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## 22 Conservation State of the Sea Turtles of the Caribbean Netherlands

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### Status

Sea turtles, resilient inhabitants of the oceans for 100 million years, embody both ecological significance and cultural value. With their highly migratory nature, these marine reptiles travel vast distances and utilize diverse habitats. Sea turtles play a pivotal role in maintaining the health of aquatic ecosystems, contributing significantly to preserving coral reefs, seagrass beds, and sandy beaches (K. A. Bjorndal & Jackson, 2002; Christianen et al., 2012; Goatley et al., 2012). Furthermore, sea turtle species are true ecosystem engineers, fulfilling multiple roles as consumers, prey, and competitors, hosts for parasites and pathogens, substrates for epibionts, nutrient transporters, and landscape modifiers (K. A. Bjorndal & Jackson, 2002; Lal et al., 2010). For instance, the green sea turtle, a keystone species for seagrass ecosystems, notably enhances sediment carbon and seagrass nutrient content (Christianen et al., 2023). These charismatic creatures also hold significant economic value, with global tourism-based revenue exceeding billions of dollars annually and ~50 million USD in the United States alone (McCrink-Goode, 2014)

The status and the need for conservation efforts to support the population recovery of these key species have sparked widespread interest from government agencies, non-governmental organisations (NGOs), and the public globally and locally in the BES islands (Bonaire, St. Eustatius, and Saba). However, the need for more data on turtles, human-turtle interactions, population status, threats, and the effectiveness of conservation measures often poses challenges to management actions. This report summarises the status of sea turtles from the BES islands and provides an overview of the threats, knowledge gaps, and recommendations for conservation and management actions.

The Netherlands follows a clear set of international and regional agreements that guide how it protects sea turtles and their habitats in the Dutch Caribbean. At the global level, the United Nations Convention on the Law of the Sea (UNCLOS) and its Straddling Stocks Agreement set out who controls different parts of the ocean, require countries to manage shared marine life carefully and forbid actions that harm the environment in territorial seas and Exclusive Economic Zones (EEZs), although sea turtles still receive little protection once they travel into the high seas. Building on these, three other global treaties each add a different layer of protection: the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) strictly controls all international trade in sea turtles; the Convention on Biological Diversity (CBD) forces countries to make national plans for protecting biodiversity; and the Convention on the Conservation of Migratory Species of Wild Animals (CMS) requires “range states” to work together to protect migratory animals like sea turtles.

Regionally, the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) creates binding rules on catching, trading, and bycatch (including mandatory turtle excluder devices). The SPAW Protocol to the Cartagena Convention (SPAW Protocol) bans taking, trading, or disturbing turtles and calls for marine protected areas; the Ramsar Convention on Wetlands of International Importance (Ramsar Convention) safeguards key coastal wetlands; and the International Maritime Organization’s Particularly Sensitive Sea Areas (PSSAs) designation protects areas like Saba Bank from

harmful shipping activities. Together, these agreements form a strong network of research, monitoring, trade controls, and habitat safeguards, yet enforcing rules on the high seas and ensuring all Dutch and Caribbean territories apply them consistently remains a challenge.

Finally, several bodies and treaty annexes rank sea turtles by how much danger they face and trigger extra protections (Table 1). The International Union for Conservation of Nature (IUCN) lists species as Least Concern (LC), Vulnerable (V), Endangered (E), or Critically Endangered (CE) based on extinction risk. Under the SPAW Protocol, species in Annex II are treated as endangered or vulnerable and must receive strict protection. CMS Annex I covers species already in danger of extinction, while CMS Annex II flags those needing better conservation cooperation. CITES Appendix I bans most international trade in species at highest risk. These categories help focus conservation efforts where they're needed most. Overall, the alignment of these international frameworks highlights that none of the sea turtle species are currently in good conservation status, and all require strong legal protection and sustained conservation efforts. Therefore, it is highly warranted to continue and extend monitoring populations and actively manage human-induced stressors such as habitat loss, pollution, bycatch, and climate change to prevent further declines and promote long-term recovery.

**Table 1.** Conservation state and legal protections for sea turtle species: IUCN: International Union for Conservation of Nature, LC = Least Concern, EN = Endangered, VU = Vulnerable, CE = Critically Endangered, SPAW Annex: Specially Protected Areas and Wildlife Protocol, CMS Annex: Convention on the Conservation of Migratory Species of Wild Animals, CITES Appendix: Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Name (Latin)	IUCN Status	SPAW (Caribbean)	CMS (Migratory) Annex	CITES (Trade) Appendix
<i>Caretta caretta</i>	VU	II	I, II	I
<i>Chelonia mydas</i>	EN	II	I, II	I
<i>Dermochelys coriacea</i>	VU	II	I, II	I
<i>Eretmochelys imbricata</i>	CE	II	I, II	I
<i>Lepidochelys olivacea</i>	VU	II	I, II	I

## Characteristics and present distribution

Sea turtles are divided into two main subgroups with a distinct family: Dermochelyidae, which includes only one species, the leatherback (Figure 1), and the family Cheloniidae, which encompasses the six hard-shelled sea turtles. Many sea turtle species undergo dietary changes during different life stages. After hatching, sea turtles typically enter a cryptic life stage, during which little information about their early years is known. Promising new acoustic and satellite transmitters could help provide information on the early life stages of sea turtles, such as the finding that different species of juvenile turtles were actively swimming and not drifting only with the currents (Phillips et al., 2025). Many of these animals settle in shallow, often coastal waters to forage in their later juvenile and subadult stages. Sea turtles show high site fidelity to their foraging and, as adults, to their nesting grounds, which brings them close activities (Shimada et al., 2020). Sea turtles typically reach sexual maturity at older ages; green turtles, for example, reach sexual maturity between 25 and 35 years. Once sexually mature, they often migrate back to their nesting beaches to mate and reproduce (Limpus, 2008; Limpus et al., 1984; Limpus & Fien, 2009). Overall, they rely on the marine and terrestrial environments of the coastal zone for their survival.

On a global level, the loggerhead turtle (*Caretta caretta*) population consists of 10 subpopulations. Post-hatchlings transition to a pelagic stage, exhibiting low-energy swimming and feeding on floating material, especially Sargassum (Witherington et al., 2012). Juvenile loggerheads move between oceanic and neritic zones for several years before adulthood (Ramirez et al., 2015). Adult females exhibit reproductive longevity, with some nesting up to 25 years. Throughout their lifecycle, loggerheads

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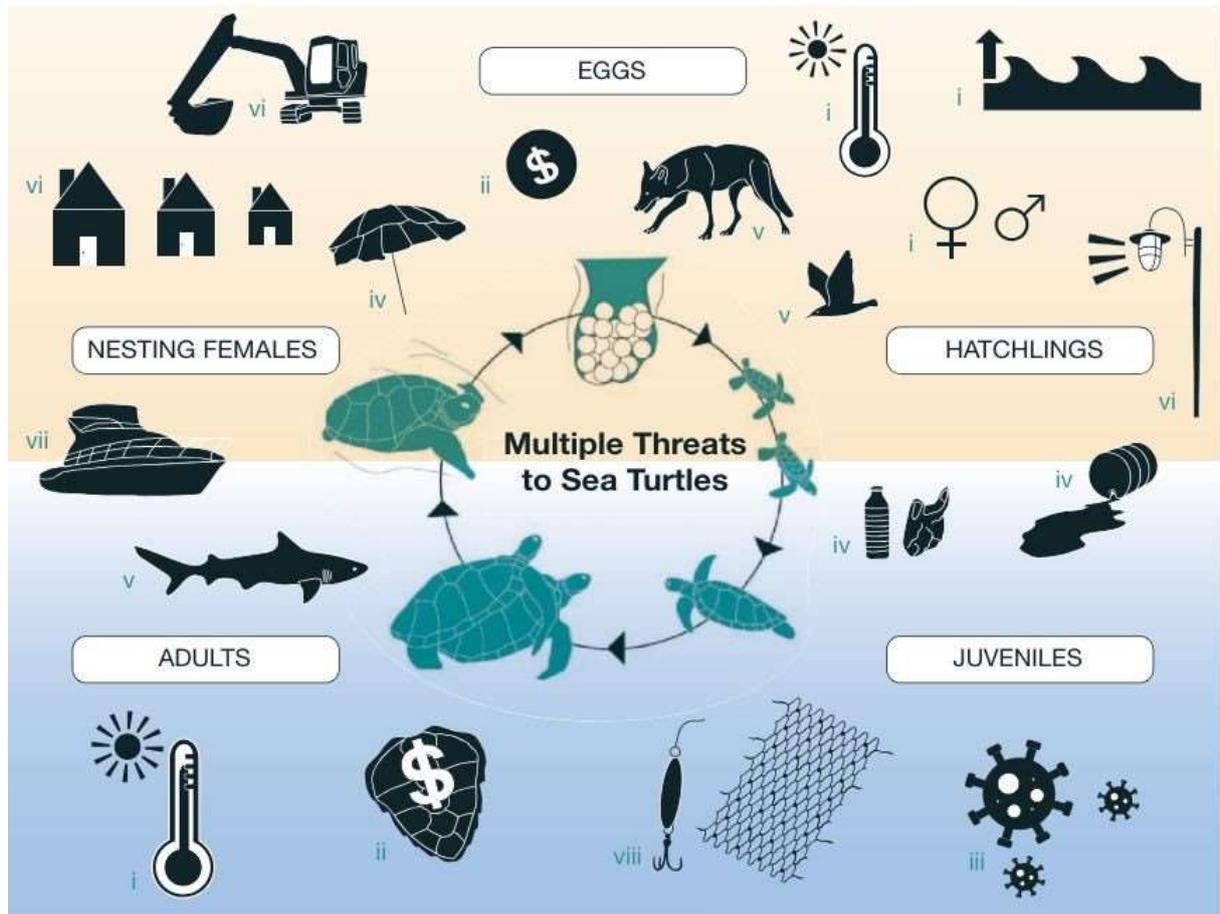
primarily consume carnivorous diets with regional and ontogenetic variations (Bjorndal, 2017). For the loggerhead turtle, mortality due to bycatch has been identified as the most severe threat globally, followed by coastal development and hunting for meat and eggs (Casale & Tucker, 2017)

The green turtles (*Chelonia mydas*) in the Caribbean grow more slowly than hawksbills or loggerheads of similar size but faster than green turtles in the Pacific. Growth functions also differ between ocean basins, highlighting the need for region-specific management (Bjorndal et al., 2000; Bjorndal & Bolten, 1988). Young green turtles undergo an omnivorous pelagic phase for several years before potentially drifting with ocean currents and settling in neritic environments where they primarily feed a herbivorous. Thus, green turtles heavily rely on seagrass fields. However, seagrasses rapidly decline through human-induced stressors such as nutrient and chemical pollution runoff and coastal development (Dunic et al., 2021), causing green turtles to aggregate in shrinking foraging habitats (Gangal et al., 2021). In addition, the exotic seagrass species *Halophila stipulacea* is rapidly expanding in the Caribbean Sea (Winters et al., 2020). Selective feeding by green turtles on native seagrass facilitated this invasive seagrass on Bonaire (Christianen et al. 2019). However, evidence from Bonaire (Becking et al., 2014) and other Caribbean sites shows that turtles opportunistically feed on this exotic species (Siegwalt et al., 2022), possibly providing an opportunity for meeting the nutritional demands of green turtle populations. An important question remains if subtropical seagrass meadows have the carrying capacity to sustain increasing green sea turtle populations that are migrating northwards because of rising seawater temperatures (Campbell et al., 2024; Rodriguez & Heck, 2021). Care should be taken to regulate turtle-tourist interactions, as swimming and feeding turtles (which occurs on e.g. Curaçao) can result in unnatural aggressive behavior, and alternative food sources may pose a risk to turtle health (Smulders et al., 2021). Green turtles are long-lived and exhibit strong fidelity to relatively narrow foraging grounds, spending more than a decade in these areas before reaching sexual maturity (Limpus et al., 1992; Shimada et al., 2020). Because they remain in the same coastal habitats for so long, they steadily accumulate contaminants from runoff and other local sources. This makes them ideal bioindicators: by measuring pollutant loads in green turtles, researchers can assess the sublethal effects of poor water quality effects that often manifest as increased susceptibility to disease and other stressors rather than immediate mortality (Dogruer, 2022; Dogruer et al., 2021; Gallen et al., 2019; Gaus et al., 2019; Weltmeyer et al., 2021).

In the Northwest Atlantic, subpopulations of Leatherback have decreased since 1990, and declines are particularly severe in French Guiana (Eckert and Hart, 2021; Eckert and Eckert, 2019). Threats for nesting females include habitat loss and sargassum influx, and at sea threats include net fisheries, pollution, and entanglement (K. Eckert & Hart, 2021; Saba et al., 2008; Tröeng et al., 2004). Key nesting beaches in the Caribbean include Grand Riviere and Fishing Pond in Trinidad, Armila in Panama, and the Gulf of Urabá, Colombia. This species primarily inhabits aquatic environments, demonstrating deep-diving behaviours and feeding on pelagic jellyfish and related mollusks. They visit the warm tropical waters of the Caribbean solely for nesting purposes.

Hawksbill turtles (*Eretmochelys imbricata*) exhibit genetic diversity among nesting populations, necessitating separate management units. Global declines of 84-87% in animal numbers over the last three turtle generations have occurred due to overexploitation of nesting females, egg collection, capture on foraging grounds, loss and degradation of nesting beaches, and bycatch in fisheries (Mortimer & Donnelly, 2008). Despite reduced trade in tortoise shells, which remains a severe threat, some protected populations have increased. Hawksbill turtles mature after 20 years or more, primarily feeding on sponges in the Caribbean. Within the Western Atlantic, hawksbill turtles migrate throughout the wider Caribbean Basin, and there is a need to protect the important corridors linking their high-use areas (Maurer & Eckert, 2024). Enhanced protection measures on nesting beaches and reduced exploitation in nearby foraging areas, especially in Cuba, have contributed to significant increases in the Caribbean (Campbell, 2014). Hawksbill turtles primarily inhabit coral reefs, feeding predominantly on sponges. Despite coral reef decline, there appears to be an adequate supply of sponges on relatively healthy reefs

in Bonaire and surrounding areas like St. Eustatius and Saba. Therefore, food availability is not a limiting factor for this species in these regions (Debrot et al., 2014).



**Figure 2.** Sea turtles face cumulative and synergistic threats across their life stages and habitats. They face threats on land and in the ocean, which may create conservation challenges. Depicted threats: (i) climate change; (ii) direct take; (iii) disease; (iv) pollution; (v) predation; (vi) coastal development; (vii) marine development; (viii) fisheries (ix). From Fuentes et al., 2023).

Olive ridleys (*Lepidochelys olivacea*) face population declines due to slow growth and human impact across different life stages and habitats, including nesting beaches, migration routes, and foraging areas spanning a wide geographic range (Abreu-Grobois & Plotkin, 2008). Coastal development poses a significant threat to nesting beaches, such as Eilanti in Suriname, which experienced a nearly complete loss of its breeding colony by 2005. Conversely, French Guiana saw significant colony increases during the same period (Abreu-Grobois & Plotkin, 2008). In the Dutch Caribbean, the olive ridley is notably absent from nesting sites, with rare sightings until 2008, when a specimen was found near Curaçao, followed by another in St. Eustatius (St. Eustatius Sea turtle Conservation Programme - Annual Report 2008). Recent observations of stranded turtles on Bonaire and Curaçao suggest an enhanced monitoring network or altered migration patterns. Like other sea turtles, the olive ridley has a complex life cycle, relying on distinct geographic areas and habitats, primarily living as oceanic carnivores and returning to the coast solely for reproduction (Abreu-Grobois & Plotkin, 2008).

A long-term study on growth rates of sea turtles from the West Atlantic highlights significant declines in growth rates among carnivorous sea turtle species, namely West Atlantic hawksbills and North Atlantic loggerheads, mirroring the patterns observed in green turtles (Bjorndal et al., 2017). Beginning around 1997 after peak growth rates, these declines are attributed to the same ecological regime shift

phenomenon affecting the broader marine ecosystem. While the study emphasizes the role of thermal stressors in driving these declines, it underscores the compounding effects of multiple stressors, including anthropogenic degradation of foraging habitats.

Furthermore, rising temperatures have been shown to reduce the survival of hatchlings and increase the female-to-male ratio of emergent hatchlings because of temperature-dependent sex determination in sea turtles (Laloë et al., 2017). Hawksbills, closely associated with coral reefs, suffer from the extensive loss and degradation of reef habitats, while loggerheads face habitat destruction from trawl fisheries and accumulation of marine debris. The cumulative impacts of these stressors exacerbate the decline in growth rates across all sea turtle species, indicating a pressing need for comprehensive conservation measures to mitigate the threats posed by climate change and human activities to sea turtle populations worldwide. Fuentes et al. (2023) recently reviewed the key threats to sea turtle populations. They listed them as climate change, direct take, disease, pollution, predation, coastal and marine development, and fisheries (see Figure 2), underscoring that these marine reptiles are animals of high conservation concern. Many of these threats can lead to direct mortality (e.g., harvesting) or indirectly reduce the resilience or health of sea turtles (e.g., pollution).

In the Dutch Caribbean, five sea turtle species inhabit the waters, each with varying levels of protection and presence, as detailed in Tables 1 and 2.

The loggerhead (*Caretta caretta*), known locally as "Kawama," is present on Bonaire with both nesting and infrequent foraging activity, while it is absent from St. Eustatius and seen infrequently on Saba. The green turtle (*Chelonia mydas*), or "Turtuga Blanku," nests and forages on Bonaire and St. Eustatius and is also observed foraging infrequently on Saba. The leatherback (*Dermochelys coriacea*), locally known as "Drikil," nests infrequently on Bonaire, regularly on St. Eustatius, and infrequently sighted on Saba. The hawksbill (*Eretmochelys imbricata*), known as "Karet," nests and forages on Bonaire and St. Eustatius, while on Saba, it is only observed foraging. The olive ridley (*Lepidochelys olivacea*), locally called "Turtuga Bastardo," is sighted infrequently on Bonaire and absent from St. Eustatius and Saba.

**Table 2.** An overview of the sea turtle species found in the waters of the Dutch Caribbean, their respective statuses in the IUCN category, and their presence on each island. Source: (Eckert & Eckert, 2019)- LC = Least Concern; EN = Endangered; VU = Vulnerable; CE = Critically Endangered; A = Absence; N = Nesting; F = Foraging; I = Infrequent (further detail unavailable); IN = Infrequent Nesting (following Eckert and Eckert, 2019).

Name (Latin)	Common Name (English)	Local Name	Dutch Name	Bonaire	St. Eustatius	Saba
<i>Caretta caretta</i>	loggerhead	Kawama	Onechte Karetschildpad	N, IF	A	I
<i>Chelonia mydas</i>	green turtle	Turtuga Blanku	Soepschildpad/Groene Zeeschildpad	N, F	N, F	IN, F
<i>Dermochelys coriacea</i>	leatherback	Drikil	Lederschildpad	IN	N	I
<i>Eretmochelys imbricata</i>	hawksbill	Karet	Karetschildpad	N, F	N, F	F
<i>Lepidochelys olivacea</i>	olive ridley	Turtuga Bastardo	Warana	I	A	A

## Assessment of National Conservation State

Nesting site fidelity, which refers to the tendency of individual adult female turtles to return to the same nesting areas within a limited geographical range, has been extensively studied in the literature.

Traditionally, information on fidelity during movements between nesting events has been gathered through tag-recapture studies, as demonstrated by Limpus et al. (1992) and (Shimada et al., 2020).

More recently, advances in satellite telemetry have further confirmed nesting site fidelity across various

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turtle species. Studies by Humber et al. (2014) and Whiting et al. (2021) have corroborated this behaviour in green turtles while Parker et al. (2009) and Walcott et al. (2012) have shown similar patterns in hawksbill turtles. Additionally, leatherback and loggerhead turtles have also exhibited nesting site fidelity, as evidenced by research conducted by e.g., Byrne et al. (2009) and Tucker (2010).

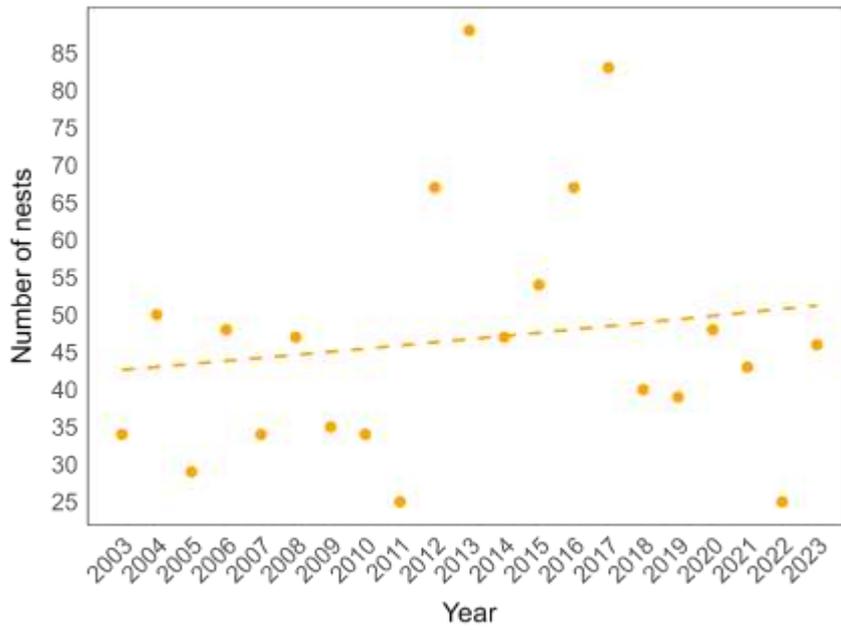
Establishing connectivity between rookeries and foraging habitats and determining phylogeography and broad-scale stock structure for most marine turtle species is important to increase the effectiveness and guidance of conservation measures. Recent genetic and migratory behaviour studies (e.g., Esteban et al. (2015); Becking et al. (2016)) show that the exchange between turtles from different nesting sites is sufficient to maintain genetic diversity in the Dutch Caribbean. Satellite tracking of sea turtles nesting at Bonaire and Klein Bonaire in the Caribbean Netherlands has provided valuable insights into their migration patterns. Becking et al. (2016) revealed migration distances ranging from 197 to 3135 km to foraging grounds across the Caribbean. These grounds include coastal waters where harvesting activities persist (García-Cruz et al., 2015; Humber et al., 2014; Lagueux et al., 2014) exposing young sea turtles to the anthropogenic threat. Both studies highlight that further research is required, particularly to unravel the migratory behaviour of male sea turtles. Both studies underscore the significance of international marine turtle conservation efforts, revealing extensive post-breeding migration routes.

The study of Esteban et al. concludes that green and hawksbill turtles nesting on St Eustatius and St Maarten in the eastern Caribbean demonstrate behavioural flexibility in their inter-nesting movements and post-nesting migration routes. While their nesting behaviour aligns with previous reports in the region, some turtles exhibited unconventional post-nesting migration behaviour, challenging the assumption of migratory behavior among adult female turtles in the Caribbean. The research also reveals varying nesting and post-nesting strategies among green and hawksbill turtles, with some individuals showing repeated nesting on the same beach and others nesting on beaches separated by significant distances. Satellite tracking data indicate that green turtles may nest on multiple islands nearby, suggesting a more comprehensive nesting range than previously thought. The study also reveals that some hawksbill turtles took indirect paths, travelling over 200 km to nest again before returning to foraging locations less than 50 km from their original nesting sites, a behaviour not previously documented.

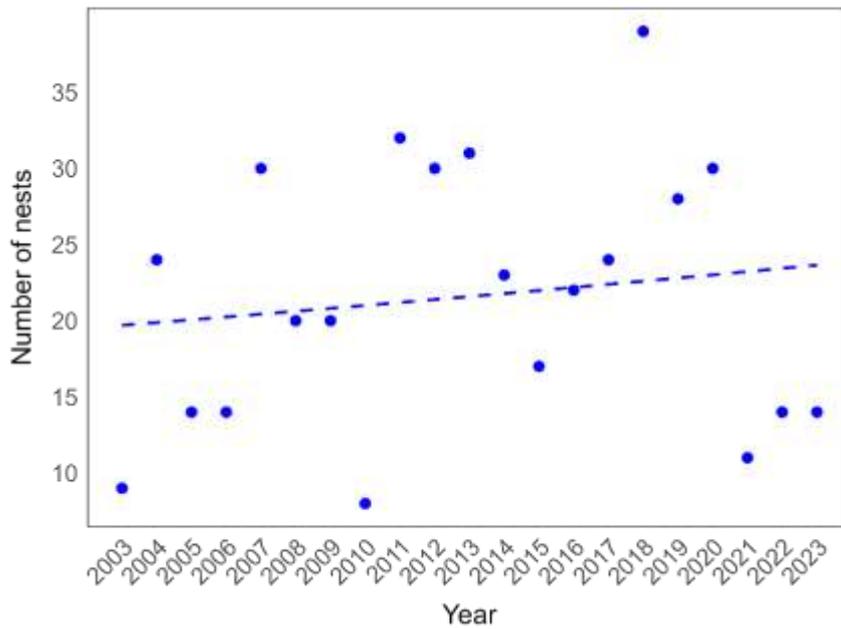
Saba has no significant permanent beaches suitable for turtle nesting, with only two recorded instances. Nesting likely occurs only sporadically, but in 2015, a green turtle nest was found and successfully hatched on Saba. In scope of the report, we have also requested the Saba Conservation Foundation for up-to-date data, however, aside from sightings of foraging turtles, no nesting has been recorded on Saba in the past years (*personal communication*, Camille Tuijnman from SCF). The two islands with a significant nesting population of sea turtles are Bonaire and St. Eustatius.

### **Trends in the Caribbean Netherlands Bonaire Nesting**

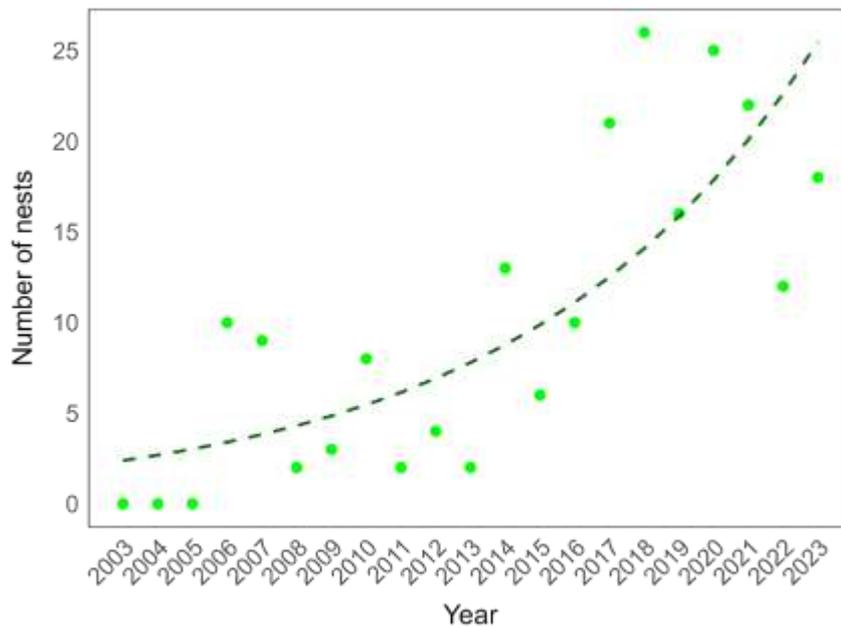
We have collected data on the number of nests per location across the islands of Bonaire and St. Eustatius (Figure 3-5). The time-series data collected by STCB and STENAPA were aggregated at the island level. Only nests with confirmed species identifications were retained (nests of unknown species were excluded), all subregions were combined, and the resulting dataset was analyzed in RStudio using generalized linear models (GLMs) with a Poisson error distribution. Figures 3, 4, and 5 illustrate the nesting trends of three turtle species: hawksbill, loggerhead, and green turtle on Bonaire from 2003 to 2023.



**Figure 3.** GLM Analysis of hawksbill turtle nesting trends in Bonaire (2003–2023). Dots represent observed annual nesting counts, while the dashed line illustrates the trend estimated by the GLM.



**Figure 4.** GLM Analysis of loggerhead turtle nesting trends in Bonaire (2003–2023). Dots represent observed annual nesting counts, while the dashed line illustrates the trend estimated by the GLM.



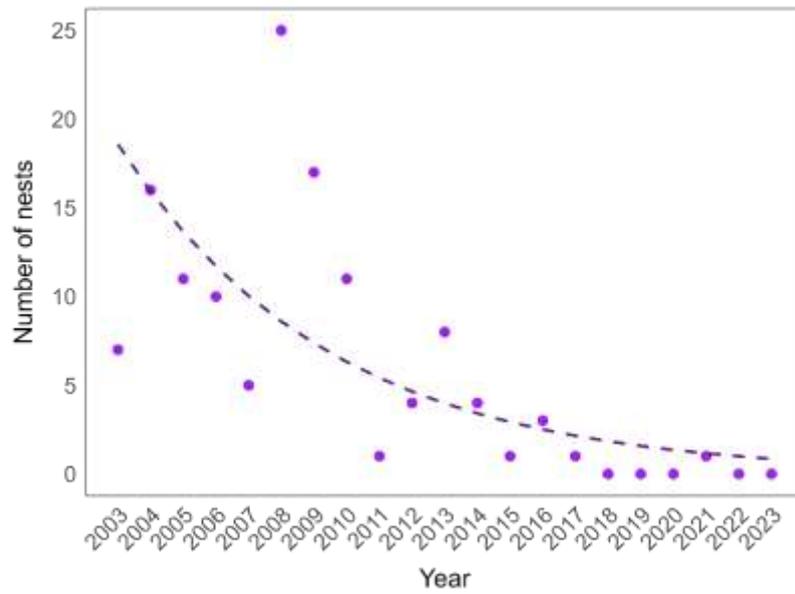
**Figure 5.** GLM Analysis of green turtle nesting trends in Bonaire (2003–2023). Dots represent observed annual nesting counts, while the dashed line illustrates the trend estimated by the GLM.

#### Key Findings

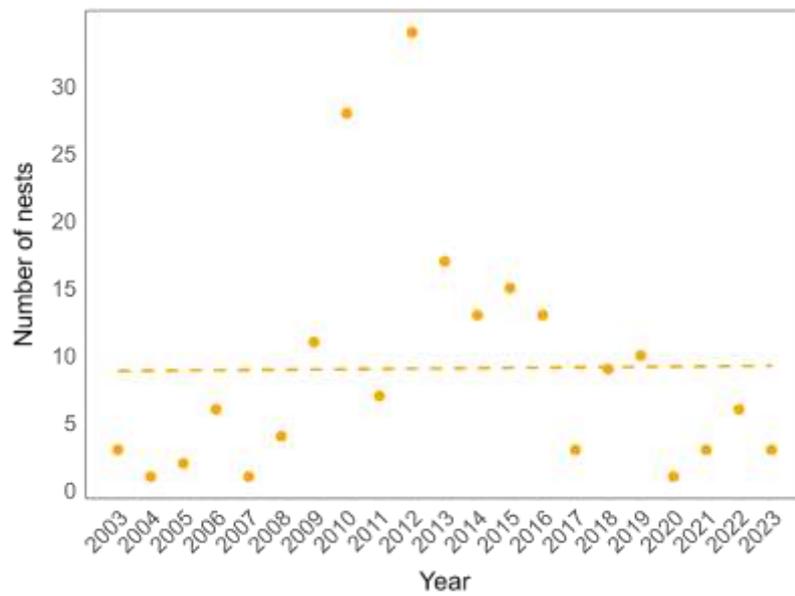
- loggerhead turtle: The analysis indicates no significant trend in nesting numbers over the years ( $p = 0.127$ ). The AIC suggests a moderate model fit.
- hawksbill turtle: The model shows a non-significant trend ( $p = 0.0616$ ), indicating a potential weak increase in nesting numbers.
- green turtle: This species exhibits a highly significant positive trend in nesting numbers ( $p < 2e-16$ ), suggesting a substantial increase in nests over the years.

#### St. Eustatius Nesting

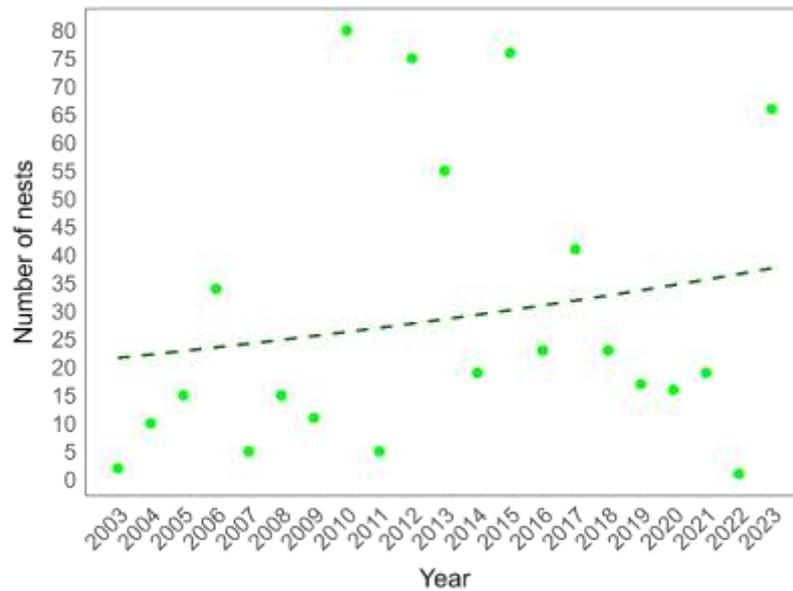
This analysis evaluates the nesting trends of three turtle species (green turtle, hawksbill, and leatherback) in St. Eustatius from the period 2003-2023 using Generalized Linear Models (GLMs) with a Poisson distribution (Figures 6, 7, and 8). Only nests with confirmed species identifications were retained (nests of unknown species were excluded), all subregions were combined, and the resulting dataset was analyzed in RStudio.



**Figure 6.** GLM Analysis of leatherback turtle Nesting Trends in St. Eustatius (2003–2023). Dots represent observed annual nesting counts, while the dashed line illustrates the trend estimated by the GLM.



**Figure 7.** GLM Analysis of hawksbill turtle Nesting Trends in St. Eustatius (2003–2023). Dots represent observed annual nesting counts, while the dashed line illustrates the trend estimated by the GLM.



**Figure 8.** GLM Analysis of green turtle Nesting Trends in St. Eustatius (2003–2023). Dots represent observed annual nesting counts, while the dashed line illustrates the trend estimated by the GLM.

### Key Findings

- green turtle: The analysis indicates a significant positive trend in nesting numbers ( $p = 0.000372$ ), suggesting that nests increase over the years. The AIC of 578.62 suggests a moderate fit of the model.
- hawksbill turtle: The model shows no significant trend ( $p = 0.686$ ), indicating that the number of nests does not significantly change over the years. The AIC value 235.18 suggests a poorer model fit than the green turtle.
- leatherback turtle: This species exhibits a highly significant negative trend in nesting numbers ( $p < 2e-16$ ), indicating a substantial decrease in nests over the years. The AIC of 130.33 indicates the best fit among the three models analysed, as shown by the lower AIC value.

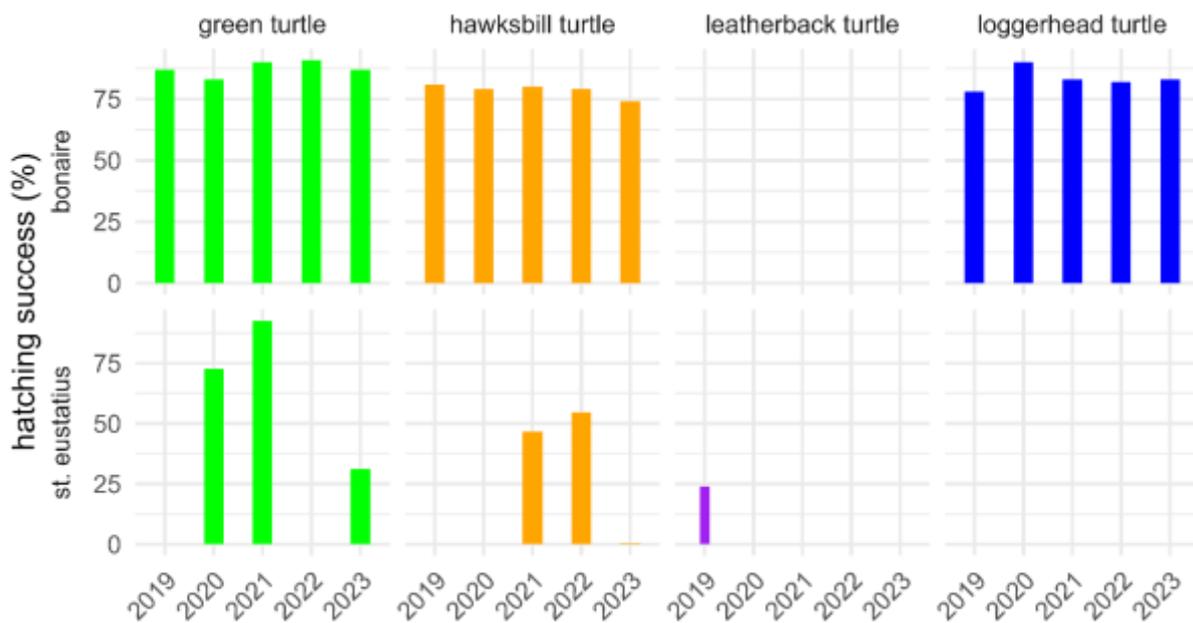
Overall, the green turtle nesting counts have significantly increased on St. Eustatius and Bonaire, indicating positive trends for this species, which is in line with global assessments (Hays et al., 2025) (Hays et al. 2025). However, such positive development does not mean that the sea turtles are not more susceptible to multiple stressors and remain threatened. This data may indicate that local and regional conservation efforts and the protective goals set by different regulations and directives, as mentioned above, lead to a positive development for this species. In contrast, hawksbill turtles exhibit a slight, though not statistically significant, increase in Bonaire, while no notable trend is observed in St. Eustatius. Similarly, no clear trends have been detected for loggerhead turtles on Bonaire. However, there is a significant and concerning decline in nesting numbers for leatherback turtles on St. Eustatius, suggesting a substantial population decrease for this species, in line with regional declines documented in the period from 2008-2017 in both the Northern and Western Caribbean (Eckert & Hart, 2021).

It must be kept in mind that the apparent rise in nest counts may accidentally reflect increased survey effort as more person-hours in the field, longer transect distances, and broader spatial coverage inevitably uncover more nests. To correct this, raw counts should be normalized by effort metrics (e.g. nests per person-hour or per km surveyed). Complementary capture–mark–recapture approaches—whether via flipper or PIT-tagging, photo-ID of individual scale patterns, or DNA-based genetic marks—can provide more robust estimates of nesting-female abundance. Although these methods require additional resources and logistical coordination, they yield critical parameters (population size, survival rates, remigration intervals) that are vital to accurate population assessments and informed management.

### Nesting success

In St. Eustatius, the green turtle nesting success increased from 72.75% in 2020 to 92.50% in 2021, followed by a drastic decline to 31.3% in 2023. Bonaire's green turtles maintained robust success, ranging from 83% to 91% during the same period, indicating a more stable nesting environment based on the provided data. Hawksbill turtles in St. Eustatius had widely varying success rates, with no data available for 2019 and a low of 0.44% in 2023. In Bonaire, hawksbill's success declined from 81% in 2019 to 74% in 2023, yet it consistently surpassed figures from St. Eustatius. Loggerhead nesting success is reported only for Bonaire, which remained steady at around 80-90%. Data for leatherback turtles is limited to St. Eustatius, with a recorded % success rate of 24% in 2019, and no further data is available. In this analysis, sub-local variation in nesting success was incorporated. Therefore, this data does show locations with high human activity, which, in turn, may still negatively impact turtle populations, highlighting the continued need for protection of these critical habitats.

We conclude by pointing out that nesting success varies strongly between St. Eustatius and Bonaire. Bonaire shows consistently high hatch-success rates across multiple turtle species, whereas St. Eustatius data are more inconsistent. These differences indicate the need for sustained monitoring and targeted conservation to research the ecological drivers behind these patterns. However, uneven reporting due to a lack of personnel capacity may make distinguishing biological fluctuations from data collection gaps challenging. By contrast, Bonaire's long-term datasets appear more complete to inform effective management strategies for sea turtle conservation.



**Figure 9.** Sea turtle Nesting Success in St. Eustatius and Bonaire. The figure consists of two sections: the upper section illustrates sea turtle nesting success data for Bonaire, while the lower section presents comparable data for Sint Eustatius.

### Foraging Grounds

The Dutch Caribbean islands are also rapidly becoming more critical as foraging areas (Debrot et al., 2005; Bjorndal, 2017). On Saba, the seagrass fields around the island are a fixed foraging area for subadult green turtles, and the hawksbill turtle regularly visits the island's reefs. There are also indications that the 2,200 km<sup>2</sup> Saba Bank is a foraging area for adult hawksbill turtles. The diversity of algae and sponges on the Saba Bank means ample food is available, especially for hawksbill turtles. Several adult hawksbill turtles were encountered during various dives on the Saba Bank (Lundvall, 2008). Also, a male hawksbill turtle equipped with a satellite transmitter in 2004 on Bonaire was tracked heading towards the Saba Bank until the transmitter's signal was lost prematurely. Leatherback turtles

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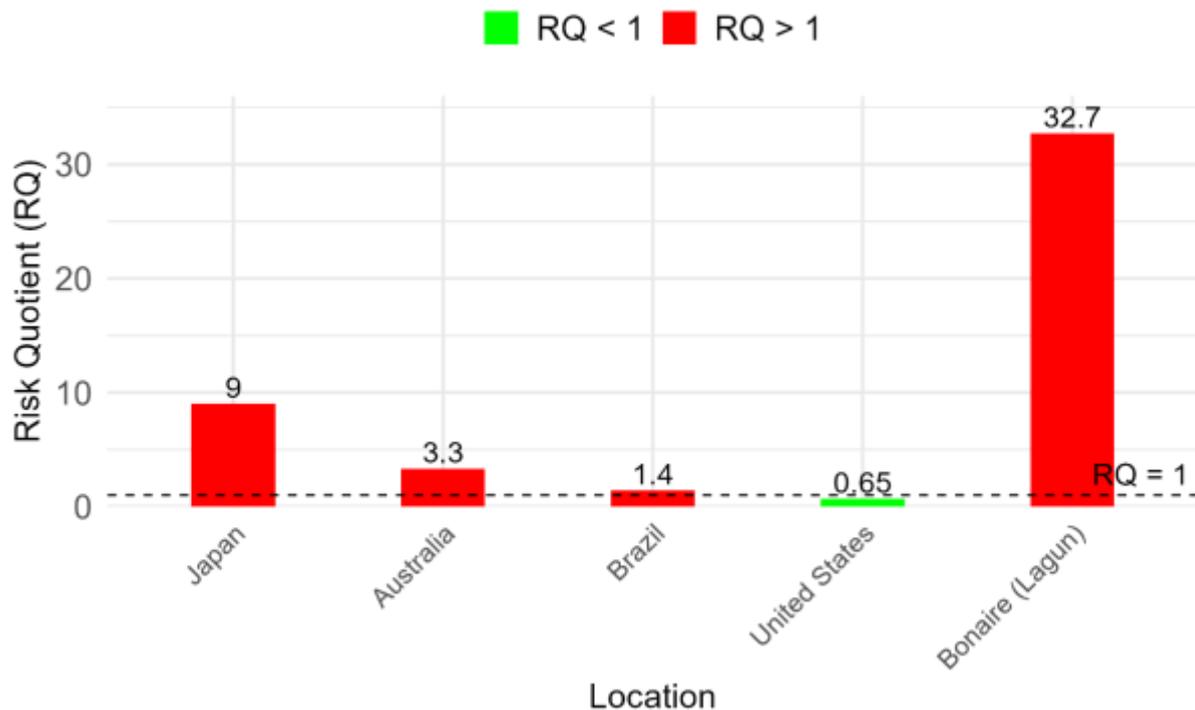
and loggerhead turtles have also been sighted on the Saba Bank. Little is known about the foraging areas of St. Eustatius, but more about the nesting beaches (as described above).

In Bonaire, hawksbill and green turtles are found island-wide in the shallow foraging areas of the coral reefs and seagrass fields. The densities of green turtles were higher everywhere compared to the hawksbill turtle. The highest concentrations of green turtles are found at Lac Bay on the east coast of the island, where the most significant food source for this species is located. In the last two decades, there has been a surge in available data from the BES islands, particularly from Bonaire, where systematic monitoring and tagging over twenty years has revealed that the total abundance of green turtles remained consistent throughout the recent years 2019 to 2022, showing no significant deviation when compared to both the survey-based estimates from 2003 to 2018 and the model-based predictions for 2019 to 2030 (Rivera-Milán et al., 2019). The forecast for hawksbill turtles from 2019 to 2022 also closely resembled those from 2003 to 2018 and the predictions for 2019 to 2030 (Rivera-Milán et al., 2019). In western Bonaire and Klein Bonaire, hawksbill turtles were less detectable from January to March compared to April. Detectability remained relatively stable for green turtles between these periods. Furthermore, genetic and demographic analyses reveal an increase in the proportion of juvenile green turtles from recovering rookeries in the northwestern Caribbean. This increase suggests a potential positive impact of sea turtle conservation measures in the region on juvenile abundance at feeding grounds. However, juvenile recruitment from the eastern Caribbean and southern Atlantic has decreased, signalling a concerning decline in reproductive output in those areas (Becking et al., 2016).

Recent analyses of marine sediments from Bonaire's 2022 heavy-rainfall and runoff event show that metal and organic contaminant concentrations exceed during this period European guideline limits, posing a significant threat to aquatic life (Dogruer et al., 2025). Because many of these contaminants bioaccumulate in organisms, sediment-based monitoring offers valuable first insights into the quality of both foraging and nesting habitats (Leusch et al., 2021). To date, however, no biological contaminant surveys have been conducted on Caribbean aquatic species, including green turtles, which feed on seagrass and are particularly vulnerable when trace metals concentrate in sediments (Talavera-Saenz et al., 2007; Thomas et al., 2020). In Queensland, Australia, studies have linked persistent organic pollutant (POP) levels in coastal sediments with internal POP burdens in green turtles, demonstrating sediment-to-seagrass bioaccumulation pathways (Hermanussen et al., 2004, 2008; Weltmeyer et al., 2021). Assessing water-column pollutant concentrations alongside sediment and biota sampling is therefore essential to fully understand—and mitigate—the health risks that elevated chemical levels pose to sea turtle habitats (Gaus et al., 2019; Leusch et al., 2021).

The Bonaire case study reports cadmium concentrations that exceed sea-turtle-specific protective thresholds (Dogruer et al., 2021). The risk quotient indicates how much the measured level exceeds (or falls below) those benchmarks; values above one signal an early warning of toxicity (Figure 10).

In Lagun, cadmium levels are markedly higher than in more urbanized and industrialized foraging grounds in Japan and Australia (Figure 10), countering the usual west-to-east decline in turtle tissue burdens. Elemental analyses of *Thalassia testudinum* leaves collected at three sites in Lagun (March 2022) revealed a mean cadmium concentration of 3.27 µg/g dry weight (Ouwersloot, 2022). Ecological studies have linked cadmium at these levels to reduced rhizome density and diminished seagrass resilience (Fraser & Kendrick, 2017), suggesting that the same protective threshold may safeguard turtle health and habitat integrity. Moreover, copper and zinc in Lagun's seagrass also exceed species-specific toxicity thresholds (Ouwersloot, 2022). Copper exposure has been implicated in fibropapillomatosis (FP), a tumour-forming disease affecting sea turtles (da Silva et al., 2016)—, and high FP rates have been reported locally (STCB, pers. comm.). These observations underline the need to assess how metal contamination influences sea turtle health.



**Figure 10.** The risk-quotient(RQ)-based risk evaluation, as described in Dogruer et al. 2021. Seagrass concentrations are evaluated against the species-specific threshold for green turtles in Australia, the United States, Brazil, Japan and Bonaire (Lagun). The concentration in seagrass was normalized to the proposed threshold values. An RQ > 1 typically signals a potential risk and the need for further investigation or mitigation.

Although these contaminant levels may not cause immediate mortality, chronic sublethal exposure erodes turtles’ resilience, making them more vulnerable to disease and environmental stressors. With cadmium’s biological half-life extending beyond 30 years, the next logical step is to measure internal cadmium burdens in turtle organs and compare them to harmful thresholds. The elevated external concentrations suggest toxicological risk, highlighting the necessity for ongoing monitoring and targeted research on bioaccumulation and long-term health impacts in these endangered species.

Based on all the above, Tables 3 and 4 give an overall assessment of the nesting turtles of the Caribbean Netherlands. In general, distribution and population size are judged as “favourable” or “unfavourable-inadequate”. Based on the criteria used, the overall CS for all species distribution is “favourable” except the leatherback turtle population of St.Eustatius is considered “unfavourable-inadequate”, while habitat is considered an “unfavourable-bad” factor for all except the loggerhead turtle, which forages mainly offshore. The population size is only for the green turtles categorised as “favourable”.

**Table 3.** Diagnostic scores for the four different State of Nature criteria for the three breeding sea turtles of Bonaire and an overall conservation assessment for the year 2024.

Aspect of sea turtles Bonaire	loggerhead turtle	hawksbill turtle	green turtle
Distribution	Favourable	Favourable	Favourable
Population size	Unfavourable-inadequate	Unfavourable-inadequate	Favourable
Habitat	Unfavourable-inadequate	Unfavourable-bad	Unfavourable-bad
Future prospects	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
<b>Overall Assessment of Conservation State</b>	<b>Unfavourable-inadequate</b>	<b>Unfavourable-inadequate</b>	<b>Unfavourable-inadequate</b>

**Table 4.** Diagnostic scores for the four different State of Nature criteria for the three breeding sea turtles of St. Eustatius and an overall conservation assessment for the year 2024.

Aspect of sea turtles St. Eustatius	leatherback turtle	hawksbill turtle	green turtle
Distribution	Unfavourable-inadequate	Favourable	Favourable
Population size	Unfavourable-bad	Unfavourable-inadequate	Favourable
Habitat	Unfavourable-bad	Unfavourable-bad	Unfavourable-bad
Future prospects	Unfavourable-inadequate	Unfavourable-inadequate	Unfavourable-inadequate
<b>Overall Assessment of Conservation State</b>	<b>Unfavourable-bad</b>	<b>Unfavourable-inadequate</b>	<b>Unfavourable-inadequate</b>

## Comparison to the 2018 State of Nature Report

Overall, compared to the 2018 assessment, several changes can be detected in the CS of different sea turtle populations of the Caribbean Netherlands. Most encouraging are the long-term increases in the nesting populations of the green turtle on Bonaire and St. Eustatius. In contrast, the substantial declines in leatherback turtle nesting on St. Eustatius are worrisome.

## Recommendations for National Conservation Objectives

### Habitat Protection and Restoration:

#### Nesting Beaches:

- Enforce regulations to limit coastal development and sand excavation (and enforcement in general, for example, also cats & dogs on beaches)
- Implement measures to control light pollution.
- Protect and restore natural vegetation on beaches to provide shade and cooling for nests.

#### Foraging Grounds:

- Improve water quality by controlling run-off.
- Protect seagrass beds and coral reefs from pollution and physical damage.
- Manage Sargassum influxes through environmentally sensitive removal methods.
- Enforcement (e.g. speed limits for boats, regulation for wind/kite/foil surfers)

### Research and Data Collection:

#### Regular Monitoring:

- Conduct regular surveys to monitor the health and population dynamics of sea turtles and their habitats.
- Ensure staff capacity to ensure consistency of monitoring on all islands to avoid disperse data

#### Chemical pollution and Disease Surveillance:

- Implement programs to monitor the prevalence of diseases such as fibropapillomatosis and the correlation with contaminants.

#### Migration Patterns:

- Use satellite tracking and/or genetic analyses to gather data on migration patterns and identify critical habitats for protection.
- Understanding the drivers in nesting success fluctuations

#### **Public Awareness and Education:**

##### Community Involvement:

- Engage local communities in conservation efforts through education and involvement in monitoring programs.

##### Tourism Management:

- Educate tourists about the importance of sea turtle conservation, the protection of their foraging (seagrass) habitat and encourage responsible behaviour on nesting beaches.

#### **Legislation and Enforcement:**

##### Enforce Regulations:

Implement and enforce existing regulations to reduce bycatch and illegal fishing.

##### Protected Areas:

Establish and enforce marine protected areas to safeguard critical nesting and foraging habitats.

#### **Further recommendations:**

Develop a new joint Sea turtle Recovery Action Plan (STRAP), as the current ones (Sybesma 1992 and Barnes et al., 1993) are highly outdated. The new STRAP should be part of the cooperative management of the marine biodiversity and fisheries of the Caribbean islands within the Kingdom of the Netherlands (EEZ MoA and Management Plan) and should include:

- Management and interventions to maintain and/or enhance nesting beach quality (in terms of beach size and setback to allow for encroaching sea level rise, sand depth, and quality natural vegetation, as well as control on disturbance of beaches and nests);
- Improve knowledge of foraging sea turtle populations around the islands and their ecosystem effects and dependence.
- Qualify, quantify, and address threats due to climate change.
- Expand regional international collaboration, especially towards countries such as Nicaragua, where the best data available shows that Dutch Caribbean nesting turtles spend part of their life cycle.
- Institutionalize essential monitoring to accurately follow population and nesting trends to evaluate strategies and interventions for adaptive management purposes.

## Key Threats and Management Implications

**Table 5.** Listing of different threat categories to sea turtle species, their predominant cause and the ensuing management implications.

Category	Threat	Description	Status: high concern/moderate/low/unknown
Nesting Beaches	Coastal development	Urbanization and infrastructure projects cause habitat loss and fragmentation, reducing available nesting areas.	Bonaire: High St. Eustatius: Moderate
	Sand excavation	Sand removal reduces nesting habitat, especially on St. Eustatius, where thin sand layers hinder egg-laying and hatching success.	Bonaire: Low St. Eustatius: Moderate

	<b>Erosion</b>	Overgrazing causes cliff erosion, increasing the vulnerability of nesting beaches on St. Eustatius.	<b>Bonaire: Low St. Eustatius: High</b>
	<b>Plastic pollution</b>	Litter on beaches and plastic in the ocean threaten adult and newborn turtles by blocking hatchlings' emergence and causing harm at sea.	<b>Bonaire: Moderate St. Eustatius: Moderate</b>
	<b>Light pollution</b>	Disorients hatchlings and egg-laying females, leading them inland, where they may die from dehydration.	<b>Bonaire: High St. Eustatius: Moderate</b>
	<b>Oil spills</b>	Risk of oil spills from cargo ships near St. Eustatius threatens nesting and foraging turtles.	<b>Bonaire: Moderate St. Eustatius: Moderate Saba: Moderate</b>
	<b>Higher temperatures</b>	Alters nesting site conditions, affecting sex ratios and hatchling survival rates. Higher temperatures can skew the sex ratio towards females, especially on beaches with less sand and vegetation (Laloë et al., 2016). For example, on St. Eustatius, where the sand is black and absorbs more heat, 85.9–93.5% of the young turtles are female.	<b>Bonaire: High St. Eustatius: High</b>
	<b>Recreational activities</b>	Increasing tourism on beaches, particularly in Bonaire, causes trampling of nests, necessitating protective measures like marking and fencing.	<b>Bonaire: High St. Eustatius: Low Saba: Low</b>
<b>Foraging Grounds</b>	<b>Chemical Pollution</b>	Land-based activities degrade water quality. Elevated chemical pollution in sediment and seagrass tissues exceeds safety thresholds, causing potential health concerns.	<b>Bonaire: High St. Eustatius: unknown Saba: unknown</b>
	<b>Coral reef degradation</b>	Human activities and climate change destroy coral reefs' essential turtle habitats and reduce food availability.	<b>Bonaire: High St. Eustatius: High Saba: High</b>
	<b>Seagrass habitat degradation</b>	Over the past three decades, Bonaire's seagrass habitat has decreased by more than 2 hectares yearly (Hylkema et al., 2014).	<b>Bonaire: High St. Eustatius: unknown Saba: unknown</b>
	<b>Sargassum blooms</b>	Large mats of Sargassum seaweed hinder hatchlings, and its decomposition destroys seagrass beds, creating anaerobic conditions harmful to marine life.	<b>Bonaire: High St. Eustatius: Moderate Saba: Low</b>
	<b>Recreational activities</b>	Aquatic tourism activities (e.g., boating, kitesurfing) can collide with foraging sea turtles in seagrass and coral reef areas)	<b>Bonaire: High St. Eustatius: Moderate Saba: Low</b>
<b>Migrating Species</b>	<b>Bycatch</b>	Turtles are unintentionally caught in fishing gear, leading to injuries or death.	<b>Bonaire: High St. Eustatius: unknown Saba: Low</b>
	<b>Poaching (regionally)</b>	Becking et al. (2016) revealed migration distances ranging from 197 to 3135 km to foraging grounds across the Caribbean. These grounds include coastal waters where harvesting activities persist.	<b>Bonaire: Low St. Eustatius: Low Saba: Low</b>

## Data Quality and Completeness

Data quality for assessing local trends in nesting frequency (e.g. and hatching success varies markedly among the Dutch Caribbean islands. Bonaire benefits from long-term, robust monitoring programs, whereas St. Eustatius suffers from fragmented turtle surveys. Green turtle monitoring is absent on Saba, although its

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expansive seagrass beds are an important foraging habitat. Because sea turtles are highly migratory, insights gained from one location may reflect regional dynamics, yet such broader datasets are often unavailable or non-standardized. Consequently, it remains unclear whether observed fluctuations in nesting are driven by local conservation measures or climate-driven shifts in migratory behaviour. With “casually”-collected data, it must be kept in mind that nest counts may reflect increased survey effort as more person-hours in the field, longer transect distances, and broader spatial coverage inevitably uncover more nests. To correct this, raw counts should be normalized by effort metrics (e.g. nests per person-hour or per km surveyed), as pointed out above. Complementary capture–mark–recapture approaches—whether via flipper or PIT-tagging, photo-ID of individual scale patterns, or DNA-based genetic marks—can provide more robust estimates of nesting–female abundance. Although these methods require additional resources and logistical coordination, they yield critical parameters (population size, survival rates, remigration intervals) that are critical for accurate population assessments and informed management. Finally, very little is known about how coastal pollution and changing beach parameters (e.g., sand temperature and moisture regimes) affect turtle health and reproductive success. Addressing these critical gaps will require harmonized, multi-island monitoring protocols and targeted studies on contaminant burdens and climate impacts at nesting beaches.

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Attn.: Melissa K. van Hoorn, Coordinator Caribbean Netherlands DG Nature and Fisheries  
P.O. Box 20401  
2500 EK Den Haag

BO 43 117-001 and BO 43 117-006

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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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