Titel projectvoorstel: Veerkrachtherstel van Natuur en Maatschappij in Caribisch Nederland
Title: Restoration of Resilience of Nature and Society in the Caribbean Netherlands.
Nummer: LWV20.63

Inzenden uiterlijk 14 september via de indienmodule (zie de website kia-landbouwwatervoedsel.nl)

Algemene informatie

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Het projectvoorstel draagt bij aan missie:
- ☐ A. Kringlooplandbouw
- ☐ B. Klimaatneutrale landbouw en voedselproductie
- ☐ C. Klimaatbestendig landelijk en stedelijk gebied
- ☐ D. Gewaardeerd, gezond en veilig voedsel
- ■ E. Duurzame en veilige Noordzee, oceanen en binnenwateren
- ☐ F. Nederland de best beschermde en leefbare delta

Of aan Sleuteltechnologie:
- ☐ ST1. Smart Technologies in Agri-Horti-Water-Food
- ☐ ST2. Biotechnologie en Veredeling

Of aan:
- ☐ Internationalisering

NB: slechts 1 vakje aankruisen

Het projectvoorstel sluit aan bij MMIP:
E2, Natuur-inclusieve landbouw, visserij en waterbeheer in Caribisch Nederland

Het projectvoorstel draagt bij aan prioriteit nr: 33

Short summary of the project proposal (max. 0.5 A4, this text will be published on the website)
The project "Resilience Restoration of Nature and Society in the Caribbean Netherlands" contributes to halting the decline of the coral reefs in the Caribbean Netherlands, improving the dependent ecosystem services and ensuring capacity building on the islands. An extensive monitoring network is being set up together with island organizations and companies to better keep a finger on the pulse of marine nature, to support nature policy and prevent negative effects, to optimize coral recovery and to build capacity on site. Coral reef restoration supports the economy and also provides coastal protection. Healthy resilient coral reefs are more resistant to the effects of climate change and thus contribute to a resilient economy. The knowledge development uses the latest technologies in remote sensing, underwater equipment, genetics, chemistry and data processing.

Projectproposal

Introduction

The marine nature of the Caribbean Netherlands, and the ecosystem services derived from it, are the most important economic resources for Bonaire, Saba and St. Eustatius. However, they are under great pressure partly due to climate change, but also due to local causes such as increasing tourism, erosion, water use, pollution and eutrophication of coastal water. Tourism and population have increased exponentially over the past 40 years and biodiversity has declined sharply. This deterioration of environmental quality was discussed in detail in the report "State of nature in the Caribbean Netherlands 2017 "[1]. The consequence of this large-scale decline is that the delivery of ecosystem services has deteriorated sharply, while these are precisely the basis of the local economy. Balancing fisheries, agriculture, tourism and water management with the natural capacity of the relevant ecosystems is therefore an urgent policy aim (KIA-LWV, Mission E, theme 2) for the Dutch Caribbean. An integrated approach and better measurements of processes on land and in the sea are therefore indispensable in order to restore the balance through targeted interventions and to increase the resilience of nature, biodiversity and thus also of society. However, there is a lack of fundamental knowledge and an integrated approach to coastal management in the Caribbean Netherlands. In this project, a new infrastructure is being set up together with local stakeholders to better monitor the status of marine nature through smart technologies and citizen science. The intended infrastructure will be used to measure the effects of land and sea use and management measures on ecosystem services and to optimize nature management. This project will contribute to the sustainability of agriculture, tourism and fishing and the adapative capacity to climate change of the islands.

Problem description

As indicated in the status report on the nature of the Caribbean Netherlands[1], the existing knowledge base is inadequate and improvement is urgent. The precarious situation of the nature of the Caribbean Netherlands (and also of the other islands within the Kingdom) is not essentially different from that of many other islands in the tropics. These islands are often referred to as SIDS, Small Island Developing States. Due to their size and development, they face similar challenges such as a rapidly growing population, few natural resources, high dependence on imports, sensitive to crises and a fragile nature. The Netherlands is committed to the United Nations Sustainable Development Goals and Goal 14, 'Living in the sea', calls for a more sustainable use of seas, oceans and marine resources (https://www.un.org/sustainabledevelopment/oceans /). The project described here therefore potentially has a wider reach than just the Caribbean Netherlands.
Since 2010, WUR has been conducting research for LNV in the Caribbean Netherlands within the Policy Support Research (BO). However, a structural monitoring program does not exist and current monitoring is carried out on the islands as far as possible by the NGOs mandated by the local government, with the support of LNV since 2010. Data from before 2012 was often collected by researchers from the Netherlands within projects paid for by NWO.
Recent scientific research underlines the decline of Bonaire's coral reef over the past 40 years[2] and shows that climate change can have very serious consequences for coastal protection[3]. Research also shows that there are opportunities for recovery from areas that are still in good condition[4]. Support from the Netherlands is indispensable for the Caribbean Netherlands to stop further deterioration of nature and to focus on recovery. There is a lack of knowledge about the functioning of the coral reef

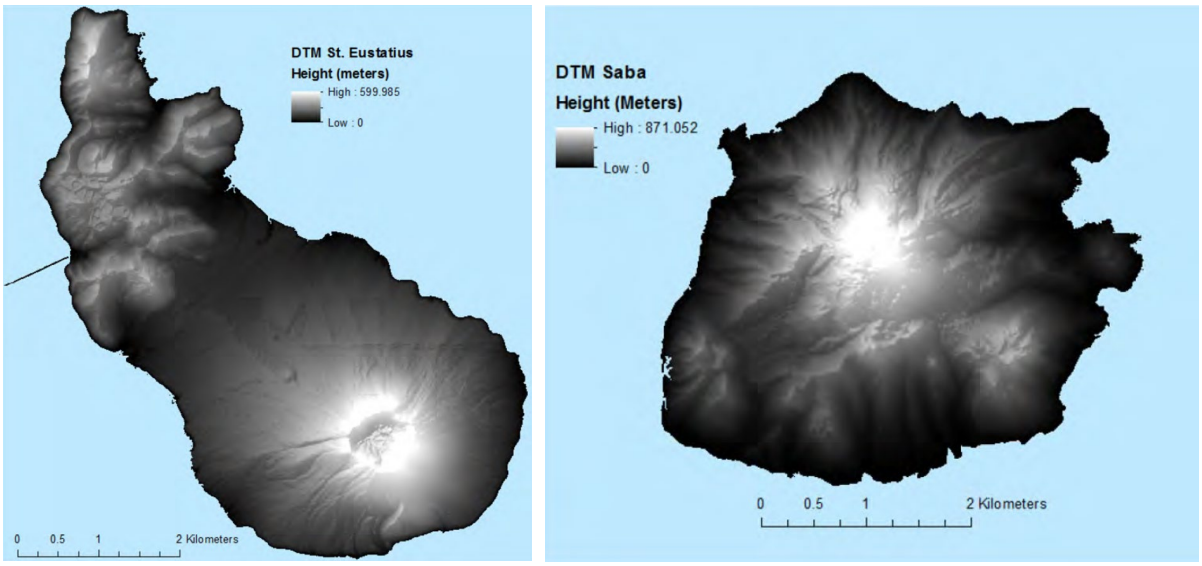
on the three islands, the influences from land and the consequences for underwater nature. A recent publication shows how inadequate information leads to incorrect conclusions about the status of Bonaire's coral reef[5] and that it is necessary to collect better spatial and temporal data. Recent technical developments have provided an extensive range of possibilities to collect data efficiently, faster and cheaper using remote sensing, drones and artificial intelligence. This proposal aims to strongly improve the inadequate knowledge base in order to obtain better insights with which policy can more effectively manage and improve nature and the services it provides. Coral restoration can make a positive contribution, but only if local conditions are right for it. The project will generate intensive cooperation with the NGOs responsible for nature management on the islands as well as collaboration with an important industry, namely the diving industry. The NGOs will have a coordinating role in data collection, outreach to the population and setting up coral restoration sites. The diving companies will actively participate in data collection. Ultimately, the islands themselves will be able to effectively monitor and manage their nature.

1. Goal and targeted results

The project increases the knowledge base of the marine nature of the Caribbean Netherlands and contributes to improving spatial planning. This will contribute to reducing the negative effects on nature in the coastal zone and increasing the resilience of the various ecosystems, making them better able to withstand climate change. Ecosystem services will improve and continue to sustainably support the local economy. Through the active participation of NGOs and diving companies, the project also ensures capacity building and a change of consciousness towards a more nature-inclusive society.

Elevation models and bathymetric data

Many of the processes that adversely affect marine wildlife have their origins on land[6], for example, the choking of coral by sediment that flows into the sea during heavy tropical rain showers when the vegetation is decimated due to overgrazing by goats and donkeys. Or the leakage of sewage water to the coastal zone because a sewer system hardly exists or does not provide the necessary protection. The latter also leads to the presence of all kinds of pathogens in the water. Understanding the processes in the sea begins by examining what is happening on land and how this translates into the sea. Height differences are of great importance here, because they determine the routes by which the transport of precipitation and waste water flows to the sea takes place. An accurate elevation model (DEM, Digital Elevation Model) with a high resolution is of great importance for this. Together with WEnR and Dotkadata, WMR has in the past made such digital models for St. Eustatius and Saba[7] based on old stereo recordings from KLM Aerocarto. Very high resolution satellite images still have a much lower resolution (pixel size) than aerial photographs and are usually only commercially available with the restriction that they may not be shared with third parties (and may only be used within the project for which they were purchased). For Bonaire there is not yet a comparable DEM as for St. Eustatius and Saba[7] and the generation of a DEM for Bonaire from existing stereo photos (and measured Ground Control Points (GCPs with xyz coordinates) on the island is one of the first goals of this project carried out.



Elevation model of St. Eustatius and Saba at 5m resolutie horizontally and 1m vertical resolution.

However, an elevation model does not stop at the waterline, but continues into the sea. Bathymetric data is important for understanding underwater spatial patterns and processes and for placing measurements in relation to subsurface and current. Coral slopes are interspersed with sand channels, which ensures the discharge of excess coral sand produced, but sediment from the land can also flow down to the deeper areas via these channels. A steep slope is less vulnerable to land-based sediment than a flat slope where sand and organic matter can accumulate, leading to the bloom of benthic toxic cyanobacteria. Together with NIOZ, WMR has also collected bathymetric data around the islands of the Caribbean Netherlands in the past, but these measurements are deeper than about 100m. The Royal Hydrography also does not have a complete dataset of the shallow coastal zones of the three islands. The solution is to use a portable multibeam sonar unit that can be installed on a small boat and with which the bathymetry around the islands can be measured in a relatively short time. The height and depth data can be integrated into a unified terrain model (above and below water) per island, making it much easier to understand and predict the effects of interventions on the island. This digital elevation model (DEM), together with additional available data and new measurements, defines the on-site transport of rainwater, sediment, nutrients and wastewater and thus also the potential effects on the various ecosystems. The model forms a spatial framework on which all further measurements and processes can be attached in order to arrive at a much better assessment framework for spatial planning and nature and environmental policy.

Water quality parameters

Together with the local partners in the project, a joint monitoring program will be set up for each island to better monitor the nature in the coastal zone. Coordination is done by the nature organizations and implementation of the water monitoring is for the most part by the diving companies. Even though it is reasonably well known what the main impacts are from land (nutrients, sediment, fishing, sunburn), we do not yet know where these influences are greatest, where they have the strongest effects, or how they reinforce or weaken each other. This project is a major step in increasing the basic knowledge of physical, chemical and biological processes. A better understanding of these processes makes it possible to deal much better with the challenges of climate change and to use policy resources more effectively to improve nature and the local

economy. Particularly with a view to climate change, it is important that interventions such as coral restoration take place in places where nature can quickly take over in order to speed up the recovery process. It is therefore necessary for policy to know where which intervention has the greatest effect. More knowledge about the spatial and temporary variation is therefore essential. Land-related processes are the main reason for the decline of the reefs of the Caribbean Netherlands8. However, most processes are not constant in time and space, but vary, mainly due to the large variation in precipitation patterns. By making use of the daily sailing trips of the diving companies and the patrol trips of the nature managers, data will be collected year round that will provide insight into the temporal variation of important water parameters. In addition, data will be collected each year for 1 month by means of an intensive spatial campaign that will provide more insight into the spatial distribution of the most important parameters.

Image data

In order to get a complete picture of the coral reefs of the Caribbean Netherlands, much more visual material needs to be collected, not only shallow as has always been the case, but also of the deeper parts of the reef. Through citizen science, diving tourists will be offered the opportunity to participate in the monitoring program and contribute to the collection of images around the islands. This under the guidance of the diving companies. It is possible that even a PADI specialization can be set up for this in order to generate extra income for the diving companies. Participation of diving companies in this project is mainly based on a sense of responsibility for preserving the vulnerable underwater nature. In addition to images of the shallow parts of the coral reef, the deeper regions will also be examined. Because research is generally limited to a maximum depth of 15m, almost nothing is known about the coral reef below the 10-15m depth. Yet this zone is often dived by tourists. The bottom time of a diver is the limiting factor for mapping the deeper part of the coral reef. Longer than 10-20 minutes is usually impossible at a depth of more than 25m. As a result, working at that depth quickly becomes too expensive and dangerous. A Remotely Operated Vehicle (ROV) will therefore be used to explore and map the deeper reef. The ROVs to be purchased will be equipped with advanced cameras, lamps and lasers.

Artificial intelligence (AI) and Deep Learning

A great deal of visual material will be collected by using citizen science and ROVs. Deep Learning techniques will be used to analyze this material. Via neural networks, the analysis of visual material can be done faster and more efficiently and many hours can be saved. WMR has already started setting up image banks for the analysis of these types of images and the identification of species is done via Deep Learning (Two Knowledge Base topics were carried out in 2020). The method is still under development and not yet operational, but the experience already gained will be used in this project.

Chasing M2 ROV

Local participation through smart technologies

By using the latest measuring instruments and technologies, much of the work can be carried out by the local partners. This creates local knowledge and capacity to determine the state of nature in the future. It may also lead to more nature-related jobs. For each island, a communication plan is drawn up together with the government-mandated NGO that explains the project and the results to the public through local media and science cafes in the field stations on Bonaire and St. Eustatius. Collected images will also be used by DCNA and WWF in its outreach to supporters on the islands and in the Netherlands.

Smart technologies and data storage in the cloud will be used to make the collected data quickly available for analysis and reporting. Tourists who dive can contribute to the collected data with underwater photos via a data entry portal to be set up. Each island will have access to a chlorophyll a measuring instrument with which intensive measurements will be made. Other parameters that will be measured are water transparency, nutrients, eDNA, soil algae and metabolomics. By collecting and analyzing this data together, it becomes possible to make links much better than in the past to events and processes that take place on land and that are important for the functioning of marine nature. With eDNA, rare animals (sharks and marine mammals) and invasive species can be detected and the vulnerability of populations can be determined through genetic diversity. Metabolomics techniques are able to detect minute amounts of land-related substances (eg faecal compounds, sunscreen, coffee, antibiotics and other drugs). The most vulnerable underwater areas can also be better identified and the most optimal places for coral restoration can be designated. In collaboration with Reef Renewal Bonaire, these places will then be provided with new coral fragments, which will contribute to the improvement of natural coastal protection. The project will use existing field stations on St. Eustatius and Bonaire.

2. Describe how his project contributes to the mission/key technology and priority

The project proposal contributes to the improvement of water quality in the coastal zone and the ecological capacity of marine nature. As a result, the project helps to increase the resilience of the coral reefs and to maintain ecosystem services. As a result, these systems can also better resist the negative effects of climate change.
Through intensive local involvement, the project contributes to the sustainability of local economies and the development of local capacity. Through outreach activities by the local partners, work is also being done on promoting the concept of a nature-inclusive economy.
Coral restoration is a characteristic form of Building with Nature, where new coral contributes to increasing diversity, dampening the waves and reducing coastal erosion, and making the underwater landscape more attractive for the benefit of tourism.
The project is also developing new monitoring using smart and innovative technologies such as eDNA, metabolomics and remote sensing via ROVs. The knowledge that is developed within the project is of great importance for the development of good spatial planning on the island to prevent further deterioration of ecosystem services (both on land and at sea). With the new knowledge, the project wants to contribute to the development of nature-inclusive spatial policy scenarios. For this purpose workshops will be organized with policymakers.
The project ties in seamlessly with priority 33 of the MMIP as it complements a lot of missing physical, chemical and biological knowledge through modern equipment and development and use of the new techniques. The project also creates an integral framework for weighing the risks of human use on the marine environment. Collaboration with NIOZ also adds a more fundamental leg to the project. Last, but not least, the project fills some of the knowledge gaps as mentioned in the Policy Plan Nature and Environment Caribbean Netherlands. Due to the capacity building during the project, the islands will be better able to make good decisions in the further economic development of the islands.

3. Impact

The proposal introduces high-tech tools on the islands and teaches the main stakeholders how to use them and thus develop knowledge and skills that positively influence the economic independence of the islands. New businesses have been created before because individuals developed new skills in this way. Socially, the project will propagate the importance of nature for the economy through its outreach activities and ensure that this will be better included in daily life and local policy. Probably the greatest impact will be the strong expansion of the knowledge base and the support services that this knowledge will have for the islands. Because the ecological processes can be better interpreted, nature management has much better tools and the impact of coral restoration activities, for example, can be better managed. Because the new knowledge base contributes to the improvement of underwater nature, it is also to be expected in the long term that the islands will excel more in quality and attractiveness for tourism and can maintain or even improve their position as a top location for diving tourism. All activities within the project will enable the new knowledge center on Bonaire to build up its function as a knowledge hub more quickly.

4. Approach

During the first year, the partners are instructed in the sampling methods to start collecting samples. During the two field trips, the bathymetry around the islands is also recorded and samples are taken to determine the spatial variation. The ROVs are also prepared and explained on the islands how to collect images on the basis of a schedule to be determined. The existing stereo aerial photos of Bonaire are converted into a DEM by means of Measured Ground Control Points (GCPs with xyz co-ordinates) that are well distributed throughout the island. A condition for this is that these GCPs are clearly visible on the aerial photos (and that as much use as possible is made of existing GCPs). ROV image analysis via Deep Learning is also set up so that the images to be collected can be analyzed as quickly as possible. At the end of the year, an overview is given of all results so far.
In the second year, sampling is continued after necessary adjustments. The results already achieved are used for outreach activities and communicated to the island governments. DEMs and bathymetry are linked together by means of interpolation techniques of all xyz points. The measured variables are analyzed in relation to the subsoil. Spatial and temporal sampling on the three islands (possibly with adjustments) will continue.
In year three, extensive reports are made on the new knowledge that emerges from all the results. Meanwhile, the sampling continues, but there is more routine and the image analyzes are faster because the neural networks are better trained. At the end of the year there is another progress report and an update of the planning for the last year.
The fourth year is mainly devoted to continuation of the measurement network (possibly in a less intensive form). An optimal measurement network is proposed through an extensive evaluation. The regular spatial and temporal sampling will continue in the last year. At the end of the year, a closing meeting will be organized in which all results will be presented in detail.

See also appendix 2 for an extensive planning

Milestones and products

Milestone	jaar
DEM Bonaire	1
Bathymetrie Bonaire	1
Bathymetrie Saba	1
Bathymetrie St. Eustatius	1
ROV images collected on all islands	1
Images analysed by DL	1
Samples and data analysed	1
Overview report year 1	1
DEM and bathymetry fused into one model for Saba, St. Eustatius en Bonaire	2
ROV images collected on all islands	2
Images analysed by DL	2
Samples and data analysed	2
Overview report year 2	2
ROV images collected on all islands	3
Images analysed by DL	3
Samples and data analysed	3

Overview report year 3	3
ROV images collected on all islands	4
Images analysed by DL	4
Samples and data analysed	4
Conclusive meeting with all stakeholders	4
Overview report 4	4

5. Organization

WMR coordinates the overview and planning of the project. The implementation on the islands is coordinated by the various NGOs (STINAPA on Boniare, STENAPA on St. Eustatius and SCF on Saba). The dive companies cooperate in collecting the samples and images. NIOZ is mainly responsible for taking the metabolomics samples, training the local partners and the analysis of the samples (nutrients, metabolomics). WMR provides the analysis and training for taking the eDNA samples. WEnR is responsible for app development and remote sensing. WFBR for AI with Deep Learning. DCNA is particularly specialized in outreach activities for all islands within the kingdom.
A clear schedule is agreed with all consortium partners, which will be regularly checked by WMR. Results will be brought to the attention of partners and stakeholders through a newsletter.

6. Knowledge valorisation and dissemination

The results of the project will be made available to all stakeholders via www.DCBD.nl. DCNA communicates the results to the supporters via its extensive platform. The results are particularly important for the various island governments for their spatial planning. The NGOs can use the data to better evaluate possible effects on nature, not only on the basis of the data collected, but also through the new knowledge and capacity built up over the 4 years of the project.
During visits to the islands, results are presented to governments, NGOs and the public. Knowledge dissemination also takes place via local, national and international communication platforms (Facebook, PR WUR, scientific publications, policy briefs).

7. Financing and budget

Tabel 1. Summary costs and budget **gevraagde =requested** **publieke = public**
Kennisinstellingen=WUR and NIOZ
Overige partners=other partners
Bijdragen=contribution

Kosten	**Bedragen in k€ (excl. BTW)**				
	2021	**2022**	**2023**	**2024**	**Totaal**
Kosten kennisinstellingen (totaal tabel 2a)	456.38	335.98	342.93	369.87	1505.16
Kosten overige projectpartners (totaal tabel 2b)	41.25	41.25	41.25	41.25	165
TOTAAL KOSTEN	**497.63**	**377.23**	**384.18**	**411.12**	**1670.16**
Financiering					
Cofinanciering	**2021**	**2022**	**2023**	**2024**	**Totaal**
In kind bijdrage private partners (totaal tabel 3a)	35.50	35.50	35.50	35.50	142.00
In kind bijdrage ov. partners (totaal tabel 3b)	0.00	0.00	0.00	0.00	0.00
Cash bijdrage private partners (totaal tabel 4a)	6.80	6.80	6.80	6.80	27.20
Cash bijdrage ov. partners (totaal tabel 4b)	0.00	0.00	0.00	0.00	0.00
Totaal cofinanciering	42.30	42.30	42.30	42.30	169.20
Gevraagde publieke bijdrage	**2021**	**2022**	**2023**	**2024**	**Totaal**
Gevraagde publieke inbreng: WR-capaciteit	455.33	334.93	341.88	368.82	1500.96
Gevraagde publieke financiering: PPS-toeslag					
Totaal gevraagde publieke bijdrage	455.33	334.93	341.88	368.82	1500.96
TOTAAL FINANCIERING	**497.63**	**377.23**	**384.18**	**411.12**	**1670.16**

Handtekening(en) voor akkoord:
Kennisinstelling:

Private trekker:
Naam en bedrijf/organisatie: DiveFriends Bonaire

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Appendix 1: Description of state-of-the-art and deliverables

Remotely Operated Vehicle (ROV; WUR & NIOZ)

The shrinking of equipment has brought about enormous changes in our world. This unprecedented miniature nationalization also leads to all kinds of new possibilities and discoveries in science, from probes in the bloodstream to GPS transmitters of a few grams that also collect data on the way pasted on birds. This trend also offers many new possibilities for marine research and monitoring. Underwater pressure plays a major role and smaller equipment is less vulnerable and the power consumption is also less. Remote sensing is important for collecting data over a large area. Under water this is still problematic and other techniques (e.g. sonar) must be used to retrieve data with sufficient resolution. In this proposal, WUR is therefore collaborating with Royal NIOZ, the Dutch specialist in the development of underwater equipment. WMR and Royal NIOZ are both research institutes with an excellent reputation. Previous collaboration between NIOZ and WMR has resulted in a large number of publications in renowned magazines. In 2017, a joint publication about the coral reefs of Bonaire and Curacao was even named best publication of the year by the renowned magazine Coral Reefs. NIOZ and WMR are continuously innovating research technology and methodology including the use of drones, sonar, eDNA, metabolomics and using the latest measuring instruments that are often adapted in-house. In analysis techniques such as deep learning are already being developed within our research team to speed up the automatic recognition of species. Together with NIOZ, the ROV will be adapted to collect images of the coral reef. The ROV will be equipped with additional cameras to measure fish communities and lasers to scale the images of the bottom of the coral reef to be analyzed.
The ROV has been on the market since 2020 and the first model will be delivered to the Dutch market in October 2020. The first reviews are very positive. However, we expect adjustments will be necessary. We will make these adjustments together with NIOZ. In the unlikely event of a setback with this ROV, we can quickly come up with adjustments together with NIOZ so that the implementation of the project is not endangered.

Deliverables:
Images to quantify the bottom cover and fish communities of the deep (and shallow) reef of Bonaire, Saba and St. Eustatius.
Quantification of land cover at different depths for the 3 islands.
Maps of coral reef composition for the islands.

Multibeam (Erik Meesters, WUR)

The Norbit multibeam is state of the art and is also used by the Royal Hydrography. The equipment is easy to transport and quick to deploy. It is estimated that the bathymetry around all three islands can be mapped within 6 weeks. That is why this instrument is rented from SeaBed. The Royal Hydrography Risk is that the weather is bad and it is too rough. The risk will be limited as much as possible by measuring in the most windless month.

Deliverables:
Bathymetric data from 1-100m for Saba, St. Eustatius and Bonaire.
Maps of bathymetry around the 3 islands.

DEM Bonaire and other islands (Sander Mucher, WEnR-WUR)

Remote sensing from WUR has made the earlier DEMs from St. Eustatius and Saba together with Dotkadata. They will make the DEM for Bonaire and WEnR will integrate this data from the islands with the bathymetric data collected within the project.
Deliverables:
DEMs including bathymetry for the 3 islands.

Metabolomics (Andi Haas, NIOZ)

Metabolomics is the study of metabolites in cells, fluids and tissues of organisms, which are influenced by both genetic and environmental factors. Collectively, these molecules and their interactions within a biological system are known as the metabolome. In addition to genomics (the study of DNA and genetic information) and transcriptomics (the study of RNA and differences in mRNA expression), metabolomics is a relatively new technique. Metabolomics has some advantages over the other "omics" as measurements directly reflect the underlying biochemical activity and state of cells / tissues. Metabolomics thus best reflects the molecular phenotype.
One of the biggest influences of terrestrial discharge to the oceans, in addition to enrichment with inorganic nutrients, is the supply of organic compounds. These compounds can disrupt the microbial balance in marine ecosystems, releasing toxic substances or other biologically active products into the environment. Specific compounds (eg humic substances) can also serve as tracers to determine the amount and origin of the land runoff. The optically active dissolved organic matter fraction (DOM), known as fluorescent DOM (FDOM), has already been used successfully to characterize and quantify some of the terrigenic inputs[9,10]. The amount and composition of organic nutrients available to coral reefs is further an important factor in directly structuring the microbial community and indirectly the macrobiota. Previous work conclusively shows that an increase in bioavailable DOM promotes more copiotrophic and pathogenic microbes that deplete the resources (e.g., oxygen) required for higher trophic levels, and lead to an increase in disease. Despite the importance of DOM for water systems, its complexity has hitherto made a thorough characterization impossible. Marine DOM is one of the most complex exometabolomes on Earth and consists of tens of thousands of compounds[11].
Methods to capture the inherent complexity of DOM have always been too expensive and failed to identify most molecular structures. The newly established high-throughput metabolomics pipeline at the NIOZ[11] provides a much more powerful tool to determine the precise molecular composition of DOM and locate the source, distribution, chemical and biologically relevant properties of terrestrial input and secondary metabolites. The new high-throughput pipeline uses coupled liquid chromatographic separation with tandem mass spectrometry (LC-MS / MS), a data analysis pipeline that performs peak extraction of extracted ion chromatograms (XIC) and calculation of molecular formulas and molecular networks (Global Natural Product Social Molecular Networking, GNPS). This allows us to more accurately identify DOM components by comparison with a rapidly growing mass spectra library[12]. In combination with microbial counts and metagenomic analysis to determine organism composition and metabolic potential (16S amplicon and metagenomic sequencing), this approach provides comprehensive information on water chemistry and microbial responses to external influences and on the internal responses of ecosystems in different biogeochemical environments. The combination of this new metabolomic pipeline and next-generation sequencing will provide detailed insight into the links between land influences and marine processes. Finally, it

allows us to identify coastal systems adaptations to the input of specific substances and how these adaptations, in turn, affect the surrounding systems.

Deliverables:
Prevention and quantification of markers for the presence of human pollution from runoff or sewage along the island.
Broad spectrum of metabolomics in relation to coral reef health. This approach can discover new biomarkers and biologically active substances related to the health status of the coral reef.

Deep learning (Freek Daniels, WFBR)

Deep learning is a discipline within machine learning, in which layered neural networks learn from large amounts of data. Referencing machine learning, algorithms improve performance the more often they are exposed to data. Deep learning is particularly well suited for recognizing objects in images and determining species. Deep learning is already being used within WMR and projects to recognize benthic species have already been carried out within the Knowledge Base Research. A lot of work is also being done on this at NIOZ and globally (eg https://coralnet.ucsd.edu/). This development will continue in the coming years and image recognition via deep learning will become increasingly easier.

Nutrients (Erik Meesters, Van der Geest, Van Duyl, WUR-NIOZ)

Water quality in the coastal zone has only been investigated incidentally in the Caribbean Netherlands[13]. As a result, there is still a lack of basic knowledge about spatial and temporal / seasonal variation in important water quality variables and the effects of incidental events. Within the program, many measurements and water samples will be taken every year to gain insight into these aspects per island. The local organizations will play a crucial role in this sampling. The parameters to be investigated are nitrogen and phosphate, dissolved organic material (DOC), algae composition, chlorophyll a, and suspended particulate matter.

Environmental DNA (eDNA; Lisa Becking, WUR)

Animals, plants and microorganisms leave traces of DNA in seawater and sediment. This DNA is called environmental DNA (eDNA) and can be detected using modern genomics techniques[14,15]. This creates opportunities to map the biodiversity in an area efficiently. For example, by amplifying eDNA in seawater, migratory species that are often difficult to detect by visual monitoring (eg sharks, turtles and marine mammals) can be detected[16]. But also microbial communities that cause diseases on coral or fish communities can be detected via eDNA. With the Minion nanopore sequencing, it is now possible to do genetic biomonitoring with a mobile lab that fits in a rolling case[17]. In this way, the offices of STINAPA, STENAPA or Saba Conservation Foundation can become a genomics lab. Real-time eDNA sequencing offers the possibility to perform a rapid assessment of biodiversity[16,18] and ensures management involvement of local stakeholders in data collection. Through training and workshops, the counterparts on the islands will learn to directly sequence themselves and visualize data. There have been many developments in sampling methods and lab analyzes for eDNA from seawater and soil samples[14,19]. Within this project, the sampling methods, laboratory analyzes and bioinformatics pipelines will be optimized so that the data are reproducible and workable for the conditions in the Caribbean Netherlands. The final product will be a standardized monitoring protocol for eDNA, which can be performed by the rangers.

Although the uses of eDNA are great, in this project we want to limit it to:

- The temporal presence of migrating megafauna, such as sharks, marine mammals and sea turtles;
- Early detection of invasive species;
- Microbial communities and germ identification.

Deliverables:

- Standardized sampling protocol.
- A mobile lab that can be used on the islands.
- Training of local partners.
- User-friendly bioinformatics pipeline.

Appendix 2: extensive work plan

2021	
Jan-Feb	Purchase of material and testing of material, adjustments, preparation of fieldwork; set up data sharing cloud facility.
Maart	1st field trip Bonaire; instruction Bonaire team; introduction OLB; testing field protocols, batymetry.
April	Evaluation, adjustments, sample and data processing, continuation of sampling through the islands.
Mei	Field trip Saba and Statia; instruction teams, introduction OL, field protocol testing, bathymetry
Jun	Sample and data processing, continuation of sampling islands.
Jul-Nov	Reporting back to the islands, intermediate report, continuation of sampling through the islands
Dec	Continuation of sampling through islands; Sample and data processing, reporting, outreach activities
2022	
Jan-Dec	Further sampling by local partners
Oct	Field trip Bonaire spatial sampling, public outreach activities
Nov	Field trip Saba en Statia, spatial sampling
Dec	Sample and data processing, reporting
2023	
Jan	Reporting, intermediate report, adjustments planning
Jan-Dec	Further sampling by local partners, outreach activities
May	Field trip Bonaire
Jun	Field trip Saba and Statia
Jul-Sep	Sample and data processing
Oct-Dec	Further sampling by local partners, reporting
2024	
Jan	Field trip Bonaire
Jan-Dec	Further sampling by local partners
Feb	Sample and data processing
March	Field trip Saba and statia
April	Sample and data processing
May	Data analysis, reporting
Jun-Oct	Further sampling, sample processing and analysis
Nov	Closing meeting
Dec	End report, project closure

Bijlage 3: detailinformatie consortiumpartners

Naam partner 1	**Dive Friends Bonaire**
KvK nr.	
Postadres en postcode	
Plaats	Bonaire
Contactpersoon	Bart Linders (General Manager)
e-mailadres	bart@divefriendsbonaire.com

Dive Friends Bonaire is a 100% AWARE, award-winning, PADI 5-star IDC Dive Center with 8 dive locations spread out over the west coast of the island, and 4 retail stores.
We want to protect our beautiful oceans for future generations of divers. Dive Friends Bonaire is a 100% AWARE partner with a PADI Green Star Award. The Green Star Award identifies dive businesses that care about the environment and are acting to protect it.
We have a strong dedication to conservation across a wide range of business functions, including water conservation, energy use (solar panels), environmentally friendly transportation practices, use of sustainable materials, conservation leadership, and donations to conservation projects through Project AWARE, Sea Turtle Conservation, STINAPA etc..
We donate and help collect data and remove devastating debris while tackling prevention and policy efforts addressing long term solutions. Secure protection for the world's most threatened shark species, strengthen shark finning bans, and closing loopholes.

Change will come through education. We have several marine biologists in our staff and all instructors are trained to teach environment friendly dive practices. You can get involved by attending one of our regular underwater cleanups, help research and protect our reefs with citizen science, or sign up for one of the many courses. Each student certified by Dive Friends Bonaire will receive a special Project Aware certification card and donation from the Sea Turtle Awareness course goes to the local Sea Turtle Conservation project.

Naam partner 2	**Stichting Nationale Parken Bonaire (STINAPA)**
KvK nr.	
Postadres en postcode	Barcadera 10
Plaats	Bonaire
Contactpersoon	Jan van der ploeg
e-mailadres	director@stinapa.org

Stichting Nationale Parken Bonaire (STINAPA Bonaire) is a non-governmental, not for profit foundation commissioned by the island government to manage the two protected areas of Bonaire: the Bonaire National Marine Park (BNMP) and the Washington Slagbaai National Park (WSNP). STINAPA Bonaire. STINAPA's team is comprised of 35 full-time employees whose duties include park operations, biological monitoring and research, education and outreach, events, accounting and administration. STINAPA's mission is to manage and share, protect and restore, educate and promote the resources, biodiversity and values of Bonaire's nature.

Naam partner 3	**Saba Conservation foundation** (**SCF)**
KvK nr.	
Postadres en postcode	Fort Bay

Plaats	Saba
Contactpersoon	Kai Wulf
e-mailadres	sabapark.manager@gmail.com

Non-profit nature management organization responsible for education, scientific research, and enforcement (SCF). It is the government-designated nature management authority and works closely with the Island Government in developing policy and legislation for nature conservation and management.

Naam partner 4	**Dutch Caribbean Nature Alliance (DCNA)**
KvK nr.	
Postadres en postcode	Kaya Nikiboko Zuid 56
Plaats	Kralendijk, Bonaire
Contactpersoon	Tadzio Bervoets
e-mailadres	director@dcnanature.org

The Dutch Caribbean Nature Alliance (DCNA) is a nonprofit organization created to protect the natural environment and to promote sustainable management of natural resources on the six Dutch Caribbean islands. DCNA's mission is to help and assist the protected area management organizations, as well as other nature conservation organizations, within the Dutch Caribbean.

Naam partner 5	**Sea Saba**
KvK nr.	
Postadres en postcode	Lambert Hassell Road #10
Plaats	Windwardside, Saba
Contactpersoon	Lyn Costenaro & John Magor
e-mailadres	mainoffice@seasaba.net

Sea Saba is a private company on Saba that organizes diving for tourists and is heavily involved with community awareness raising through the Sea and Learn program, a yearly event where nature experts from around the globe are on Saba to share their expertise with the public.

Naam partner 6	**Reef Renewal Bonaire**
KvK nr.	
Postadres en postcode	85 Kaya Gob. N. Debrot
Plaats	Kralendijk, Bonaire
Contactpersoon	Francesca Virdis
e-mailadres	coordinator@reefrenewalbonaire.org

Reef Renewal Foundation Bonaire (RRFB) is a non-profit organization funded in 2012, dedicated to protecting and restoring coral reefs in Bonaire. Through large-scale propagation, outplanting, and monitoring of genetically diverse corals, RRFB works to assist the reefs' natural recovery. To give corals a better chance to survive in the long-term future, RRFB's focus is to enhance coral populations by producing outplants using coral gardening and larval propagation as restoration methods.
While promoting awareness and engaging tourists and local volunteers, RRFB developed a large scale reef restoration program. To date, RRFB has oversees 9 nurseries for a total capacity of more than

15,000 corals and has outplanted more than 25,000 corals back to the reef at 11 different sites in Bonaire and Klein Bonaire.

Naam partner 7	**Golden Rock Dive Center**
KvK nr.	
Postadres en postcode	Gallows Bay
Plaats	St. Eustatius
Contactpersoon	Sarah and David Hellevang
e-mailadres	info@goldenrockdive.com

Golden Rock Dive Center is a private company that has been collaborating with underwater research projects and marine scientists all over the world for many years.

Naam partner 8	**Scubaqua Dive Center**
KvK nr.	
Postadres en postcode	PO box 16 lowertown
Plaats	St. Eustatius
Contactpersoon	Mike Harterink
e-mailadres	mike@scubaqua.com

Scubaqua Dive Center is an eco-friendly dive center on St. Eustatius.

Naam partner 9	**Saba Divers**
KvK nr.	
Postadres en postcode	Fort Bay no. 9
Plaats	Saba
Contactpersoon	Casey and Jilliann Hanson
e-mailadres	info@sabadivers.com

Private diving company on Saba.

Naam partner 10	**Royal Netherlands Institute for Sea Research (NIOZ)**
KvK nr.	41150068
Postadres en postcode	Landsdiep 4 1797 SZ
Plaats	't Horntje (Texel)
Contactpersoon	Marcel van der Linden
e-mailadres	Marcel.van.der.Linden@nioz.nl

NWO-NIOZ Royal Netherlands Institute for Sea Research is the national oceanographic institute and principally performs and promotes academically excellent multidisciplinary fundamental and frontier applied marine research addressing important scientific and societal questions pertinent to the functioning of oceans and seas. NIOZ serves as national marine research facilitator (NMF) for The Netherlands scientific community.

Naam partner 11	**Wageningen Marine Research (WMR)**
KvK nr.	09098104
Postadres en postcode	Ankerpark 17, 1781AG
Plaats	Den Helder
Contactpersoon	Erik Meesters
e-mailadres	Erik.Meesters@wur.nl

Wageningen Marine Research is the Netherlands research institute established to provide the scientific support that is essential for developing policies and innovation in respect of the marine environment, fishery activities, aquaculture and the maritime sector. Our mission is to explore the potential of marine nature to improve the quality of life. Wageningen Marine Research is an independent, leading scientific research institute conducting research with the aim of acquiring knowledge and offering advice on the sustainable management and use of marine and coastal areas.

Naam partner 12	**Wageningen Environmental Research (WEnR)**
KvK nr.	09098104
Postadres en postcode	Droevendaalsesteeg 3, 6708 PB
Plaats	Wageningen
Contactpersoon	Sander Mucher
e-mailadres	sander.mucher@wur.nl

Wageningen Environmental Research, the leading research institute for our green living environment provides "Nature-based solutions for a greener world" and offers a combination of practical, innovative and interdisciplinary scientific research across many disciplines related to the green world around us and the sustainable use of our living environment. Aspects of our environment on which Wageningen Environmental Research focuses include soil, water, the atmosphere, the landscape and biodiversity – on a global scale as well as regionally, from the Dutch polders to the Himalayas and from Amsterdam to the Arctic.

Naam partner 13	**Wageningen Food & Biobased Research (WFBR)**
KvK nr.	09098104
Postadres en postcode	Bornse Weilanden 9, 6708 WG
Plaats	Wageningen
Contactpersoon	Freek Daniels
e-mailadres	freek.daniels@wur.nl

Wageningen Food & Biobased Research develops insights and technologies that support companies, governments and other research institutes in creating innovative solutions for a healthier, more sustainable and prosperous world. We partner in the creation and production of healthy and tasty foods, of truly-sustainable food chains, and in developing chemicals and materials that use biomass instead of fossil resources. Our in-depth knowledge of the entire chain, from raw materials through processing to end product, drives our approach. WFBR has much experience in image analysis using Deep Learning.

Bijlage 4: Kostenbegroting en financiering

Tabel 1. Samenvatting kosten en financiering (deze tabel kopiëren naar de hoofdtekst)
In deze tabel vult u bij kosten de totalen in van tabel 2a (kosten kennisinstellingen) en tabel 2b (kosten overige projectpartners). Bij financiering vult u de totalen in van tabel 3 (in kind bijdrage projectpartners) en tabel 4 (cash bijdrage projectpartners). Tot slot vult u de gevraagde bijdrage in (uitgesplitst in WR-capaciteit en PPS-toeslag).

Kosten	**Bedragen in k€ (excl. BTW)**				
	2021	**2022**	**2023**	**2024**	**Totaal**
Kosten kennisinstellingen (totaal tabel 2a)	456.38	335.98	342.93	369.87	1505.16
Kosten overige projectpartners (totaal tabel 2b)	41.25	41.25	41.25	41.25	165
TOTAAL KOSTEN	**497.63**	**377.23**	**384.18**	**411.12**	**1670.16**
Financiering					
Cofinanciering	**2021**	**2022**	**2023**	**2024**	**Totaal**
In kind bijdrage private partners (totaal tabel 3a)	35.50	35.50	35.50	35.50	142.00
In kind bijdrage ov. partners (totaal tabel 3b)	0.00	0.00	0.00	0.00	0.00
Cash bijdrage private partners (totaal tabel 4a)	6.80	6.80	6.80	6.80	27.20
Cash bijdrage ov. partners (totaal tabel 4b)	0.00	0.00	0.00	0.00	0.00
Totaal cofinanciering	42.30	42.30	42.30	42.30	169.20
Gevraagde publieke bijdrage	**2021**	**2022**	**2023**	**2024**	**Totaal**
Gevraagde publieke inbreng: WR-capaciteit	455.33	334.93	341.88	368.82	1500.96
Gevraagde publieke financiering: PPS-toeslag					
Totaal gevraagde publieke bijdrage	455.33	334.93	341.88	368.82	1500.96
TOTAAL FINANCIERING	**497.63**	**377.23**	**384.18**	**411.12**	**1670.16**

Tabel 2a. Projectkosten kennisinstellingen

Projectkosten	Kosten in k€ EXCLUSIEF BTW				
	2021	2022	2023	2024	Totaal
	in k €				
naam kennisinstelling					
WMR	191.4	196.2	201.1	206.1	794.8
WEnR	40.3	41.3	42.3	43.4	167.3
NIOZ	25.2	25.8	26.5	27.1	104.6
WFBR	10.1	10.3	10.6	10.8	41.8
TOTAAL PERSONEEL:	**266.9**	**273.6**	**280.5**	**287.5**	**1,108.5**
Onderhoud duikuitrusting	1.0	1.0	1.0	1.0	4.0
Nutrientenanalyses	7.5	7.5	7.5	7.5	30.0
Edna analyses	14.4	4.9	4.9	4.9	29.1
Isotopenanalyses	3.0	3.0	3.0	3.0	12.0
DTM	40.0				40.0
Huur multibeam	30.0	0.0	0.0	0.0	30.0
Onvoorzien	4.0	4.0	4.0	4.0	16.0
ROV aanpassingen	20.0				20.0
Afsluiting				20.0	20.0
Consumables NIOZ	4.5	4.5	4.5	4.5	18.0
TOTAAL MATERIEEL:	**124.4**	**24.9**	**24.9**	**44.9**	**219.1**
Gopro Hero 8 met OW huis	2.6				2.6
BenthoTorch	1.9	1.9	1.9	1.9	7.6
FluoroProbe	4.6	4.6	4.6	4.6	18.4
ROV	17.0				17.0
Stromingmeters	8.0				8.0
Algae torch	6.0	6.0	6.0	6.0	24.0
TOTAAL INVESTERING:	**40**	**12**	**12**	**12**	**78**
Naam kennisinstellling					
Reiskosten WMR	15.0	15.0	15.0	15.0	60.0
Reiskosten WEnR	5.0	5.0	5.0	5.0	20.0
Reiskosten NIOZ	5.0	5.0	5.0	5.0	20.0
TOTAAL OVERIG:	25.0	25.0	25.0	25.0	100.0
KOSTEN TOTAAL (excl. BTW):	**456.4**	**336.0**	**342.9**	**369.9**	**1,505.16**

Tabel 3. Specificatie *in-kind* financiering consortium

3a. Private partners (incl. private kennisinstellingen)	MKB	Waarde in kind bijdrage in k€ (excl. BTW)				
		2021	2022	2023	2024	Totaal
SCF	Nee	4.50	4.50	4.50	4.50	18.00
STINAPA	Nee	5.00	5.00	5.00	5.00	20.00
Dive friends Bonaire	Ja	5.00	5.00	5.00	5.00	20.00
Sea Saba	Ja	2.00	2.00	2.00	2.00	8.00
Saba Divers	Ja	2.00	2.00	2.00	2.00	8.00
Golden Rock	Ja	2.00	2.00	2.00	2.00	8.00
Scubaqua	Ja	2.00	2.00	2.00	2.00	8.00
DCNA	Nee	1.00	1.00	1.00	1.00	4.00
Reef Renewal Bonaire	Nee	2.00	2.00	2.00	2.00	8.00
TOTAAL PERSONEEL:		**25.50**	**25.50**	**25.50**	**25.50**	**102.00**
In kind bijdrage materiele kosten						
SCF		1.25	1.25	1.25	1.25	5
STINAPA		1.25	1.25	1.25	1.25	5
DiveFriends Bonaire		3.50	3.50	3.50	3.50	14
Sea Saba		1.00	1.00	1.00	1.00	4
Golden Rock		1.00	1.00	1.00	1.00	4
Scubaqua		1.00	1.00	1.00	1.00	4
Saba Divers		1.00	1.00	1.00	1.00	4
TOTAAL MATERIEEL:		**10.0**	**10.0**	**10.0**	**10.0**	**40**
KOSTEN TOTAAL (excl. BTW):		**36**	**36**	**36**	**36**	**142**

Tabel 4. Specificatie *in cash* bijdragen consortium

Naam Partner	MKB	Waarde in cash bijdrage (k€)				
		2021	2022	2023	2024	Totaal
DCNA	Nee	**6.8**	**6.8**	**6.8**	**6.8**	**27.2**
TOTAAL excl. BTW		**6.8**	**6.8**	**6.8**	**6.8**	**27.2**

This contribution is requested by DCNA from the WWF biodiversity fund. WWF is positive about a contribution to the project from the biodiversity fund. An application for this will be submitted, but the decision by the WWF will not be made until December.

Given the current situation with regard to Covid 19 and the continuing poor economic outlook for the private partners heavily dependent on tourism, the estimated private contribution is the maximum possible.