

28 The Climate Change Threat to Biodiversity in the Caribbean Netherlands

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Introduction

Climate refers to the average weather conditions (temperature, humidity, air pressure, wind, cloud cover, and precipitation) over a specific period. Climates are not stable and change under both natural and anthropogenic influences (KNMI, 2016; KNMI, 2023). The warming of the climate system is unequivocal, and the changes observed since 1950 have been unprecedented for decades to millennia. The last ten years make up the top ten hottest years on record of the Earth's surface. By 2024, the global average temperature has increased by more than the Paris policy target of one-and-a-half degree Celsius for the first time above pre-industrial level (Copernicus, 2025). Most of the heat is absorbed by the oceans, resulting in thermal expansion which is one of the factors leading to rising sea levels (Widlansky et al., 2020). The current sea-level rise in the Caribbean is 3.40 ± 0.3 mm/year (1993–2019), which is similar to the 3.25 ± 0.4 mm/year global mean sea-level (1993–2018) (Maitland et al., 2024). The world's oceans will continue to warm, with the heat reaching the deep sea and affecting ocean circulation (Van Westen et al., 2024). The atmospheric concentration of carbon dioxide, methane, and nitrous oxides is higher than at any point in the past 800,000 years. Due to the absorption of 30% of human-emitted carbon dioxide (from fossil fuel emissions and land use changes), the ocean has become more acidic and will continue to acidify. On a global scale, the contrast in precipitation between wet and dry regions will further increase (IPCC, 2022).

Current Climate

The Caribbean climate can be characterized as a tropical climate with dry and wet seasons. Storms and hurricanes are the primary sources of rainfall, with significant local differences due to elevation and topography. The windward islands (St. Eustatius and Saba) have a tropical monsoon climate with a wet late summer and autumn. The average daily temperature is around 30 degrees Celsius. The leeward island (Bonaire) has a tropical arid climate. Annual and local climate variations can be significant.

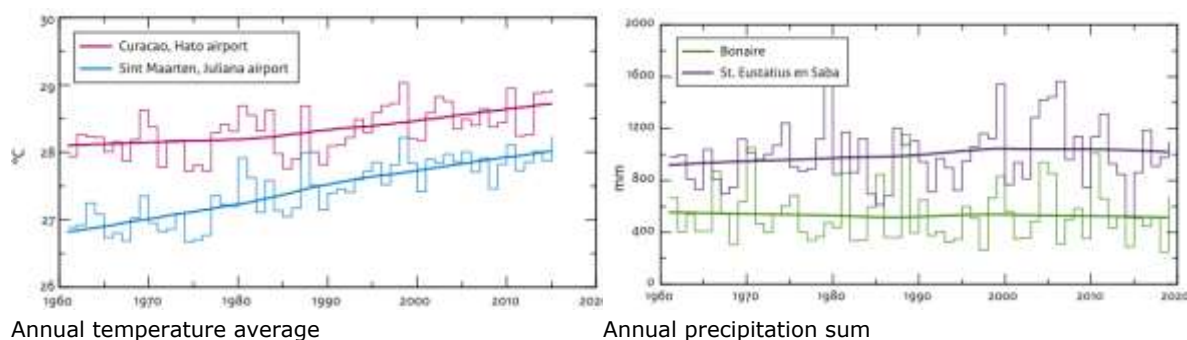


Figure 1. Observed trends of temperature and precipitation (KNMI, 2021).

Long-term trends are observed via weather stations in the vicinity of the Dutch islands, via Curaçao as representation of Bonaire (leeward islands), and via St. Maarten as representation for Saba and St. Eustatius (Windward islands) (Figure 1). Every 10 years, the average temperature has increased by 0.15 degrees Celsius for the Leeward islands and 0.23 degrees Celsius for the Windward islands. Since the 1960-ies annual precipitation patterns have varied, but without any derivable statistical trend (KNMI, 2021). Annual variations in weather in the Caribbean vary and are strongly influenced by recurring events like El Niño and La Niña. KNMI (2023) illustrates this annual deviation of the long-term average in Figure 2. Based on the long-term trend, projections have been made.

Caribbean Netherlands

The weather in the Caribbean in 2023 was strongly influenced by La Niña, which ended around March, El Niño, which developed from April onwards, and the extremely warm North Atlantic. During El Niño (see page 13), the Caribbean typically experiences less rainfall, more wind and fewer hurricanes. However, the warm North Atlantic can actually cause more rainfall and hurricanes. In Europe and globally, 2023 was the warmest year on record. This was not the case in the Caribbean, mainly due to colder temperatures in the early months of the year under the influence of La Niña.



Figure 2. Deviation of weather parameters of the year 2023 from the long-term average (1991-2020). In 2023, the dry season (December-April) was wetter and colder than the long-term average, while the wet season was dryer and warmer for all Dutch islands in the Caribbean (KNMI, 2023).

Anthropogenic Influences on Climate Change

Greenhouse gas emissions from small islands are negligible compared to total global emissions, but the threats from climate change, sea-level rise, and global warming are significant for those same small islands. In recent decades, human use of land and sea has intensified considerably. Many small islands in the Caribbean have experienced coastal erosion, negatively affecting buildings, amenities, infrastructure, agriculture and the (natural) vegetation.

Projected Climate Change

KNMI (2023) projects a rising temperature (1 to 3.5 degrees Celsius) for 2100, increasing average windspeed and decreasing precipitation (0 to 48%), especially in the dry season (December – April) (Figure 3). The median of the projections (2081-2100) for temperature increase is 1.4 degrees Celsius, a 5% decrease in precipitation, and a sea-level rise of 0.5 to 0.6 meters for the RCP 4.5 scenario (a comparatively low emission scenario) (KNMI, 2024). Figure 3 shows the historical trends of

temperature and precipitation projected into the future. For all islands, the climate is projected to become warmer and dryer (KNMI, 2023).

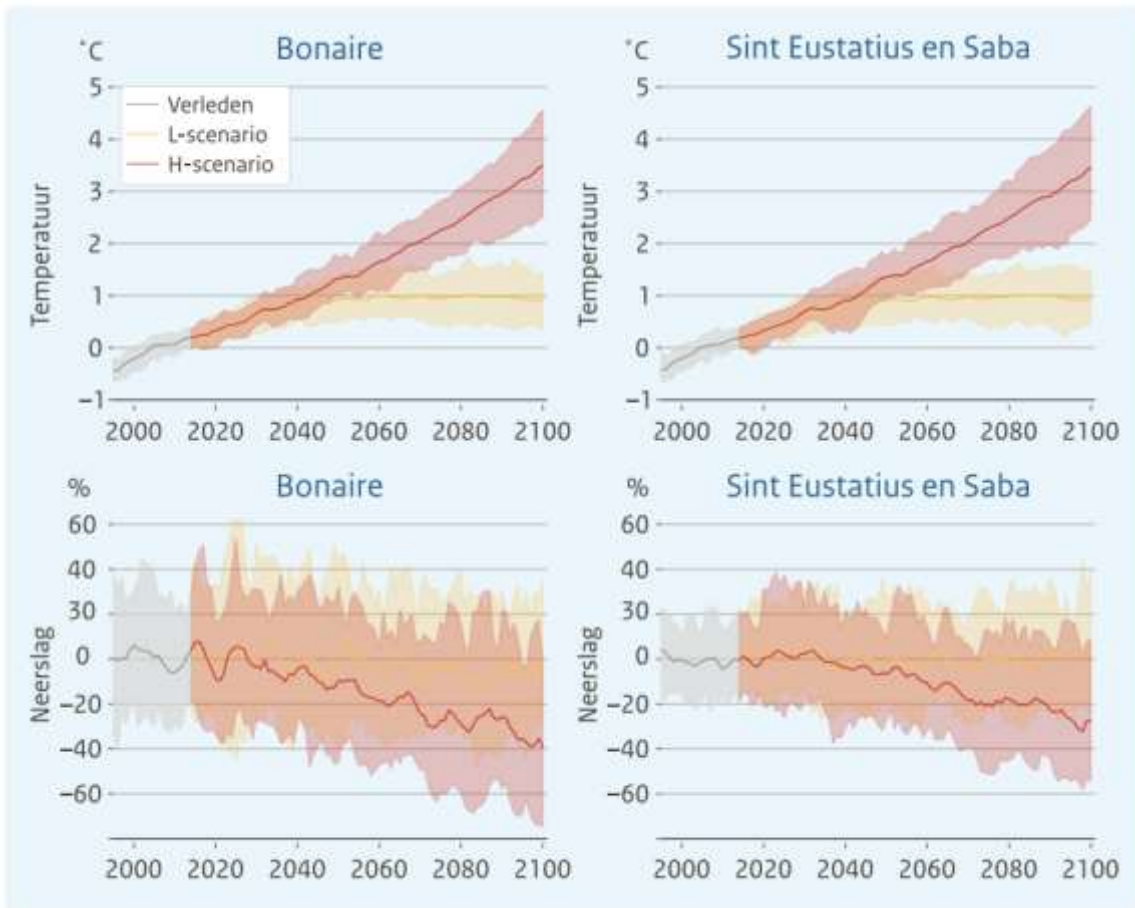


Figure 3. Projected precipitation and temperature for Bonaire, St. Eustatius and Saba (KNMI, 2023).

The Dutch Leeward islands are located outside the hurricane belt, resulting in significantly fewer hurricanes than on the windward islands (Figure 4).

Climate Risks

Because small islands have close connections between the settlements and coastal environments, they are particularly exposed to climate hazards associated with the ocean and water cycle, including sea-level rise (and surges), tropical cyclones, marine heatwaves, and ocean acidification (Thomas et al., 2020; Nurse, 2014). Human influence closely impacts climate vulnerability: for example, poor land management has greatly influenced erosion, increasing the vulnerability of natural areas, agro-ecological systems and waterways to climate hazards, such as heavy rainfall. Due to the mix of changes, it can sometimes be difficult to attribute specific effects to a specific cause (IPCC, 2022). The effects of climate change will be most significant where the natural environment is already under pressure from human activities (IPCC, 2022; Bijlsma et al., 1996). Climate change poses a serious threat to the sustainable development of the countries in the Caribbean community (CARICOM) and may even jeopardize the long-term existence of those countries (CCCCC, 2009). Figure 5 illustrates the observed effects of climate change on small tropical islands and biodiversity hotspots. Climate risks for the Dutch Caribbean include loss of livelihoods, damage to coastal settlements and infrastructure, loss of ecosystem services and ultimately risk of loss of economic stability. Specifically for nature climate change poses a risk to coral reefs.

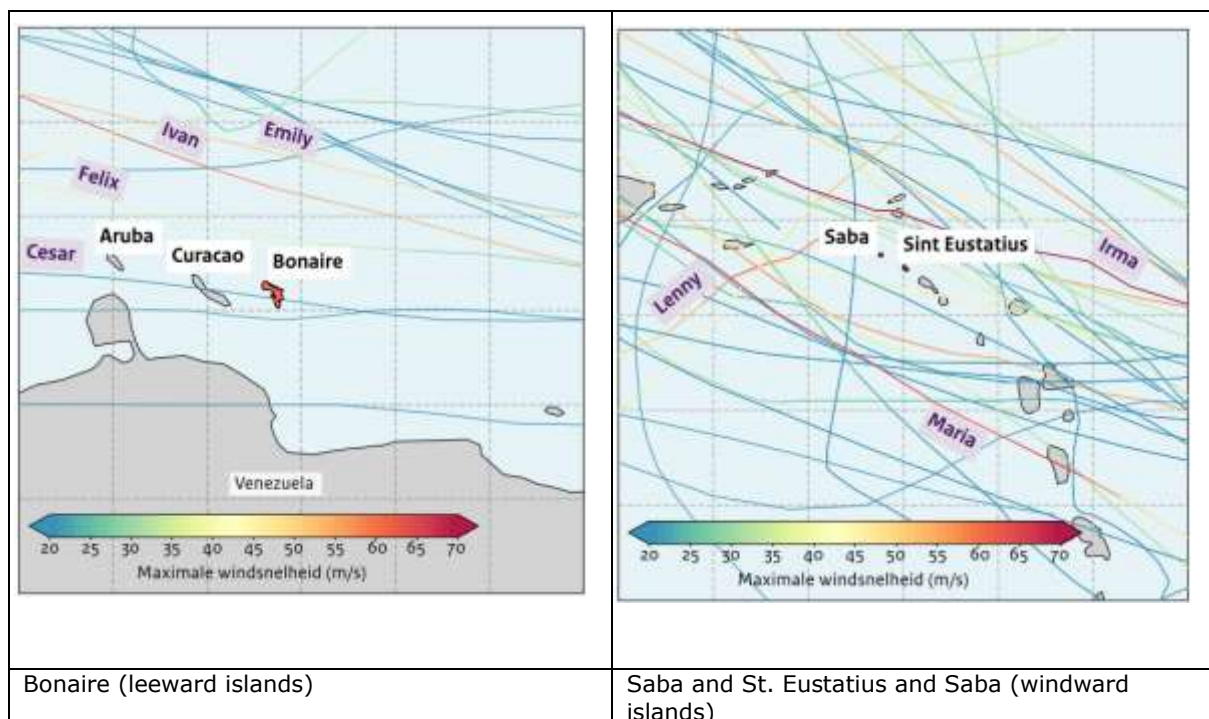


Figure 4. Hurricanes with windspeeds over 18 m/s within a 250 km radius between 1981-2020 (KNMI, 2021).

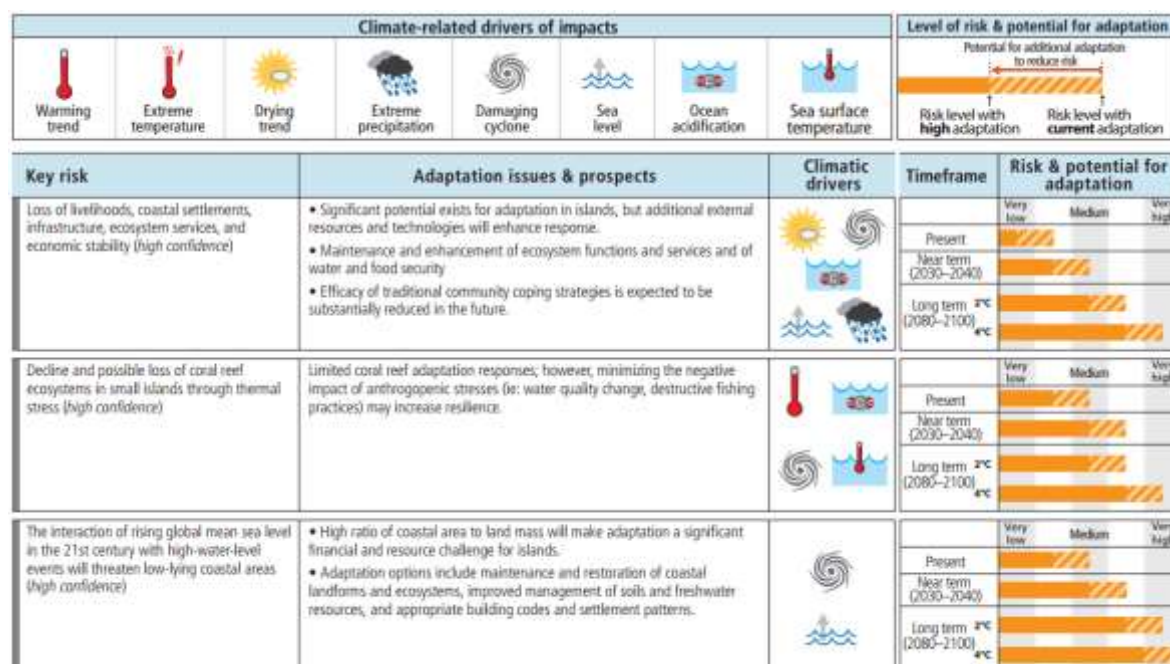


Figure 5. Climate risks for small islands (Nurse et al., 2014).

Impacts of Climate Change Within the Caribbean

The climate affects all natural systems and the functions they provide that are important for the Caribbean Netherlands (see Figure 6), including:

Coastal effects – Barrier coral reefs are dying due to warmer and more acidic seawater (coral bleaching) (Frieler et al., 2013). Additionally, the intensity of extreme storms that damage coral reefs,

mangrove forests, and seagrass beds is increasing. A potential shift or widening of the hurricane belt to the south would also increase hurricane/storm risks for the leeward islands of the Dutch Caribbean.

Fisheries – The deterioration of coral reefs as fish habitat negatively impacts the entire food chain, including important commercial fish species such as snappers (Bari and Cochrane, 2011). Shifts in migration patterns of key deep-sea fishery target species due to warming ocean water could also have negative effects.

Exotics and pests – A warmer and more humid climate provides favourable conditions for mosquito populations (and the associated risk of related diseases such as West Nile virus, Dengue Fever (Mokhtar, 2024) of which the Antilles experienced an outbreak around 2010 and in 2023, Chikungunya, and Zika) and increases the likelihood of foodborne infections (e.g., Salmonella) and animal infections (e.g., Lyme) (EPA, 2014; de Hamer, 2015).

Mass stabilization and erosion control – Coral bleaching leads to coral death, and corals then no longer produce sediment. An increase in the intensity of storms, and possibly their frequency (more uncertainty exists regarding the latter), will erode coasts and beaches (Esteban et al., 2009). Healthy vegetation holds soil in place; at the coast, but also inland. An increase in extreme drought and rainfall will affect vegetation health and increase erosion.

Biodiversity – The islands are part of the international Caribbean biodiversity hotspot based on species richness and the presence of endemic species (Myers et al., 2000; Roberts et al., 2005) but face significant and increasing human pressure. This includes coral reefs, seagrass beds, mangrove forests, salt flats, cactus landscapes, and cloud forests. All habitats are strongly influenced by the climate; for instance, rainforests and cloud forests are sensitive to extreme drought and damage from severe storms (van 't Hof, 2010). Sandy beaches are warming, causing sea turtle eggs to become too hot to hatch, and causing changes in sex ratios to occur. Also, sandy beaches disappear underwater due to rising sea levels, resulting in the loss of nesting habitat for sea turtles (Laloë et al., 2016; Patino-Martinez et al., 2014; Fish et al., 2005). Hurricanes can decimate the island populations of endangered or vulnerable species (Van den Burg et al. 2022; Rivera-Milán et al., 2021). Furthermore, climate change and deteriorating habitat conditions create more opportunities for invasive species to establish themselves (Winkel, 2003). Finally, because in the tropics temperatures are already closer to the lethal maximum for most higher life forms than in temperate and polar regions, such areas are also believed to be more sensitive to the effects of global warming (Calosi et al., 2008; Gutiérrez-Pesquera et al., 2016; Diamond, 2017). Major species shifts can be expected.

Tourism – Rising temperatures, an increased likelihood of severe storms, and dead or deteriorating coral reefs, cactus landscapes, rainforests, and cloud forests, along with diminishing (coral) sandy beaches, make the area less attractive as a tourist destination. The current impacts of climate change on the nature and biodiversity of the Dutch Caribbean islands are summarized below based on the categories by Nurse (2014):

- Loss of coastal habitat (quality) – very unfavourable
- Coral bleaching – very unfavourable
- Elevation shifts in cloud forest – moderately unfavourable
- Acidification of surface waters – moderately unfavourable
- Deterioration of groundwater – moderately unfavourable
- Coastal erosion – moderately unfavourable
- Declining coastal fish catch – moderately unfavourable
- Loss of terrestrial habitat quality – moderately unfavourable.

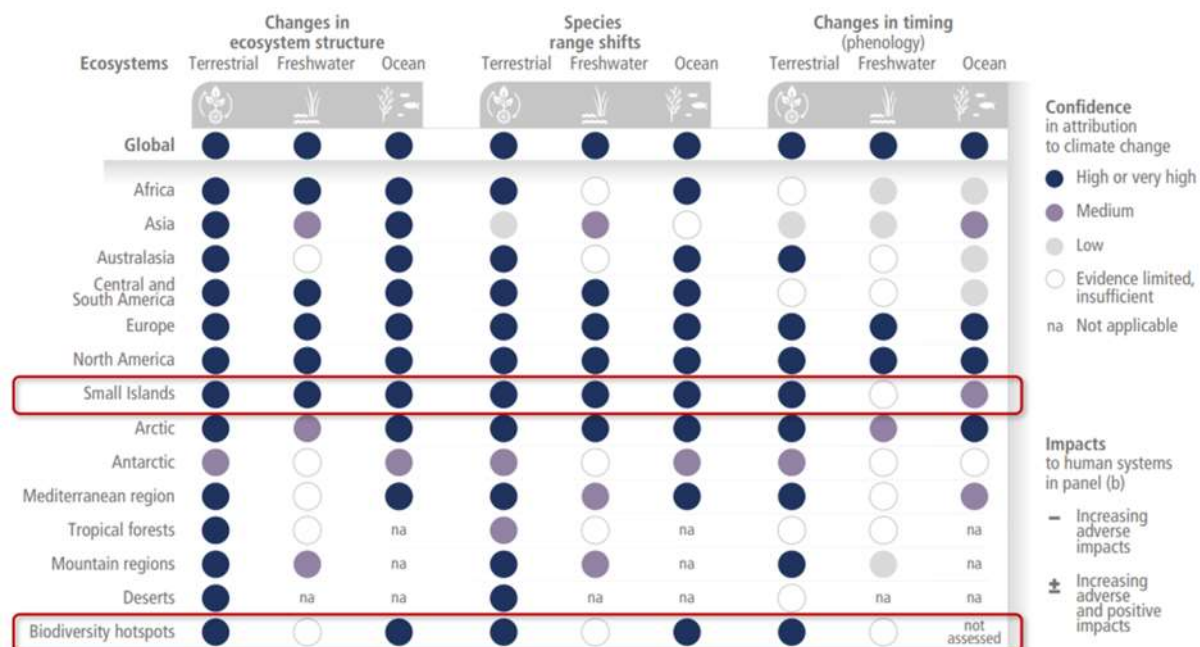


Figure 6. Observed Impacts of Climate Change on ecosystems (IPCC, 2022). Small island and biodiversity hotspots, both characterising the Dutch Caribbean islands, are highlighted with a red circle.

Assessment of Future Prospects

For the future, the islands face a high risk regarding the categories mentioned above (see also *Table 1*). Even optimistic scenarios about climate change (RCPs) and biological evolutionary adaptation predict dramatic prospects for coral reefs (Frieler et al., 2013; Lindeboom and Jackson, 2016), cloud forests, and rainforests.

Many of the effects of global climate change are beyond the control of small island nations. In the Caribbean, the largest costs are associated with storm damage, loss of tourist revenue, and damage to infrastructure. The impact of hurricanes Irma and Maria in September 2017 is illustrative of the size of potential damage. The Netherlands prepared 550 million euros for the Island of Sint Maarten in 2017 (Algemene Rekenkamer, 2018). Smaller occurrences, such as the recent floods in Kralendijk are illustrative (see box) of a high exposure to flooding in the built environment and coastal areas.

Annual costs for the Caribbean region are estimated at USD 22 billion around 2050 and USD 46 billion around 2100, which represent 10% and 22% of the total Caribbean economy, respectively. It is important to note that these figures pertain only to the three largest damage categories resulting from

climate change, assuming no action is taken (Bueno et al., 2008). The results regarding threat status are summarised in Table 2.

Table 1. Expected climate risk to natural and human systems.

	Climate change impact (11)	Risk at 1°C (17)	Risk at 1.5°C (17)	Risk at 2°C (17)
Ecosystem				
Coral	Negative	H	VH	VH
Coastal wetlands	Negative	M ^a	H ^a	H ^a
Mangrove	Negative	U	M	M
Human system				
Fisheries	Negative	M	H	VH
Tourism	Negative	U-M	M	M

^aThe specified data use coastal flooding risk provided in Reference 17.

Abbreviations: H, high; M, moderate; U, undetectable; VH, very high. (11, 17).

Table 2. Summary overview of the threat status of climate change to biodiversity of the Caribbean Netherlands via habitat impacts and Future prospects.

Aspect Climate Change	2024
Habitat	Unfavourable-bad
Future prospects	Unfavourable-bad
Overall Assessment of Threat Status	Unfavourable-bad

Heavy rainfall and climate change on Bonaire – flood event November 2022

Bonaire – one of the Dutch Caribbean islands – experienced heavy rainfall in November 2022. This event led to flooding in the urban area of Kralendijk and damaged the coral reefs in the Marine Park surrounding the islands. Extreme weather events and their subsequent impacts add to the many challenges the island is already facing, managing tourism and influx of new inhabitants, high erosion rates, rapid urban expansion, wastewater management, and reversing the degradation of terrestrial and marine ecosystems. The outlook of climate change - changing weather patterns and sea level rise – underpins the urgency to start working on climate resilience in Bonaire.

Bonaire is situated in the so-called Southern Caribbean Dry Zone and is characterized by a semi-arid to arid climate, with a distinguishable dry and rainy season, and sustained moderate easterlies (Caribbean Meteorological Department Curaçao, n.d.; Verweij et al., 2020). The dry season runs from February till June, whereas the rainy season starts in September and ends in January. The months of July and August can be considered as transitional months. During the rainy season, rain showers occur usually during the early mornings or early to late evening hours (Meteorological Department Curaçao, n.d.; Schmutz et al., 2017).

From June to November, but especially from August to October, Atlantic tropical cyclones pose a significant threat to communities in the Caribbean. True hurricanes are relatively rare at the latitudes of Bonaire compared to the rest of the Caribbean, as Bonaire is situated on the southern fringes of the

Atlantic hurricane belt. However, hurricanes passing by at relatively short distance, and less-intense tropical storms and depressions and the associated hazards of heavy rainfall and large swells can still cause significant damage on Bonaire (Bries et al., 2004; Scheffers and Scheffers, 2006).

Neglecting the natural environment in the future development of Bonaire will exacerbate many of these issues but also misses an opportunity to let nature aid Bonaire in its societal challenges. Instead, restoring the natural environment can improve the climate resilience of Bonaire while simultaneously addressing several key issues like biodiversity loss and flood security. The concept of using nature to enhance resilience is known as 'Nature-Based Solution' (NbS). Tackling urban flooding and the impact of heavy rain on the Marine Park requires an integral approach with hybrid solutions. NbS implementations can support in ameliorating flood resilience on Bonaire. A study on NBS concluded that restoring and revitalizing the natural system on Bonaire has potential (De Boer et al., 2023).



Runoff over the coral reefs near Kralendijk (Bonaire) after heavy showers (Photo: Caspar Douma, 8 November 2023)

Recommendations for National Conservation Objectives

The vulnerability of natural and human systems to climate change must be reduced within the Caribbean Community (CARICOM countries) (CCCCC, 2012). By removing anthropogenic stressors, ecosystems become more resilient and better able to withstand climate change (IPCC, 2022). The NEPP for the Caribbean Netherlands (Min. LNV et al., 2020) states: "It is not possible to influence climate change from the islands; however, it is possible to improve the resilience of ecosystems so that they can better withstand changes and minimize the consequences." The key sectors for conservation policy are spatial planning and terrestrial and marine nature conservation policy (Debrot and Bugter, 2010), by interweaving nature in all sectors (i.e. 'Nature Inclusive', Verweij et al., 2020), as well as building regulations, maintenance and restoration of coastal areas, habitats, and improved management of soil and freshwater resources (IPCC, 2022).

The Kralendijk Declaration (2016) confirms that the communities of the Caribbean region are threatened by the combined effects of climate change along with ecological degradation resulting from local human activities:

- The Caribbean coasts will face the consequences of more frequent and intense storms and rising sea levels.
- Caribbean landscapes and cultural heritage will be impacted or even destroyed by a combination of poor management and coastal erosion.
- Coastal ecosystems are one of the most important (economic) resources for the livelihoods of Caribbean communities. Population development and the associated pressure on ecosystems, combined with climate change, require a re-evaluation of how people live and utilize the coast.

- Environmental disruption from increasing coastal development, climate change, and rising sea levels will negatively affect tourism, which is the primary source of income for many Caribbean islands.

Climate change can often be viewed as an additional pressure factor on top of other pressures, many of which are caused by human activities. Solutions must therefore be developed in conjunction with these other factors.

Key Threats and Management Implications

Coastal Protection Through Spatial Planning

Rising sea levels and increased intensity of tropical storms pose a direct threat to all coastal human constructions (Min. HEN, 2014). Additionally, these infrastructures disrupt the proper functioning of natural coastal protections such as reefs and mangroves, and they destroy the coastline as a green-blue connection zone that many animals depend on for survival, such as land crabs, hermit crabs, and freshwater shrimp. A spatial policy aimed at implementing a coastal development set-back from the shoreline (setback policy) has numerous economic and ecological benefits (IUCN, 2007; Debrot and Bugter, 2010).

Increased Resilience of Ecosystems by Maintaining or Strengthening Connections Between Ecosystems

Healthy ecosystems have a higher resilience to the pressures of climate change. An ecosystem encompasses all habitats necessary for communities of organisms in all their life stages. Furthermore, these habitats need to be large enough and connected to each other to function effectively (Soule and Simberloff, 1986). A coherent system of nature reserves with connection zones contributes to greater resilience and robustness of systems (van der Sluis et al., 2004) and allows species to adapt their range to changing climatic conditions and vegetation zoning (Cormont, 2011; Vonk et al., 2010).

Reduced Erosion Through Reforestation and Protection of the Food Web by Combating Overfishing

Warmer and more acidic seas make coral sensitive to bleaching and mortality. Coral is vital for coastal defence by serving as wave breakers, generating sediment supply, providing habitat for fisheries, and supporting dive tourism. Additional stressors, such as suffocating erosional materials from land, nutrient enrichment from wastewater (Gast et al., 1999; Duyl et al., 2002; Slijkerman et al., 2011), or disruption of the food web balance due to overfishing (Roberts, 1995; Coblentz, 1997), make coral reefs more vulnerable to the effects of climate change.

Sensitivity to erosion is determined by many factors such as geology, terrain slope, rainfall levels but in wilderness areas is primarily exacerbated by free-roaming livestock (goats, donkeys, cattle, and chickens) (de Freitas et al., 2005; Debrot et al., 2013; Coolen, 2015), which destroy soil-holding vegetation while simultaneously causing mechanical erosion. The hardening of the substrate (buildings, (semi-) paved roads) accelerates water runoff, leading to increased erosion, especially in combination with poor drainage, such as a lack of water buffering areas and flow-reducing systems. Free-roaming livestock also creates opportunities for invasive species (such as Coralita and Rubber vine) to establish themselves and weaken the health of terrestrial ecosystems. Smith et al. (2014) provide comprehensive advice on how to curb the spread of invasive species, including border controls, a mandate to remove invasive species (on private land), making resources available for action, and monitoring for early intervention.

Reforestation of damaged areas counters erosion and offers a chance for ecosystem recovery. Recent reforestation efforts in Curaçao and (Klein) Bonaire have been successful (Debrot, 2009). A reforestation plan has been proposed for Saba (Debrot, 2006).

Overfishing has resulted in the disappearance of (endangered) large grouper (Toller et al., 2010), creating a niche for invasive species such as the Lionfish, which is now spreading across all islands

(Debrot and Bugter, 2010). In addition to the existing ban on spear fishing, a control mechanism could be implemented for the amount of fish caught, fishing methods, and the species and size limits.

Data Quality and Completeness

The climate is a global system with regional differences. Local data has been used for the current situation. The KNMI (Royal Netherlands Meteorological Institute) monitors meteorological data in the Caribbean Netherlands. The scenarios for the future come from global models that have been specified for island regions such as the Caribbean (Nurse et al., 2014). Bugler et al. (2017) warn that higher resolution can be misinterpreted (more precision does not necessarily mean more accuracy). However, downscaling increases overall uncertainty. As part of the PRECIS project (Providing Regional Climates for Impact Studies), Tailor et al. (2013) are working on a Caribbean regional model that may provide more reliable detailed predictions for the Caribbean in the future. This method is being applied in regional training workshops. Besides the official meteorological stations on the islands, also numerous personal weather stations that are openly available can be used as a data source for event analysis (De Boer et al., 2023).

The climate has usual episodes of extreme weather phenomena. Annual measurements of climate parameters (temperature, precipitation, number of cyclones, etc.) are not a direct representation of the climate. For management, it is effective to monitor effect indicators: species and habitats. However, the number of monitored indicators is low, making it difficult to make quantifiable statements. Verweij et al. (2015) recommend that, in addition to maintaining ongoing monitoring activities, several monitoring activities should be added to track the health of habitats. It is important to analyse how observed changes are related to climate change and other environmental and socio-economic developments. However, existing uncertainties do not justify ignoring the aforementioned serious threats.

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Conclusions and Recommendations

Assessment of Conservation State and Comparisons to the EU

Based on the newly available assessments in this report, we conclude that, without exception, the combined SoN in the Caribbean Netherlands must be assessed as unfavourable to unfavourable-bad. However, it is important to note that due to the general lack of data after 2020, our assessment cannot fully measure the more recent effects of the NEPP as implemented in 2020. Figure 1 provides an overview of the pooled assessments for habitats and species/species groups within the Caribbean Netherlands, and allows a comparison with the latest update in the EU (EEA, 2020). Almost, without exception, the current Conservation State (CS) of biodiversity in the Caribbean Netherlands is assessed as unfavourable to unfavourable-bad. This applies to both the habitats and the species(-groups) that depend on them. This appears a bit worse than the situation in the European Union where a significant portion of assessed habitats (15%) and species(-groups) (27%) are considered as being in a favorable CS (Fig. 1).

In the previous assessment period (see Debrot et al., 2018), 45% of assessed habitats and 50% of assessed species and species groups were considered to be in an unfavourable-bad CS. The percentages of habitats and species or species groups assessed to be in an unfavorable-bad state has increased to respectively, 60% and 71%. This may not be due to a measurable decline in CS, but due to the inclusion of several more sensitive species or species groups which were not included in the 2017 assessment. The focus for conservation purposes has been on species/species groups that are at risk (like bats and butterflies) and not species that are widespread and abundant (like the Bananaquit, *Coereba flaveola*, and the Tropical Mockingbird, *Mimus gilvus*). Because most monitoring worldwide (and in Europe) is done on common and widespread species (Forister et al., 2023), composite metrics can easily hide declines in sensitive species, whereas in the Caribbean Netherlands most of our work has focused on sensitive species. Also, composite trends over time should really be compared using the identical habitats and species. With sufficient numbers of species and hopefully the research needed for a quantitative update, a valid comparison of temporal changes in CS should be possible with the next SoN reporting.

The CS for both habitats and species/species groups assessed in this reporting period is lower than in the prior reporting period but (in both periods) the assessed habitats remain in a better CS than species/species groups (Fig. 1). In the EU, the opposite is the case whereby the percentage of species/ species groups) in a favorable CS is higher than the percentage of habitats.

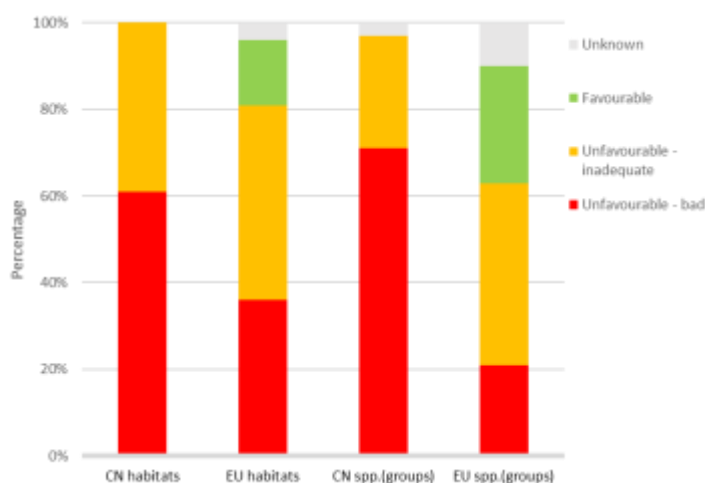


Figure 1. Assessment of the current Conservation State (CS) (2024) of 18 habitats and a selection of 31 species(-groups) in the Caribbean Netherlands with a comparison to the most recent assessment for the EU as a whole (EU data from: EEA, 2020).

For the European Netherlands, the opposite is also the case whereby in 2022, 61% of species were not seriously threatened but only 38% of habitat coverage was considered to be fairly high to high in terms of CS (IPO and LNV, 2023).

The opposing comparisons between the CS of habitats between the Caribbean Netherlands and the EU (and the European Netherlands) we especially ascribe to the still fairly low influence of urbanization, agriculture and industry on natural habitats of the Caribbean Netherlands. Only recently is urbanization pressure coming into play on Bonaire and, to a lesser extent on St. Eustatius. As for the quite contrasting comparisons between the CS of species/species groups between the Caribbean Netherlands and the EU, we especially ascribe that to the large number of rare species that survive on these islands in critically low population sizes. Low population sizes are inherent to the small sizes of islands that provide low total habitat availability. However, this generalization is in no way meant to negate the major effects of habitat degradation which have clearly also occurred in the Caribbean Netherlands (e.g., chapters 3, 4 and 10, this report).

When examining the four indicators (distribution, area, quality, future prospects) used to assess habitats (on which the species depend), 43% of the scores are "favourable" (Fig. 2a). Habitat distribution and habitat area score most favourable while habitat quality scores least favourable and future perspective is a mix of "unknown" and low scores. Habitats already in poor condition lack the resilience needed to withstand the current and future impacts of climate change and will likely be unable to sustain sufficient populations of vulnerable species. As climate change is further difficult to influence directly, there is an urgent need for holistic management measures to reduce the cumulative stressors on ecological systems.

Using the same four indicators to assess species status, 31% of the scores are 'favourable' (Fig. 2b). For species, distribution scores are most favourable while population size and habitat suitability have the highest proportion of unfavourable-bad scores, while future prospects are scored principally as unfavourable-inadequate. Hence, in the Caribbean Netherlands, habitat distribution and area, as well as species distribution are least of an issue, but population size and habitat quality are all-around poor. Future prospects for habitats are unfavourable-inadequate to uncertain and for species unfavourable-bad to unfavorable-inadequate.

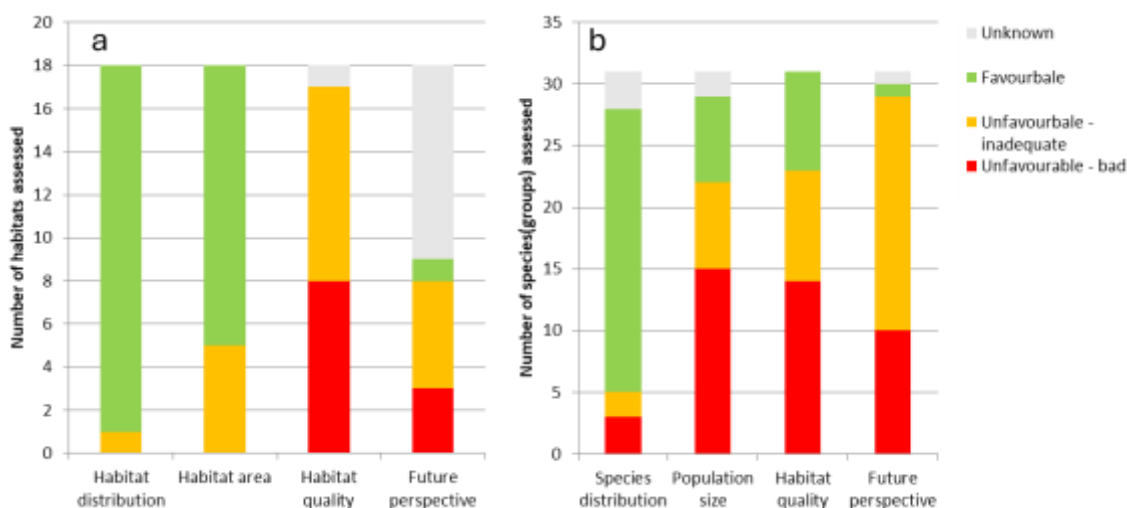


Figure 2. Scores on the various indicators used to assess the Conservation State of a) 18 habitats and b) 31 species(-groups).

A Handful of Drivers of Decline

Two key findings from the most up-to-date EU State of Nature report (EEA, 2020) were that climate change is a rising threat, and that agricultural activities, land abandonment and urbanization are the major pressures on habitats and species, followed by pollution. As for the Caribbean Netherlands,

climate change is also clearly a rising threat, whereas the factors agriculture, land abandonment and urbanization, only the latter has started to develop into a more serious threat.

Natural/semi-natural habitat areas are relatively much more abundant (in terms of cover percentage) in the Caribbean Netherlands than in the EU where terrestrial Natura 2000 areas on land only are 18% of the land surface and marine Natura 2000 areas are only 10% of marine waters (EEA, 2020). In the EU human land-use has longer been a major threat. Today, on Bonaire increasing urbanization is taking place around the capital of Kralendijk and infringing on rural and wilderness areas, and seemingly unbridled urbanization is starting to become a factor in the evergreen forests on the south-western slopes of the Quill volcano of St. Eustatius.

Aside from climate change, in the Caribbean Netherlands key threats to habitats and species at present inside terrestrial natural habitat areas, are roaming livestock and invasive species. Of course, for specific habitats, additional factors come into play. For colonial nesting birds (like terns and flamingos) and bats, which depend on quiet caves for pupping and roosting, human recreational disturbance can be added as a growing risk. Because in the tropics, temperatures are already closer to the lethal maximum for most higher life forms than in temperate and polar regions, such areas are also believed to be more sensitive to the effects of global warming (Calosi et al., 2008; Gutiérrez-Pesquera et al., 2016; Diamond, 2017).

For marine habitats, climate change is also a serious risk while for coral reefs in particular, the eutrophication of coastal waters and diseases must be added as a key threat (e.g., Pepe et al., 2025), including excess fishing pressure in near-shore areas.

All these factors may be seen as partially linked to increasing urbanization and tourism development which go hand in hand with a rapidly increasing human population size (for Bonaire). For Bonaire, with a current population of around 24,000, and projected to grow towards 50,000 by 2050 (CBS, 2023) and with 80% of sewage produced on the island estimated to enter the coastal zone through dysfunctional septic tanks and cesspits and not through the sewage treatment plant (Haskoning, 2023), the prospects for coral reef recovery are not bright. Even at the governmental level, the environmental risks of further population growth are not acknowledged, as the governments of Bonaire and the Netherlands have agreed to facilitate even further growth of the population (Rijksoverheid, 2024). Current population size increases and clustered urbanization for Bonaire wouldn't even be so problematic if it were not for the lack of sufficient restrictions (to recreational densities and behavior) or environmental safeguards (like sewage treatment, development planning and guidelines for land clearance). More strict enforcement of existing regulations is also urgently needed. It must be kept in mind that nature can not only be managed merely through nature policies but requires incorporation by and integration through other policy areas. Nature policy does not function independently from other essential policy areas such as land use, spatial planning, agriculture, waste(water)management, tourism, immigration, and economic development. However, the focus in this report is on those policy issues directly affecting CS and which normally fall inside the scope of nature management.

For the mangroves of Lac Bay in Bonaire, accumulated sediments (from runoff due to overgrazing and other suboptimal land use practices) which reduce the aquatic surface of the bay and thereby destroy mangrove and seagrass habitat, can be identified as the principal threat (Debrot et al., 2019). Added to this are unrestrained and excessive recreational use of the bay which is a threat to water quality and the sea grass beds due to trampling (Eckrich and Holmquist, 2000; Skilleter et al., 2006; Debrot et al., 2012), as well as to the larger iconic fauna that depend on these habitats. These include the (IUCN) *Vulnerable* Rainbow Parrotfish, the Queen Conch and the *Endangered* Green Turtle.

Finally, new research on contaminants leaching from the landfill at Lagun suggests that, in addition to eutrophication and bacterial water-quality stressors, serious chemical contaminants are an emerging environmental threat to marine habitat quality, certainly around Bonaire (de Leijer et al., 2023; Dogruer et al., 2024).

Our assessments show that none of the habitats studied are considered to be in a favorable CS (Fig. 1). The habitats in the poorest condition are the terrestrial vegetation habitats affected by goats, the

beach habitat affected by sea-level rise, intensive development and recreational pressure by man, and nearshore reefs and seagrass habitats affected by local overfishing, sedimentation, aquatic pollution impacts and climate change-related meteorological effects. Conversely, habitats where disturbance and exploitation by goats and man are less, are in better shape. Examples are the mangrove habitat, salt pans and salt lakes, and cave systems, all of which are areas that are less visited or used by man or goats. Included in this category of less-impacted habitats are also the deep sea habitat which is difficult for man to influence directly and algal fields which are principally found on the Saba Bank and along the exposed eastern coasts of the islands where human disturbance is restricted due to the heavy wave and surf conditions.

Of the species/species groups studied this time, the fraction found in unfavourable-bad Conservation State has worsened from 50% to 71% since the last assessment (Debrot et al., 2018). For the marine species and species groups studied, overfishing and habitat degradation (coral reef decline) are principal factors impacting their CS. For terrestrial species/species groups, the three main deleterious factors causing a reduced CS are overgrazing, principally by uncontrolled roaming livestock (which cause aridification, erosion, plant species loss and greater vulnerability to climate change; Debrot et al., this issue), predation by invasive predators (foremost of which are the feral cat; van den Burg et al., this issue) and genetic swamping due to introduced invasive iguanas (van den Burg et al., this issue). Hence, all three of these impacts are directly ascribable to the overarching problem of invasive alien species.

Since the last inventories (2011 and 2012), no less than 710 new records of non-native (exotic) species have been recorded in the wild on one or more Dutch Caribbean islands. This is an average increase of no less than 54 species per year. However, the current rate of increase is certainly higher because the process is exponential and which means that the “average” always underestimates the most recent status. Invasive species are a veritable flood and while they are an enormous risk to biodiversity, only few have so far only been addressed in pilot studies and short-term opportunistic projects.

Best chances for combatting or preventing invasive species are on land. A great deal of research has been spent on the Lionfish but, quite predictably, there is little that can be meaningfully done about this species that achieves its highest densities in deep waters well-beyond safe diving limits. Most urgent is to address invasive species structurally throughout the Caribbean Netherlands. This is because, following habitat loss (due to a variety of factors), invasive species are considered the second-most important threat to biodiversity world-wide; Kaiser, 1999; Mooney, 2001). For instance, according to the US national Wildlife federation, approximately 42 percent of endangered species on land in the USA are at risk of extinction due to invasive species (<https://www.nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife/Invasive-Species>). In the Caribbean Netherlands the situation is at least as urgent as in the USA. In the Caribbean region there are several Red List predatory invasive species for which accidental introduction to the Caribbean Netherlands would be no less than disastrous (e.g., Mongoose, Boa Constrictor). However, at present there is no legislation or effective control to prevent such an introduction, neither accidental nor purposeful.

Intervention Approach

The passive biodiversity management approach, in which management came down to simply putting a “fence around nature” and managing park visitor access and behaviour is no longer sufficient. This old approach to natural areas management was based on the premise that nature was still resilient enough to bounce back on its own. That approach may work in very large undisturbed tracks of nature but today we know that under current circumstances this will not be sufficient. The impact of man’s activities and invasive species has become so large and pervasive, that the old passive approach to nature conservation no longer is sufficient. For the 2020-2030 first phase of the NEPP for the Caribbean Netherlands, the Kingdom has made available a total budget of 35 million Euro’s (IPO and LNV, 2023). Therefore, for the coming years there should be considerable scope for achieving some principal objectives.

Active intervention to give nature a helping hand has become more important than ever and essential to reversing negative feedback loops (for instance between overgrazing, plant species loss and climate vulnerability). Also, in the Caribbean Netherlands this realization has come with many recent initiatives to intervene, and these have often been proving successful. Examples are the success in vegetation recovery on Klein Bonaire following goat removal (Debrot, 1997; Debrot, 2016; Proosdij et al., this issue) as well as the success in various reforestation initiatives aimed at bringing back rare and endangered plants, such as (among others) on Klein Curaçao (Debrot, 2015). Other examples of the successes of active intervention are those that show that removing cats from the wild can save many smaller animals such as endangered seabirds from being killed (Terpstra et al., 2015; Debrot et al., 2022a; 2023), the successful removal of invasive iguanas which is key to saving the genetic integrity of endangered island populations of iguanas (Debrot et al., 2022b; van den Burg et al., 2023), and the construction of artificial islands to protect nesting terns against predation exposure (Bertuol et al., 2015).

Other initiatives that show potential and are bearing results are the culturing of corals for outplanting (Cook et al., 2022; Dehnert et al., 2023), the use of artificial reefs to help restore fish populations (Hylkema et al., 2020) and efforts with potential to contain or even eradicate invasive Giant African Land Snails (Debrot et al., 2016). Also, the importance of joint management to maintain and improve productive fisheries, such as those of the Saba Bank and St Eustatius (Amelot et al., 2021; Brunel et al., 2021), appear high. Fisheries management for both these areas are based on active and productive cooperation between science, management and the fishing sector (Fig. 3).

So today, much more than ever, nature protection and management are much more than maintaining territorial integrity of conservation areas as it has been practiced for decades. A much more active approach to nature management in the Caribbean Netherlands continues to grow especially now that different pilot projects have shown potential. Now it is time to institutionalize this intervention approach into nature and park management for lasting success. However, in selecting from the wide range of possible interventions it is important to prioritize those which have broad and proven impact.



Figure 3. LVV Bonaire and WMR in conversation with the fishing sector, November 2023. Photo: LVV, Bonaire).

The current NEPP (Min. LNV, 2020) for the Caribbean Netherlands has a total of 96 points requiring serious attention. Many of the mentioned threats are already significantly being addressed within the

implementation agenda of the current NEPP (Min. LNV et al., 2020). For instance, these include action points for a) the prevention and control of invasive species, b) the control of free roaming livestock, c) effective waste and wastewater management, d) investments in sustainable fisheries, e) coral reef restoration, and f) the conservation of keystone and flagship species. While ambition is good to have, too much ambition (96 items on the agenda) can also complicate decision making, especially in light of limited funding. Where do we begin and what comes first? Therefore, in suggesting and setting priorities for action it may be helpful to focus on actions that have multiple cascading benefits instead of actions directed to single species solutions. An example would be the issue of coastal eutrophication. Adequately addressing that issue will help not only all endangered coral species but also all coral reef fish species which depend on shelter created by corals and on clean water to remain free from disease. Addressing the problem of roaming livestock is another good example. Removal of goats allows vegetation to recover, which will reduce vulnerability to erosion, increase available habitat for threatened terrestrial species, and help prevent sedimentation runoff that stresses reefs and contributes to climate resilience. As climate change is difficult to influence directly, there is an urgent need for holistic management measures that together reduce the cumulative stressors on ecological systems. Many such interventions can be considered as being “Nature-based Solutions” (NbS) whereby interventions focus on key issues whereafter most recovery will be based on the natural resilience of the system. For instance, instead of planting mangroves and culturing larval fish, the less-complicated removal of sediments threatening mangrove wetlands can restore water depth for both mangroves and larval fish. Once suitable conditions are created, then nature largely takes over. Another example would be how the efficient removal of a small island population of an invasive predator (cats) was sufficient to open the way for major seabird recovery on Klein Curaçao (Debrot et al., 2023).

Exceptions to this rule might be highly specific actions needed to safeguard iconic endemic species or populations. An example of that might be to remove small populations of highly impactful invasive species before they spread and become unmanageable (like invasive iguanas that interbreed with native iguanas; see van den Burg et al., this issue). Nevertheless, in suggesting priorities, ideally, the focus needs to be on “holistic” actions, which are preferably “nature-based” and that trigger cascading positive benefits.

Priority Conservation Actions

Terrestrial Nature

- 1) Address the roaming livestock and poultry issues through intensified culling and modernization of husbandry practices (e.g., Neijenhuis et al., 2015). (All three islands with variations per island: Feral goats and chickens for Saba; Feral goats, chickens and cattle on St. Eustatius and; Feral goats, swine and donkeys on Bonaire)
- 2) Focus reforestation efforts on propagating and reestablishing rare and endemic plant species. (All three islands; priority species differ per island)
- 3) Take special measures at seabird breeding sites to combat invasive predators (cats and rats) and eradicate them if feasible (such as on uninhabited islands or outcrops). (All three islands, with as exception that rats only seem to be a major problem on Saba, but not Bonaire or St. Eustatius)
- 4) Introduce and enforce biosecurity legislation and measures to stem the flood of invasive species, and establish rapid action teams to reduce risks of accidental introduction of deleterious species and carry out needed eradications. (All three islands are in crisis on this matter; see also Smith et al., 2014)
- 5) Continue culling of invasive iguanas (introduced to Saba and St. Eustatius) with as aim eradication of non-native iguana presence. Also, identify other bio-risk species which still are in an early stage of introduction and eradicate those which are still feasible for successful eradication.

Marine Nature

- 1) Address the problem of eutrophication and pollution of nearshore waters, particularly around Bonaire, by implementing large-scale sewage effluent treatment and reuse. (Urgent especially on Bonaire due to high and growing population pressure)

- 2) Restore freshwater catchments on land to limit unnecessary runoff while recharging depleted subterranean water tables. (All three islands, but especially urgent on Bonaire)
- 3) Assess and address the apparent emerging pollution threat emanating from landfills of Bonaire. (All three islands have urban landfills close to the sea)
- 4) Introduce measures directed at reducing the vulnerability to fishing for the formerly abundant large reef piscivores (using any of a combination of measures like area closures, fish reserves, size limits, gear restrictions) (All three islands, but most urgent on Bonaire due to the high and growing population pressure)
- 5) In addition to keeping mangrove channels clear, also dredge and reuse eroded topsoil from the backwaters of Lac Bay in order to restore water depth needed for healthy mangrove and fish habitat. Circular reuse of dredged sediment helps close the sediment cycle by restoring soil fertility on land, without the need for costly imports. (Only relevant to Bonaire as only Bonaire has mangrove has conditions suitable for mangrove habitat)

The ranking of priority conservation actions differs between islands. For ease of overview, the results are ranked by urgency as follows: none = green; low = yellow; intermediate = orange; high = red; highest = dark red in Table 1.

Table 1. Priorities in conservation action and intervention for the three islands of the Caribbean Netherlands ranked according to urgency from none (green) to most high (dark red).

Interventions for Terrestrial Nature

	Bonaire	Saba	St. Eustatius
1) Controlling/culling feral livestock and poultry			
goats	red	red	red
cattle	green	green	orange
swine	yellow	green	green
donkeys	orange	green	yellow
chickens	green	red	red
2) Reforestation of rare plant species			
various	red	red	red
3) Controlling introduced predators at seabird breeding sites			
cats	red	red	yellow
rats	green	red	green
4) Introduce biosecurity legislation and establish rapid action teams	dark red	dark red	dark red
5) Continue successful and start new removal campaigns for non-native species where still feasible			
green iguana	green	red	red
New Guinea flatworm	dark red	green	green

Interventions for Marine Nature

	Bonaire	Saba	St. Eustatius
1) Marine eutrophication and pollution	red	yellow	yellow
2) Restore freshwater catchments	red	yellow	orange
3) Address emergent pollution from landfills	red	yellow	orange



4) Reduce fishing pressure on large reef piscivores



5) Mangrove habitat restoration

restore water depth

restore connectivity



Monitoring Needs

In the European Netherlands, trends for nearly all major species groups, such as birds, butterflies, and plants, are monitored through the *Netwerk Ecologische Monitoring* (NEM). Most of the NEM monitoring networks are carried out by Private Data-Managing Organisations (PGO's), and Statistics Netherlands (CBS) processes these data into nature statistics, enabling close tracking of nature and policy results. NEM serves as the backbone of terrestrial nature monitoring in the European Netherlands, ensuring high data quality and availability. In addition, it is worth mentioning the program for Statutory Research Tasks (WOT; "Wettelijke Onderzoekstaken"), and the aquatic monitoring program of the Netherlands Ministry of Infrastructure and Water management ("Monitoring Waterstaatkundige Toestand des Lands"; MWTL) that both fund a large portion of the ecosystem and environmental monitoring needs in the European Netherlands. The Caribbean Netherlands, which boasts the highest biodiversity within the Kingdom of the Netherlands, and are highly vulnerable to climate change and other environmental pressures, does not have any comparable monitoring systems. To assess the results of biodiversity policies in the future and meet international obligations (e.g., Cartagena, CBD, CMS, SPAW and Ramsar Conventions), trend analyses are essential. This requires selecting indicator species and parameters and developing monitoring plans. However, so far very little biological monitoring has actually taken place in the Caribbean Netherlands, even for the many legally protected species (see Appendix 1).

A few notable exceptions regard coral reefs (Meesters et al., this issue), sea grass beds (van der Geest and Engel, this issue), sea turtle nesting (Dogruer et al., this issue) and fisheries (Debrot et al., this issue). Past and current level of investment in monitoring is insufficient to accurately track population trends as can be witnessed by wide error margins for even those species/species groups for which some monitoring is available. In addition, the KNMI provides some selected long-term monitoring of meteorological parameters. Other than that, practically no long-term monitoring efforts are available for the Caribbean Netherlands. Firstly, monitoring programs are costly and such activities have been considered to primarily be a (management) responsibility residing first and foremost with the island public entities and the designated management entities. Hopeful in this respect is that the need for monitoring is given ample attention in the implementation agenda of the 2020-2030 NEPP, where it is mentioned no less than six times (Min. LNV et al., 2020).

A consequence of this all is that very few of the conservation state assessments in this report are based on long timeseries of consistently and uniformly collected measurements. Most are based on accumulated results of opportunistic and chance research that was lucky enough to be completed. For reliable and consistent assessments, consistent monitoring of important habitats and species (and environmental pressures) should ideally become statutory research tasks, as should be the storage and accessibility of such data (such as currently being done within the Caribbean Biodiversity Data Base (CBDB) project of Wageningen).

Monitoring priorities for the Caribbean Netherlands should be to:

- 1) Decide on selected monitoring required to assess and evaluate the success of chosen management interventions which are intended to reverse certain declining trends (see Verweij et al., 2015).

- 2) Aside from monitoring single dependent variables through time (like flamingo counts) always also monitor relevant independent variables (like salinity, temperature or food density) to be able to assess the causes of changes and trends.
- 3) Focus monitoring on indicator variables and indicator species that preferably are also endemic, rare and/or endangered. For instance, monitoring the endemic but also hardy and ubiquitous subspecies of the Caribbean Mockingbird, *Mimus gilvus rostratus*, has little added value even though it is endemic.

A list of top monitoring priorities is presented in Table 2.

Research Needs

Analysing trends can indicate correlations between monitored variables and suggest causality but typically additional research is needed to demonstrate real cause and effect. Also, the ecology of many Caribbean Netherlands species and especially rare endemic species remains practically unstudied. Most research from the past has had an “academic” observational focus on ecosystem functioning but very little work has been further done on the “applied” question of how to best enhance or restore certain systems or species. Therefore, significant additional applied research will be needed to understand different systems and species and on how to best protect and restore them. As in the case of monitoring, priorities for hypothesis-driven research also need to be decided. Storage of, and accessibility of, the resulting data, reports and publications (such as currently being done within the CBDB project) are essential.

Research priorities should include:

- 1) Quantitative baseline understanding of species functioning and use of different systems. Such data also happen to be an important starting point for biodiversity monitoring. Examples to mention are the total lack of quantitative community baselines for the various habitats found on the Saba Bank (e.g., Meesters et al., 2024) and the vegetations of the steep inner slopes of the Quill on St. Eustatius (van Proosdij et al., this issue).
- 2) Quantitative understanding of the distribution, abundance and ecological conservation needs of the many endemic and rare species of the islands.
- 3) Investigate which conservation measures and interventions can be most effective for ecosystem and species recovery.

A breakdown of key conservation research priorities is presented in Table 3.

Table 2. Priorities in monitoring needs for the three islands of the Caribbean Netherlands.

Conservation Monitoring Priorities

1) Environmental indicators

meteorology of terrestrial habitats
marine water quality
environmental contamination

2) Biological indicators

forest cover and species
seabirds and land birds
butterflies
several protected terrestrial species (e.g., iguanas, bats)
coral, seagrass and mangroves
fish communities
fish catches

sea turtles
marine mammals

3) Biodiversity management and intervention effectiveness

Public awareness and support
Invasive species at ports of entry
Eradication and control programs
Fishing reserves
Propagation and reforestation success

Table 3. *Priorities in conservation research needs for the three islands of the Caribbean Netherlands.*

Conservation Research Priorities

1) Baseline habitat descriptions and faunal use

St. Eustatius Quill crater vegetation
Bat shelter habitat of Saba and St. Eustatius
Saba Bank benthic habitats
St. Eustatius benthic habitats
Bonaire east coast algal fields and reefs
Fish species distribution Saba Bank

2) Ecological research on endangered species

Quantifying rare plant abundance and distribution
Ecological needs of rare and endemic animals
Nest habitat use and needs for endemic iguanas

3) Research into intervention options and effectiveness

Livestock and poultry removal
Predator control for seabirds
Mangrove restoration
Artificial reefs
Reef restoration
Fishing reserves

State of Nature Report for the Caribbean Netherlands, 2024: a second 6-year assessment of the Conservation State, threats and management implications for habitats and species in the Caribbean Netherlands. Wageningen Marine Research Wageningen UR (University & Research centre), Wageningen Marine Research report C001/25. 399 pp.

Keywords: biodiversity, conservation state, climate resilience, environmental threats, drivers of decline, active intervention, cascading benefits.

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Photo cover: An extreme example from St. Eustatius of how uncontrolled livestock husbandry can overgraze vulnerable slopes to the point at which even infrastructure at the top of the cliff comes in danger from erosion.

Photo: J. Hazenbosch

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