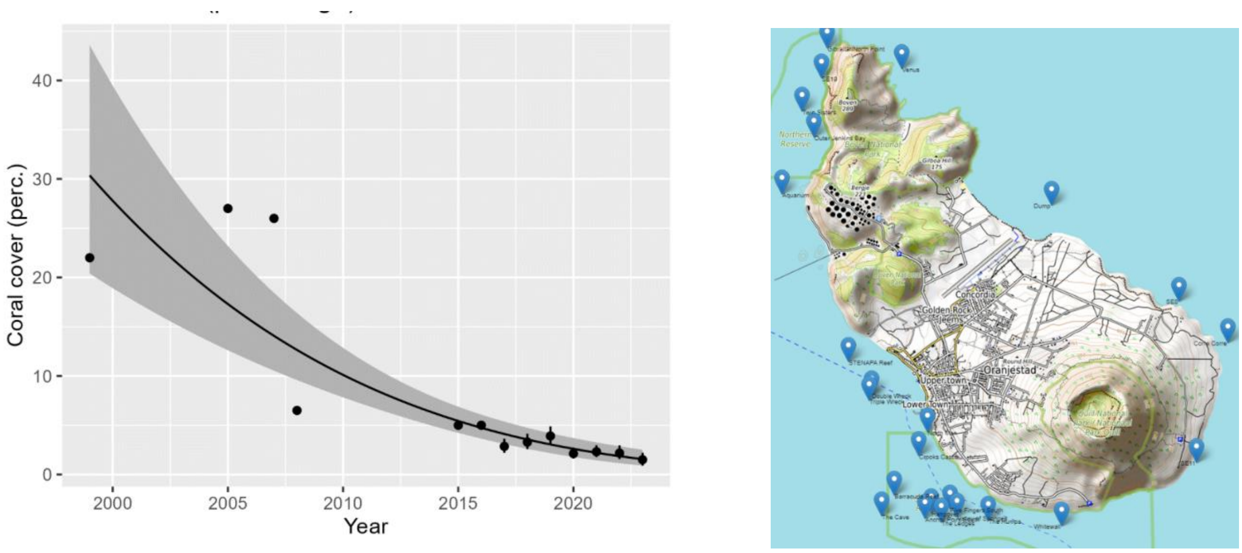

Figure 7. *Average coral cover around St. Eustatius (left) and a map (©OpenStreetMap) of the different monitoring locations around the island (right) and locations of the two marine reserves (green lines). Data used for this graph include only the 15 sites in the northern and southern reserves so the data could be combined with data collected before 2017. The line is the best non-linear fit to the data with the grey band indicating the 95% confidence interval.*

6.1.5 Saba Bank

The Saba Bank has been extensively described in the previous State of Nature (2017). A first expedition happened in 1972 by the Dutch Navy with van der Land (1977). The Saba Bank covers some 2500 km², but the areas of coral reef habitat are approximately 255 km² according to van der Land (1977). In terms of depth there are four main areas that can be distinguished on the bank (***Figure 8***). The eastern half ranges between a minimum depth of 12m and approximately 35m. The western half between 35 and 60m and a northern part that lies below 60m depth. The last part is known as the Luymes bank in the north which may have a very different origin than the rest of the bank.

Figure 8. *Bathymetric map of the Saba bank. Background from ESRI ocean. The islands of Saba and Statia can also be seen in the map.*

The Saba Bank has been visited occasionally by researchers and given the size of the bank, there is only limited quantitative data. Since 2010, there have been expeditions to the bank to investigate the status of the corals and fish at 10 locations. An overview of the coral cover from the reports and scientific literature is given in ***Figure 9***. This figure also indicates events that likely led to the large decrease in coral cover. Especially, hurricane Lenny and two periods of very warm sea water are probably the main causes of the observed decline.
Although the Saba Bank may hardly be affected by pollution from land due to its location, the data also show a drastic decline in coral cover. Most likely, periods of extremely warm seawater are the main reason for this decline on the Saba Bank. New data are being collected in 2024 and will be available in 2025, however, given the fate of corals on Saba and Statia it must be feared that coral cover on the Saba Bank has also further declined.

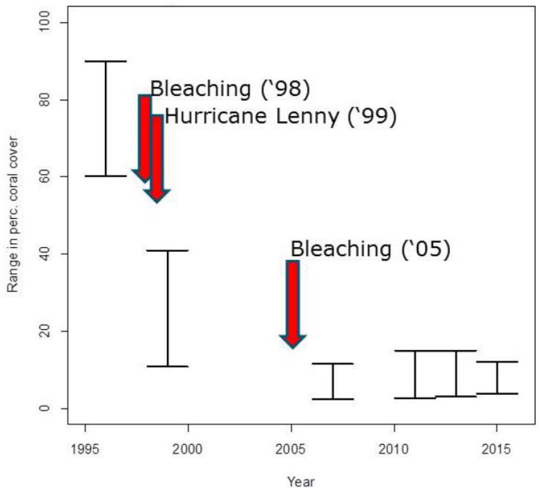

Figure 9. *Reported minimum and maximum values of coral cover on the Saba bank. (Data 1996, (Meesters et al. 1996); 1999, (Klomp and Kooistra 2003), 2007; (Toller et al. 2010); 2011 en 13, (Beek and Meesters 2013)).*

An extensive study on the different habitats on the Saba bank (Meesters et al. 2024) has resulted in a map of the most likely distribution of habitats over the bank (***Figure 10***) based on machine-learning techniques. From this analysis it becomes clear that the coral reef area of the Saba bank constitutes by far the largest continuous reef area of the Dutch Caribbean (***Table 6***). Therefore, its preservation and management is of international importance.

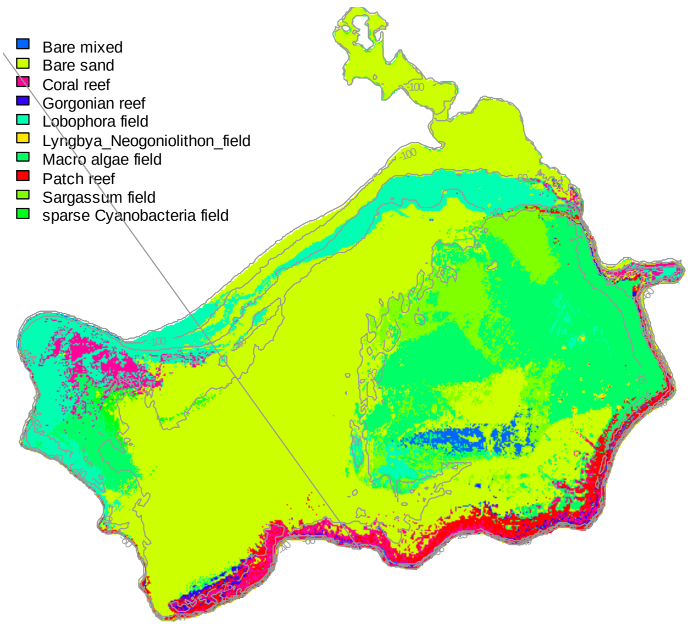

Figure 10. *Habitat prediction of the Saba bank based on the weighted K Nearest Neighbour analysis using data extracted more than 2000 georeferenced images from the bank.*

Table 6. *Approximate areas of the different habitats on the Saba bank.*

Habitat	Estimated area (km^2) based on Weighted K Nearest Neighbor analysis
Bare sand with mixed algae	26.65
Bare sand	1108.19
Total sand	**1135**
Coral reef	84.89
Gorgonian reef	14.79
Patch reef	86.18
Total reef	**186**
Lobophora fields	240.94
Macro algae fields	412.51
Sargassum fields	150.77
Total algae	**804**
Neogoniolithon-Lyngbya habitat	3.17
Cyanobacteria fields	13.31

7 Assessment of Future Prospects

The outlook for coral reefs around the world is looking grim (Core Writing Team, 2023). Under current emission trajectories exceeding 1.5 °C in temperature increase is more and more becoming a realistic possibility (Möller et al., 2024) increasing the probability of triggering climate tipping points (Armstrong McKay et al., 2022). For the Caribbean coral reefs the situation may even be worse as there is limited functional redundancy since there are much less coral species in the Caribbean than for example in the Indo-Pacific (McWilliam et al., 2018). Furthermore, the Caribbean Sea is surrounded by densely populated countries and islands with limited possibilities to reduce their impact on the marine environment. At the same time global pressures are increasing as a result of climate change. Marine heatwaves in the Caribbean are predicted to increase in duration and intensity to such an extent that by 2100, heat wave conditions may have become very common (Bustos Usta et al., 2024). This is likely to also increase hurricane intensity and frequency. The year 2023 was the warmest on record, and 2024 is headed to surpass 2023 (**Figure 1** and ***Figure 2***). During 2024 sea surface temperatures remained much warmer than average and bleaching of corals (***Figure 11***) is predicted to continue till the end of 2024 which will cause additional coral mortality. In September 2023 the world global temperature reached 1.5 degrees Celsius-increase above pre-industrial levels (1850-1900) (Copernicus, 2023) and there are no signs that our CO_2 emissions are decreasing. For Bonaire specifically the threats appear to be mounting as the population, now around 24 thousand, is estimated to grow to 30 to 50 thousand in 2050 (CBS, 2023) and 80% of sewage produced on the island is estimated to enter the coastal zone through non-working septic tanks and cesspits and not through the sewage treatment plant (Haskoning, 2023). Even at the governmental level the environmental risks of further population growth is not acknowledged, as the governments of Bonaire and the Netherlands have agreed to facilitate further growth of the population (Rijksoverheid, 2024). Population growth has always been one of the strongest indicators of reef degradation, mostly linked to a decrease in water quality (Cramer et al., 2020). Together with rising sea levels, increasing sea water temperature and acidification, water quality is likely to seal the fate of Bonaire's reef. Only a policy directed at improving water quality and limiting terrestrial runoff together with strict enforcement and combined with active restoration of corals and herbivores may be able to improve the condition of Bonaire's reef (van der Geest et al., 2020). But even then, the outcome is unsure in the face of failing international attempts to halt climate change. However, not to act should not be an option, given our responsibility towards future generations.

8 Comparison to the 2018 State of Nature Report

Overall, the CS of the coral reef habitats of the Caribbean Netherlands has measurably worsened compared to the 2018 assessment (Debrot et al., 2018), especially due to climate change effects and the effects of the Stony Coral Tissue Loss Disease.

Table 7. *Overview of the status of the coral reefs of the Caribbean Netherlands with respect to different ecological aspects.*

Aspect coral reefs	**2024**
Distribution	Favourable
Surface area	Favourable
Quality	Unfavourable-inadequate
Future prospects	Unfavourable-bad
Overall Assessment of Conservation State	**Unfavourable-bad**

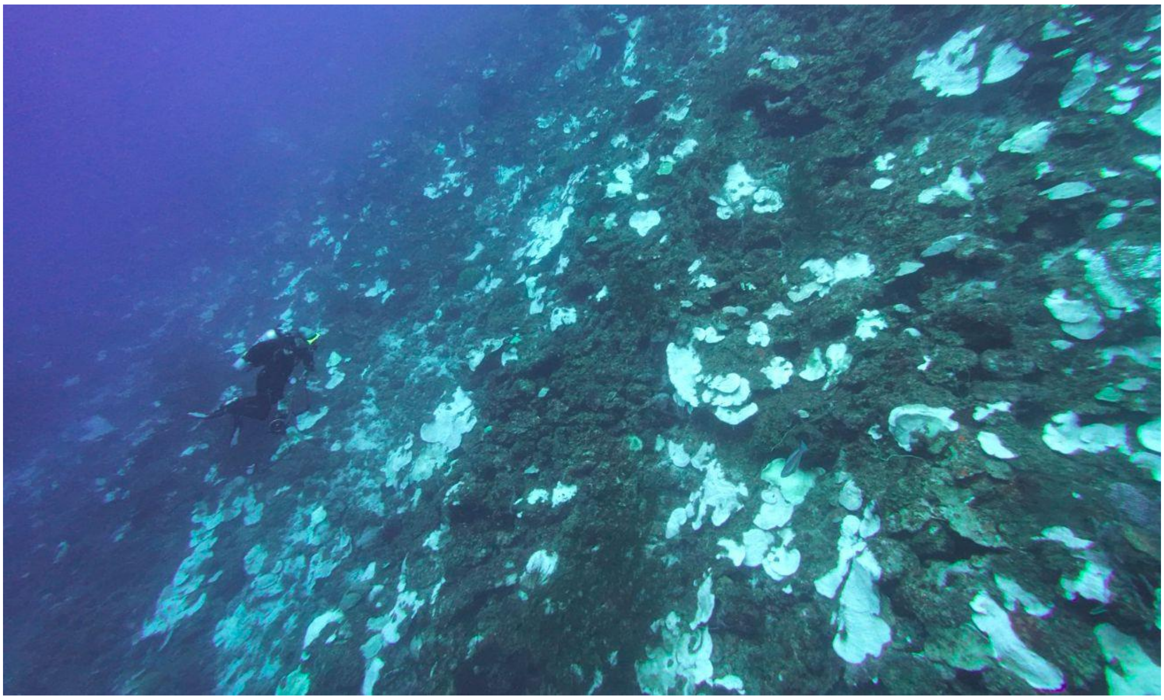

Figure 11. *Bleaching in November 2024. Image by T. Kemenes van Uden.*

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9 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. The organisation has been certified since 27 February 2001. The certification was issued by DNV.

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

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