Indicators on the status and trends of ecosystems in the Dutch Caribbean

Indicators, monitoring and assessment methods and capacity estimates

Peter Verweij, Erik H. Meesters and Dolfi Debrot

WAGENINGEN UR
For quality of life

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1 Alterra
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Preface

This report presents the inventory of proposed biodiversity and nature monitoring activities as formulated by international treaty reporters based on their requirements and supplemented with knowledge from local and international experts active in the Dutch Caribbean.

Many thanks to the international reporters, statisticians, domain experts and local experts for sharing their experience, knowledge and constructive feedback on various versions of this report. Without them we would not have been able to give the broad vision and specific interpretation as described in this report. We specifically wish to thank: Anne Schmidt, Rene Henkens and Leo Soldaat from the Wettelijke OnderzoeksTaken (WOT, Alterra and Statistics Netherlands) for specifying requirements for the international reporting obligations based on their many years of experience; Sander Mucher for his knowledge of terrestrial and marine remote sensing; Joop Schaminee and Stephan Hennekens for advice on vegetation monitoring; Martin de Graaf on fisheries and sharks and rays; Adrian Delnevo on birds; John de Freitas on vegetation and habitat quality and; Leon Braat for his input on potential, actual and the (economic) valuation of ecosystem services and their integration into the political debate. Finally, I would like to thank Anouk Cormont for her excellent notes from the initial workshop.

List of consultations

Who	Where and when	Why
Dolfi Debrot (WUR), Rene Henkens (WOT), Erik Meesters (WUR), Anne Schmidt (WOT), Leo Soldaat (Statistics Netherlands), Peter Verweij (WUR)	Amsterdam, November 25 2014	A one-day workshop with treaty reporters and Caribbean biodiversity experts to create an inventory of (minimum) required indicators for habitats/ ecosystems and species based on treaty requirements and local needs, more specifically: • Inventory of treaty requirements and local needs; • Selection of relevant indicators based on the above; • Formulation of monitoring methods for the selected indicators
Sander Mucher (WUR	Wageningen, January 9 2015	Expert consult on proposed habitat indicators and method
Joop Schaminee (WUR), Stephan Hennekens (WUR)	Wageningen, January 9 and 26 2015	Expert consult on proposed vegetation indicators and method
Martin de Graaf (WUR)	Telephone, January 12 and 27 2015	Expert consult on proposed fisheries indicators and method
Adrian Delnevo (Applied Ecological Solutions Inc.)	Mail, January 26 2015	Expert consult on proposed bird indicators and method
Mark Vermeij (CARMABI)	Feedback requested on January 26 2015	Expert consult on proposed coral and fish indicators and method
John de Freitas (CARMABI)	Mail, February 3 2015	Expert consult on proposed vegetation indicators and method
Leon Braat (WUR)	February 4 2015	Expert consult on Ecosystem Services and the link with politics
Diana Slijkerman (WUR)	February 9 2015	Expert review of report on behalf of TripleP@sea (KB-14-007)
Leo Soldaat (Statistics Netherlands)	February 10 2015	Expert review of report
Rene Henkens (WUR)	February 15 2015	Expert review of report
Anne Schmidt (WOT)	February 16 2015	Expert review of report

Summary

The Caribbean islands of Bonaire, Saba, St.Eustatius, Aruba, Curacao and St. Maarten are part of the Kingdom of the Netherlands. The islands have a rich biological diversity and a variety of globally threatened ecosystems. These ecosystems are important for their services such as the production of food, coastal protection, tourism attraction, erosion control, medicine, carbon sequestration and climate change resilience, water and air purification and/or retention, and non-material benefits such as heritage and recreational experiences. Robust monitoring indicators are needed to assess ecosystem health in relation to environmental change and socio-economic stressors and exploitation.
The Kingdom of the Netherlands has ratified international treaties and conventions, signed regional agreements and implemented national law for the protection of nature and biodiversity in the Dutch Caribbean. These treaties call for reporting on status and trends of biodiversity.
Currently considerable effort is being invested in collecting baseline data and local monitoring to support local policy on and management of nature and biodiversity. These activities partially overlap with the demands of treaty reporting requests, but do not provide all the data necessary to satisfy the needs of either the reporting obligations or the local policy and management needs. The main issues are that:

- Existing monitoring programmes on the islands do not cover all required biodiversity and nature topics;
- Several existing monitoring programmes are based on methods that cannot be used to generate the indicators required.

This report concludes that monitoring all the separate species identified would require considerable resources. Monitoring in the Dutch Caribbean cannot be compared to the Netherlands which has a long history of monitoring the natural environment and many periodic reviews of the efficacy of monitoring techniques. Holistic monitoring of ecosystems using key indicators is a good alternative to detailed monitoring as the ecosystem health implicitly considers all dependent species. However, some additional species monitoring is necessary of keystone species, endangered species, commercially important species and invasive species.

1 Introduction

The Caribbean islands of Bonaire, Saba, St.Eustatius, Aruba, Curacao and St. Maarten are countries within the Kingdom of the Netherlands. The first three form the Caribbean Netherlands, three special municipalities of the country of the Netherlands. The islands have a large biological diversity and a variety of globally threatened ecosystems including coral reefs, mangrove forests and sea grass fields. These ecosystems are important for their services such as the production of food, coastal protection, medicine, carbon sequestration and protection against climate change, water and air purification, and non-material benefits such as heritage and recreational experiences.

To be able to assess the health and overall state of the ecosystems periodically, some form of monitoring is essential (MinEZ 2010) as input for management decisions. Caribbean ecosystems are facing major threats and are undergoing considerable change at local, regional and global level due to overexploitation, fragmentation, pollution, eutrophication, climate change and invasive species (Linton and Warner 2003, Jackson *et al.* 2014). Robust monitoring indicators are needed to gauge ecosystem health in relation to environmental change and socio-economic stressors and exploitation (Dahl, 1981; Linton and Warner 2003). European nature legislation does not apply to the Caribbean Netherlands. The EU Habitats Directive and the EU Birds Directive which together form the legal framework for the Natura 2000 network of protected areas in European Netherlands do not apply. Obligations resulting from international treaties and conventions for the Caribbean Netherlands are implemented at the national level in the "*Wet grondslagen natuurbeheer- en bescherming BES*". The legal mandate lies with the Ministry of Economic Affairs of the Netherlands (referred to in the following as MinEZ) not only with regard to the joint Exclusive Economic Zone of the Dutch Caribbean, but also with regard to overall terrestrial and marine biodiversity of the three islands that have become special Dutch municipalities. Among other things this mandate has led to the formulation of the "*Nature policy plan Caribbean Netherlands*" (MinEZ 2013). The Nature Policy Plan stresses the importance of jointly managing nature and that a good result can only be achieved if all stakeholders and interest groups involved are fully committed. The Nature Policy Plan is a means to ensure continuous involvement of those stakeholders while acknowledging each of their tasks and responsibilities.

The Kingdom of the Netherlands has ratified international treaties and conventions and made regional agreements and national law for the protection of nature and biodiversity in the Dutch Caribbean. On the basis of these legal obligations these treaties require reporting on status and trends of biodiversity, ecosystems and threatened species. In recent years the Ministry of Economic Affairs has invested in many studies in the Caribbean Netherlands to provide ecological baseline data. These studies have contributed to our knowledge of biodiversity, and stimulated further policy development and implementation. This extended knowledge base has also contributed to the latest Nature Policy Plan Caribbean Netherlands (MinEZ 2013) for the period 2013-2017 and to the latest five-year evaluation of nature policy and management in the context of the reporting obligation for the Convention on Biological Diversity (MinEZ 2014).

Currently a great amount of effort is being invested by local nature organisations in ongoing monitoring and assessment activities to support local policy on and management of nature and biodiversity. These activities partially overlap with the demands of treaty reporting requests, but do not provide all the data necessary to satisfy the needs of either the reporting obligations[1] or the local management and policy needs. Generally.

[1] Leo Soldaat (Statistics Netherlands), Rene Henkens (WOT), December 2013, personal communication during workshop and in emails during preparation of CBD report 2014

- Existing monitoring programmes on the islands do not cover all required biodiversity and nature topics;
- Several existing monitoring programmes are based on methods that cannot be used to generate the indicators required.

Based on consultations with experts this report investigates how nature monitoring in the Caribbean Netherlands can be expanded or adapted to give enough coverage to satisfy at least the indicator demands from international treaties. We also investigate whether monitoring can be easily adjusted to support local needs as well. This report is an initial inventory. Elaboration on the statements within this report may result in future adjustment of our conclusions.

Within this report a minimum set of indicators with accompanying methods is proposed to further facilitate management, to enable early detection of change in important ecosystems and species, and to address more adequately existing and future reporting obligations to treaties and conventions.

We first describe the historical perspective of monitoring in the Caribbean Netherlands and the relevant ecosystems; this is then followed by the presentation of the conceptual indicator framework for biodiversity monitoring (chapter 2). In chapter 3 we summarise the treaties and advise on how to report for the treaties. Chapter 4 lists the indicators per ecosystem that were identified as relevant, both for treaty reporting and local management. Finally, Chapter 5 makes a recommendation on the activities necessary to organise the proposed framework by linking the previous chapters together.

2 Considerations and assumptions

2.1 Monitoring and assessment in the Caribbean Netherlands: a historical perspective

In this report we consider the purpose of nature monitoring to be able to assess the status and the development trend of a species or habitat. Furthermore we want to understand the effect of human policy and management measures on that status and trend. To clarify the causes of change, monitoring must also include measurements of environmental, social and economic pressures. Preferably, we would like to know as soon as possible if '*things are moving in the wrong direction*' because to stop the further degradation of a habitat or decline of a species, necessary interventions are most effective in an early stage. There are several important issues when deciding what to monitor: indicators of interest, methods, institutional setting, organisational and financial aspects.

It is important to make a clear distinction between research and monitoring. Research typically addresses ecological questions and actual population parameters, such as actual population size or actual density, and has a limited duration. Determining population parameters is often complicated and costly. As monitoring largely serves as a warning system for change for an indefinite amount of time, a more cost-effective approach may be to identify and use a simpler proxy measure to indicate changes in important parameters. For instance, dung density is often used as a proxy for herbivore density and strip or point counts collected from a limited number of sites can be used as a proxy for presumed population size.

In this report an indicator is a standardised unit of measure that summarises information relevant to a particular phenomenon (Gallopin, 1974) based on (seasonally or periodically) repeated measurements. To set up a good indicator each phenomenon should be assessed on its (natural and methodological) variability to evaluate the conclusions that can be drawn from it. For example, a phenomenon that varies a lot from one year to another may need many years of monitoring to be able to provide conclusive evidence that a (significant) change has occurred. An indicator that varies a lot from one site to another will not be very useful for comparing two areas unless many sites in each area are sampled. Thus, the quality of indicators including repeatability and costs to collect them should determine the setup of a monitoring method.

Methodological issues include the *monitoring technique* (e.g. remote sensing, photographs, field surveys, fixed meters or questionnaires), the *spatial strategy* (e.g. permanent points, permanent plots, large number of random plots, tracker devices, etc.) and the *temporal strategy* (e.g. every year, every week during relevant season, every hour, etc.). Although in practice often difficult, it can be advantageous to set up monitoring that can be used to address multiple questions. A good example is the coral monitoring of Bonaire and Curacao which uses photographs of coral quadrants to monitor coral cover and coral diversity. Recently these photographs have been reassessed to determine the increase of algae over the last 30 years. If the composition of the method's elements is incorrect, the monitoring efforts easily result in useless data from which no indicators or conclusions can be derived. In some cases it is possible to change the methodological elements over time (e.g. use a new technology), but this should be done with care. Consequences of changing methods later on are often that previously gathered monitoring data cannot be used anymore; many characteristics of the monitoring may change which alters assumptions of the techniques used for data analysis.

On the islands of the Caribbean Netherlands the island governments have outsourced nature management including monitoring and assessment to NGOs. However, often the NGOs did not have enough manpower or continuity to engage in structural long-term monitoring. Something as simple as changing the person or company that carries out the monitoring can render a monitoring dataset useless if this is not done without the utmost care. As a consequence, many available monitoring data sets are short time series, have gaps or have been set up without integrating the reporting obligation demands. The latter is frequently the case when monitoring is set up to answer a short-term research question. Where long-term data sets are available, it is often due to a single person's determination and perseverance. In 2010 the Ministry of Economic Affairs started with an inventory of monitoring activities in the Caribbean Netherlands (MinEZ 2010). A number of actions were taken to improve monitoring and a central database (www.dcbd.nl) was set up to hold all the monitoring results. In 2014, when CBS and WOT conducted a preliminary evaluation of the initiatives that had been developed, it was concluded that the data currently available in the database are not sufficient to cover all the reporting obligations. Within this report a minimum set of indicators with accompanying methods is proposed to facilitate management, to enable early detection of change in important ecosystems and species, and to address more adequately future reporting in line with treaties and conventions.

A comparison with monitoring in the Netherlands is often made, but this is hardly justified given the amount of effort and manpower that is invested in monitoring in the Netherlands and the duration of monitoring programmes there. More than 70 monitoring programmes were identified in the Netherlands (Meesters *et al.* 2009).

2.2 Indicator framework

Considering that there is monitoring in place in the Caribbean Netherlands, the task is not only to identify a feasible set of indicators, but also to address the monitoring that already exists and how this can be incorporated in a future monitoring strategy. The objective is therefore not only to fulfil treaty reporting obligations more effectively, but also to make current monitoring more useful for local nature management.

Monitoring all the separate species identified (see Debrot 2006, Jongman et.al. 2009) requires a lot of resources. Monitoring of the surface area, the fragmentation and the health of ecosystems is an accepted alternative to start with (Noss 1990) as the ecosystem implicitly considers all dependent species. Table 1 shows the identified important ecosystems for the Dutch Caribbean. However, additional species monitoring is necessary for:

- Keystone species (e.g. columnar cacti).
- Endangered species (e.g. sea turtles, groupers, whales).
- Target species for their economic importance (e.g. fish, lobster or conch).
- Invasive species (e.g. coralita, lion fish).

When a species is a true indicator of the status of an ecosystem, it may be more economical to monitor that species rather than the whole ecosystem.

Table 1

Important ecosystems for the Dutch Caribbean.

Ecosystems / habitats	Bonaire	St. Eustatius	Saba	Saba bank
Beaches	X	X		
Cactus forests	X			
Caves	X			
Coral reef	X	X	X	X
Deep sea	X	X	X	
Mangrove forests	X			
Rain forest and cloud forest		X	X	
Salinas	X			
Sea grass beds and algal beds	X	X	X	X

When looking at the state of ecosystems, species and potential interventions to manage or direct trends, it is crucial to understand how the drivers and pressures that impact those ecosystems and species change. Ideally these pressures should also be monitored. Periodic evaluation of ecosystems, species and their management is supported by indicators derived from monitoring activities. Figure 1 shows the considered framework of ecosystems, species and monitoring (see also DPSIR[2]).

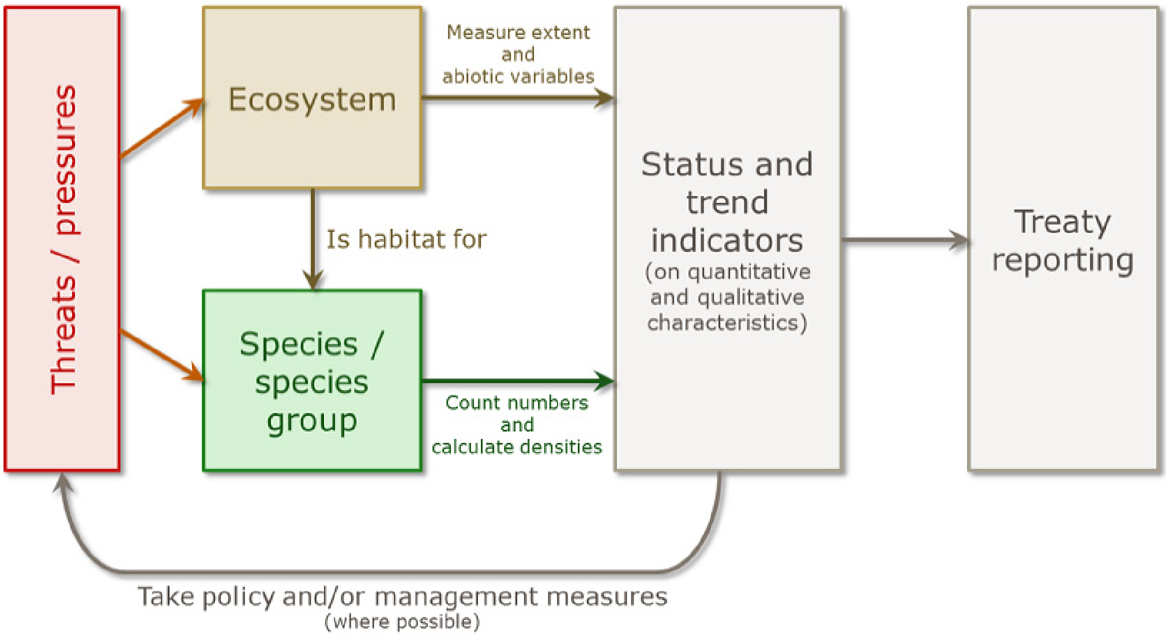

Figure 1 *Indicators for the evaluation of ecosystems and species. Indicators are used for treaty reporting and to trigger counteracting of threats.*

2.3 Prioritisation

Because of the large number of potential species (taxa), ecosystems and variables that can be monitored, it is necessary to set priorities that take account of the following requirements:

a. Simple and cost effective methods and protocols to safeguard smooth knowledge transfer across data gatherers either professional, volunteers or students;
b. Allow both short-term and long-term change to be documented on appropriate spatial and temporal scales;

[2] Driver, Pressure, State, Impact and Response (DPSIR), EEA

c. Preferably tie into existing initiatives;
d. Link to long-term management and treaty priorities;
e. Be useful for evaluating management success, management adaptation as well as policy effectiveness and policy efficiency.

3 Reporting obligations

The Netherlands has signed several international treaties, conventions and Memoranda of Understanding with the overall objective of managing important and vulnerable ecosystems wisely (see Table 2). Treaties carry reporting obligations (e.g. SPAW art. 19.1; IAC art. XI.1; CITES art. VIII.7) on '*good governance*' and may require quantitative indicators on the state and trend of nature (e.g. SPAW art. 19). Non-compliance with treaty obligations can have far-reaching consequences. For instance, a development permit from the Bonaire government was overturned by intervention of the governor and an appeal by the Dutch State Council that determined that RAMSAR regulations were legally binding.[3]

Recent Dutch Caribbean CBD, RAMSAR and CMS reports have been mostly based on local tacit knowledge and expert knowledge. However, it is commonly regarded as good practice to provide evidence-based information. To do so, nations repeatedly make measurements in order to collect data.

Table 2
List of treaties

Treaty	Scale	Reporting frequency
CBD	Global	Every 4 years
SPAW	Regional	Every 4 years
RAMSAR	Global	Every 3 years
CMS	Global	Every 3 years
IAC	Continental	Yearly
CITES	Global	Yearly
IPPC	Global	None

A short description of the objective of each treaty and advised reporting topics is given below.

3.1 Convention on Biological Diversity (CBD)

The CBD has 3 main objectives: the conservation of biological diversity, the sustainable use of the components of biological diversity and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources[4].

3.1.1 Specially Protected Areas and Wildlife (SPAW) in the Wider Caribbean Region

The Protocol acts as a vehicle to assist with regional implementation of the broader and more demanding global CBD. The SPAW protocol seeks to take the necessary measures to sustainably protect, preserve and manage areas that require protection to safeguard their special value, and threatened or endangered species of flora and fauna [5]. Reporting is required on the status of threatened or endangered species listed in SPAW Annex I (plants) or II (animals) insofar as they occur in the wild within the Caribbean Netherlands, as well as endemic species that are locally threatened or endangered, and on management of species listed in Annex III.
We recommend reporting on:

[3] http://caribischnetwerk.ntr.nl , 'Nederland en Bonaire buigen zich opnieuw over bezwaren Karels pier' (June 12, 2014)
[4] https://www.cbd.int
[5] http://www.cep.unep.org/content/about-cep/spaw

- Status and trends on population size (number of individuals) and distribution through time of
  - Birds: Selected list of key species with a mix of seabirds, forest birds, migratory birds and birds of prey: Audubon's shearwater, brown pelican, peregrine falcon, caracara (Bonaire only), least tern (Bonaire only), roseate tern (Bonaire only), yellow-shouldered Amazon (Bonaire only), flamingo (Bonaire only), red billed tropic bird, white-tailed tropicbird, Caribbean elaenia, brown trembler (Saba only), scaly-breasted thrasher, bridled quail dove, white-tailed nightjar, white-crowned pigeon, red-necked pigeon and apex raptors;
  - Mammals: whales, dolphins and bats;
  - Reptiles: All sea turtles, Iguana delicatissima (St. Eustatius only);
  - Fish: rainbow parrotfish (Bonaire only).
- Status and trends in area and quality of ecosystems: beaches, cactus forests, caves, coral reefs, mangroves, rain forests, Salinas, sea grass fields;
- Indicate if and what migratory species have been taken into account in the selection of protected areas, when new areas are designated;
- Status and trends of threats, including a description of counteractive measures;
- Status and trends of ecosystems and the services they provide for society.

3.2 Convention on wetlands (RAMSAR)

RAMSAR is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources[6].
We recommend that reporting should focus on:
- Maps of the location and names of the RAMSAR sites;
- Indicate for each RAMSAR site:
  - Whether the area supports vulnerable, endangered or critically endangered species or threatened ecological communities (criterion 2). Mangroves, sea grass, coral reef, sea turtles;
  - Whether the area harbours more than 20,000 water birds at any moment in a year (criterion 5);
  - Whether the area has more than 1% of a bio-geographical population of a bird (sub) species within a year (criterion 6). The criterion does not distinguish between breeding and foraging individuals; Species of interest are: Caribbean flamingo (500 individuals) and terns (least tern, common tern and yellow billed sandwich tern). Other species do not make up more than 1% of a bio-geographical region;
  - Whether the area has more than 1% of a bio-geographical population of other species within a year (criterion 9). Not applicable.

3.3 Convention on the Conservation of Migratory Species of wild animals (CMS)

CMS provides a global platform for the conservation and sustainable use of migratory animals, their habitats and migration routes[7].
We recommend reporting on:
- Trends in population size, distribution, threats to and countermeasures in favour of:
  - birds (flamingo);
  - fish (sharks and rays);
  - reptiles (sea turtles).
- Indicate whether migratory species have been taken into account in the selection of protected areas. If yes, include:
  - maps of terrestrial and marine parks and Important Bird Areas if applicable;

[6] http://www.ramsar.org
[7] http://www.cms.int

– the coverage of protected marine and terrestrial areas as a percentage of the total marine and terrestrial area.
- Contingency plans for addressing threats (e.g. oil spills).

3.4 Inter-American Convention for the protection and conservation of sea turtles (IAC)

IAC is an intergovernmental treaty that provides the legal framework for countries in the Americas and the Caribbean to take actions for the benefit of sea turtles. The treaty promotes the protection, conservation and recovery of sea turtles and those habitats on which they depend on the basis of the best available data and taking account of the environmental, socioeconomic and cultural characteristics of the Parties.[8]
We recommend reporting on:
- Status and trends of population size and distribution for all sea turtle species.
- Status and trends of nest densities and hatching success of all sea turtle species.

Indicators are currently being developed to measure the impact of climate change on nesting beaches. This might include indicators to measure water and sand temperature, sea roughness, the amount of cooked eggs or the change in sex ratio from hatchlings

3.5 Convention on international trade in endangered species of wild fauna and flora (CITES)

The aim of CITES is to ensure that international trade in specimens of wild animals and plants does not threaten their survival.[9]
We recommend reporting on:
- Annual overviews of all recorded (legal or illegal) trade, whether passing through or originating from the island, in terms of species, number, origin, party identity and country of destination.

3.6 International Plant Protection Convention (IPPC)

The aim of IPPC is to protect cultivated and wild plants by preventing the introduction and spread of pests[10]. The IPPC has no periodic reporting requirements or specific lists of species. The IPPC does contain significant management obligations such as an active Invasive Alien Species Plan.
We recommend reporting on:
- Spatial and temporal trends of corallita on St.Eustatius and Saba;
- New records of exotic species recorded for the islands.

[8] http://www.iacseaturtle.org/defaulteng.htm
[9] http://www.cites.org/
[10] http://www.ippc.int

4 List of indicators

The indicators and monitoring methods listed below are based on the current situation and information demands as specified by experts during consultation. The proposed indicators with accompanying methods provide a solid basis that can be used to clarify the status and development of many ecosystems and species. However, unforeseen/future questions or sudden trend changes may trigger research questions necessitating additional (short-term) monitoring or research.
A monitoring strategy concerns a monitored object (such as species or ecosystem), a variable to measure (e.g. surface area), a unit (e.g. km^2), and spatial and temporal coverage (sampling density and measurement frequency). An assessment is made given a certain reference (e.g. given the status at a specific time) or a target (e.g. population size with a minimum of ‘x’ individuals).
Based on the framework of Figure 1 each ecosystem may be under pressure from a number of threats. The following sections present indicators and also group the indicators by ecosystem, species and threat (coded ES, SP, TH and coloured brown, green and red, respectively). The monitoring methods have been inventoried and capacity estimates have been made using expert consultation where available. The capacity estimates given here were made by the consulted experts. However, a formal and substantiated quotation should still be requested from the implementing organisations.

4.1 Beaches

	Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
1	Beaches	ES	1a	Total area [ha], distribution [map] and fragmentation [index]	remote sensing interpretation, every four years. Very high resolution, 2-5 metres (*WorldView*, or *quickbird*)	4 scenes (1 Saba, 1 St.Eustatius, 2 Bonaire): total 10 kEuro + 30 days (Bonaire) + 15 days (Saba) + 15 days (St.Eustatius) to process the satellite data, gather ground truth and report on findings
		ES	1b	Substrate coverage [%] of {*rubble*, *sand*, *stone*}	visual assessment during turtle nest survey (nightly during nesting season, May to January)	Already in place by STCB and STENAPA
		SP	1c	Turtle hatching success per species per island [%]	Turtle nest visual survey. Percentage of hatched eggs per nest;	“
		SP	1d	Turtle nests per species per island [#]	Turtle nest visual survey. Total number of nests per island	“
		SP	1e	Turtle nest distribution Bonaire and St.Eustatius	Turtle nest survey.	“
		TH	1f	Storm frequency and intensity;		
		TH	1g	Garbage [index]	Estimate by visual assessment	
		TH	1h	Tourists [#]		
		TH	1i	Cruise ships [#ship, #days, #passengers]		
		TH	1j	Divers[#]	Island statistics. Dive shop administration	

4.2 Cactus forests

Ecosystem / habitat				Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
2	Cactus forests	ES	2a	Total area[ha], distribution and fragmentation [index]	See 1a	Included in 1a
		ES	2b	Density [index]	Field survey of 3 permanent plots sized 100x100m in Lima, Karpata and Washington Slagbaai NP. Once every 4 years	
		SP	2c	Floral species richness [#], total and structure per different layers {herb, shrub, tree}	Field survey of 10x10m permanent plots	5 permanent plots a day
		SP	2d	Bat[#]	Walk transect through '2b' plot with bat-detector. Twice every year.	
		SP	2e	Bird species richness[#] and numbers per bird species	Field survey in a permanent plot (see 2c) each year during migration season	
		TH	2f	Goats and donkeys [#]		
		TH	2g	Population size [#]		
		TH	2h	Urban expansion [ha]		

4.3 Caves

Ecosystem / habitat				Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
3	Caves	ES	3a	Water level [cm]	Permanent automatic logger at 3 Bonaire caves: Kueba, Watapana and Lima	
		ES	3b	Temperature [Celsius]	Permanent automatic logger at 5 Bonaire caves: see 3a and 2 key nursery dry caves	
		ES	3c	Air humidity [%]	Permanent automatic logger at 5 caves: see 3b	
		TH	3d	Tourists[#]		
		TH	3e	Population size [#]		
		TH	3f	Urban expansion [ha]		
		TH	3g	Water level [cm]		
		TH	3h	Divers [#]		
		TH	3i	Water transparency [%]		
		TH	3j	Contamination		

Caves form the sleeping habitat for bats. Bats are hard to count from within the cave so instead we propose that bats should be counted in the cactus forest, their foraging habitat.
In Bonaire there are both dry caves and caves (partially) filled with water. The water caves are visited by diving tourists.

4.4 Coral reefs

Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
4 Coral reefs	ES	4a	Live coral cover [%] and cover by algae and sponges [%]	Bonaire: field survey, yearly photographs of 8 permanent plots. Sababank, Saba and St.Eustatius: yearly 2x10m photo transects at 10 sites per island/area. Analyse photographs every 4th year. Only analyse photographs of years in between if necessary due to events. 5 yearly full coverage of the leeward side of Bonaire.	Bonaire: fieldwork 5 days, photo analysis 10 days (in place since 1973. Currently run by IMARES) Sababank, Saba, St.Eustatius: fieldwork 5 days per area, photo analysis 10 days per area.
	SP	4b	Coral species richness [#]	See 4a	Included in 4a
	SP	4c	Fish densities [#]	Yearly 2x25m transects at 10 sites per location (Bonaire, Saba, St.Eustatius and Saba bank). Divers record what is encountered[11] 5 yearly full coverage of the leeward side of Bonaire.	5 days per location. Total 20 days. Excluding video analyses. Days p.p.
	SP	4d	Fish population structure [length categories grouped by carnivores, herbivores, coral munchers and omnivores]	See 4c	Included in 4c
	SP	4e	Shark and ray densities [average # per dive] per species	Dive schools to record sightings	
	SP	4f	Shark densities	Stereo Baited Remote Underwater Video (BRUV). Once every four years.	
	TH	4g	Sea water temperature [Celsius]		
	TH	4h	Storm frequency and intensity		
	TH	4i	Urban expansion [ha]		
	TH	4j	Water transparency [%]		
	TH	4k	Change in fish densities and population structure		
	TH	4l	Lion fish [#]		
	TH	4m	Cruise ships [#ship, #days, #passengers]	Statistics on tourist numbers and days of visit	
	TH	4n	Port calls [# per origin]	(proxy for invasive pressure)	

Key invertebrate densities (sea urchins and sea cucumbers) can be estimated from the coral cover monitoring (4a). At this stage we do not include them on the indicator list.
Current research measures coral recruit densities and algae canopy height. Both can be explanatory or even causative variables for the decline of living coral cover (4a). Coral recruits contain information on reproduction and algae canopy and could be a proxy for the amount of available nutrients and/or the amount of grazing (e.g. by parrotfish).

[11] AGRRA protocol, Atlantic and Gulf Rapid Reef Assessment

4.5 Deep sea

	Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
5	Deep sea			UNCLEAR OBJECTIVES	RESEARCH REQUIRED	

4.6 Mangroves

	Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
6	Mangroves	ES	6a	Total area [ha], distribution and fragmentation [index]	See 1a	Included in 1a
		SP	6b	Floral species richness [#], total and structure per different layers {herb, shrub, tree}	3 Permanent plots of 10x10m	Half a day per year
		SP	6c	Bird species richness[#] and numbers per bird species	Field survey of 6 minutes in a permanent plot (see 6b) each year during migration season	Half a day per year
		TH	6d	Land expansion [ha]	Remote sensing	
		TH	6e	Urban expansion [ha]	Remote sensing	
		TH	6f	Garbage cleaning [volume] (as proxy for amount of garbage)		
		TH	6g	Goats and donkeys [#]		

4.7 Rain forest and cloud forest

	Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
7	Rain forest and cloud forest	ES	7a	Total area [ha], distribution and fragmentation [index]	See 1a	Included in 1a
		ES	7b	Air humidity [%]	Permanent automatic logger at 2 locations at mount scenery (Saba) and 2 locations at the Quill (St.Eustatius)	
		SP	7c	Floral species richness [#], total and structure per different layers {herb, shrub, tree}	Permanent plot of max 10x10m	5 permanent plots per day
		SP	7d	Bird species richness[#] and numbers per bird species	Field survey in a permanent plot (see 7b) each year during migration season	10 point counts a day
		TH	7e	Temperature [Celsius]	Permanent automatic logger	
		TH	7f	Storm frequency and intensity		
		TH	7g	Invasive Coralita coverage [ha]	Remote sensing	
		TH	7h	Goats and donkeys [#]		

Cloud forests are very sensitive to local climate and are strongly affected by global climate change. Monitoring floral species richness (indicator 7c) in the cloud forest will function as a sentinel for climate change.

4.8 Salinas

	Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
8	Salinas	ES	8a	Total area [ha], distribution and fragmentation [index]	See 1a	Included in 1a
		SP	8b	Flamingo [total #]	Monthly field survey	Already in place
		TH	8c	Land expansion [ha]	Remote sensing	

4.9 Sea grass beds and algae beds

	Ecosystem / habitat			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
9	Sea grasses	ES	9a	Total area [ha], distribution and fragmentation [index]	See 1a	Included in 1a
		SP	9b	Vegetation species richness [#]	Field survey of permanent plots. Once a year	
		SP	9c	Conch densities	Video camera transects	Every 4 years
		TH	9d	Sea water temperature [Celsius]		
		TH	9e	Storm frequency and intensity		
		TH	9f	Water transparency [%]		
		TH	9g	Garbage [index]	Visual assessment	
		TH	9h	Land expansion	Remote sensing	
		TH	9i	Tourist [#]		

4.10 Other species

Not all species are directly linked to one of the ecosystems classified in Table 1. There are also species that are listed separately due to their special status within treaties or local importance. These species and their indicators are listed in the table below.

	Species			Indicator (quantitative / qualitative)	Monitoring method	Capacity estimate
10	Red Billed Tropic Bird	SP	10a	bird numbers [#]	Once a year count individuals in most important colonies. During nesting season	
	Yellow-shouldered Amazon	SP	10b	Roosting birds [#]	Once a year count individuals when they fly out of their roosts. During nesting season.	
	Birds of prey	SP	10c	Bird numbers [#] per species (cara cara, white tailed hawk, merlin, peregrine falcon)	Record birds of prey when driving to all salinas to do flamingo counts (see 8b)	
	Lesser Antillean iguana	SP	10d	Iguana [#]	Survey permanent transects every 4 years (Debrot *et al.* 2013)	7 days of fieldwork every 4 years + 3 days to report
	Tern	SP	10e	Tern [#]	Count tern pairs on Bonaire	
		SP	10f	population size and distribution of all sea turtles		
		TH	10g	Cats removed [#]	Cats threaten breeding success of 10a and 10e	

4.11 Pending species groups

As species and population counts for both butterflies and dragonflies are highly variable in the Dutch Caribbean (Paulson *et al.* 2014) we recommend waiting for well-accepted methods before setting up monitoring activities for standardised reporting indicators.
The first study based on passive acoustic monitoring of cetaceans in the Dutch Caribbean has just been published (Risch *et al.* 2014). This approach will form the main thrust for cetacean research and monitoring in the Dutch Caribbean in coming years at IMARES (Lucke *et al.* 2014). Twice yearly ship surveys are undertaken by the French Agoa Sanctuary and these also include the northern Dutch EEZ waters and participation from each of the marine parks of Saba, St. Eustatius and St. Maarten. Currently it is not clear whether a population density assessment can be based on the low detection rate of cetaceans obtained from the ship surveys. Geelhoed *et al.* (2014) state that ship and plane-based surveys are too costly and too complicated to organise and yield little information for the costs and effort due to low density/detection in the Caribbean. As with the butterflies and dragonflies, we recommend waiting for well-accepted methods before setting up monitoring activities for standardised reporting indicators.

5 Recommendations

5.1 Overview

We recommend:

- Keep supporting the following current activities: Maintain existing monitoring on: turtle nests, coral cover, shark and ray densities, flamingo counts, yellow-shouldered amazon roost counts and terns. Adjust the existing monitoring for: fish densities and population structure, bird species richness, red billed tropic bird, Lesser Antillean Iguana;
- Set up ecosystem/habitat monitoring;
- Set up vegetation monitoring;
- Link forest and migratory bird monitoring to vegetation monitoring;
- Link bird of prey monitoring to flamingo monitoring on Bonaire;
- Collect data on pressures and abiotic conditions from other sources (e.g. from Statistics Netherlands);
- Stimulate the use of volunteers for monitoring.

To maximise capacity development and cooperation whilst keeping costs low, data collection should be conducted locally as much as possible, while data analysis and reporting should take place jointly with shared expertise that would otherwise be too expensive to finance on site. Stakeholders would like to involve more participants in the data gathering and data analysis to raise awareness; this would presumably have a positive spin-off for local accountability and the objectives of the treaties.
Based on these considerations we recommend the organisation of a monitoring system in the Dutch Caribbean as described below. The indicators listed in chapter 4 that are supported by each component of the monitoring system are mentioned in parentheses. For each indicator the power to detect a certain amount of change within a defined duration of monitoring should be assessed to avoid collecting unusable data (e.g. Meesters *et al.* 2007). Furthermore, this kind of analysis can help to improve monitoring and even make it more cost-effective.

5.2 Keep supporting current activities

It is recommended that ongoing activities that easily fit into the indicator and monitoring activities described in this report should be continued. These include:

- Turtle nest monitoring on Bonaire and St.Eustatius (1b, 1c, 1d, 1e);
- Coral cover on Bonaire and Curacao (4a, 4b);
- Shark and ray densities on Saba and St.Eustatius (4e);
- Flamingo counts on Bonaire (8b);
- Yellow-shouldered Amazon roost counts on Bonaire (10b);
- Terns on Bonaire (10e).

Other monitoring activities may need adjustment or should use less capacity-intensive methods for reporting:

- Fish densities and population structure (4c, 4d) as have been used in research on Saba, St. Eustatius and Bonaire.
- Bird species richness assessment has been carried out on St. Eustatius (7d). The monitoring method should be adapted in line with the objectives stated in this report. See section 5.4.
- Harmonise coral monitoring on St. Eustatius and Saba Bank with activities on Bonaire (4a, 4b).
- The Red Billed Tropic Bird monitoring as carried out on St. Eustatius and Saba generates relevant data for research, management and treaty reporting. For treaty reporting in itself, the method can be simplified (10a).

- A baseline for the population size of the Lesser Antillean Iguana (10d) was established in research on St. Eustatius (Debrot *et al.* 2013). Due to current low population densities, density estimation will be highly variable and unreliable unless population densities recover. Simple conservation and awareness action were indicated as priorities. New assessments are recommended once every 10 years, unless conservation and awareness action are taken to accelerate recovery. In that case more frequent monitoring (e.g. per 5 years) may be meaningful.
- In-water turtle surveys on Bonaire and sightings by dive schools on St. Eustatius provide, amongst other things, information on the population size and distribution of all sea turtle species. Methodological analysis is required to determine whether the data collected can be used to derive status and trend indicators (10f).

5.3 Set up ecosystem monitoring

We recommend that remote sensing analyses should be carried out regularly as this is an efficient technique to gather ecosystem data on: changes in areal size, shifts in location and fragmentation development. These data provide crucial status and trend indicators for ecosystems (1a, 2a, 6a, 7a, 8a, 9a). Remote sensing also provides data on impervious surfaces (artificial surfaces and soils compacted by urban development), both on land and sea, from which threat indicators can be derived (2h, 3f, 4i, 6d, 6e, 8c, 9g). It can also be used to provide data on the spread of the invasive Corallita on Saba and St. Eustatius (7g).

Remote sensing also provides relevant information on the quality of some habitats by interpretation of the texture, such as the amount of bare soil in a cactus forest, but no indicators have been linked to the structural information obtained from remote sensing at this stage.
Remote sensing for the monitoring of coral reef quality is currently being researched and as such is not included within this report.

Finally, the interpreted satellite imagery provides information on land use. Land-use maps can also be used in other governmental tasks such as spatial planning for a variety of societal needs.

5.4 Set up vegetation monitoring

The structure and species composition of the terrestrial vegetation provides the living environment for many animal species, including insects, small mammals, reptiles, amphibians and birds. Monitoring permanent quadrants (PQ) provides information on the change of that living environment (indicators 2c, 6b, 7c and 9b):

- Roughly take 150 PQs for the 3 islands jointly
- spread the PQs over the main vegetation types (2 to 3 PQs per main vegetation type per island). Use the available vegetation, geological, soil and geomorphological maps[12] to locate the PQs. On Bonaire include the permanent herbivore exclosures plus control monitoring sites as already established by Carmabi and Stinapa;
- A PQ is about 10x10 metres, but may be reduced to 3x3m if vegetation is very rich (e.g. in grassland on Bonaire or the cloud forest of Saba). Columnar cacti are very grazer vulnerable (Malo *et al.* 2011), but are keystone species in the leeward island ecology (Petit and Pors 1996; Petit 2001); they are also relatively spread out so meaningful monitoring of stand development requires much larger plots (100 x 100). On average 5 PQ field surveys can be carried out in one day;
- In each PQ the horizontal and vertical variety and coverage must be surveyed, including measurement of DBH (diameter at breast height) for all tree species (Bakker *et al.* 1996; Tomas 1996);

[12] http://www.dcbd.nl

- Document the disturbance of the vegetation by human activities by distinguishing the three ordinal expert opinion categories: *disturbed*, *developed*, *best developed*;
- Year 1: inventory of all PQs to set baseline and determine likelihood of changeability to adjust monitoring efforts over following years. PQs that change little need few field visits, while others might need more frequent surveys, e.g. cloud forest is expected to change slowly, in which case visiting a PQ every 4 years will provide enough change information. A currently grazed grassland is likely to change rapidly if grazing stops, in which case a yearly inventory must be made.
- Knowledgeable personnel with local knowledge is a prerequisite to carry out the floristic monitoring. Each individual surveyor has personal qualities and biases. Changing a surveyor might impact the continuity of the observations. Taking photographs while doing a field survey and storing them for possible future analysis is recommended. There is a dispute amongst experts on the need to have knowledgeable personnel on site. While some suggest that locals should visit the permanent plots, place a grid with known sizes and take pictures that are sent over to experts for them to analyse, others dismiss this proposed alternative method.

5.5 Link forest and migratory bird monitoring to vegetation monitoring

By linking avifauna monitoring with vegetation monitoring (see section 5.3) relevant information on the living environment of these bird species can be gathered, making it possible to link habitat change with changes in species diversity and abundance over time (indicators 2e, 6c, 7d). Habitat change can be derived from vegetation structure and composition in combination with ecosystem monitoring consisting of habitat size, fragmentation and spatial configuration (see section 5.2). Specialist bird species are easier to link with vegetation monitoring, while generalist bird species require more elaborate analysis combined with ecosystem monitoring.

Personnel with local knowledge is a prerequisite to carry out the required bird counts and identifications. A local expert shared his concern that the quality of species determination of a surveyor may decrease rapidly if not constantly practised. The expert suggested the alternative of having local personnel take audio recordings at the sites and sending them over to experts to analyse bird species and abundance by audio only.

5.6 Combine bird of prey monitoring with flamingo monitoring

On Bonaire bird of prey surveys (indicator 10c) can be carried out during the same field visits to count the flamingos (indicator 8b). Individuals can be counted while driving the route from one flamingo habitat, a saliña, to the next. Birds of prey of relevance for Bonaire are: caracara, white tailed hawk, merlin and the peregrine falcon.

5.7 Pressures and abiotic conditions

Information on the pressures and abiotic site conditions of ecosystems is essential to understand and clarify the status and trends of ecosystems and on which to base evasive or adaptive management actions. However, good indication of the status and trends of the quantity and quality of the ecosystems is the first step.
Statistics on environmental pressures might be obtained from sources other than those described in the previous sections of this chapter:
- Storm frequency and intensity;
- Total number of tourists;
- Number of divers;
- Number of cruise ships, number of passengers and origin;

- Number of port calls and port of origin for non-cruise ships (as potential source of invasive species);
- Population size;
- Number of cat removals. Cats predate on red-billed tropic bird nests on Saba and St. Eustatius, terns on Bonaire and the Lesser Antillean Iguana on St. Eustatius;
- Volume of garbage removed;
- Number of lion fish removed;
- Water quality (nutrients and eutrophic state).

The grazing pressure by goats and donkeys (indicators 2f, 6g and 7h) may be monitored once every 4 years for all three islands using the “dung density” method. Dung density serves as a proxy for actual animal density and grazing pressure. Dung densities are more stable indicators of livestock presence in an area than actual counts (Freitas *et al.* 2014) using the distance method along a number of transects (Buckland *et al.* 1993).

Permanent automatic loggers for temperature, humidity and water level (indicators 3a, 3b, 3c, 7b and 7e) should be tested in the field prior to implementation.

5.8 Seek collaboration with volunteers for monitoring

Monitoring is often time intensive and costly. Many countries use trained volunteers aided by standard protocols to carry out (part of) the monitoring. The USA and the Netherlands are examples of countries where trained amateurs are heavily involved in monitoring.
In the island setting the availability of resident volunteers is generally too limited. One option to explore is the use of visiting groups of (college) students in annual recurrent monitoring exercises. Far from being a cost, hosting such research groups should be regarded as an additional potential income source for management and form the main basis of the business model for research institutes throughout the region. Use of volunteers depends on the development of robust and simple monitoring protocols. Some of these protocols have already been developed, such as AGGRA for corals and fish and the protocols from Caricomp for sea grass and mangrove communities. The quality of the generated data might be insufficient for rigorous scientific inference, but it is useful to indicate long-term general trends and allow comparisons at regional level (van Tussenbroek *et al.* 2014).

5.9 Set up monitoring for the socio-ecological domain

An overview of the status and trends in ecosystems can be made using 4 yearly TEEB-like assessments by monitoring: (1) natural capital and potential ecosystem services, (2) the actual services and (3) the actual material and non-material benefits and social-economic monetary and non-monetary values (Braat and de Groot, 2012):

- Identify the EcoSystem Services (ESS) that produce benefits, preferably linked to a standard such as the Common International Classification of Ecosystem Services (CICES)[13];
- Identify the area providing the services;
- Estimate the benefits of each of the services in terms of stakeholders and money. Monitor how benefits and stakeholder composition change;
- Map the services to provide information on where services occur and which services can be linked to management activities (including protected zones);
- Analyse trade-offs between the use of services taking sustainability – the capacity of each island – into consideration;
- Harmonise with target 6 ‘*Step-up action to tackle the global biodiversity crises*’ and the procedures for Ecosystem Assessment of the European Commission (See Braat *et al.* 2015 and Perez-Soba *et al.* in prep.).

[13] http://cices.eu

Parts of the above have been carried out as baseline studies for the Dutch Caribbean (e.g. Tieskens *et al.* 2014; van Beek *et al.* 2011).

References

Bak, RPM, Gerard Nieuwland and Erik H Meesters 2005. Coral reef crisis in deep and shallow reefs: 30 years of constancy and change in reefs of Curacao and Bonaire. Coral Reefs 24(3): 475-479.

Becking and Slijkerman (2012) Generic ecological assessment framework for coastal ecosystems in the Caribbean Netherlands. IMARES Report C122/12, 44 pp.

Beek, I.J.M., A.O. Debrot, P.A. Walker and I. Kingma. 2014. Shark protection plan for the Dutch Caribbean EEZ. IMARES Report C209/13, 104 pp.

Bowen, R.E. and C. Riley. 2003. Socio-economic indicators and integrated coastal management. Ocean & Coastal Management 46 (2003) 299–312.

Braat, L.C., Bouwma, B. Delbaere, S. Jacobs, N. Dendoncker, M. van Eupen, A. Grêt-Regamy, M. Perez-Soba, J. Peterseil, F. Santos-Martin, P. Scholefield, A. Torre-Marin, P. Verweij and B. Weibel (2015), Mapping of Ecosystems and their Services in the EU and its Member States (MESEU), report no. ENV.B2/SER/2012.0016

Braat, L.C. and de Groot, R., 2012, The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy, Ecosystem Services, 1,1, pp 4-15

Buchan, K. Saba, Netherlands Antilles. In CARICOMP—Caribbean Coral Reef, Seagrass and Mangrove Sites, ed. B. Kjerfve. Paris: Coastal Region and Small Island Papers 3, UNESCO.

Debrot, A. O. 2006. Preliminary checklist of extant endemic taxa of Aruba, Bonaire and Curaçao, Leeward Antilles. Carmabi Report, Carmabi, Curaçao. 28 pp.

Debrot, A. O., J. Y. Miller, L. D. Miller and B. T. Leysner. 1999. The butterfly fauna of Curaçao, West Indies: 1996 status and longterm species turnover. Car. J. Sci. 35: 184-194.

Debrot, A.O., H. Madden, L. E. Becking, A. Rojer and J. Y. Miller The butterflies of St. Eustatius, Saba and St. Maarten (in review)

Debrot, A.O., Hylkema, A., Vogelaar, W., Meesters, H.W.G., Engel, M.S., R. de León, W.F. Prud'homme van Reine and I. Nagelkerken. 2012. Baseline surveys of Lac bay benthic and fish communities, Bonaire. IMARES-Wageningen UR Report C129/12. 52 pp.

Fancy, S.G., J.E. Gross and S.L. Carter. 2009. Monitoring the Condition of Natural Resources in US National Parks. Environmental Monitoring and Assessment 151: 161-174.

Freitas, J. A. de, B. S. J. Nijhof, A. C. Rojer and A. O. Debrot. 2005. Landscape ecological vegetation map of the island of Bonaire (Southern Caribbean). Royal Netherlands Academy of Arts and Sciences, Amsterdam. 64 pp. (+ maps)

Freitas, J.A., de, A.C. Rojer, B.S.J. Nijhof and A.O. Debrot. 2014. A landscape ecological vegetation map of Sint Eustatius (Lesser Antilles). Amsterdam: Amsterdam University Press. 67 pp.

Jackson, J. B. C., M. K. Donovan, K. L. Cramer and V. V. Lam (2014). Status and Trends of Caribbean Coral Reefs: 1970-2012. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland. 304 pp.

Jameson S.C., *et al.* (2003) Establishing reference conditions for the diagnostic monitoring and assessment of coral reefs http://www.coralseas.com/doc/RC8.pdf

Jongman, R.H.G., E.H.W.G. Meesters and A.O. Debrot, 2009. Onderzoeksvragen en verplichtingen op het gebied van Biodiversiteit voor de BES eilanden: Bonaire, Saba en St. Eustatius. Alterra-IMARES. 57 pp.

Klomp, K. D. and D. J. Kooistra. 2003. A post-hurricane rapid assessment of reefs in the Windward Netherlands Antilles (Stony corals, algae and fishes). Atoll Res. Bull. 496: 404-437.

Kuenen, M. M. C. E. and A. O. Debrot. 1995. A quantitative study of the seagrass and algal meadows of the Spaanse Water, Curaçao, Netherlands Antilles. Aquat. Bot. 51: 291-310.

Linton, D.M. and George F. Warner, 2003. Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. Ocean & Coastal Management 46: 261–276.

Lucke, K., *et al.* 2014. Marine mammals in the Wider Caribbean – Current research and priorities for future studies. IMARES Report C007/14, 38 pp.

Lucke, K. 2014. Noise logger overview. (One size does not fit all). IMARES internal report, 44 pp.

Madden, H., R. Hensen, S. Piontek, J.P. Verdaat, S.C.V. Geelhoed, J. Stapel and A.O. Debrot. New bird records for the island of St. Eustatius, Dutch Caribbean, with notes on other significant sightings (in review)

Meesters H.W.G., Reijnders P.J.H., Brasseur S.M.J.M., Tougaard S., Stede M., Siebert U. and Härkönen T. 2009. An effective survey design for harbour seals in the Wadden Sea: tuning Trilateral Seal Agreement and EU-Habitat Directive requirement. Trilateral Working Group. In: The meeting of the Trilateral Working Group TWG 07/1, Delfzijl, The Netherlands, 18 - 19 April, The Netherlands. - Wilhelmshaven : Trilateral Working Group, 2007 - p. 82.

Meesters, H.W.G., Brinkman, A.G., Duin, W.E. van, Lindeboom, H.J. and Breukelen, S. van. 2009 Graadmeterstelsel biodiversiteit zoute wateren : I. Beleidskaders en indicatoren. Wettelijke Onderzoekstaken Natuur & Milieu, (WOt-rapport 92) - pp. 30.

Meyer, K. de. 1998. Bonaire, Netherlands Antilles. In CARICOMP—Caribbean Coral Reef, Seagrass and Mangrove Sites, ed. B. Kjerfve, 127-140. Paris: Coastal Region and Small Island Papers 3, UNESCO.

Miller, J. Y., A. O. Debrot and L. D. Miller. 2003. Butterflies of Aruba and Bonaire with new species records for Curaçao. Car. J. Sci. 39(2): 170-175.

MinEZ (Dutch Ministry of Economic Affairs) 2013. Nature policy plan The Caribbean Netherlands. Nature policy for The Caribbean Netherlands 2013-2017. 55 pp.

MinEZ (Dutch Ministry of Economic Affairs) 2014. Convention on Biological Diversity. Fifth National Report of the Kingdom of the Netherlands. The Hague, the Netherlands. 96 pp.

MinEZ 2010. Biodiversity monitoring in the BES islands: past present and future. Department of Nature, Landscape and Rural Affairs, Team International. The Hague, the Netherlands. 43 pp.

Mittermeier, R. A., N. Myers and C. G. Mittermeier (eds.). 1999. Hotspots. Earth's biologically richest and most endangered terrestrial ecoregions. CEMEX, S.A.; Mexico City, Mexico. 431 p.

Myers, N., R. A. Mittermeier, C.G. Mittermeier, G. A.B. da Fonseca and Jennifer Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:854-858.

National Park Service. 2012. Guidance for designing an integrated monitoring program. Natural Resource Report NPS/NRSS/NRR—545. National Park Service, Fort Collins, Colorado.

Noss, R.F., Indicators for monitoring biodiversity: a hierarchical approach, Conservation biology, 4, pp. 355-364

Ojaveer, H., *et al.* 2014. Ten recommendations for advancing the assessment and management of non-indigenous species in marine ecosystems. Marine Policy 44: 160–165.

Pérez-Soba, M., Braat, L., Verweij, P., van Eupen, M., Cormont, A., Wiebel and B., Zulian, G. 2015. Training member states on ecosystem services mapping through hands on workshops. Final report to DG ENVIRONMENT'S CONTRACT N° ENV.B.2/SER/2014/0045r. Alterra Wageningen UR, JRC and ETHZ (in preparation)

Pors, L. P. J. J. and I. A. Nagelkerken. 1998. Curaçao, Netherlands Antilles. In CARICOMP—Caribbean Coral Reef, Seagrass and Mangrove Sites, ed. B. Kjerfve, 127-140. Paris: Coastal Region and Small Island Papers 3, UNESCO.

Sandin, S.A., Sampayo, E.M. and M.J.A. Vermeij. 2008. Coral reef fish and benthic community structure of Bonaire and Curaçao, Netherlands Antilles. Caribbean Journal of Science 44: 137-144.

Smith SR, Mucher CA, Debrot AO, Roupioz L, Meesters, HGW Hazeu and GW, Davaasuren N. 2013. Use of satellite data for the monitoring of species on Saba and St. Eustatius. IMARES Report C124/13, 86 pp.

Smith, S.R., W.J. van der Burg, A.O. Debrot, G. van Buurt and J.A. de Freitas. 2014. Key Elements Towards a Joint Invasive Alien Species Strategy for the Dutch Caribbean. IMARES Report C020/14, 104 pp.

Tieskens, K.F., Schep, S.W., van Beukering, P.J.H., van Beek, I.J.M. and Wolfs, E.M., 2014, Mapping the economic value of ecosystems on Saba, IVM, report R-14/14

Toller, W., A. O. Debrot, M. J. A. Vermeij and P. C. Hoetjes. 2010. Reef fishes of Saba Bank, Netherlands Antilles: assemblage structure across a gradient of habitat types. PloS ONE 2010/5/5/e9202

Van Beek, I.J.M., 2011, Functional valuation of ecosystem services on Bonaire – an ecological analysis of ecosystem functions provided by coral reefs, Wageningen University MSc report aquatic ecology and water quality management, report no. 009/2011 van Tussenbroek BI, Corte´s J, Collin R, Fonseca AC and Gayle PMH, *et al.* (2014) Caribbean-Wide, Long-Term Study of Seagrass Beds Reveals Local Variations, Shifts in Community Structure and Occasional Collapse. PLoS ONE 9(3): e90600. doi:10.1371/journal.pone.0090600

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