From Data to Decisions

Examining how water quality monitoring feeds into local policies around reef resilience on Sint Eustatius

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Acknowledgements

The completion of this thesis would not have been possible without the support, guidance, and encouragement of several individuals and institutions. I am grateful to all those who have contributed their time, expertise, and/or insights to this research, helping ensure it is both academically sound and relevant in practice.

First and foremost, I would like to express my gratitude to my supervisor, Dr Machiel Lamers, for his support, constructive feedback, guidance, and especially patience throughout this research journey. By accepting to supervise my research, he allowed me to explore a topic I have always been curious about but never had the opportunity to fully unpack in an environment I would have never otherwise been able to research in. I would also like to thank Dr Gülşah Doğruer and Dr Erik Meesters for the same reasons, and for their confidence in me to deliver a unique angle to the WMR water quality research programme.

I also extend my appreciation to the interviewees and stakeholders on Sint Eustatius, whose willingness to share their experiences, perspectives, and knowledge formed the foundation of this study. Their insights into the island's science-policy interface and environmental governance challenges, amongst many other things, have helped reshape my ideas and views about local conservation action and decision-making. A special thanks goes out to the dedicated individuals at STENAPA and the PPMO, particularly Erik Boman, Francois Mille, Adam Mitchell, Anna Maitz, and Kimani Kitson-Walters whose work and commitment to conservation inspired me greatly. It was an honour and a privilege working with so many talented and insightful people both on the island and in the Netherlands.

On a personal note, I would like to thank my family and friends for their continuous encouragement and patience. Their belief in my work, even during the most challenging moments, has been a source of strength and motivation. Juggling a full-time job and thesis writing was challenging but with their support I persevered and was able to deliver.

Finally, I want to acknowledge Wageningen University and Wageningen Marine Research for their financial and logistical support, without which this research would not have been possible.

To all who have played a role in this journey, whether directly or indirectly, I extend my gratitude. I hope that my work provides insights into the decision-making challenges on Sint Eustatius and lays the groundwork for solutions to be sought in the future.

Abstract

The integration of scientific knowledge into environmental decision-making is a critical challenge, particularly in small island contexts where governance structures are often fragmented and stakeholder priorities may not always align. This thesis examines how water quality monitoring data informs local decisions around coral reef health and resilience on the Dutch Caribbean island of Sint Eustatius, exploring the roles of key actors in the science-policy interface and assessing the extent to which data collection, dissemination, and uptake align with the principles of joint knowledge production and boundary work. The study also evaluates the usability of the local water quality monitoring programme by analysing its legitimacy, credibility, and salience and the water quality indicators being developed through it.

Drawing on qualitative data from interviews with scientists, policymakers, and conservation practitioners, as well as an analysis of several governance frameworks such as the Dutch Caribbean Nature and Environment Policy Plan, reveals that the science-policy interface on the island is complex and multi-layered. While organisations like the Sint Eustatius National Parks Foundation and the Programme- and Project Management Office serve as boundary organisations, mediating between academic and policy actors, numerous challenges hinder the full integration of monitoring data into policy.

One such challenge, as outlined in this thesis, is the limited legitimacy of the water quality monitoring programme, stemming from the exclusion of local stakeholders in its initial design and the development of reef resilience indicators. This lack of participatory engagement has, in some instances, led to perceptions of the programme as externally imposed, undermining local ownership and policy uptake. However, credibility is high, with the programme's indicators grounded in rigorous scientific methodologies and adhering to international standards. Credibility is further strengthened through tailored communication to local decision-makers and consistent dissemination of data in more impactful ways. In terms of salience, the programme demonstrates partial alignment with local priorities and challenges but stops short of fully considering local perceptions around how to deal with them.

Ultimately, this thesis highlights that while the water quality monitoring programme demonstrates elements of co-operative knowledge production and boundary work, gaps remain in ensuring that scientific data is effectively translated into actionable policies. Strengthening stakeholder engagement, enhancing capacity-building initiatives, and ensuring iterative feedback mechanisms are essential for bridging the science-policy divide and promoting more effective environmental governance on Sint Eustatius.

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Chapter 1: Introduction

Although coral reefs cover less than 1% of the seafloor, they play a crucial role in sustaining marine biodiversity and provide a myriad of direct- and indirect benefits and ecosystem services to millions of people around the world (Souter et al., 2020). As habitat for an estimated 32% of marine species (Fisher et al., 2015), coral reefs are some of the most diverse and important ecosystems on the planet. With populations in coastal zones and cities estimated to steadily increase for years to come (Neumann et al., 2015), more and more people are expected to derive some value from the ecosystem services and benefits that coral reefs provide. These are diverse and many, and include food provisioning, shoreline protection, erosion regulation, biogeochemical cycling, cultural value, tourism revenue, and recreation opportunities (Giglio et al., 2023; Woodhead et al., 2019). As such, healthy coral reefs hold a tremendous value across social, economic, and ecological realms, all of which are interconnected. They act as natural protectors of coastlines, buffering them from currents, waves, and storms, helping prevent loss of life and property damage (Ferrario et al., 2014; Zhao et al., 2019), their high levels of biodiversity and biomass sustain local communities that rely on reef fishery yields (Brown et al., 2020; Liu et al., 2025), and they contribute to the cultural identity and heritage of coastal peoples around the world (Breckwoldt et al., 2022). Their financial contribution to local economies, and that derived from their ecosystem services, has been estimated at over 3.4 billion USD (Brander & Van Beukering, 2013) in the United States, and around 6.2 billion USD on the Mesoamerican Reef in the Caribbean (UN Environment et al., 2018).

Taking all of this into account, it is essential that coral reefs are protected, and where destroyed, restored. The potential long-term benefits of pursuing coral reef conservation and restoration have been well documented (Cinner et al., 2016; Toth et al., 2023). Alarmingly, current estimates suggest that only 2.5% of the world's tropical coral reefs are formally protected through area-based laws and regulations (McClanahan, 2020). It is important to note, however, that any efforts to enhance coral reef health need to be situated within the broader context of climate change – something that marine reserves cannot provide direct protection against (Bruno et al., 2018; Selig et al., 2012).

As such, things are looking quite dire, and coral reefs around the world are in significant trouble. Since 2009, global average hard coral cover has been receding rapidly. Data from the Global Coral Reef Monitoring Network (GCRMN) suggests that between 2009 and 2018, average hard coral cover dropped from around 33% to 28.8% (Souter et al., 2020). Although this is "only" a roughly 4% change, it equates to a loss of 11,700km^2 of the world's hard corals (Souter et al., 2020) – an area that is equivalent to the size of South Korea's capital Seoul (Andersson & Ghesquiere, 2020). Coral cover decline is primarily linked to large-scale coral bleaching events (Souter et al., 2020), triggered mainly by increases in water temperature. With global temperatures continuing to climb, the frequency at which bleaching events are occurring is rising. In 2016, the median time between major bleaching events was around six years, with the likelihood of annual bleaching increasing steadily (Hughes et al., 2018). With such events becoming more frequent and severe, corals have less time to recover, making them more susceptible to local and regional pressures. It has been documented that synergistic interactions between global and local pressures have significant negative impacts on coral reefs (Donovan et al., 2021) with local stressors, such as overfishing, nutrient pollution, disease, and tropical storms lowering reef resilience and exacerbating coral mortality after bleaching events (Howells et al., 2020; Zaneveld et al., 2016).

While increasing temperatures linked to climate change need to be addressed globally, it is essential that other stressors are reduced on a local scale. Empowering local managing authorities and communities to engage in reef conservation is paramount to ensure that reef resilience increases (Knowlton, 2021). Resilience, which partially refers to the capacity of an ecosystem to withstand disturbance without changing its overall identity in terms of structure and function (Holling, 1973)[1], relates to a coral reef ecosystem's ability to maintain diverse hard coral dominance (*Figure 1*). Signs of resilient coral reefs include healthy and disease-free corals, high periodic coral recruitment, and robust populations of herbivorous fish (McClanahan et al., 2012). The last sign (and the role that herbivores play in shaping coral reef resilience) has been studied extensively (Adam et al., 2015; Burkepile & Hay, 2008; Lefcheck et al., 2019; Sheppard et al., 2023), with loss of herbivory being identified as a key factor in determining whether a coral reef will undergo a so-called phase shift – usually from a coral dominated state into a macroalgae dominated one (Cheal et al., 2010; Greiner et al., 2022; Mumby, 2009).

It has been documented that corals' lowered resilience and slow recovery times have correlated globally with increases in algal cover (Donovan et al., 2021), with the amount of algae on coral reefs rising by approximately 20% in the last decade (Souter et al., 2020). Increases in algal cover on reefs have been exceptionally noticeable in the Caribbean where, since 2003, average algal cover has been progressively increasing, reaching 52.4% in 2019 (Souter et al., 2020). This suggests that in some areas of the Caribbean, a coral-algal phase shift has occurred (Meltvedt & Jadot, 2014). Such a shift in ecosystem state follows from the deterioration of local environmental conditions and is extremely difficult to reverse when optimal survivability thresholds are crossed (van de Leemput et al., 2016). However, predicting when these

[1] Holling developed two concepts: *ecological resilience* and *engineering resilience*. The former is described above, while engineering resilience is defined as the time a system takes to return to equilibrium once disturbed.

thresholds will be crossed is challenging, as oftentimes too little is known about the local baseline conditions under which corals and algae can co-exist harmoniously (Bruno et al., 2014). Nevertheless, many potential triggers of coral-algal phase shifts can (and have) been studied extensively around the world (Fong et al., 2020; McManus & Polsenberg, 2004).

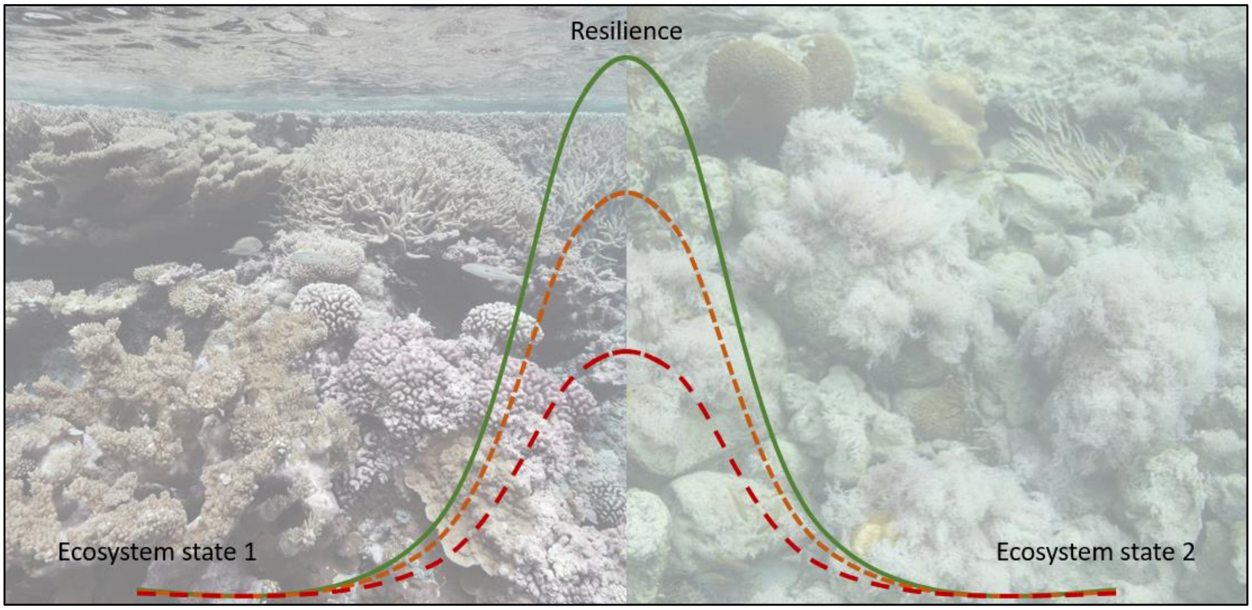

Figure 1: *Schematic representation of resilience. High resilience (green) correlates with an ecosystem staying in its current state (i.e. the ecosystem and its components can withstand pressures better). Lower resilience (orange & red) can lead to a more rapid shift to another ecosystem state.*

In the Caribbean, at least three widespread ecological phenomena have negatively impacted coral reefs since the 1970s and contributed to phase shifts (Cramer et al., 2021; Souter et al., 2020). These are: 1) the mass mortality of the sea urchin *Diadema antillarum*, which before 1983 was the most abundant herbivore on many Caribbean coral reefs (Carpenter, 1988), 2) the outbreak of White-Band disease, which caused the collapse of elk-horn (*Acropora palmata*) and staghorn (*Acropora cervicornis*) populations, and 3) mass coral bleaching events in the 1990s and 2005. Furthermore, recent assessments indicate that reefs throughout the Caribbean are now facing an additional new stressor: stony coral tissue loss disease (SCTLD), a highly lethal disease that was first recorded in the region in 2014 (Bernardo et al., 2025; Estrada-Saldívar et al., 2020).

The reefs around the small island of Sint Eustatius (informally known as Statia), which together with Bonaire and Saba make up the BES-islands of the Caribbean Netherlands[2], have not been spared from the negative impacts of the above-mentioned phenomena (Buchan et al., 2014). Erosion and untreated

[2] Since 2010, all three islands are part of the Kingdom of the Netherlands and considered municipalities.

wastewater leaching into the ecosystem have further exacerbated the degraded state of the reefs around the island (Meesters et al., 2019). Survey data suggests that coral cover in 2015 had declined to around 5% compared to around 20% before 2007 and that macroalgae cover was at a critically high level (de Graaf et al., 2015). With almost 10% of Sint Eustatius' 107 million USD gross domestic product (GDP) estimated to come from coral reef associated tourism and fishing (Bervoets, 2010), and with ecosystem services contributing to 24% of the island's GDP (Debrot et al., 2018), it is vitally important that the health and resilience of the reefs around the island are improved rapidly.

Doing so requires the development of a management plan with clearly defined indicators and quantifiable objectives, targets, and reference points, as well as a standardised and continuous reef health monitoring framework. Without such a plan and monitoring framework, effective evaluations of coral reefs may be hampered (de Graaf et al., 2015). Monitoring is an indispensable component of ecosystem management, providing key ecological data through empirical measurements and enhancing understanding of coral reef conditions and health trends (Lindenmayer & Likens, 2010; Souter et al., 2020). Resilience assessments, which aim to collect integrated ecological, environmental, and socio-economic information through the quantification of reef stress indicators (McLeod et al., 2021), often take place within the context of monitoring programmes and are a fundamental first step in developing a robust coral reef management plan (Lam et al., 2017). By collecting data on ecological processes that affect reef function, as well as data on anthropogenic impacts and natural disturbances, reef resilience assessments can help managers and decision-makers anticipate changes, identify areas with high resilience prospects, and prioritise management actions (McLeod et al., 2021). Being able to project what a reef might look like in the future provides a basis for management strategy evaluation, an integral part of ecosystem management. Ensuring that a management plan can determine and address the recovery potential of an ecosystem and measure the success of any management actions or interventions is key (Mumby & Anthony, 2015).

It is also essential that the monitoring underpinning a management plan be hypothesis driven and that the collected data become available to local decision-makers so that more robust management decisions can be made (Flower et al., 2017; Lonsdale et al., 2022). To ensure buy-in, it is vital that local management authorities and decision-makers are encouraged and empowered to engage in coral reef conservation efforts, particularly when it comes to addressing local reef stressors. With data suggesting that coral reefs vary spatially in their resilience to anthropogenic and natural stressors and their resulting impacts (van Hooidonk et al., 2016), driving forward local management measures and finding local solutions is crucial for coral conservation. Indeed, numerous examples exist that highlight the importance of local actions in improving coral reef health and resilience (*see* Abelson, 2019; Cortés-Useche et al., 2021; Gurney et al., 2013; Harris et al., 2017). However, the transition from local-scale assessments to implementing local actions is usually riddled with challenges. Oftentimes, socio-economic factors are disregarded in the development of management measures and the execution of monitoring programmes, leading to compliance and enforcement issues (Polasky, 2008). Where local costs exceed management benefits and where livelihoods are diminished by interventions, conservation outcomes are limited (Booth et al., 2019; Green et al., 2018). Furthermore, efforts that only focus on improving the ecological aspects of an ecosystem while disregarding the needs of those most reliant on its services will rarely succeed. That is, when a shared vision is not achieved between those that develop plans, those that implement them, and those that need to abide by them, translating assessments into sustained on-the-ground conservation measures is difficult. Collaboration between typically diverse stakeholder groups, and accounting for their different values and perspectives, is key in closing the planning-implementation gap (Biggs et al., 2011). This can be facilitated through the development of a transparent decision-making framework that encompasses conservation objectives, economic development needs, and social and cultural identity, with active participation from all relevant stakeholders from the start.

The Netherlands has attempted to draft such a framework for its islands in the Caribbean. Together with the public entities of the BES-islands, and taking a bottom-up approach involving relevant stakeholders from a wide range of sectors, the Dutch government has developed its so-called Nature and Environment Policy Plan for the period 2020-2030 (hereafter NEPP). This plan envisions "*a prosperous society and cultural identity in balance with a resilient and healthy environment*" and aims to "*provide an integrated framework addressing responsibilities, policy targets, and legal obligations related to management of the natural environment in the Caribbean Netherlands*" (*NEPP*, 2020, p. 5). Through the NEPP, the Dutch government hopes to be able to align the socio-economic needs of the local island communities with national and international commitments to biodiversity conservation. The plan lists four strategic goals to be reached by the end of 2030 (*Figure 2*): 1) to reverse coral reef degradation, 2) to restore and conserve unique habitats and species, 3) to sustainably use land and water for the development of the local economy, and 4) to create the local conditions to ensure sustainable results of nature policy. As coral reefs are one of the most important economic drivers on all three of the BES-islands, improving their health, while increasing their resilience to natural and anthropogenic pressures, has been given a high priority. To restore and conserve coral reef ecosystems, the NEPP outlines the need to invest in solutions for the most significant local pressures and sets three targets: 1) to control erosion and runoff, 2) to implement effective waste and wastewater management, and 3) to improve coral reef restoration programmes.

However, achieving these three targets will vary from island to island, as each one differs physically, economically, and in its capacity to fulfil its obligations. To take these differences into account, and to set local priorities and targets, the NEPP highlights the need for individual island implementation agendas. According to the NEPP, drafting these plans should take place in close cooperation with Dutch ministries and local park authorities, as "*the complex nature of the challenges ahead can only be addressed through a collaborative effort*" (*NEPP*, 2020, p. 7). Monitoring, coordinating, and evaluating the implementation agendas will be led by individual island steering committees, made up of various local authorities and national ministries. To facilitate the steering committee's work, the NEPP outlines a monitoring framework that will track expenditure and monitor progress around the implementation of targets. The NEPP highlights, however, that to be able to do so, performance indicators[3] need to be developed. Defining these indicators "*should be based on existing data and monitoring efforts by local experts*" (*NEPP*, 2020, p. 44). Sufficient data is not always available though. Taking this into account, the NEPP calls for local environmental monitoring programmes to be established, in which "*local experts should define indicators, collect, and monitor data ensuring long-term monitoring on the island*" (*NEPP*, 2020, p. 44).

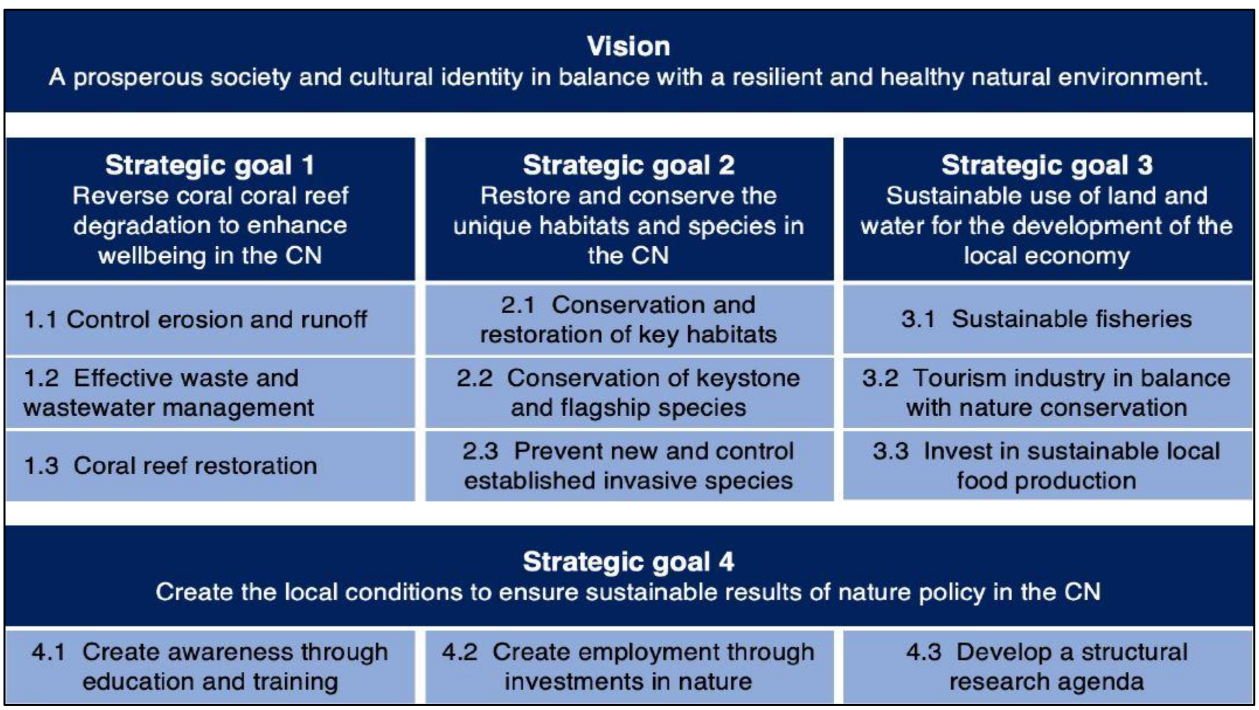

Figure 2: *The four strategic goals outlined in the NEPP. Each goal is broken into targets that, once attained, will feed into achieving the main goal. Reversing coral reef degradation has been attributed the highest priority. [Extracted from: NEPP, 2020]*

[3] Indicators help us construct a simple picture about a phenomenon or factor using a limited set of relevant measurable parameters (Turnhout et al., 2007). The abundance of reef fish, for example, can be used as an indicator of coral reef health and resilience (Knudby et al., 2013).

As part of these efforts, and feeding into addressing the NEPP target to implement effective waste and wastewater management to subsequently reverse the trend of coral reef degradation, a water quality monitoring programme has been developed (Foekema et al., 2021). The overarching aim of the programme is to determine the status of the water parameters that are critical for coral health in the coastal zones of all three BES-islands (i.e. define local coral health and water quality indicators). Based on these indicators, each island should be able to assess and address the most likely pressures impacting their coral reefs. For this to happen, local decision-makers must take collected data into consideration and use them to draft effective, evidence-based policies. This condition is, in fact, echoed in the water quality monitoring programme for the BES-islands, which states that the goal of the parameter analysis is *"[…] to provide policy makers with reliable information of sufficient quality […]*" (Foekema et al., 2021, p. 20).

Unfortunately, integrating science into policy and decision-making processes is not linear as is often thought, but a messy and complex process. Several factors, many mirroring those outlined above that hinder local-scale policy implementation, make bridging science and policy effectively a significant challenge. These factors include the involvement of multiple stakeholders, agendas, institutions, and knowledge systems, all of which contribute to the "*noisy environment*" that decision-makers operate in (French, 2018, p. 430). In addition, issues surrounding communication, political and cultural ideals, and institutional rules inhibit effective integration of scientific knowledge into practical conservation measures (Dale et al., 2019). The results of a survey conducted by Pullin et al. (2004) in the UK showed that a mere 30% of decision-makers used scientific publications in developing policies. The majority made decisions based on internal reports, of which around 8% were based on published, peer-reviewed information. Although this study is relatively old it still holds true, with more recent literature suggesting that barriers between science and policy have still not been fully overcome (*see* Fabian et al., 2019; Hewitt et al., 2022; Tessnow-von Wysocki & Vadrot, 2020).

For this to happen at least partially, policymakers and researchers need to move to a philosophy of co-management and build an understanding of how knowledge translates into practice. Factors such as power, values, and social norms can influence how knowledge is received, interpreted, and applied (Stern et al., 2021). Oftentimes influential and trusted actors are those that have the power and authority to sway policy and practice in certain directions (Nursey-Bray et al., 2014). It is the build-up and maintenance of solid relationships and trust between decision-makers and researchers that lead to knowledge being used in an iterative co-productive manner (Roux et al., 2006). However, often scientists struggle to communicate their research and findings in a way that is easily absorbed by policymakers (Cvitanovic et al., 2015), with some scientists expressing that it is not their role to communicate their science to others (Rose & Parsons, 2015). This uncollaborative attitude can greatly hamper a decision-making process and lead to less impactful management outcomes and policies (Lemos & Morehouse, 2005).

Neither the NEPP nor the water quality monitoring framework outline explicitly how science will be used in decision-making and how knowledge will be transferred between actors. Although there is acknowledgement in the NEPP of the need for a "*structural knowledge base [for the conservation, restoration and sustainable use of nature in the Caribbean Netherlands] in which important indicators are assessed on a regular basis*" (*NEPP*, 2020, p. 24), there is no indication of which indicators will feed into this knowledge base, who will take ownership of it, and how, once established, it will be utilised to develop local environmental policies. In general, the NEPP falls short in explaining in what capacity scientific information will be incorporated into local policies and decisions to improve reef resilience. Consequently, a knowledge gap exists in understanding how the scientific data collected through the water quality monitoring programme will be communicated to decision-makers and inform the development of implementable and enforceable policies.

Research Objectives

Using the Caribbean Netherlands island of Sint Eustatius as a case study, this thesis research aims to examine the so-called science-policy interface[4] between the water quality monitoring programme developed for the BES-islands and local management authorities. By exploring how the two interact and how information flows between them, it is possible to critically examine how the collected monitoring data and its associated indicators are communicated to policymakers, as well as how they are used in reef resilience decision-making. Assessing this knowledge production- and dissemination process will enhance insight into the challenges both scientists and decision-makers face in collaborative and adaptive coastal zone management.

Answering the question *"How is water quality monitoring data collected and used in decision-making around coral reef health and resilience on Sint Eustatius?"* will lead to an improved understanding of how scientific knowledge is integrated into local conservation policymaking in the Caribbean Netherlands and to what extent resilience is considered when doing so. By analysing the governance structure of Sint Eustatius and assessing how those involved in monitoring efforts and policy developments communicate

[4] The science-policy interface is the intersection between science and policymaking, encompassing relations between academics, decision-makers, and other societal actors and facilitating exchange and co-creation of knowledge with the aim of enriching the process of policymaking (van den Hove, 2007).

and interact, this thesis aims to shed light on the opportunities and challenges scientists and decision-makers face when developing and implementing environmental policies on a small island developing state (SIDS), such as Sint Eustatius. The insight gained from this research will contribute to addressing some of the monitoring ambitions outlined in the NEPP, particularly relating to the creation and use of indicators and the development of a biodiversity monitoring strategy, making it easier for local authorities to assess and measure the progress of the strategic goals outlined in the NEPP and the resulting Sint Eustatius implementation plan.

Structure

This thesis is structured into six main chapters, each of which builds upon the previous to provide a comprehensive analysis of how scientific data feeds into local decision-making on Sint Eustatius. The introduction above provided background information and context, highlighting the ecological and socio-economic significance of healthy and resilient coral reef ecosystems. It noted ongoing efforts to address water quality issues on the island and stressed the importance of bridging the science-policy interface and moving towards co-management to improve the integration of scientific knowledge into policy and management frameworks.

To establish the theoretical foundation of this thesis, the second chapter introduces key concepts that were used to analyse the science-policy interface on the island. It begins with a breakdown of informational governance, noting how it forms the foundation to assess how data flows through decision-making processes. It then explores the joint knowledge production model, highlighting how collaboration and co-production between knowledge producers and users makes it easier to overcome challenges in decision-making processes. The role of boundary work and boundary organisations is also explored, with the chapter explaining how institutions function as intermediaries that facilitate the translation and integration of scientific findings into policy. The roles of environmental indicators and monitoring data as boundary objects are also elaborated. Finally, the chapter discusses indicator usability by drawing on the concept of usability profiles, assessing the legitimacy, credibility, and salience of the water quality monitoring programme on the island.

The third chapter outlines the research approach used to examine how water quality monitoring data is collected, disseminated, and used on Sint Eustatius. It highlights that the study employs a qualitative research design, utilising semi-structured interviews with local and external knowledge producers, mediators, and users. The chapter provides a description of the study area and elaborates upon the data collection methods, describing how interviews were conducted and how their outputs were systematically coded and analysed.

In chapter four, the outcomes of this analysis are presented. First, the views and sentiments from interviewees on reef health and the water quality monitoring programme are shared. Following this, the role of different actors within the science-policy interface on the island are examined. The chapter then delves into responses on data collection, dissemination, and uptake in decision-making.

Building on the results, the fifth chapter examines the findings in relation to the conceptual frameworks introduced in chapter two. It begins with an interpretation of the science-policy interface on Sint Eustatius, assessing the extent to which different actors collaborate in the production, translation, and use of scientific knowledge. It then evaluates the strengths and limitations of joint knowledge production on the island and explores the role of boundary work, elaborating on which institutions constitute boundary organisations and which initiatives function as boundary objects. The discussion then shifts to the challenges of communication and policy uptake. Finally, the chapter also provides an in-depth analysis of indicator usability, building on the criteria laid out in chapter two.

The final chapter synthesises key findings and reflects on how successfully water quality monitoring data feeds into decision-making processes. It concludes with a set of recommendations for strengthening the science-policy interface on Sint Eustatius.

Chapter 2: Conceptual Framework

Environmental Monitoring & Informational Governance

Environmental monitoring is a systematic process of collecting, analysing, and interpreting data to assess the state of natural ecosystems, track environmental changes, and inform decision-making. It serves as a critical tool for understanding ecological dynamics (Pörtner & Knust, 2007), detecting trends in environmental health (Li et al., 2018), and identifying human-induced pressures on ecosystems (Sousa et al., 2018). The data collected through monitoring help scientists, conservationists, and policymakers evaluate the impacts of pollution, climate change, and restoration on marine ecosystems, for example. However, environmental monitoring is not solely about data collection; it is an inherently social and political process that involves multiple actors who engage in the curation, interpretation, and dissemination of information. The manner in which environmental data is framed and communicated, as well as by whom, influences whether and how it is integrated into policies. This makes monitoring an inherent part of *informational governance theory*, which aims to examine and explain how information flows through a decision-making process, who is involved, and what kind of information is being used. This theory refers to the idea that information is "*fundamentally restructuring processes, institutions, and practices*" (Mol, 2006, p. 501), including in environmental governance. The term *information* encompasses both empirical data and the informal knowledge accrued around a certain topic or in a specific field (Mol, 2008). While information has always been of major importance in environmental governance processes, conventionally, these took a top-down approach and relied heavily on authoritative resources and state power to drive forward decisions and policies.

In informational governance, "*information becomes a crucial resource with transformative powers for a variety of actors and networks*" (Mol, 2006, p. 501). Now more than ever, through rapid developments in information technology, informational processing, and expanding informational networks, informational governance is shifting the governance landscape and transforming the way environmental problems are solved (Mol, 2008). With increased access to and use of information, power dynamics between governments, companies, and society are being challenged, with policies and measures increasingly relocated around access to, production of, and control over information (Soma, MacDonald, et al., 2016). Enhanced monitoring and collection of environmental data, growing transparency and public availability of information, and the wider application of environmental knowledge in social processes all contribute greatly to the transformative capacity of information in environmental governance (Mol, 2006), and shift societies towards more cooperation, empowerment, self-organisation, private governing, and interconnectedness (Soma, Termeer, et al., 2016).

As governing bodies and institutions are increasingly unable to effectively solve (environmental) problems and manage global resources on their own, the need for more diverse actors and informational avenues arises. Mol (2006) outlines that conventional environmental institutions are being called into question due to their deficiency in sustaining trust, a loss of legitimacy, and poor effectiveness. Taking on a more collaborative approach to governance increases accountability, transparency, and openness in information gathering and sharing (Mol, 2006), which ultimately leads to more robust conservation measures that are accepted by a broader societal audience. Research suggests that with a diverse representation of actor groups, and when participants expectations are at least somewhat met, the public sees a decision-making process as fairer and is, thus, more willing to accept its outcome (Ernst et al., 2017; Newig, 2007). In addition, active participation in decision-making processes can lead to a sense of ownership, increasing the effectiveness of policies and reducing the likelihood of non-compliance and conflict (Karcher et al., 2022).

Linear Knowledge Production

Informational governance breaks down the hierarchical governance structures which have long dominated decision-making processes across various disciplines (Soma, MacDonald, et al., 2016). It also critically examines the science-policy interface, questioning the role that science plays in society and the impact it has on policymaking (Mol, 2006; Spruijt et al., 2014). Until the end of the 1970s the so-called *linear model of expertise* dominated the way science and politics interacted with one another (Sokolovska et al., 2019). In this model, communication takes place in a one-way direction, with scholarly knowledge traveling exclusively from science to political decision-makers. The model is supported by three core ideas: (1) that more scientific research will lead to more certainty, (2) that science is a harmonising force, with more and better scientific research helping to solve political disagreements, and (3) that keeping science separated from politics leads to more rational evidence-based policies (Beck, 2011). However, the assumption that science is neutral and disconnected from political contexts, as well as the idea that science compels policy, has been called into question by many (*see* Dressel, 2022; Fischer & Karcher, 2022; Hegger et al., 2012). In fact, in their paper, Beck (2011) reveal that the linear model does not adequately conceptualise the relationship between science and policy in a decision-making context, particularly not in the 21st century.

Joint Knowledge Production

The inadequacies of the linear model, and a paradigm shift to post-normal science[5], led to a gradual change in science-policy arrangements toward more co-productive alternatives, where politically relevant knowledge is developed in a continuous interaction between scientists, policymakers, and societal actors (*Figure 3*). During the conceptualisation of these models, public participation was viewed as an important aspect of policy-making due to a lack of public trust in expertise (Sokolovska et al., 2019). The *joint knowledge production model*, which assumes that politics and science are inherently inseparable and co-constituted, is one such model and emphasises the value of societal engagement and non-scientists in knowledge development (Hegger et al., 2012). Many have argued that the blurring of boundaries between science, policy, and society through co-operative knowledge production makes it easier to overcome challenges in decision-making processes and their outcomes (Turnhout et al., 2013).

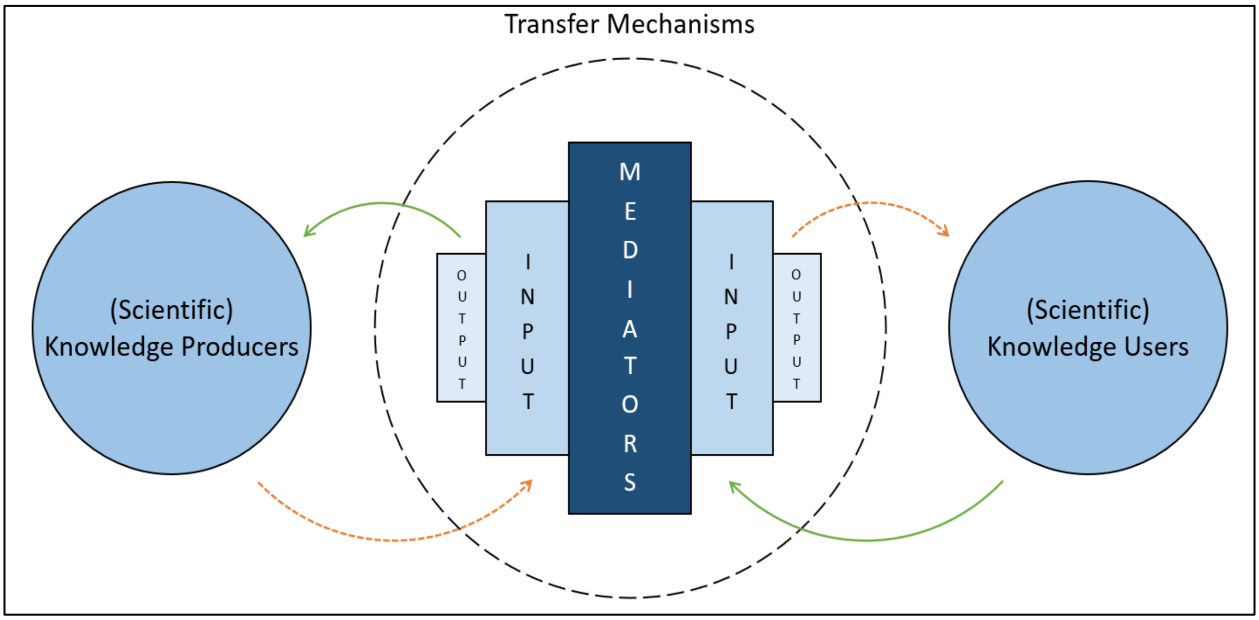

Figure 3: *Generalised schematic representation of the science-policy interface. Knowledge producers (scientists, researchers, academic institutions) provide mediators (policy advisors, knowledge brokers) with input that is translated for and communicated to knowledge users (policymakers, government agencies, regulatory bodies). The form of communication is captured in the transfer mechanisms (reports, policy briefs, consultations). It is important to note that the science-policy interface is bi-directional (i.e. knowledge and feedback flow in both directions).*

With the production of knowledge happening at the intersection between science and policy, the role of a scientist has shifted from that of an external advisor to more of an internal governance assistant (Wyborn

[5] *Post-normal science* assumes that facts are uncertain and that values are in conflict, while recognising the plurality of legitimate perspectives within a societal context (Funtowicz & Ravetz, 1993). It is in direct conflict with *normal science*, where the role of a scientist is to accumulate value-free knowledge towards the "truth" (Kuhn, 1962).

et al., 2019). This shift is well outlined in *The Honest Broker*, a book by Pielke (2007) attempting to make sense of science in policy. The book distinguishes between four ideal types of academics*: the pure scientist*, *the science arbiter*, *the issue advocate*, and *the honest broker of policy alternatives*. The former two provide scientific advice to policymakers in a detached manner and unilateral direction that corresponds to the linear model. The *issue advocate* and the *honest broker* are scientists that are intrinsically part of decision-making processes, advocating either for a specific outcome or providing various policy alternatives, respectively. *Honest brokers* explicitly integrate stakeholder concerns with available scientific knowledge, drawing on diverse perspectives to help overcome contexts of uncertainty (Pielke, 2007). This role has taken a strong foothold in the marine realm, where collaborative governance and knowledge co-production are increasingly adopted (*see* Cisneros-Montemayor et al., 2021; Cooke et al., 2021; Di Franco et al., 2020; Olvera-Garcia & Neil, 2020).

Within collaborative marine governance[6], scientists can participate in the development of robust environmental policies through the creation of inclusive and actionable forums that increase interpersonal trust and have direct benefits for all partners involved (Cooke et al., 2021). Monitoring programmes, such as the one on Sint Eustatius which collects data on water quality, can be such a forum. By engaging with stakeholders and working alongside knowledge users, monitoring initiatives can ensure that scientific findings remain relevant while promoting *legitimacy*, *credibility*, and *salience*[7] (Cash et al., 2003; Scrich et al., 2024), three fundamental qualities that form the basis for effective scientific information. Furthermore, through the development of indicators (as outlined previously), monitoring programmes can act as intermediary interfaces between policymaking and science. Indicators are intended to inform decision-makers about monitoring progress and can act as management tools, help with data communication and awareness raising, and improve policy evaluation (Lehtonen et al., 2016). They, therefore, bridge the science-policy interface gap by transferring and integrating scientific information into usable knowledge for policymakers while also facilitating the translation of policy demands into research questions (Turnhout et al., 2007).

[6] Collaborative marine governance can take on many forms but is underpinned by the sharing of policy making competencies in a system of negotiations between government actors and civil society organisations to govern resources and activities in the ocean (Hoefnagel et al., 2013).

[7] *Legitimacy* reflects the perception that a process or outcome has respected divergent stakeholder values and beliefs, treating opposing views and interests fairly. *Credibility* entails the trust that actors have in the information provided to them. *Salience* deals with the relevance of the assessment to the decision-makers.

Boundary Work

The idea that monitoring programmes and their associated indicators connect the science and policymaking realms can be further operationalised through the concept of *boundary work*[8] (*Figure 4*). At the science-policy interface, boundary work takes place to soften the demarcation between scientific and political responsibilities (Miller, 2001). Oftentimes, this is facilitated by intermediary organisations, otherwise known as *boundary organisations* (Guston, 2001), such as those involved in ecosystem monitoring. The Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES) are both relatively well-known examples of boundary organisations (Hoppe & Wesselink, 2014; Morin et al., 2017). These organisations involve the participation of actors from both sides of the boundary, as well as professionals who serve a mediating role, and are accountable to both political and scientific institutions (White et al., 2010). Because of this, it is important that boundary organisations refrain from "politicising science" or "scientising politics" and instead provide an arena for negotiation and collaboration across boundaries (Cash et al., 2003).

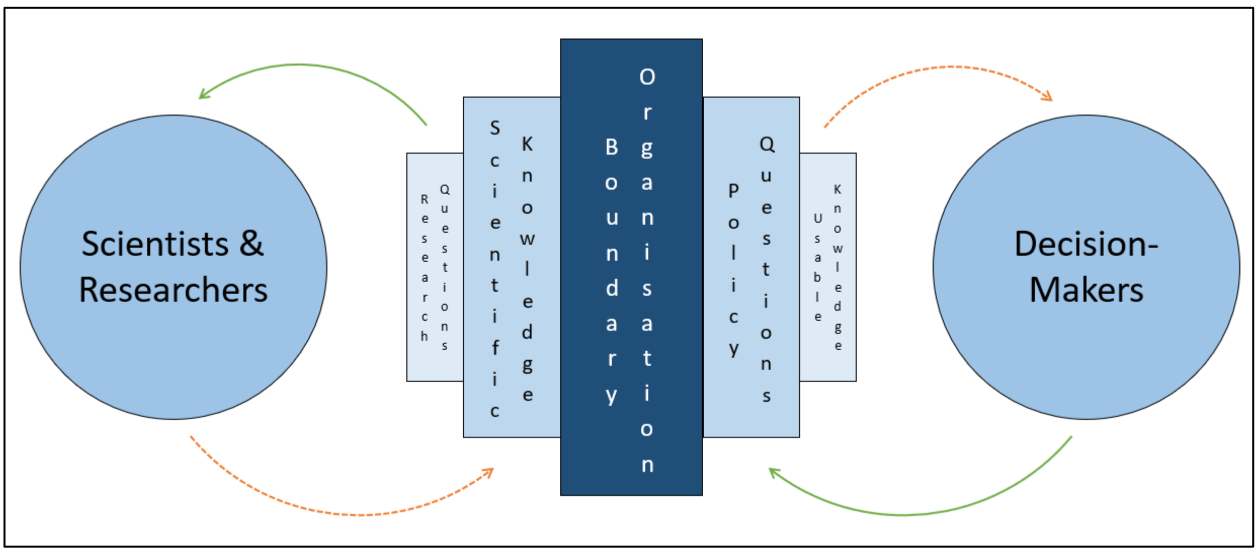

Figure 4: *Building on Figure 3, the concept of boundary work has been adapted to the schematic of the science-policy interface. Academics provide scientific knowledge (usually in the form of data) to boundary organisations that then translate this into policy-relevant and understandable knowledge for decision-makers. As the science-policy interface is bi-directional, decision-makers can in-turn outline their policy priorities that boundary organisations can help frame into research questions for scientists.*

This can be helped along by creating combined scientific and social perspectives through the generation of so-called *boundary objects*. Boundary objects sit between two different social worlds, such as science

[8] Initially defined as a concept that explains how scientists maintain their boundaries against threats from non-science (Gieryn, 1983), boundary work has found policy-relevant applications and shifted towards a concept that can facilitate the blurring of boundaries between two social worlds, often leading to more productive policymaking (Jasanoff, 1987).

and politics, and can facilitate communication about divergent ideals, principles, and objectives between actors within a shared space. They open up dialogue, information sharing, learning, and consensus-building across boundaries, such as between experts and non-experts or higher-order governments and lower-order governments (Holden, 2013). While they have different meanings in diverse social worlds, their structure is common enough to make them recognisable and usable in both (Star & Griesemer, 1989). Simply put, they are commonly understood objects that can be used in different ways by different people. An example may help further clarify this concept: A roadmap leading to a beachfront could be classified as a boundary object when used by different groups. For one group, this map leads to a place of recreation and the landscape they pass on their journey means very little to them. For another group, the road on the map passes countless important rare habitats and the map, thus, highlights collection sites for vital environmental data. The way the map is used depends on who is using it and what perspective they take. The boundary object (in this case the map) connects the two groups – i.e. they are using an *object* that connects their *worlds*. It is important to note that a boundary object does not necessarily have to be something tangible but rather something that people act towards and with, with its materiality deriving from action (Star, 2010).

As monitoring programmes connect science and policy domains, they operate as boundary objects. They serve as shared reference points that facilitate communication and coordination between diverse stakeholders and generate data that is interpreted and used by different actors, each of whom has distinct objectives and perspectives. Within monitoring programmes, one could argue that indicators act as "nested boundary objects": They are smaller, more specific tools that function within the larger framework of the programme itself. While they are based on scientific knowledge and data, they are shaped by political preferences and considerations and developed specifically to serve policymakers in understanding the effectiveness of a measure (Turnhout, 2009). Furthermore, they may help actors better frame and understand policy implementation challenges and could help decision-makers operationalise their policy measures (Holden, 2013). The monitoring framework currently being developed to track implementation progress of the Kunming-Montreal Global Biodiversity Framework (GBF), a framework adopted by the Convention on Biological Diversity in 2022 which sets out to halt and reverse global biodiversity loss, is a great example that highlights how indicators work across scientific, political, and social boundaries (Hughes & Grumbine, 2023). The ability of indicators to act as boundary objects stems from their flexibility, ambiguity, and vagueness, which allows them to transcend into both the scientific and policy domains while retaining a common identity (Turnhout, 2009). More specifically, indicators are ambiguous enough to allow for different interpretations and meanings between scientists and policymakers and flexible enough to account for the demands of developers and users, allowing for modifications as circumstances change (Turnhout, 2009).

Indicator Usability

Despite all this, the uptake and use of indicators to influence policy decisions is not always straightforward and actors may face challenges when trying to do so. Three factors can help explain this: 1) *indicator factors*, 2) *user factors*, and 3) *policy factors* (Sébastien et al., 2014). The first encompass the validity and reliability of indicators, as well as how they are communicated. If indicators are not presented to users in a reliable and interpretable way that makes them easy to incorporate into decision-making processes, they may not be able to fulfil their function (Borgnäs, 2016). User factors relate to the perceptions of those involved in both the development and use of indicators. That is to say, the uptake of an indicator depends on how it aligns with a policymaker's political agenda or a scientist's views (Hezri & Dovers, 2006). Typically, broad stakeholder consensus is a prerequisite for effective indicators, with those complying with dominant belief systems expected to be more influential than those reflecting controversial issues or views (Haas, 1992). Finally, policy factors denote the social-political setting within which indicators are developed and used and include shifting political landscapes or the social conditions under which an indicator is produced. Indicators that do not contradict established institutions and fit within a legislative framework are more likely to exert influence (Lehtonen, 2012). Ultimately, the effectiveness of indicators is governed by their legitimacy, credibility, and salience, which can be considered as umbrella criteria that collectively influence the indicator-, user-, and policy factors (*Figure 5*). Having said that, indicator factors are most closely linked to credibility, policy factors to legitimacy, and user factors to salience. Nevertheless, addressing these factors and their overarching qualities collectively and taking them into account when developing and implementing indicators is crucial to secure their inclusion in policy measures.

While challenging, this can be facilitated through an adaptive and iterative evaluation of indicators, something that has been addressed by concepts such as *adaptive management* (Holling, 1978) and *reflexive governance* (Feindt & Weiland, 2018). Reflexive governance, for example, notes that indicators are among the best instruments policymakers can use to integrate (scientific) expertise more successfully into decision-making processes but that for this to happen, they themselves need to be governed and their usability assessed (Bauler, 2012). Assessing the usability of indicators, i.e. the *"inherent, mostly implicit, potential of indicators to be considered by policy actors during their decision activities"* (Bauler, 2012, p. 39) and creating a so-called *usability profile* can help determine their value and impact across boundaries, such as at the interface between science and policy (Maiello et al., 2015; Sébastien et al., 2014).

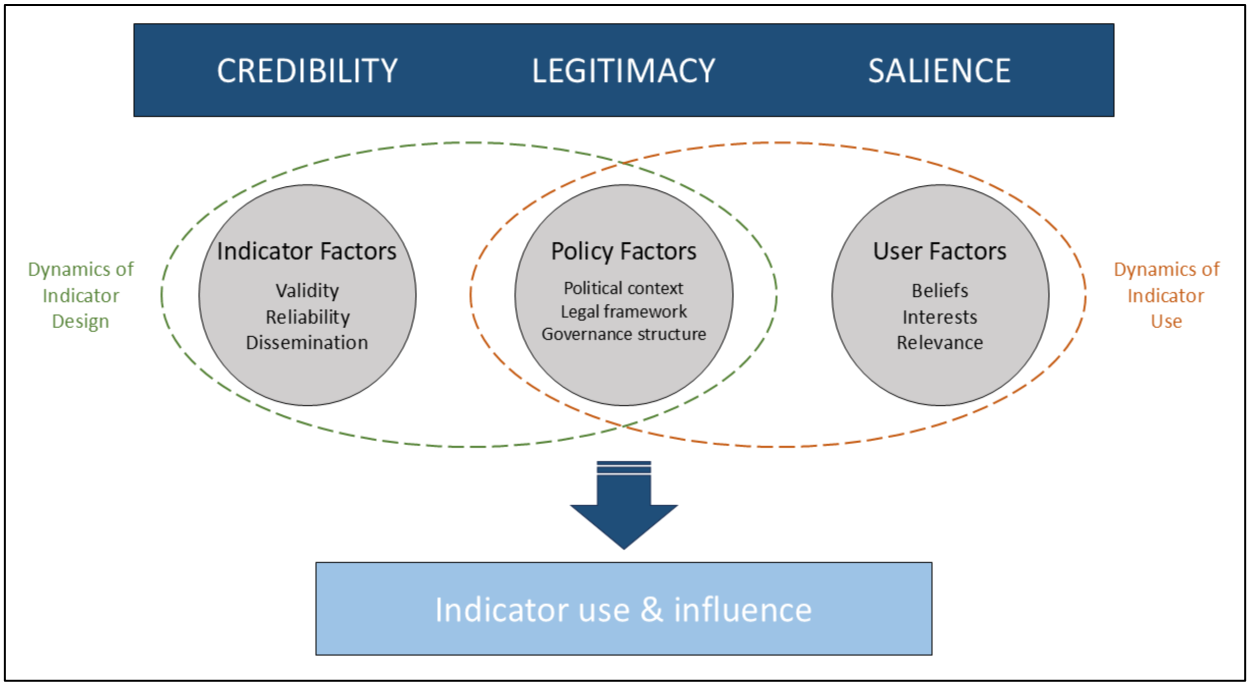

Figure 5: *A schematic representation of how indicator-, policy, and user factors determine the effectiveness and uptake of indicators. Policy factors play both a role in indicator design (together with indicator factors – circled green) and indicator use (together with user factors – circled orange). Legitimacy, credibility, and salience are overarching criteria that influence all factors collectively: to be influential, indicators should be legitimate in the way they have been designed, credible regarding their scientific methods, and salient within a political context and to potential users.*

It is important to note that the concepts explored in this chapter are interconnected in shaping how scientific knowledge informs decision-making. The science-policy interface serves as the overarching structure within which scientific data is produced, translated, and applied in policy contexts. However, as interactions within the science-policy interface are often fragmented, mechanisms such as joint knowledge production and boundary work are needed to foster collaboration between scientists, policymakers, and other stakeholders. Joint knowledge production directly strengthens the science-policy interface by ensuring that knowledge generation is not one-directional but rather an iterative and inclusive process. Boundary work operationalises this process, as it defines how different actors negotiate their roles and responsibilities in bridging science and policy. Boundary organisations play an important role in mediating between knowledge producers and users (Nunes et al., 2016), using boundary objects as shared reference points that facilitate communication. Taken together, these concepts form a multi-layered system where the science-policy interface provides the structural foundation, joint knowledge production drives inclusive knowledge creation, and boundary work enables interaction and negotiation. Their use in analysing how water quality data feeds into decision-making on Sint Eustatius is further elaborated in chapter 3.

Chapter 3: Methodology

The question *"How is water quality monitoring data collected and used in decision-making around coral reef health and resilience on Sint Eustatius?"* can be answered by adapting the concept of a usability profile for indicators to the entire water quality monitoring programme on Sint Eustatius, and by applying the concept of boundary work to the science-policy interface between the programme and local management authorities. As such, assessing the programme's efficacy and analysing the interactions and barriers between those involved in monitoring efforts and those pursuing environmental policy developments helps achieve the research objective to improve understanding of how scientific knowledge is integrated into local conservation policymaking in the Caribbean Netherlands.

Data Collection

Taking a participatory approach

To do so effectively, a participatory approach was taken in this research, i.e. I immersed myself into the water quality monitoring programme by participating directly in the collection of water quality data on Sint Eustatius.

With ecologists increasingly aware of the social implications of ecological systems, more interdisciplinary work between natural- and social sciences is taking place. By being integrated into ecological data collection and research, social scientists are able to make observations about the ways in which ecological data impacts and influences the social-ecological system (Ciesielska & Jemielniak, 2018). However, oftentimes these observations are done from an *outsider position*. Researchers working from such a position usually answer research questions using third-party literature, making them *"detached, impartial onlooker[s] who gather[…] data"* (Van de Ven, 2007, p. 269). Although this can be beneficial in some instances, like when a researcher's closeness to a study leads to questions about integrity or conflicts of interest, taking on a more involved observational role can lead to valuable insight. A researcher in such an *insider position* is a *"participant immersed in the actions and experiences within the system being studied"* (Van de Ven, 2007, p. 270). By engaging in participatory observation, a researcher can collect and interpret information and data that is only accessible to someone who is actively involved in a situation or scenario (Jhangiani et al., 2019). Participation also has the potential to engage people in all aspects of a research process, making the researcher a facilitator working collaboratively with all actors (Clark, 2009). In addition, participant observation gives the researcher first-hand experience of behaviours and developments, which enables them to come to their own conclusions rather than relying on prior conceptualisations (Clark et al., 2009).

Together with staff members from the local National Parks Authority, the Sint Eustatius National Parks Foundation (STENAPA), I visited 13 pre-determined water quality sampling sites scattered around the island (*Figure 6*). These sites accounted for variations in coral reef conditions (i.e. reefs differing in coral cover and diversity) as well as expected and known pressures (i.e. areas close to anthropogenic activities and natural disturbances). Of the 13 sites, two offshore locations likely not affected by pressures from the island were picked as references (sites ERef1 and ERef2). Trips took place once every two week and typically lasted between four and five hours, depending on weather- and water conditions. Additional sampling was done shortly after periods of heavy rainfall to capture water quality fluctuations directly after a pulse disturbance.

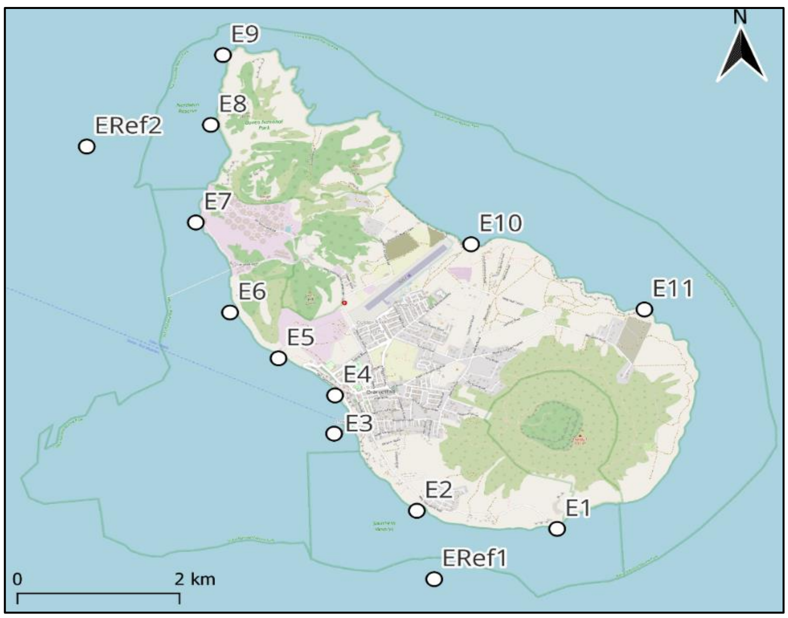

Figure 6: *Map of the 13 sampling sites around Sint Eustatius. Two sites (ERef1 and ERef2), picked for their distance to the coast and human activities, acted as reference sites. Map curtesy of Haanskorf, 2024.*

At each site, apart from the reference locations where measurements were made at 50m and 90m respectively, water quality samples were taken at two depths: 5m and 10m. This was to account for differences in depth-dependent nutrient concentrations as surface waters often differ to deep waters in their physicochemical characteristics (Millero, 2005). *Table 1* outlines the water quality parameters measured throughout the programme, gives a rationale for their inclusion, and highlights possible drivers contributing to measurement fluctuations, as suggested by Foekema et al. (2021). A more comprehensive description of the water quality sampling method can be found in *Annex I*.

Table 1: *Water quality parameters measured for the monitoring programme [adapted from Foekema et al., 2021].*

Water Quality Parameter	Unit	Rationale	Main driver/source[1]	Equipment used
Physical-Chemical				
Salinity	‰	Salinity changes can indicate large emissions of fresh waste/run-off water or high salinity water (brine) from salt pans or drinking water installations.	Wastewater run-off, brine	CTD
Temperature	°C	Indicative for climate change periods; elevated temperature can cause coral bleaching and mortality.	Climate change	CTD
Nutrients				
Nitrogen (NO2, NO3, NH4)	μMol/L	Serves as a nutrient for primary producers. Too high concentrations can lead to eutrophication with the risk of adverse effects on corals.	Wastewater run-off, overflowing of septic tanks	Niskin Bottle
Phosphorus (PO4)	μMol/L	Serves as a nutrient for primary producers. Too high concentrations can lead to eutrophication with the risk of adverse effects on corals.	Wastewater run-off, overflowing of septic tanks	Niskin Bottle
Organic Matter				
Dissolved Organic Carbon (DOC)	μMol/L	Can indicate the presence of sanitary wastewater, indicative of the risk of pathogens that could threaten corals. It can also indicate run-off of plant material or animal feces.	Wastewater	Niskin Bottle
Particulate Organic Carbon (POC)	μMol/L	Indicates presence of organic suspended material, can be from sanitary wastewater run-off or naturally occurring organisms (e.g. pelagic Sargassum).	Wastewater and run-off	Niskin Bottle
Biological				
Chlorophyll a	μg/L	Proxy for phytoplankton; high values can indicate eutrophication. High concentrations also decrease light levels for phototrophic organisms like corals.	High nutrient loads from wastewater and run-off	CTD

[1]As suggested by Foekema et al. (2021)

In addition to sampling water quality, I volunteered to take part in various activities for STENAPA, including helping further develop and implement the local *Diadema antillarum* re-establishment programme, collecting algal samples for isotope analysis, and controlling the local population of invasive lionfish (*Pterois spp.*). Participating in these additional activities allowed me to build a more robust relationship with the STENAPA staff members, helped establish a mutual level of trust between those involved in the water quality monitoring programme and myself, and enabled me to expand the network of people I could approach for my research.

Semi-structured interviews

In addition to participating directly in the water quality monitoring programme, semi-structured interviews were conducted with directly and indirectly involved key actors. Interviews, in general, can be used to collect data about people and their preferences, ideals, thoughts, and behaviours in a systematic way (Bhattacherjee, 2012). Semi-structured interviews are a powerful, versatile, and flexible qualitative data collection method in which the interviewer does not follow a rigorous set of predetermined questions (DiCicco-Bloom & Crabtree, 2006). Instead, questions are formulated using an interview guide and their relevance determined throughout each interview. This allows a researcher to improvise with follow-up questions based on a participant's responses (Rubin & Rubin, 2005). The idea is to explore the research area by providing participants guidance on what to talk about rather than forcing them into a certain direction (Gill et al., 2008).

Semi-structured interviews were conducted with three target groups: 1) scientists/academics, 2) practical conservationists, and 3) decision-makers. The aim was to collect information encompassing the different stages of the monitoring programme – from data collection, through the policy-making process, to implementation. Interviews served to explore the relationships between actors and assess their perceptions of the water quality monitoring programme on the island. Local actors were interviewed in person whilst those abroad were interviewed online. In total, 18 interviews were conducted across three months – November 2022 to February 2023 (*Table 2*). A list of interview questions was developed towards the beginning of the research process and adapted based on the interviewee. Questions were formulated around three core themes: 1) perceived reef resilience and health, 2) stakeholder roles, and 3) information communication. An emphasis was placed on assessing the challenges that actors face within and throughout the entire monitoring programme (i.e. from data creator to user, and vice versa). The full list of interview questions can be consulted in *Annex II*. All interviews were audio recorded[9] and transcribed.

Table 2: *Interviewees, anonymised and assigned numbers, categorised by function, organisation, and their general science-policy roles. In total, 18 interviews were conducted, spanning academics, conservation actors, local policymakers, and Dutch government officials. NB: not all respondents wanted to be quoted and thus not all interviewees can be found in the results section below.*

Interviewee	Type of Function	Type of Organisation	Science-Policy Role		
Interviewee 1	Park Ranger	Conservation	Knowledge Producer		
Interviewee 2	Project Coordinator	Conservation		Mediator	
Interviewee 3	Park Ranger	Conservation	Knowledge Producer		
Interviewee 4	Data Officer	Academic	Knowledge Producer		
Interviewee 5	Director	Conservation		Mediator	
Interviewee 6	Director	Academic		Mediator	
Interviewee 7	Owner	Conservation			User
Interviewee 8	Senior Advisor	Dutch Government	Knowledge Producer		
Interviewee 9	Program Manager	Local Government		Mediator	
Interviewee 10	Program Leader	Academic	Knowledge Producer		
Interviewee 11	Program Coordinator	Academic	Knowledge Producer		
Interviewee 12	Advisor	Local Government			User

[9] With permission given from each interviewee, respectively.

Interviewee	Type of Function	Type of Organisation	Science-Policy Role		
Interviewee 13	Marine Biologist	Conservation	Knowledge Producer		
Interviewee 14	Registrar	Local Government			User
Interviewee 15	Volunteer	Conservation	Knowledge Producer		
Interviewee 16	Director	Local Government			User
Interviewee 17	Program Manager	Dutch Government		Mediator	
Interviewee 18	Former Exec. Director	Conservation		Mediator	

Data Analysis

Interview Coding and Analysis

Transcriptions were coded and analysed using the qualitative data analysis software Atlas.ti. Both a *thematic analysis* and a *sentiment analysis* were performed. Using both techniques captured not only patterns and themes echoed across interviews but also the opinions and attitudes of interviewees towards a person or subject. Across numerous themes, interviewees were asked to elaborate on roles, challenges, and expectations. The full list of defined codes and examples of their corresponding guiding questions can be reviewed in *Table 3*.

Table 3: *Interview codes and corresponding example questions that guided the coding process.*

Interview Code	Guiding Question (Example)
Collaboration	How much (and what kind of) collaboration occurs between the national park foundations and other scientific institutes on each island?
Communication	Who do you think should be involved in communicating scientific data to policymakers on the island?
Data Collection	What kind of ecological and environmental data is being collected?
Ecological Indicators	In your opinion, what are important indicators of a resilient and healthy reef?
Funding	How can water quality monitoring continue once Wageningen Marine Research is no longer receiving funding for the project?
Implementation and Enforcement	Once conservation policies have been drafted and implemented, what hurdles stand in the way of enforcement?
Laws and Regulations	What is the mandate of your organisation for conservation policymaking?
NEPP	To what degree do you believe the NEPP is an effective policy plan?
Policymaking	How much does conservation work feed into local policies/local policy development?
Pressures	Do you believe there to be negative pressures impacting reef health? If so, what are these pressures?
Priorities	Do you believe that the Public Entity prioritises socio-economic factors of the island over nature?

Interview Code	Guiding Question (Example)
Reef Health & Resilience	What state do you perceive the reefs around Statia to be in?
Relationships	How do you perceive the relationship between STENAPA and decision-makers to be?
Roles	Who do you think should oversee the monitoring of water quality (and reef health)?
Scientific Understanding	How effectively do you think scientific data is being used in conservation policymaking?
Translation Work	What translation work is needed for policymakers to understand the scientific data and information that is being presented to them?

Creating and Assessing a Usability Profile for the Monitoring Programme

The usability of the monitoring programme, and its potential success in impacting the development of local environmental policies, was assessed across three main criteria: legitimacy, credibility, and salience. As mentioned before, these three fundamental qualities determine the effectiveness of scientific information in influencing decisions (Cash et al., 2003). When enhanced, they facilitate the exchange and communication of knowledge across boundaries, such as the science-policy interface.

Each criterion was evaluated individually and ranked either as *poor*, *moderate*, or *high*. The evaluation process was based on the input received through interviews, i.e. answers given to questions were analysed and context clues extracted to deduce whether the monitoring programme is 1) perceived as fair and taking into account divergent stakeholder values (i.e. legitimate), 2) understood well and considered trustworthy (i.e. credible), and 3) accepted and used by actors both directly and indirectly involved (i.e. salient). All answers were considered collectively. A poor ranking entailed that the monitoring programme was perceived not to address the respective criterion at all. A moderate ranking entailed that the monitoring programme was perceived to somewhat consider the respective criterion. A high ranking entailed that the monitoring programme was perceived to (almost) completely account for the respective criterion.

Chapter 4: Results

Reef Health

Perceptions of Reef Health

Out of 18 interviewees, 10 commented directly on the health of the coral reefs around Sint Eustatius. Answers were very homogenous, with all but one respondent stating that they thought the reefs were in a dire state. Many interviewees expressed concerns over the continual degradation of the reefs, with several mentioning that while the reefs in Sint Eustatius may be better off compared to other locations in the Caribbean, they are still in poor condition when viewed through a global lens. Interviewee 1, for example, noted that "*by the standards of the region they are quite good. By global standards, they're quite poor.*" Similarly, interviewee 2 mentioned that although the reefs in the Caribbean Netherlands, including Sint Eustatius, have benefited from some protective measures, they have still deteriorated compared to previous decades. He emphasised the fact that "*the reefs are in better shape than many other places in the region […]*" but their quality "*is in no way comparable to the state it was in 50 years ago.*"

A fifth of all respondents also commented on the observable declines in coral cover. Interviewee 3 recalled how the health and abundance of corals had noticeably decreased over time, stating "*the first time I made an inventory of all the coral, it took me over an hour to capture them all. Two years later, it only took me twenty minutes.*" This was echoed by interviewee 4 who explained "*coral cover should be high, and the algae cover should be low and we're the complete opposite.*"

A sense of urgency to increase coral cover and improve the reef's condition was evident. Although he noted that for the moment "*all […] ecologically important groups [are] present,*" interviewee 5 expressed concerns that if immediate action is not taken, restoration efforts may become futile, stating, "*if we don't do anything now, it may not be a case of restoration. It may be a case of can you rebuild something from nothing.*"

When asked about the signs of a healthy and resilient reef, those mentioned by interviewees for Sint Eustatius were similar to those identified as general factors by McClanahan et al. (2012), outlined in the introduction of this thesis. Although often drawing from general and global ecological principles, respondents always shared their opinions and observations about the local reefs in Sint Eustatius. Highlighting indicators of a healthy reef, interviewee 1 mentioned that the "*presence of top predators is one of the major ones,*" noting that "*if you have lots of sharks […] that's a very good indicator.*" He contrasted this with Sint Eustatius, stating that the island's reefs lack significant numbers of predators, signalling an imbalance in the ecosystem and that the reefs are in poor shape. He also mentioned that the reefs around Sint Eustatius are "*not especially complex,*" noting that healthy reefs often have high branching corals that provide habitat for fish to hide and breed.

Interviewees 6 and 3 both shared this sentiment, highlighting that declines in herbivorous fish diversity and *Diadema antillarum* abundance are also evident on the reefs around Sint Eustatius. Both noted that this lack of grazers is contributing to the unchecked growth and proliferation of algae on the reefs. This rapid expansion of algae was identified by most interviewees as the key indicator of reef degradation. Interviewee 4 provided his insights on what healthy coral and algae proportions should look like, stating that ideally "*the amount of algae on [the reef] should be less than 10%.*" As mentioned above, he noted that around Sint Eustatius, algae seem to be much more abundant and dominant than hard coral – far exceeding the 10% threshold. Similar observations were made by interviewee 3 who shared "*while I knew algae was growing on the reef, when sargassum was all I could see, it was a bit scary.*"

Interviewees also noted the spread of SCTLD as a major concern, with one respondent expressing that they had "*a special concern about SCTLD,*" noting concerningly that they had "*not heard of any recommendations made about this.*" Although also mildly concerned about the outbreak of SCTLD, interviewee 7 uniquely mentioned that he thought "*the flamingo tongue [snail (*Cyphoma gibbosum*)] is a bigger problem than any lionfish and every coral disease combined.*"

Despite all the alarming factors shared about Sint Eustatius' reef health and resilience, and despite over half of all interviewees expressing concerns about the future of the reef, the general sentiment shared by most was that the marine environment and coral health are not economically important enough for the island and, as such, a low priority for local politicians. Noting that fisheries and dive centres are "*pretty minor industries*" on the island, interviewee 1 stated that "*from a point of view of the economy, the health of the reefs is probably a minor consideration for most people.*" He also highlighted that decision-makers would consider doing more to conserve the reefs "*provided that there were direct effects*" on the local economy by doing so. Interviewee 2 shared this sentiment, outlining that politicians' "*ambition isn't that large when it comes to fixing the problems for the coral reef.*" Interviewee 3 went one step further, stating that "*most people don't really care. Even the fishermen don't realise that the loss of coral will impact their income.*"

Nevertheless, some interviewees highlighted that there is a growing recognition that, as Sint Eustatius transitions from an industrial-based to a tourism-based economy, the importance of healthy coral reefs will increase. In this regard, interviewee 5 noted that "*nature will become more and more important.*" Interviewee 4 also mentioned that as the local population is made more aware of the ecosystem services that the reef provides, such as protection from storm surge, they may prioritise reef conservation more.

Identified Reef Health Stressors

For conservation to be successful, however, it is important that the underlying pressures impacting reef health and resilience are properly addressed. When asked to identify negative pressures, interviewees' answers comprised both global and local reef stressors, many overlapping with those described by Howells et al. (2020) and Zaneveld et al. (2016) in the introduction of this thesis. Furthermore, throughout the interview process, it became evident that respondents were well aware of the synergistic relationships and interactions between local and global pressures.

At the global scale, climate change was identified as the most significant pressure affecting the health of coral reefs. Several interviewees pointed to rising ocean temperatures and acidification, leading to wide-spread coral bleaching, as major threats. Interviewee 2 referred to climate change as "*the big elephant in the room,*" stating that it is greatly contributing to mass coral die-offs around the world. However, he noted that climate change does not have to be "*a killing event […] because if the events of bleaching are far enough apart, coral can recover in the meantime.*" With bleaching events occurring more frequently though, it is becoming increasingly unlikely that reefs will have the necessary "*10 to 20 years of no major disturbance to recover properly,*" as outlined by interviewee 4.

This is further exacerbated by hurricanes in the Caribbean, mentioned by many as one of the most significant factors impacting reef health on the regional level. Both interviewee 4 and 6 suggested that stronger and more frequent hurricanes have made it harder for corals to recover, with the former recounting how not too long ago Sint Eustatius, as "*a tiny dot in the middle of the ocean,*" was hit by "*a number of hurricanes that came back-to-back.*"

On top of these global and regional pressures, Sint Eustatius also experiences local stressors. Those mentioned by interviewees were diverse and many. A fifth of all interviews mentioned that sewage and wastewater are major threats to the reefs around the island. With a sewage system and treatment plant lacking on Sint Eustatius, wastewater is not dealt with adequately. Interviewee 4 bluntly explained that "*everybody just puts their wastewater into the ground, and then it leeches out into the sea eventually.*" This can lead to eutrophication and increases in nutrient concentrations, possibly fostering algal growth, as outlined by interviewees 2 and 6. The former noted, however, that perhaps "*the background* *eutrophication of the whole Caribbean Sea is too high,*" suggesting that even if local wastewater treatment were improved, there might still be unsuitable nutrient levels in the region's waters for coral reefs to thrive due to "*the gigantic runoff from the agricultural sector in the US and other places.*" Whilst the sentiment about agricultural runoff was shared by interviewee 8, he was the sole interviewee who mentioned that he had "*the feeling that in Statia, we have a really high rate of natural refreshment that we can handle the extra nutrients.*"

Regardless of whether this may be the case, 60% of interviewees noted that wastewater and sewage are not the only polluters possibly impacting reef health and resilience. The discharge from the island's only desalination plant and the dropping of ballast water from anchored ships were two additional stressors mentioned by respondents. The lack of reporting of oil spills to local authorities was also highlighted as a major concern, with interviewee 7 expressing that "*oil spills never make it into the newspaper, but there's a bunch […] they don't report.*"

By far the most mentioned negative pressures on reef health were erosion and free-roaming goats. According to interviewees 4 and 5, roaming goats have been persisting on Sint Eustatius for centuries, their sheer numbers leading to overgrazing of vegetation which could, in turn, be resulting in erosion. Most interviewees shared the opinion that the goats on the island are an issue for reef- and island health, with interviewee 9 noting that "*the entire nature conservation and nature preservation on the island is very much dependent on the roaming animal situation,*" and interviewee 3 linking the possible nutrient influxes to the goats, making the observation that "*perhaps the amount of nutrients being pushed into the system through the goats on the islands are causing more algal growth.*"

Three respondents were more sceptical about this link, however, noting not only that the goat issue is extremely multi-faceted and complex, but that erosion has always been an issue. Interviewee 4 remarked that he did not "*know how big of a problem the goats [are],*" explaining that "*they eat a lot of vegetation, sure. That causes erosion. But erosion has always been happening. But has the erosion that has been happening, been significant enough to cause damage to the reefs? That I'm not so sure about.*" Interviewee 7 also questioned the impact of erosion on declining reef health, outlining that "*only when it rains heavy, you have a bit of mud here and a day later it's totally clear. And coral can clean itself a little bit, so I don't think erosion has anything to do with it.*" In agreement and whilst referring to the impacts of roaming goats, interviewee 8 outlined that he too did not think that rain runoff was a major concern for the reefs. Interviewee 6 expressed similar views, noting that "*the runoff of the rain does not carry the nutrients* *because when it rains, the [nutrient] concentration goes down and only when it is dry, the concentration goes up.*"

Whilst many interviewees mentioned similar or the same pressures impacting reef health and resilience, it is apparent that a lot of unknowns still exist both about which local stressors are impacting Sint Eustatius' coral reef ecosystem and how severely they do so. Particularly the uncertainty about the impacts of roaming goats on erosion and nutrient influxes became clear throughout the interviews, with about 80% of respondents who mentioned the issue indicating that it is highly sensitive and political. It is evident that more data collection needs to take place so that the true drivers of declining reef health and resilience can be correctly identified. In this regard, the water quality monitoring programme is well placed to provide important water quality information and fill many persisting data gaps.

The Water Quality Monitoring Programme

General Sentiments

Interviewees 10 and 11 outlined that the water quality monitoring programme aims to establish comprehensive baselines for nutrient levels and assess which sources are affecting Sint Eustatius' reefs the most. Both explained that the programme's overarching objective is to inform the creation of "safe boundaries" that will increase coral health and resilience. They also mentioned that achieving this requires not only a better understanding of the parameters mentioned in *Table 1* above but also the collection of isotopes, eDNA, and metabolomic data.

When other interviewees were asked about their knowledge of the water quality monitoring programme on the island, and the data that should be collected to help improve Sint Eustatius' reefs, they gave mixed responses. Some stated that they were not even aware that water quality monitoring and data collection was taking place. Most respondents, however, had at least a vague idea of the existence of the programme and the data needing to be collected to reach its objective.

All STENAPA staff interviewed highlighted the importance of the monitoring programme and commended Wageningen Marine Research for their efforts, with interviewee 5 noting that it was high time water quality was properly addressed and explaining that he had "*tried previously to kind of raise the alarm when it comes to water quality, but [did] not received any positive response on it.*" Whilst interviewee 3 concurred with this, he went on to state that too often, data collection begins only once significant damage is observed, expressing that "*when something happens, all of a sudden we say 'Oh let's start to collect data.' But it's already nearly too late. You should already have the data.*"

When asked to outline his views, interviewee 2 noted that there "*are point sources of wastewater […] that are probably causing eutrophication around the island,*" highlighting that what he expected the programme to do was "*identify those sources and use that proof to identify which problems you need to solve and where.*" Whilst generally aligning himself with this statement, interviewee 6 pointed out the challenges in interpreting the collected nutrient data, explaining that understanding the timeline of nutrient travel from land to sea is complex. He noted that "*what you measure in the sea, [are these] nutrients from a day ago, or a week ago, months ago, a year ago or maybe even longer than that? It's very hard to assess.*" Regardless, both interviewees 2 and 6 mentioned that they expected any newly developed data collection protocols to contribute to a more systematic approach to water quality monitoring for the BES islands, with the former explaining that "*the experiences you have with whether or not these protocols work, or how they can best be implemented should feed into [the] development of a structural monitoring protocol for the islands.*"

Whilst such a harmonised approach could be pursued in the future, it became evident from speaking with interviewee 9 that coordination and alignment between water quality monitoring efforts is a current and ongoing challenge for Sint Eustatius. When asked about her duties, she explained that she was "*also working on that sea water quality monitoring programme with I&W*" (the Dutch Ministry of Infrastructure and Water Management). When asked whether this project was in any way related to the water quality monitoring programme being conducted by Wageningen Marine Research, she stated "*That I don't know. […] Probably not and that is something that should be aligned,*" further noting that, in a coordination call for the I&W project, someone remarked that there was no existing water quality monitoring on the island indicating a lack of knowledge management and awareness of existing initiatives.

Amongst the most prominent, and mentioned by both interviewee 6 and 9, was the now dissolved CNSI water quality monitoring project which had existed for years. Explaining CNSI's history, interviewee 6 outlined that the institute used to work "*with Rijkswaterstaat about what to measure and not, about what to monitor and not, finding the sources of pollutants.*" It became apparent that although CNSI was no longer collecting data, Rijkswaterstaat, under the mandate of the I&W project, still was – in parallel to Wageningen Marine Research. This lack of coordination is, according to interviewee 9, a common occurrence in the Caribbean region, with "*many projects that start and then go […] and then another person comes in and does the same.*" Although data from Wageningen Marine Research was freely available to Rijkswaterstaat, according to interviewee 10, more senior project coordinators in I&W seem unaware of past or current monitoring efforts, resulting in an apparent duplication of data collection efforts. Varying scopes of monitoring across these unrelated initiatives and the different methodological approaches these individual projects might be taking could complicate efforts to arrive at a harmonised picture of water quality parameters, potentially yielding conflicting interpretations of reef health and resilience in the BES islands.

This is further reflected in the coordination challenges observed between actors within a single initiative, such as the programme led by Wageningen Marine Research. When asked about who should be responsible for various aspects of the programme, such as data collection, communication, or implementation, interviewees highlighted that allocating such responsibilities on the island is a complex issue.

Many respondents expressed that a collaborative approach is crucial, with responsibilities shared between (Dutch) national and local entities. Interviewee 1 highlighted that any monitoring efforts should ideally be "*a cooperation between STENAPA and LVV,*" – the local authority responsible for agriculture, animal husbandry, and fisheries – as well as the Dutch Ministry of Infrastructure and Water Management. He emphasised that STENAPA's expertise in managing the national parks on Sint Eustatius makes it a logical partner for any monitoring programme, particularly seeing as, according to him "*there's certainly no monitoring expertise*" at LVV. In this regard, he noted that STENAPA often feels obligated to step in, exclaiming "*who else is going to do it?*" – a sentiment echoed by others who recognised that STENAPA frequently takes on roles beyond park management and their mandate due to limited alternative local capacities. Hearing this, one interviewee proposed that expanding STENAPA's mandate could formalise their involvement in future monitoring efforts, provided the necessary financial support is allocated by the Dutch government.

In line with this, interviewee 5 expressed a desire for the local government to take a more strategic interest in STENAPA's activities, stating that ideally, the organisation would be "*a tool for the public entity to execute their nature management strategy,*" but noting that at present, there is no cohesive framework in place. He advocated for the local authorities "*to influence what we do, because it means that they are interested and that they have a strategy.*" Interviewee 3 shared these sentiments, further highlighting that he believes "*the government should be involved in the quality of the water, but the problem is I don't think they really want to [be]*." In contrast, another interviewee, when asked about the extent to which local politicians and government officials can influence what STENAPA monitors, i.e. what data is being collected, stated "*they can and […] do.*"

Data Collection

In terms of specific responsibilities for data collection, interviewees noted that the programme has relied heavily on temporary or external support, such as university students and short-term monitoring officers. This reliance raises longevity concerns, particularly considering additional challenges around securing funding for any future monitoring efforts. Interviewee 4, who outlined that he used to oversee fisheries and reef monitoring, noted that the position was not guaranteed long-term funding. He stated that "*it's all down to money,*" and explained that the question was not about who wanted to take responsibility for data collection but rather "*who wants to pay to do this?*" Interviewee 6 concurred, highlighting that for the funding question to be answered, water quality monitoring "*should be a legal obligation,*" further explaining that "*if there is no obligation to do it, I don't see a party who would like to fund it.*" He stated that, in his opinion, the Dutch government had this responsibility and obligation and proposed that the Ministry of Infrastructure and Water Management, as the body responsible for water quality, should fund the monitoring, while local entities such as STENAPA or contracted staff could "*do the monitoring and collect the data and send it to the Netherlands.*" Irrespective of who would officially take on the role of collecting data, the importance of having an entity take ownership of it was stressed by many, with interviewee 9 stating, "*to have a date monitoring officer to be able to go and collect all kinds of data that is required by ministries, helping out universities, would be of the utmost importance.*"

Whilst both interviewees 3 and 5 agreed that STENAPA could take on such a role, however "*not without extra funding for it,*" the former pointed out that the present approach of sending samples all the way back to a lab in the Netherlands posed both logistical challenges and additional financial burdens. Both were among several interviewees who expressed frustration at the fact that CNSI, which, as mentioned above, was previously engaged in water quality monitoring efforts, had been shut down and could no longer be used as a local data collection or analysis hub. Interviewee 4 highlighted that the Dutch government "*wanted people based on the islands to do it. But they're closing the only institute that was able to do it.*" Regardless, and despite all the challenges, all interviewees acknowledged the importance of gathering water quality data and advocated for the programme's continuation.

Data Dissemination & Communication

The fact that two water quality monitoring programmes – one undertaken by Wageningen Marine Research and the other by I&W – are co-occurring with little interaction and seemingly little knowledge of one another suggests that communication between stakeholders is an ongoing challenge on Sint Eustatius. This sentiment was echoed by almost all interviewees, who highlighted the challenges they face in communicating not only scientific data, but information in general, from source to user. It is important to note that respondents often made general statements about communication rather than going into details about the dissemination of water quality data, mainly due to the fact that, at the time of writing this thesis, the programme had only recently started and communicable data from it was not available.

When asked about who is currently taking on the role of communicating data to decision-makers and informing the wider public about scientific findings, respondents generally agreed that the responsibility often falls on individuals within local nature management organisations, such as STENAPA, even though this task may not be part of their mandate. Interviewee 5 succinctly stated "*I will assume that responsibility, whether or not it is truly mine,*" adding that it is always helpful if the scientific entities interested in the collected data and its outcomes, such as Wageningen Marine Research, are also involved in communication. This sentiment was shared by a handful of other interviewees, including interviewee 2, who noted that he thought "*if scientists would consider that [communication is] part of their job, the problem would largely be solved.*" He went on to highlight that "*ideally, in every research project you have a communicator that does exactly that. I think that should be mandatory in any kind of research program*." Interviewee 6 built on this, remarking that, for data to be effectively communicated and taken up, "*scientists can only act as the honest broker,*" meaning that, as explained above in this thesis, they intrinsically need to be part of decision-making processes. In line with this, interviewee 5 advocated for scientists to adapt their communication methods to the local context.

However, he also acknowledged that properly understanding and translating scientific data is "*very difficult if you don't have people who can do it,*" stating that "*you have to train people, you have to ask people to do it for you*." In this regard, interviewee 5 stressed the need for an official local entity or dedicated team to manage scientific outreach. Together with interviewee 4, he noted that CNSI had once fulfilled this role, but he highlighted that the recently established Programme- and Project Management Office (PPMO)[10] of the public entity could now take on this responsibility and "*have such a function independent from all the directorates.*" He stressed the importance of ensuring that the PPMO had enough capacity, resources, and technical expertise, suggesting that the organisation help ensure data accuracy, reliability, and broader understanding by "*assess[ing] these data, or explain[ing] certain claims in the [STENAPA] report.*" Furthermore, he recommended that the PPMO "*evaluate the lack of knowledge needed for policy*

[10] The PPMO was established in 2021 by the Public Entity of Sint Eustatius with the aim to implement programmes and projects centrally. The PPMO is supposed to help formulate, execute, and implement programmes and projects more effectively and efficiently. More information can be found here.

development or implementation of policy," adding that "*the articulation of knowledge questions or knowledge needs is something that should improve for sure*."

Interviewee 9 echoed interviewee 6's sentiments and aligned herself with his statements, stating that the PPMO is "*a massive benefit for the island.*" Outlining her role within the organisation, she stressed that "*it's my task to try to be the bridge between as much as I can*." In relation to helping ensure that data is communicated in an understandable and context-specific manner, she noted that "*because I have my biological background, […] I hope to be able to interpret the data and persuade people, why it's important, what we can do, and how we can do it.*"

In this regard, interviewee 9 outlined how she actively tailors her communication strategies to resonate with diverse audiences, particularly policymakers, emphasising the disconnect between those who collect and process data and those who make decisions, stating that "*scientists do not speak the same language as policymakers.*" She also highlighted the importance of framing messages in a way that aligns with political priorities, explaining the need "*to aim the message to their interest, depending on their politician view,*" and noting that messaging "*has to be individualised.*" Stating that she has frequent contact with the local decision-makers, interviewee 9 further noted that she must ensure they fully comprehend what they agree to, as decisions are sometimes reversed due to misunderstandings or misaligned expectations. She explained, "*I really want to make sure they understand what they are agreeing to. So not four weeks down the line they say 'no, no, no' and back up, because that's what happens. And that's what happened before. And it happened so many times.*" To help ensure that decision-makers are on board and understand the data in front of them, interviewees stressed the importance of simplifying scientific language to bridge the communication gap. Interviewee 2 noted that "*information should be presented in such a way that it allows the island government to say, 'Oh, we have a problem, and we need to fix it',*" further outlining the need for "*easily understandable but scientifically valid problem descriptions […] and ideally also some recommendations on how to move forward.*" Interviewee 5 built on this, mentioning that, when dealing with monitoring data, "*it's important not to just throw out the number but to explain what that number means.*"

It is for this reason that efforts are being made on Sint Eustatius to enhance proactive engagement between data collectors and decision-makers. Historically, data on the island was primarily communicated through written reports. However, with widespread scepticism about their effectiveness and recognising that they often go unread, interviewee 5 explained that STENAPA strives to present data in a digestible format, therefore opting increasingly for presentations and one-on-one meetings. He highlighted that he meets with and communicates with public entity representatives weekly through both formal and informal channels, with his main contact point at the local government level being Anthony Reid, the Director of the Department of Economy, Nature, and Infrastructure (ENI). In addition, he has monthly meetings with the director's policy advisors. Despite such frequent contact, some interviewees expressed frustration about local government officials' lack of responsiveness to STENAPA's work, with interviewee 1 noting "*there's no feedback that comes back to you to say, 'Adam, we want to amend this or change this'*."

This lack of feedback was acknowledged by interviewee 12, who highlighted that insufficient prioritisation of time and a lack of resources within local government were hindering engagement with stakeholders. She noted that the public entity had been asked for feedback on priority actions on a handful of occasions, admitting that "*we don't make enough time to think about stuff and to have a proper discussion*." She went on to state that this could be creating a cycle where stakeholders feel unacknowledged or unsupported, potentially diminishing collaboration. To address this, interviewee 12 called for more frequent and deliberate conversations about data use, particularly on smaller, actionable topics where focused debates could lead to meaningful outcomes. While interviewee 9 aligned herself with this strategy, she further outlined the importance of adapting presentations to emphasise overarching goals and aspirations rather than granular daily issues, recognising that policymakers have limited time and are more likely to engage when presented with the bigger picture.

According to interviewee 9 and a few others, this is especially true when communicating with the Dutch government. Illustrating her point, interviewee 9 noted that, when Dutch officials visited Sint Eustatius to meet with stakeholders, she "*did a presentation for the delegation [where she had] 45 minutes to sell nature and environment.*" This need to communicate complex issues, often under time pressure, adds an additional challenge to the already complex and disjointed communication efforts between local actors and the Dutch government, several interviewees confirmed. Interviewee 5 explained that STENAPA's communication with the European ministries usually involves navigating complicated bureaucratic processes and varies in effectiveness depending on the ministry involved. He highlighted a significant disconnect with the Ministry of the Interior and Kingdom Relations (BZK), which has been officially in charge of governing Sint Eustatius since 2018. In relation to new and ongoing projects on the island, interviewee 5 remarked that "*BZK, in general, know nothing. Just assume they know nothing.*" He stated that the Ministry of Agriculture, Nature, and Food Quality (LNV) was more engaged and informed, although noting that communication with them was still challenging and lacking continuity. Describing the process leading up to the implementation of a project on the island, interviewee 5 explained that LNV rarely reached out proactively to involve STENAPA in relevant discussions, stating that "*LNV would never call me and say, 'Hey, they're going to do a project with you. How much money do you need to be part of this project?',"* and stressing further that *"there's never that connection. That discussion needs to happen.*" He outlined that, rather than proactively enquiring about local capacity, resources, and needs, so as to better integrate STENAPA's perspectives into on-the-ground action, the Dutch government preferred to communicate with European institutions and partners.

This lack of integration was also outlined by interviewee 13 who stated that consulting local actors is "*often an afterthought,*" and that the Dutch government "*forget that the people who need to implement the plan should also be involved.*" She also highlighted the challenges posed by scheduling meetings that are often Eurocentric, making it difficult for those in the Caribbean to participate meaningfully. Expressing frustration, interviewee 13 shared that "*sometimes it comes down to the little things, like organising meetings at 10 in the morning in the Netherlands. I don't want to be up at 4:00, right? And it's these small things that people don't think about.*" She pointed out that small adjustments, such as holding meetings at more suitable times, could significantly improve communication dynamics. She also suggested that the BES islands ought to coordinate when communicating with Dutch authorities, arguing that collaboration between them would enhance their collective influence and help articulate shared priorities.

Data Uptake & Decision-Making

Throughout the interviews it became apparent that the challenges faced by many local stakeholders around communication with the Dutch government bleed into decision-making processes on the island. Some interviewees, when asked about the roles and dynamics of policymaking on Sint Eustatius, conveyed frustration that important decisions are often made with little regard for local circumstances. Outlining the incompatibilities between Dutch frameworks and local realities, interviewee 6 mentioned that "*you cannot just copy paste these [Dutch] rules because the situation is completely different.*" Further illustrating this point, interviewee 14 told a story about the time a new fire department was built on Bonaire under Dutch building codes and regulations. He explained that "*the building has central heating. Central heating! Why? Because that's in the rules of Holland that a fire department needs a central heating system. You can of course, ask how many times a year they use the central heating? Never of course.*" He also illustrated the time he was confronted by a local politician on Sint Eustatius who exclaimed "*you have only Dutch solutions, and we [the locals of Sint Eustatius] are on the island.*" Interviewee 14 made it very clear that he was frustrated with the engagement and understanding (or lack thereof) from the Dutch government around local needs and priorities, noting that "*Den Haag is only afraid of the reaction of the parliament. They don't think about here. They don't understand here.*"

Further outlining the unsuitableness of applying Dutch rules to an island with distinct challenges, interviewee 6 highlighted the issues with Sint Eustatius' status as a Dutch municipality, observing that not a single Dutch municipality of comparable size has to manage the array of responsibilities borne by the island and asked, "*Which municipality in the Netherlands of 3500 people has an international airport, international harbour, a hospital, a police force, a fire brigade and everything? None.*" According to interviewee 14, the fact that the island is obliged to communicate directly with ministerial-level authorities, as opposed to municipal- or state authorities, causes a lot of strain for the under-resourced and underfunded local government.

Both interviewees 6 and 14 also highlighted that Dutch priorities are often imposed without adequate consultation of Sint Eustatius' highest administrative body, the Island Council[11]. It is important to note that the Dutch government dissolved the Island Council in 2018, citing mismanagement, inadequate oversight of finances, and legislative failures, and replaced it with a Dutch-appointed Government Commissioner, as mentioned in the chapter above. While the Council was reinstated after elections in 2020, it was stripped of substantive power, resulting in significant frustration and friction between its members and the Dutch government. According to interviewee 14, power and decision-making capabilities have essentially been centralised with "*no checks and balances*."

Since its reinstatement, the Island Council's role has been largely symbolic, with little control over policies, budgets, or ordinances. Nevertheless, according to interviewee 12, engaging with the Council about local developments is important, leading to better collaboration and more trust. Expressing frustration that this is not happening, interviewee 14 illustrated how major infrastructure development projects, for example, are often decided and implemented without consulting the Island Council. Sharing a story about the expansion of the island's airport, he explained that "*the only thing the Island Council was informed about was the opening of the works. Before they were not involved in it,*" further noting that "*the only thing they get an invitation for is the first spade in the ground.*" He also described how the island's annual progress report for 2023, presented to the Dutch parliament that same year, was not prepared in consultation with, nor shared with, the Island Council despite being of direct relevance and interest to them. When criticising

[11] The Island Council adopts the island's budget, policies, and regulations and consists of five members who are elected by general election every four years. It oversees the work of the Executive Council, responsible for the island's day-to-day governance and decision implementation.

this, interviewee 14 stated that he was told "*they can find it on the internet.*" Calling attention to the fact that the Island Council was and has been systematically left out, he noted "*if you are concerned about something, then you must get material to make a policy. But there is no material offered to the Island Council, so they cannot make policy.*"

The Island Council is not the only group not adequately informed about policies or involved in decision-making on the island, as pointed out by about a fifth of all interviewees. Public engagement with environmental and policy issues is severely lacking. A handful of respondents, mainly from STENAPA, expressed partial responsibility for this, highlighting significant gaps in engaging the public regularly on such issues. Interviewee 5 acknowledged that the public often remains unaware of the work being done by STENAPA, admitting that this is partly due to insufficient outreach efforts. In alignment with this sentiment but noting the lack of capacities and resources to improve on public outreach, interviewee 4 stressed that this could be influencing the public's participation at town hall meetings, the turnout for which is often low. He explained that, although the meetings are open to everyone, publicised on social media, and offer an opportunity for community members to review and discuss policies, "*most of the time, no one turns up.*" Most interviewees agreed that this lack of attendance is a result of too little participatory information dissemination and limits the public's influence on decision-making.

Lacking public engagement could also partly stem from differences in cultural and political dynamics. Interviewee 5 and others referenced the contentious debates over a new nature ordinance[12], which has been criticised for reflecting external rather than local priorities. Similarly, interviewees 9 and 14 described administrative and public resistance to policies attempting to deal with the roaming goats on the island, highlighting that the topic is highly sensitive, as public opinion is shaped around the idea that prohibiting free grazing across the island could have significant impacts on local livelihoods. Interviewee 14 further explained that political willpower to deal with the issue is lacking because "*every goat is a vote,*" a phrase that perfectly encapsulates the tension between pursuing necessary regulations and navigating the politics around them. Building on this, interviewee 2 stated that political dynamics often lead to inaction more generally, with data gaps, for example, exploited as reasons to continue with business as usual. He noted that often "*policymakers would say, 'Yeah, we don't know exactly what the status is. We don't know exactly*

[12] Sint Eustatius' nature ordinance currently in force dates to 2010. Aiming to update it, a new ordinance was drafted in 2021. It has still not been ratified by the Island Council and has thus not been adopted. The draft ordinance can be consulted here.

what the problem is, so let's not do anything and do more research.' That's what the Dutch Government really likes to do."

A limited understanding of scientific data and its implications could be a further barrier for public engagement and decision-making. Interviewee 1 highlighted the disconnect between scientific explanations and public perceptions, noting that when he clarifies to people that "*the reason that the fishermen have declining fish stocks is because of the goats on the island […] people think that's nonsense*" unless explained in depth. Many interviewees stated that such a gap in understanding leads to scepticism, with people questioning the relevance or validity of scientific findings. In line with this and referring to a broadening global mistrust in scientific data, interviewee 6 outlined that "*you need to have belief in these conclusions. If you don't believe those conclusions, those data, the evaluation, then look at what's happening in the Netherlands with the farmers [who are protesting evidence-based policies].*"[13] He stressed that continuing with a business-as-usual approach without addressing the growing scepticism in data "*doesn't change the level of trust the community has in the outcome and the conclusions of that [data].*"

This is further compounded by the fact that scientific initiatives are often perceived to disregard cultural and socio-economic factors. Interviewee 2 noted that unless the benefits of an intervention backed by science, such as the removal of the roaming animals, are made clear, local resistance is inevitable. He stressed that "*if people don't understand what the benefits could be of removing those goats, then they will never agree to it because it's part of the culture by now.*" Building on this, interviewee 4 illustrated how economic contexts shape perceptions, with some locals viewing scientific endeavours as a misallocation of resources when immediate socio-economic needs remain unmet. Interviewee 5 further highlighted that projects that lead to tangible and perceivable socio-economic benefits gain more traction than those dealing with poorly understood challenges, such as the desalination brine.

Aligning with the challenges outlined above, most interviewees noted that scientific data has only been used moderately in policymaking thus far. Interviewee 6 outlined that he thought data was being used "*to a certain extent*" with a lot to be desired for regarding its effective uptake. He highlighted, for example, that a "*legal basis on which you can build your policy plan*" is lacking, noting that "*there is no procedure to ask for research permits,*" for example.

[13] See here or here.

Overall, respondents stated that the absence of alignment among key actors, little regard for socio-economic circumstances and local capacities, lacking scientific understanding, and a top-down approach by the Dutch administrators hinder effective governance and decision-making on Sint Eustatius. Many stressed the importance of ensuring that local and ministerial stakeholders are on the same page, noting that without this, even well-intentioned policies risk stalling or failing.

Implementation into the NEPP

As outlined in the introduction of this thesis, the NEPP is an attempt to overcome the hurdles mentioned above and achieve an aligning of local views with international and Dutch biodiversity conservation priorities whilst considering socio-economic needs. Elaborating on the drafting process for the NEPP and its Sint Eustatius implementation agenda, interviewee 12 noted that it was a comprehensive and collaborative effort that involved multiple stakeholders and coordination across various sectors. She explained that the process began with extensive stakeholder consultation, with the island hosting three thematic sessions that brought together local farmers, fishers, businesses, policy advisors, and organisations such as WWF to discuss fisheries, agriculture, and waste management, respectively.

Interviewee 12 further elaborated that this stakeholder input was then translated into implementation goals and sub-goals and fed into identifying needed resources and expertise. "*I think it took us over a year to translate that in goals and sub-goals and what we needed, […] what kind of expertise, stakeholders we need to do work with, who was the owner, stuff like that,*" she outlined, further noting that STENAPA and ENI played a pivotal role in coordinating the process and ensuring that the NEPP and its Sint Eustatius implementation agenda included timelines and priority actions that are both feasible and aligned with local needs. Interviewee 12 also highlighted that discussions had taken place with Dutch ministries to ensure that Sint Eustatius priorities and ideas reflected international perspectives. She noted that the final implementation agenda[14], which the local authorities and the Dutch government signed off and published in April 2021, highlights erosion and runoff control, land restoration, and roaming animals as key priorities.

Although a third of the interviewees described the NEPP and its Sint Eustatius implementation agenda as important tools to address environmental concerns on the island – not least through the allocation of around €36 million in the first implementation phase – many noted the challenges in translating this funding into effective action. Interviewee 9, for example, highlighted that "*there's no money if there's no projects being put forward,*" outlining that it is up to the local authorities to develop proposals and sign

[14] The Sint Eustatius NEPP implementation agenda can be accessed here.

off on projects eligible for funding before even a fraction of the NEPP budget can be used. She explained this using the roaming goats example, noting that "*with the roaming animals, we needed a strategic plan to be able to ask for the second term of money.*" This, coupled with lacking human resources and capacity, has cast doubts on the achievability of the ambitious NEPP target to have zero roaming animals on the island by 2025. Getting there, according to interviewee 9, "*means we have to remove a minimum of 8500 animals per year. That means 177 animals per week.*" In light of this, some interviewees called for the entire NEPP timeline to be adjusted, with one labelling the plan as "*overly ambitious*."

However, most interviewees expressed optimism around the NEPP, with interviewee 5 explaining that it is a "*a good enough framework for us to rely on and prioritise from,*" and interviewee 12 expressing that "*I think we made a good start [and] I'm really happy that everything is approved. […] We are starting to have all the people in place.*" Despite this, implementing the plan effectively and successfully is a daunting task that requires clear commitment and accountability from all involved, as outlined by interviewee 2, who stated that "*the problem lies not necessarily with what's in the implementation agenda, but rather the commitment of the different parties to do it.*" Although generally aligning himself with the fact that lacking commitment will lead to shortcomings, interviewee 4 also noted that lacking actionable details within the NEPP's broad goals will hamper effective implementation, explaining that "*when I looked at the implementation agenda, it just said, 'We will restore reefs.' It didn't say how much or how they're going to grow corals […].*"

Chapter 5: Discussion

Based on interviewee outputs, it is evident that the collection, dissemination, and use of scientific data on Sint Eustatius is a complex process involving numerous actors that is riddled with challenges. Whilst this thesis has so far captured the general sentiments of those involved in translating scientific knowledge into policies in varying capacity, it is now time to align this knowledge with the conceptual frameworks described earlier in the thesis and elaborate more specifically on how water quality monitoring data is used in decision-making around coral reef health and resilience on Sint Eustatius.

The Science-Policy Interface on Sint Eustatius

Roles

The flow of knowledge within the science-policy interface on Sint Eustatius is not shaped by distinct roles of knowledge producers, mediators, and users. Whilst some organisations and individuals on the island can be classed within one specific category, such as Wageningen Marine Research solely as knowledge producer, many local actors operate across roles, successfully blurring the boundaries between science and policy. STENAPA, for example, is core to data collection activities on the island, including in the framework of the water quality monitoring programme, but also an important mediator between scientists and decision-makers. The organisation's abilities to synthesise technical reports and data into accessible formats for diverse stakeholders, and its active role in facilitating communication with local government authorities, makes it a critical bridge within the island's science-policy interface (Vallury et al., 2023). The PPMO plays a similarly important role, albeit at the interface between mediator and user, by coordinating projects and ensuring that adequate and relevant scientific data underpins any planned developments. Although only established for a handful of years, the PPMO has already emerged as a significant asset for aligning research outputs with policy agendas. It is also key for streamlining communication between STENAPA and local policymakers, although it is greatly lacking in resources and capacity to fully leverage this strength. What is interesting to note is that CNSI seems to have been a hub that spanned the entire science-policy interface, engaged not only in data collection and analysis but also in translation work and use (i.e. CNSI acted as a knowledge producer, a mediator, and a user organisation). Its dissolution is to the detriment of more inclusive conservation engagement and decision-making, particularly seeing as it was a respected institution that had built rapport and trust with the local community. For a more complete picture of Sint Eustatius' science-policy interface, a full list of science-policy roles for each organisation can be found in *Table 4.*

Table 4: *The science-policy interface roles of organisations from which interviewees came, based on definitions from van den Hove (2007). To note: The roles have been assigned solely based on work being done in relation to the water quality monitoring programme on Sint Eustatius.*

Organisation	Science-Policy Role(s)		
Caribbean Netherlands Science Institute (CNSI)	Knowledge Producer	Mediator	
Dutch Caribbean Nature Alliance (DCNA)		Mediator	
Public Entity of Sint Eustatius			User
Programme- and Project Management Office (PPMO)		Mediator	User
Rijkswaterstaat (RWS)	Knowledge Producer		
Scubaqua Dive Center			User
STENAPA	Knowledge Producer	Mediator	
STINAPA Bonaire	Knowledge Producer	Mediator	
Wageningen Marine Research (WMR)	Knowledge Producer		
WWF Netherlands		Mediator	User

Joint Knowledge Production on Sint Eustatius

Building on the fact that organisations such as STENAPA and the PPMO have taken on multiple roles and fostered collaboration and communication between actors in relation to the NEPP, it is evident that the science-policy interface, at least in relation to water quality monitoring, on Sint Eustatius aligns with the *joint knowledge production model* elaborated in Chapter 2. Particularly in the context of developing and drafting the NEPP, the intertwined nature of politics and science is apparent, with non-scientists and civil society engaged in decision-making. Based on interviewee responses, it seems that the NEPP was developed with co-operative knowledge production at its core, with scientific actors like E. Boman and A. Maitz acting as *honest brokers* by explicitly integrating local concerns and views into the plan's drafting process. Not only were stakeholders invited to share their concerns in relation to nature conservation on the island, but they were also asked to actively contribute to identifying key priorities. Whilst this may be the case, it is arguable whether these concerns and priorities are well reflected in the final NEPP document and within Sint Eustatius' implementation agenda. Although both were developed together with local actors (including farmers and fishers), interviews revealed that neither document contains consensus-agreed measures to help address the roaming goats, for example. Yet, the roaming animal issue is elaborated as one of the NEPP's top priorities and one of the first issues the island has committed to tackling. This misalignment in priorities casts doubt on the salience of the knowledge production process and could be the reason why, although co-operation and collaboration across social realms was sought out, challenges in conservation decision-making and implementation persist, aligning with the observations of Jarvis et al. (2020).

These challenges could bleed over into the water quality monitoring programme led by Wageningen Marine Research, which, based on interview responses and personal experience, does not seem to fully exemplify the dynamics of joint knowledge production. The parallel monitoring initiative overseen by the Dutch Ministry of Infrastructure and Water Management hints at a lack of coordination and a fragmentation of efforts. WMR's and I&W's operating in silos undermines opportunities for co-production and, with a unified framework lacking, will likely lead to varying data collection protocols and methodologies despite both organisations working towards similar goals and objectives. Furthermore, there seems to have been limited local stakeholder engagement when establishing scientific and technical priorities within the monitoring programme. Whilst knowledge producers like Wageningen Marine Research are highly competent, their focus on international scientific standards often overlooks local capacities and concerns, aligning with findings by Andrade and Rhodes (2012) and Sheil (2001). Not consistently involving local businesses, fisheries representatives, and other community members in helping to set the research agenda could mean that the programme may fall short of fully addressing the issues that matter most to local stakeholders.

While the WMR water quality monitoring programme falls short of fully characterising the joint knowledge production model, it does demonstrate many important aspects of knowledge co-production that should also be highlighted. For example, it lays the foundation for iterative feedback, a core characteristic of co-creation (Singletary & Sterle, 2020), through the identification of additional key reef stressors that have the potential to inform iterative management strategies and allow for reflections and refinements. Furthermore, the partnership with STENAPA – and indirectly the PPMO – that Wageningen Marine Research has established enables cross-sector collaboration and provides a foundation for connecting science with practical management and policy needs. The involvement of STENAPA staff in data collection and monitoring efforts helps ensure that scientific findings are informed by on-the-ground experiences, creating a feedback loop between research and implementation.

STENAPA and the PPMO as Boundary Organisations

Building on the above, it is evident that STENAPA and the PPMO act as *boundary organisations* on Sint Eustatius. Both aim to engage with scientific data and align with political priorities. By mediating between knowledge producers and users within the science-policy interface, they embody the principles of *boundary work*.

In addition to STENAPA being fundamental for the delivery of both the NEPP and the WMR water quality monitoring programme, the organisation has been playing a more general role in bridging scientific research and local environmental governance through various avenues. By translating and synthesising data into more digestible formats, as well as by contextualising findings, STENAPA helps ensure that policymakers are well equipped to make evidence-based decisions. The organisation also facilitates stakeholder engagement through initiatives such as public workshops and by organising townhall meetings for conservation-related discussions. These efforts align with the boundary work concept of creating spaces for interaction across the science-policy divide (Osmond et al., 2010).

The PPMO, whilst still expanding on its abilities and reach, already plays an important part in centralising project and programme coordination. It is through the PPMO that initiatives such as the roaming animal control efforts and those related to water quality and wastewater are scientifically sound and aligned with government priorities. By providing technical and academic expertise and bringing together local and Dutch decision-makers, the PPMO fosters a more integrated approach to addressing environmental and conservation challenges on Sint Eustatius. The organisation being able to provide a platform for collaboration across scales reflects boundary work's emphasis on negotiating the boundaries between different governance levels and scientific communities, in alignment with findings from Cash et al. (2006) and Koehrsen (2017).

Considering the above, it is evident that both STENAPA and the PPMO exemplify various important aspects of boundary work, including both *boundary maintenance* and *boundary blurring*. In relation to the former, evidence suggests that both organisations maintain the distinction between scientific and policymaking roles, ensuring that data and scientific knowledge remain technically sound and rigorous while adapting them for use in policymaking contexts. Nevertheless, acting in their roles as coordinator and mediator, and through the creation of shared spaces for dialogue, collaboration, and co-production, both organisations also engage in deliberate blurring of boundaries.

The NEPP & Water Quality Monitoring Programme as Boundary Objects

By acting as boundary organisations, STENAPA and the PPMO provide the institutional support necessary to operationalise initiatives like the NEPP and the water quality monitoring programme, both of which can be classified as *boundary objects*. Due to their functioning as shared reference points across diverse stakeholder groups, both facilitate collaboration and alignment of actions within the science-policy interface. They embody the characteristics of boundary objects by being flexible enough to be interpreted differently by various actors while retaining core objectives that provide coherence and structure to collective efforts (Star & Griesemer, 1989). In other words, whilst the underlying objectives of successfully implementing the NEPP (and water quality monitoring programme) may differ between actors and groups, their structure and use is familiar across social worlds, such as science and policy.

The NEPP serves as a boundary object by integrating diverse perspectives and creating a shared framework for decision-making. Its drafting process brought together multiple stakeholders, aiming to incorporate socio-economic, cultural, and environmental dimensions. Through this participatory approach, the NEPP sought to ensure that the plan accounts for different values and priorities, making it adaptable to varying contexts. The requirement for each of the BES islands to develop their own implementation agenda, for example, makes sure that enough flexibility is given to each island to pursue and achieve the overarching NEPP goals within their own capacities and capabilities. This flexibility aligns with the concept of boundary objects, as the NEPP remains independently interpretable across islands (and stakeholder groups) while shared objectives are maintained. As such, it provides a shared vision for collective action and offers a unifying framework that bridges overarching biodiversity commitments and local needs.

The water quality monitoring programme delivers a similar function, providing a standardised approach to monitoring that provides policymakers with reliable data to inform decisions. Its focus on identifying the most significant local pressures ensures that any outputs are directly relevant to each of the BES islands. This aligns with the boundary object principle of being adaptable to different stakeholders' requirements while maintaining a unified purpose. This unified purpose is exemplified through the programme standardising monitoring methods and creating common indicators, the latter of which themselves serve as tools to bridge scientific data and policymaking, aligning with boundary work's emphasis on creating shared frameworks for understanding. As such, metrics such as nutrient thresholds and coral health indices also function as boundary objects, facilitating dialogue among scientists, decision-makers, and mediators. They operationalise and simplify complex, multidimensional scientific data into tangible actions on the island. A nutrient threshold, for example, might be expressed as the maximum allowable concentration of nitrogen or phosphorus in coastal waters, which is a clear and standardised metric that allows decision-makers to understand and evaluate whether any local management practices relating to water quality are effective or not. In this regard, the indicators developed by the water quality monitoring programme are usable across the science-policy interface, their flexibility also aligning with the concept of boundary work (Turnhout, 2009). For scientists and data collectors on Sint Eustatius, nutrient thresholds and isotope analyses provide a basis for monitoring and identifying sources that affect coral health and/or algal growth. Policymakers, on the other hand, can use these thresholds as benchmarks for setting regulatory standards and pursuing specific management measures. The metrics established through the water quality monitoring programme, such as coral reef health indices, can also be used by other local non-expert stakeholders, providing a tangible way to understand the ecological status of reefs. Thus, the fact that actors with varying expertise and priorities can engage with the same reference points without losing their core meaning implies that the water quality monitoring indicators are effective boundary objects.

However, this very much depends on their integration and uptake into local policies – the linking of results and outcomes to management actions being a continuing challenge in monitoring (Lam et al., 2017). With the monitoring programme still being fully built out, it remains to be seen whether and how monitoring data translates into concrete changes in policies and management practices (relating to roaming animals or wastewater, for example). Having said that, and building on the above evidence, the harmonised governance framework provided by the NEPP provides a solid foundation for co-operative decision-making that can facilitate the effective blurring of the science-policy interface on Sint Eustatius. Furthermore, with STENAPA and the PPMO taking on important mediator and translation roles, the actors needed to successfully bridge the island's science-policy divide, and enhance co-operative knowledge production, are in place.

Challenges

Despite this, and as evidenced throughout numerous interview responses detailed in Chapter 4, several challenges exist on Sint Eustatius that could hamper the successful uptake of monitoring data and indices into decision-making. Many of these challenges, including the one relating to misalignments in priorities between local- and Dutch decision-makers touched upon above, closely align with broader governance issues identified by Veenendaal (2016).

One of the most pertinent issues relates to governance on Sint Eustatius being fragmented and built on imposed structures, an observation that aligns with the general sentiment of respondents interviewed for this thesis. Referring to interviews he himself conducted, Veenendaal notes that supervision from the Dutch government has become a source of tension between the European Netherlands and the island. He highlights that the integration of Dutch laws, norms, and administrative practices do not align with local governance capacities and perspectives, giving some the feeling that governance structures are being forced onto them. This is further exacerbated by the limited local capacity and reliance on external expertise, with Veenendaal noting that the island's dependency on Dutch civil servants and outside experts has created a disconnect between interventions and community realities. His paper states that many interviewees felt that "*more positions in the administration should be filled by local Statian people*" (Veenendaal, 2016, p. 273). Addressing local capacity- and resource constraints, and empowering the local community, are vital to overcome governance barriers on the island and could lead to more stakeholder buy-in, engagement, and long-term monitoring (Dushkova & Ivlieva, 2024). This is especially important on SIDS, where politics is very personal in nature and interpersonal relations influence political developments (Jugl et al., 2024). According to Veenendaal, the overlapping of private and professional relationships on small islands generates conflicts of interest. This in turn can have implications for implementation and uptake of management measures, as highlighted by Maiello et al. (2015), who – referring specifically to indicators – note that the proximity between users and producers hinders their effectiveness.

Usability Profile of the Water Quality Monitoring Programme

Building on the above, the usability of the water quality monitoring programme can be evaluated. That is to say that although the monitoring programme aligns well with the concept of boundary work, its effectiveness as such an object still needs to be assessed. Developing a usability profile of the programme, as described in Chapter 3, based on legitimacy, credibility, and salience can help in this regard and illustrate how well monitoring efforts are bridging the gap between science and policy on Sint Eustatius.

Evaluating the legitimacy of the monitoring programme entails considering whether it and its indicators were developed through inclusive, fair, and transparent processes that involved local stakeholders. The findings presented in Chapter 4 indicate that this was only partially achieved, likely due to structural aspects of the programme's design rather than the intentions or actions of those carrying it out. As the monitoring programme was developed largely by external scientific institutions (i.e. Wageningen Marine Research), with local decision-makers and many community members not fully aware of its existence, its legitimacy is undermined. This lack of inclusivity could lead to local actors feeling disconnected from the monitoring efforts, reducing the likelihood that they will embrace any resulting management efforts (Kainer et al., 2009).

This could be further exacerbated by lacking salience, which measures the relevance of the monitoring programme and its indicators to the specific needs and priorities of Sint Eustatius. As such, not accounting for the unique socio-economic and ecological contexts of the island could further amplify any mismatches between external standards and local priorities (Waylen et al., 2010). This thesis has already elaborated on this in the context of the NEPP and the, at times, lacking alignment of priorities between local- and external actors. The proposed management measures to be put in place to tackle the roaming goat issue are an example of this. Assessing the salience of the water quality monitoring programme reveals a somewhat different picture; one in which the wastewater management actions it will feed into, such as the decommissioning of cesspits by 2030 (*see* Sint Eustatius' implementation agenda p. 31), align well with local needs and expectations, at least according to those who were interviewed for this thesis. Nevertheless, and as just mentioned, any relationship between (bad) water quality and the roaming goats is likely not going to find a lot of traction within the island community, lowering the salience of the monitoring programme.

In fact, unless this relationship is adequately communicated and explained to local actors, the credibility of the monitoring programme could also be impacted. If trust is not developed between knowledge producers and users, those tasked with implementing any management measures related to improving water quality and reef resilience could face sharp pushback (Kliskey et al., 2023). However, with organisations like STENAPA and the PPMO taking on the responsibility of tailoring communication and consistently disseminating data in more impactful ways, the monitoring programme on Sint Eustatius is well on its way to demonstrating high credibility. This is further strengthened by its robust scientific credibility; the programme's indicators being developed along international standards and grounded in rigorous scientific methodologies.

Taking all the above into account, the water quality monitoring programme exhibits good usability. Whilst it demonstrates somewhat lacking legitimacy, both in its development and its implementation, it is fairly salient and holds good credibility. It has been and continues to be incorporated into local decision-making frameworks through boundary organisations such as STENAPA and the PPMO and aims to feed into tangible management measures that align with local priorities, with the exception of those related to the roaming goats. Nevertheless, improvements can always be made. As such, efforts should focus on engaging more with local community members in co-developing solutions to the goat issue and providing them with the resources to better understand any linkages between the animals and decreasing coral health and resilience. By addressing this gap, monitoring efforts can better serve as a bridge between science and policy, enabling more effective environmental governance on the island.

Chapter 6: Conclusion & Recommendations

This thesis illustrates the complex and multidimensional nature of the science-policy interface on Sint Eustatius. On-the-ground experiences and stakeholder interviews have revealed that the process of collecting, disseminating, and using scientific data to inform policies for coral reef health and resilience is dynamic and multifaceted. The existence of boundary organisations such as STENAPA and the PPMO, and their ongoing efforts to effectively communicate findings and engage with decision-makers, demonstrates significant potential for bridging the science-policy interface and enhancing joint knowledge production. They embody the principles of boundary work by creating shared spaces for dialogue and collaboration while negotiating the delicate balance between maintaining the rigour of scientific knowledge and addressing practical policy needs.

However, several challenges still hamper the successful integration of scientific knowledge into actionable policies. These challenges highlight the need for improved alignment between scientific priorities and local governance capacities, as well as more inclusive and adaptive approaches to knowledge production and policy integration. The water quality monitoring programme led by Wageningen Marine Research exemplifies both the opportunities and limitations of the science-policy interface on Sint Eustatius. Whilst it provides scientifically robust data, and therefore embodies credibility, its development process had limited local stakeholder engagement, undermining its legitimacy. Furthermore, the misalignment of priorities between local and external actors, as seen in the context of the roaming goat issue, underscores the difficulties of ensuring the programme's salience. Working together with local actors to implement the programme and conduct monitoring is an important step in the right direction to ensure that data uptake and indicator usability increase. Furthermore, strengthening stakeholder inclusion, formalising co-production processes, and enhancing mediation mechanisms would allow Sint Eustatius to better bridge scientific research and policy decision-making, ultimately contributing to the resilience and sustainability of coral reef ecosystems on the island.

Greater engagement with local stakeholders is essential to ensure that scientific initiatives, such as the water quality monitoring programme, reflect the lived realities and priorities of the island's community. This includes involving farmers, fishers, and other community representatives in defining research agendas and co-developing solutions to pressing issues like roaming goats and wastewater treatment. Enhancing communication pathways between knowledge producers, mediators, and users is equally critical, with organisations like STENAPA and the PPMO needing additional resources to fulfil their roles as boundary organisations. These resources should support the translation of complex scientific findings into actionable policy recommendations and facilitate the dissemination of information through workshops, townhall meetings, and accessible reporting formats. Furthermore, the integration of any monitoring efforts into local governance systems must be strengthened, ensuring that scientific outputs directly inform decision-making processes and management actions. By aligning external scientific priorities with local governance capacities and providing iterative feedback mechanisms, Sint Eustatius can foster a more effective and inclusive science-policy interface that bridges the gap between knowledge and action.

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Annexes

Annex I – Water Quality Sampling Method Description

This section describes the water quality sampling method in more detail. *In situ* water parameters were measured using a CTD[15] at a depth of 10m only (*see Table 1 for more details on the measured parameters*). For parameters needing lab analysis, water samples were collected with a Niskin bottle – a tube-like device used to obtain samples at a specific depth.

For deployments at 5m, a dive weight was attached to the Niskin bottle, which is positively buoyant and floats if not weighted down. For 10m samples, the CTD was lowered into the water column attached to the Niskin bottle. The devices were lowered into the water using a winch connected to the boat. Deployment time and depth were noted down. As the CTD stopped measuring if/when pulled upwards, we ensured that the device was lowered at a continuous pace until the desired depth was reached.

Once at the desired depth, a small weight was clipped onto the winch wire and dropped into the water. This weight, when hitting a spring-loaded trigger on the Niskin bottle, forced the plugs on either end of the device to close, sealing the water sample in so that it could be brought back to the surface uncontaminated.

To extract each water sample from the Niskin bottle, a 60ml syringe was connected to the tap located at the bottom of the device via a small plastic tube. To avoid contamination between samples, the syringe was flushed three times with seawater before being filling with a sample. Once extracted from the Niskin bottle, each sample was transferred to a labelled plastic vial through a thoroughly washed filter. To allow the water to expand when frozen, each vial was filled to about 3mm from the top and then placed in a cooler box.

Water samples collected with the Niskin bottle were stored in a freezer on the island before being transported to a lab in the Netherlands for analysis. CTD data was extracted using the Valeport Ocean software, downloaded as individual VP2 files and converted into .csv for cleaning and analysis in R (R Core Team, 2024).

[15] A CTD is a device primarily used to detect how conductivity and temperature of the water column change relative to depth. By measuring the conductivity of seawater, the salinity can be derived from the measured temperature and pressure. Information collected through a CTD can provide a more detailed understanding of the ocean water's characteristics.

Annex II – Full List of Interview Questions

Interviewees were asked the following questions (in no particular order and following a semi-structured approach):

What state do you perceive the reefs around Statia to be in?
In your opinion, what are important indicators of a resilient and healthy reef?
Are you aware that good water quality promotes coral reef resilience?
Do you believe there to be negative pressures impacting reef health? If so, what are these pressures?
Do you think a decline in reef health will have a negative impact on Statia's economy? If yes, what impacts? If no, what could be impacted instead?
How is Statia's economy linked to nature (particularly a healthy reef)?
What efforts to increase reef resilience are you aware of and what do you think of these efforts?
(If not in above answer) Are you aware that water quality monitoring is taking place on the island?
What do you think about Wageningen Marine Research's (WMR) work on water quality and reef resilience?
How often, if at all, do you communicate with WMR?
What is your relationship with WMR like?
How do you expect the water quality monitoring programme findings will feed into your work?
How can water quality monitoring continue once WMR is no longer receiving funding for the project?
What does [organisation] need for the water quality monitoring to continue effectively?
Who do you think should oversee the monitoring of water quality (and reef health)?
What kind of ecological and environmental data is STENAPA collecting?
What is being done to combat erosion on the island? What needs to happen for this to take place more robustly?
How can waste and wastewater be more effectively managed on the island?
How do you perceive the damage to the environment caused by roaming livestock?
Who do you think should be responsible for paying for monitoring efforts, conservation projects, and ensuring implementation?
How much does conservation work feed into local policies/local policy development?
To what extent can local politicians influence what STENAPA monitors/what data is being collected?
How is the monitoring that the Ministry of Infrastructure and Water Management wants to do on the island related to the monitoring that WMR is doing?
What are your expectations in relation to the outcomes of the water quality monitoring programme?
What role does [organisation] play in conservation policymaking?
What is [organisation's] mandate for conservation policymaking?

How effectively do you think scientific data is being used in conservation policymaking on Statia? If not effectively, do you think it needs to take on a more prominent role?
What challenges do you face when implementing/discussing new conservation measures and regulations?
Does the local government have enough resources/power to implement new conservation measures and regulations? If not, what needs to change?
Do you believe that the Public Entity prioritises socio-economic factors of the island over nature?
In your opinion, does the Public Entity need to take nature into more consideration?
What conservation measures would you want implemented to increase reef health and resilience?
Once conservation policies have been drafted and implemented, what hurdles stand in the way of enforcement?
To what extent are policymakers involved in developing ecological indicators? Can they give their input on the use of ecological indicators?
How do you perceive the relationship between STENAPA and decision-makers to be?
Do you feel like STENAPA should take on more/less responsibilities?
How are the findings made by/through STENAPA communicated to decision-makers?
(If not addressed above) How will the findings of the water quality programme be communicated to local decision-makers and stakeholders?
What translation work is needed for policymakers to understand the scientific data and information that is being presented to them?
Who do you think should be involved in communicating scientific data to policymakers?
Do you communicate with Dutch ministries/decision-makers?
How often do you meet/communicate with local government officials?
What challenges do you face when communicating your findings to decision-makers?
How much (and what kind of) collaboration occurs between the national park foundations and other scientific institutes on each island?
What role did you play in drafting the NEPP? At what stages were you involved in the discussion on/drafting of the NEPP?
To what degree do you believe the NEPP is an effective policy plan?
How involved were you in the drafting of the Implementation Agenda?
How effective do you feel the Implementation Agenda is/will be?
To what extent can local politicians influence what is being prioritised within the NEPP?
Who are your main funders? How much funding do you receive from the Dutch government?