Managing coastal lagoon ecosystems in the Caribbean

An economic appraisal of nature-based versus man-made solutions for enhancing ecosystem service provisioning by the Simpson Bay Lagoon, Saint Martin

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Date: 28-06-2019

Word count: 14998

Picture of the Simpson Bay Lagoon in Saint Martin. *Source: (Gilders, 2018)*

ENVIRONMENTAL PROTECTION IN THE CARIBBEAN

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Abstract

Like many Caribbean coastal wetlands, the Simpson Bay Lagoon in Saint Martin suffers from heavy development, wastewater pollution, and overexploitation. This has severely degraded its ecological integrity. This is problematic, not only for ecological reasons, but also because local livelihoods depend on the ecosystem services provided by the Lagoon, such as for storm protection and water purification. An important reason for the Lagoon's continued degradation is that decision-makers undervalue these ecosystem services. This study conducts an economic valuation of the Simpson Bay Lagoon, as to ensure that its full economic value is considered. With that, it provides the first economic valuation of a Caribbean coastal lagoon. The valuation methods that are employed are a choice experiment and value transfer. The obtained value estimates are used in a cost-benefit analysis of three environmental management scenarios for the Lagoon: business as usual, the construction of a sewage treatment plant, and mangrove restoration. The valuation results show that the current annual total economic value of the Lagoon is nearly $20 million and would rise to $28 or $31 million, respectively, in a mangrove restoration or sewage plant scenario. Business as usual would annihilate the economic value of the Lagoon. The cost-benefit analysis reveals that the alternative environmental management scenarios always economically outperform the business-as-usual scenario. It also indicates a strong economic rationale for mangrove restoration compared to the construction of a sewage treatment plant. This latter finding provides further empirical evidence for the favorability of nature-based solutions for enhancing ecosystem service provisioning.

Keywords:

Caribbean, coastal lagoons, ecosystem services, economic valuation, choice experiment, cost-benefit analysis, nature-based solutions

Preface

This research is part of a collaboration between the Institute for Environmental Studies at the Vrije Universiteit Amsterdam and Environmental Protection in the Caribbean. Together with two other students from the Vrije Universiteit, the author has conducted research on the Simpson Bay Lagoon in Saint Martin. While the author focuses on the economic valuation of the Simpson Bay Lagoon and on the economic appraisal of future environmental management scenarios, the other two students pay their attention to the socio-cultural and environmental/geographical aspects of the problem. Together this provides a comprehensive picture of the sources of and solutions for the environmental degradation of the Simpson Bay Lagoon. A main component of the research project was the design and implementation of a household survey and an accompanying choice experiment among the local population of Saint Martin. Although the students worked in close collaboration during the design and implementation phase of the household survey, this thesis is written fully independently by the author.

Acknowledgements

There are many people I would like to thank for their help during the project. First of all, I would like to thank Rueben, for always being there for us, for touring us around the island, and for introducing us to many important stakeholders. I would also like to thank Tadzio, for organizing field trips on the Lagoon, for making his drone available for aerial photography, and for providing his insights on the Lagoon. Thank you Kippy, for always being available for answering our questions. Thank you Mark and Jenn from Le Fruit de Mer, for letting us promote our research project on your endemic animal festival. Thank you Elea, Mahaut, and Morgane, for helping us implement the household survey at the French side of the island.

I would also like to extend my gratitude to Pieter, who as a supervisor provided us with a lot of helpful insights, support, and critical thinking. Thank you Liselotte and Rosa, for giving extensive feedback on the survey and the choice experiment. Thank you Natalia, for always being in close contact about our research needs. I am also very grateful for the help of Mark Koetse, who found time to make the statistical design of the choice experiment, and to help me get acquainted with the NLOGIT econometric software. I could write another page about all the people that helped me during the research project and during our stay on Saint Martin; it was very much appreciated!

Table of contents

List of figures

List of tables

List of abbreviations

Abbreviation	Description
BCR	Benefit-Cost Ratio
EU	European Union
GDP	Gross Domestic Product
GIS	Geographic Information Systems
IUCN	International Union for Nature Conservation
MEA	Millennium Ecosystem Assessment
MNL	Multinomial Logit
NPV	Net Present Value
RPL	Random Parameter Logit
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total Economic Value
The Lagoon	The Simpson Bay Lagoon
VIF	Variance Inflation Factor
WTP	Willingness To Pay

1. Introduction

Coastal lagoons are shallow water ecosystems situated at the interface between terrestrial and marine ecosystems. They occur along 13% of the coastlines worldwide (Newton et al., 2018). These areas are some of the most productive ecosystems and provide many ecosystem services such as food provisioning, storm protection, nutrient cycling, recreation, and climate regulation (Barbier et al., 2011; Brito et al., 2012; Pérez-Ruzafa & Marcos, 2012). Coastal lagoons are also of great ecological importance, as they are generally rich in biodiversity and provide nursery grounds and shelter for a great variety of marine species and birds (Anthony et al., 2009; Franco et al., 2006). However, these precious ecosystems are threatened throughout the world, due to land-use change, water pollution, overfishing, and other anthropogenic pressures (Anthony et al., 2009; UNEP, 2006). Their shallow waters and proximity to the sea make coastal lagoons also highly susceptible to climate change-induced temperature and sea level rise (Chapman, 2012; Newton et al., 2018).

Most ecosystem services provided by coastal lagoons do not have a direct market price and are therefore often undervalued by decision makers. This contributes to the continued unsustainable use of these ecosystems (Lopes & Videira, 2013). Economic valuation of ecosystem services is proposed as a solution here, as it makes explicit what values ecosystems provide to humans (Häyhä & Franzese, 2014). Although the valuation of ecosystem services has gained popularity in the last 20 years, valuation studies on coastal lagoons are underrepresented. Those studies that have been conducted so far focus predominantly on coastal lagoons in (Mediterranean) Europe (Newton et al., 2018). This research adds to the existing literature by providing an economic valuation of the Simpson Bay Lagoon in Saint Martin. To the author's knowledge, this study provides the first economic valuation study of a Caribbean coastal lagoon.

Like many Caribbean coastal wetlands, the Simpson Bay Lagoon suffers from heavy development, wastewater pollution, and overexploitation (Gilders, 2018; Yáñez-Arancibia et al., 2011). This has severely degraded the ecological integrity of the Lagoon. Almost all previously present mangrove forests have been removed for development, and sewage inflow and illegal dumping have deteriorated the water quality. This is problematic, not only for ecological reasons, but also because local livelihoods depend on the services provided by the Lagoon (e.g. for tourism and storm protection). Fanning et al. (2011) identified that a lack of understanding of the economic value of Caribbean coastal and marine ecosystem services by decision-makers and the general public is a key driver of the continuous degradation of these ecosystems. Hence, to prevent further destruction of this important ecosystem, it is vital to estimate the economic value of the ecosystem services that the Simpson Bay Lagoon provides. However, often valuing ecosystem services is not enough to ensure protection and conservation, as it just focuses on benefits and disregards the costs of environmental management (Birch et al., 2010; Martínez-Paz, Perni, & Martínez-Carrasco, 2013). Therefore, the main output of this thesis is a cost-benefit analysis of alternative environmental management scenarios, for which the economic valuation is used as a key input.

Consequently, the research question of this thesis is: "*What is economically the most favorable environmental management scenario for enhancing ecosystem service provisioning by the Simpson Bay Lagoon?"* This main research question is answered with the use of two sub-research questions. The first sub-research question is: *"What is the total economic value of the ecosystem services provided by the Simpson Bay Lagoon?"* The second sub-research question is: *"What are the economic costs and benefits of the environmental management scenarios for enhancing ecosystem service provisioning by the Simpson Bay Lagoon?"* Three feasible management scenarios have been identified: business as usual, the construction of a sewage treatment plant, and mangrove restoration. While a sewage treatment plant is a man-made solution, mangrove restoration is a nature-based solution for enhancing ecosystem service provisioning by the Simpson Bay Lagoon. By assessing which of these management scenarios is economically most favorable, this thesis contributes to a prevailing debate in the academic literature on the effectiveness and efficiency of nature-based versus man-made solutions for ecosystem service enhancement (Eggermont et al., 2015; Keesstra et al., 2018; Nesshöver et al., 2017).

The analytical framework that guides this thesis is the TEEB (The Economics of Ecosystems and Biodiversity) framework, which is specifically designed for the economic valuation of ecosystems and biodiversity. The economic valuation methods that are employed are a choice experiment and value transfer. For the choice experiment, household surveys are held under the population of Saint Martin. The costs of the management scenarios are estimated with the use of local insights and the scientific literature. Several sensitivity analyses are employed to test the sensitivity of the cost-benefit outcomes to changes in core assumptions underlying the economic valuation.

The structure of this thesis is as follows. Chapter 2 provides a literature review and explains the added value of the study. It also discusses the theory behind ecosystem services, ecosystem service valuation and nature-based solutions, and presents the conceptual framework of this thesis. Chapter 3 describes the Simpson Bay Lagoon, what ecosystem services it provides, and the environmental management scenarios considered for its restoration. Chapter 4 explains the employed data and methodologies. Chapter 5 presents the results of the economic valuation and the cost-benefit analysis. Chapter 6 discusses these results. Finally, chapter 7 encompasses the conclusion. It summarizes the main results and provides recommendations for policy makers and further research.

2. Theory and literature

2.1 Ecosystem services and the conceptual framework

The term ecosystem services was first coined by Ehrlich and Ehrlich (1981). Ecosystem services are most commonly defined as “the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005). The ecosystem services approach emphasizes the benefits of ecosystems for human-wellbeing as to facilitate the embeddedness of the value of nature in decision-making, and to assure its protection and conservation (Luck et al., 2012; Schröter et al., 2014). The concept has been promoted by many as the last promising opportunity for making nature conservation attractive and mainstream worldwide (Daily et al., 2009). Other frameworks to analyze the interaction between socio-economic and ecological systems include the Driver, Pressure, State, Impact, Response (DPSIR) model and the Earth Systems Analysis model (Binder et al., 2013). The ecosystem services approach is unique in that it translates ecological processes and structures into value-laden entities (de Groot et al., 2002). The Millennium Ecosystem Assessment (MEA) identifies four categories of ecosystem services (Millennium Ecosystem Assessment, 2005): provisioning, regulating, supporting, and cultural services. Provisioning services are the products obtained from ecosystems (e.g. food). Regulating services help to maintain the regulation of ecosystem processes (e.g. flood regulation). Supporting services are essential for the production of all the other ecosystem services (e.g. primary production). Cultural services contribute to spiritual welfare (e.g. recreation).

Instead of the MEA framework, the conceptual framework of this thesis follows the TEEB framework and classification of ecosystem services (Böhnke-Henrichs et al., 2013; de Groot et al., 2010). Figure 1 shows this TEEB-based conceptual framework that links the ecosystem services provided by the Simpson Bay Lagoon with the human well-being of people in Saint Martin. The

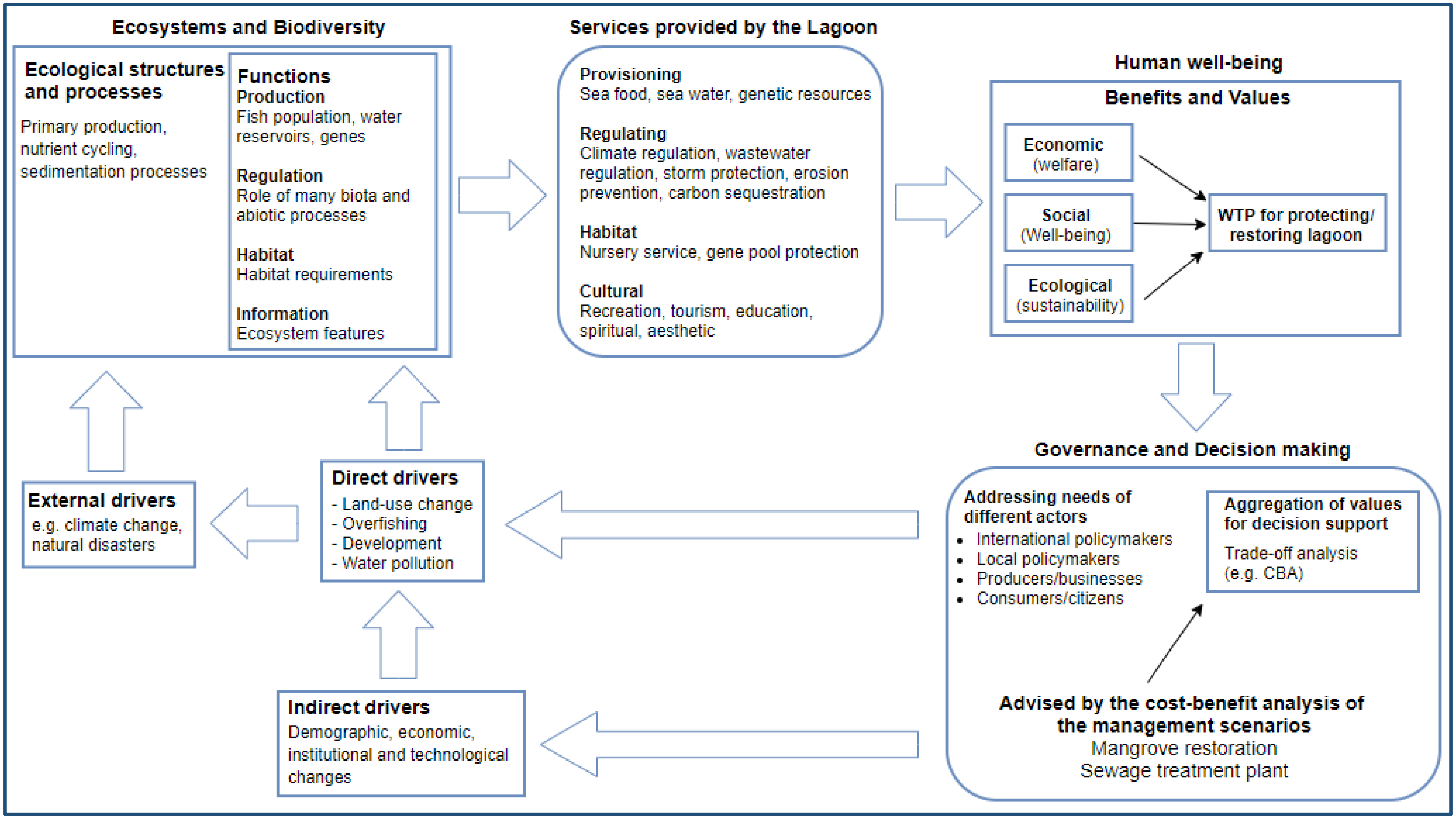

Figure 1: Conceptual framework for linking the Simpson Bay Lagoon ecosystem with human well-being

reason for following the TEEB framework is that it is specifically developed for the valuation of ecosystem services and biodiversity (de Groot et al., 2010; Fisher et al., 2013). In contrast to the MEA, the TEEB framework sees supporting services as ecological processes instead of as a separate service category, which helps to avoid double counting in economic valuation. In the TEEB framework, the provisioning of ecosystem services depends on the functions of the ecosystem, which in turn depends on ecological structures and processes (de Groot et al., 2010), as visualized in Figure 1. For instance, primary production (ecological process) is essential for a viable fish population (function) which can be used for seafood provisioning (service). Instead of supporting services, habitat services are identified as a service category, as ecosystems often provide important habitats for species and natural selection processes. Another advantage of the TEEB framework is that the inclusion of a governance and decision-making box explicitly highlights the importance of valuation for decision making (through, for instance, cost-benefit analyses), and how decision-making impacts pressures on ecosystems.

As this study focuses on the economic valuation of ecosystem services, and on the cost-benefit analysis of environmental management scenarios, the components of the conceptual framework that are most relevant for this study are the human well-being and governance and decision-making component. However, to fully appreciate the work done in this study, it is important not to lose sight of the impact and dependence of these components on the other (more ecological) pillars in the framework.

2.2 Valuing ecosystem services

The economic valuation of ecosystem services is often useful, as decision makers have to make trade-offs between different choices to improve human well-being (Costanza et al., 2017). As policy decisions are often made based on cost-benefit analyses, providing the monetary value (and costs) of ecosystem services could better ensure their inclusion in the decision-making process. However, economic valuation in monetary terms is just one source of information and by no means is meant to replace ecological, ethical, intrinsic, and other nonmonetary values (Schröter et al., 2014). Consequently, to obtain estimates of the overall value of an ecosystem, in this case that of the Simpson Bay Lagoon, additional analyses are needed (e.g. vulnerability or livelihood assessments; de Groot et al., 2010).

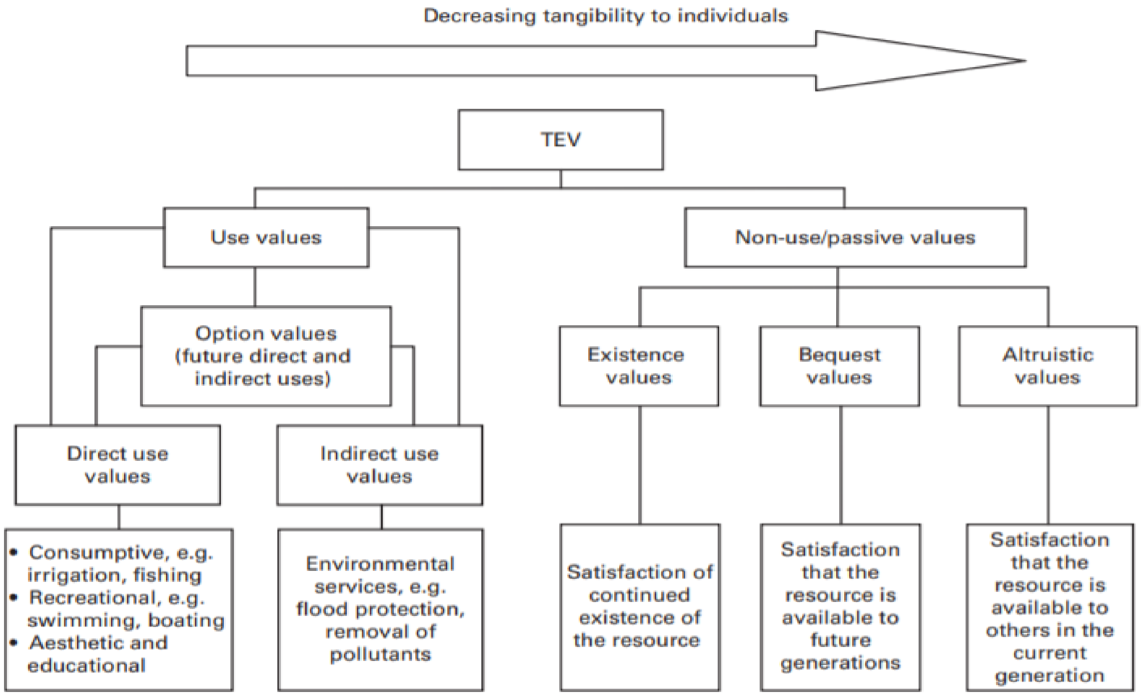

Figure 2: Items of the total economic value of ecosystem services. *Source: (van Beukering et al., 2015)*

The economic value of ecosystem services is often defined as the willingness-to-pay (WTP) for these services (Costanza et al., 2017). The Total Economic Value (TEV) is a common way to classify the types of economic values associated with ecosystem services (Häyhä & Franzese, 2014; van Beukering et al., 2015). Figure 2 displays the TEV and its constituent parts. As can be seen in Figure 2, a distinction is made between use values and non-use values. Use values directly relate to the use of ecosystem services by humans, while non-use values do not relate to the current or future use of ecosystem services. Use values are further separated into direct use (e.g. fish used for food), indirect use (e.g. storm protection), and option values (e.g. the potential use of biodiversity). Non-use values are subdivided into existence (e.g. satisfaction of the continued existence of a coastal lagoon), bequest (e.g. satisfaction that future generations can enjoy a coastal lagoon), and altruistic values (e.g. satisfaction that others can currently enjoy a coastal lagoon). As the previous examples show, coastal lagoons provide ecosystem services that could be relevant for each type of economic value. However, due to the common-good characteristics of most ecosystem services, generally only those services of direct consumptive use (e.g. fish) have a market price, which often leads to the undervaluation of all other services (Balmford et al., 2002; Hardin, 1968). An economic valuation of these ecosystem services can resolve this undervaluation.

Already, at least more than 1600 ecosystem service valuation studies have been published, with the large majority of these studies being conducted in developed countries (Christie et al., 2012). Perhaps, the most well-known (and controversial) valuation study is that of Costanza et al. (1997), which estimated the total value of the ecosystem services provided by the world's biomes to be in the range of $16-54 trillion. Despite the many valuation studies that have been conducted so far, studies on coastal lagoons remain scarce (Newton et al., 2018). Figure 3 shows the distribution of coastal lagoon studies, where each red dot represents a study that summarized, quantified, and/or valued the ecosystem services provided by a lagoon. The figure displays that no ecosystem service assessment studies have been conducted on coastal lagoons in the Caribbean islands. For the two depicted coastal lagoons in the wider Caribbean region, the Yalahau Lagoon in Mexico and the Cartagena Bay in Colombia, ecosystem services have not been valued, but have only been summarized (Herrera-Silveira & Morales-Ojeda, 2010; Restrepo et al., 2006; Tosic et al., 2019) When complementing this finding with an own extensive literature review, it seems that there has not been any economic valuation study done on coastal lagoons in the Caribbean. Table 1 summarizes this result. It shows three of the most influential studies for the economic valuation of ecosystem services in general, for coastal and estuarine ecosystems more specifically, and for coastal lagoons even more specifically. However, for Caribbean coastal lagoons no valuation studies are available. For the coastal lagoons for which valuation studies have been conducted, provisioning and cultural services have the highest average monetary value (Newton et al., 2018).

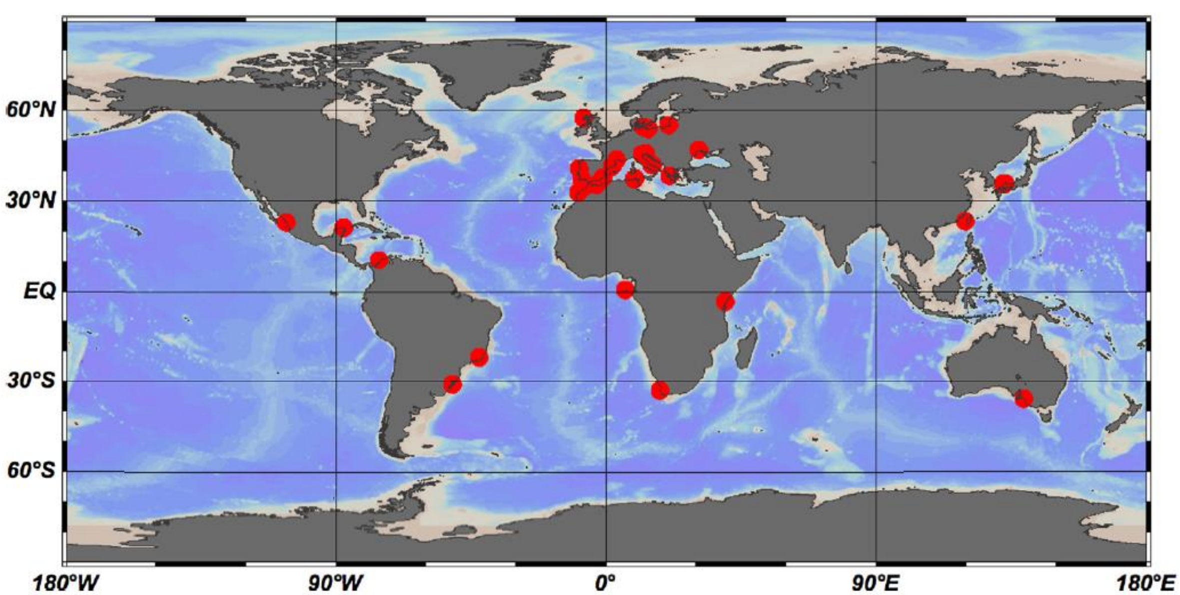

Figure 3: Geographic location of ecosystem assessments of coastal lagoons. *Source: Newton et al. (2018)*

Table 1: Influential ecosystem service valuation studies conducted on certain types of ecosystems

Ecosystems	Influential studies
All ecosystems	Costanza et al. (1997); Costanza et al. (2014); de Groot et al. (2012)
Coastal and estuarine	Barbier et al. (2011) Martínez et al. (2007); Barbier et al. (2008)
Coastal lagoons	Newton et al. (2018); Tuan et al. (2009); Martínez-Paz et al. (2013)
Caribbean coastal lagoons	? → this study

This is surprising, as de Groot et al. (2012) find that, in general, the most valuable services provided by coastal and estuarine ecosystems are regulating services. This contrast might be due to the only very few and mostly European-based coastal lagoon valuation studies that have been conducted so far. This makes the results sensitive to outliers and non-representative for coastal lagoons worldwide. Consequently, more (non-European) ecosystem service valuation studies on coastal lagoons are certainly needed.

However, often the valuation of ecosystem services is not enough to ensure the protection and conservation of these services, as it only focuses on benefits and disregards the costs of environmental management. Policy decisions are often made based on cost-benefit analyses, so knowing the costs of protecting and restoring ecosystems is vital (Birch et al., 2010; Daily et al., 2009; Martinez-Harms et al., 2015). Nonetheless, in a TEEB review of more than 2,000 restoration case studies, it was found that less than 5% of these studies provided useful cost data, and none of them analyzed both costs and benefits (TEEB, 2009). A study by Martínez-Paz et al. (2013) is an exception to the rule. They used several cost-benefit analysis techniques to assess restoration opportunities for the Mar Menor coastal lagoon (Spain). They found that when both market and non-market values were taken into account, the benefits of restoration measures such as peripheral wells and wastewater tanks far exceeded their costs. However, when only market values were considered, these restoration measures were not found to be cost-effective.

2.3 Nature-based solutions for ecosystem service enhancement

Related to the costs and benefits of alternative environmental management scenarios is the discussion on nature-based versus man-made solutions for enhancing ecosystem service provisioning. There are many definitions of nature-based solutions (see Nesshöver et al., 2017), and they are often related to the use of nature for solving complex sustainability challenges. In the context of this study, nature-based solutions can be defined as the use of nature for improving the provisioning of ecosystem services. Although ‘nature-based solutions’ is a relatively new concept, it is already actively promoted by the IUCN (International Union for Nature Conservation) and adapted in policy programs such as the EU's Horizon 2020 framework program (Eggermont et al., 2015). The rationale for nature-based solutions is twofold. Firstly, nature-based solutions are more sustainable than conventional (man-made) solutions as they use natural flows of energy and matter, are more easily adapted to local needs, and follow the temporal and seasonal changes of the ecosystem (Keesstra et al., 2018). Secondly, nature-based solutions are argued to be more cost-effective as they need less maintenance and have less unwanted ecological side effects (Keesstra et al., 2018; Temmerman et al., 2013). As further explained in the upcoming paragraphs, this study looks at a nature-based solution (mangrove restoration) and a man-made solution (sewage treatment plant) for enhancing ecosystem service provisioning by the Lagoon. Following the theoretical rationale of nature-based solutions, the following hypothesis can be derived:

H1: A nature-based solution is economically more favorable than a man-made solution for enhancing ecosystem service provisioning by the Simpson Bay Lagoon

Temmerman et al. (2013), for instance, already find that in many locations around the world flood protection through ecosystem restoration and creation can be a more sustainable and cost-effective approach than conventional coastal engineering solutions. Nevertheless, not many empirical studies have yet been conducted, and hence more knowledge generation is needed on the effectiveness and cost-efficiency of nature-based compared to man-made solutions (Fitter, 2013; Kabisch et al., 2016).

2.4 Main contributions of this study

This study contributes to the existing literature in multiple ways. First, it adds to the few economic valuation studies on coastal lagoons, and to the author's knowledge it provides the first valuation study of a Caribbean coastal lagoon. Second, scientific studies on coastal wetlands in Saint Martin are scarce in general. Knowledge about the (value of) ecosystem services provided by the Simpson Bay Lagoon is valuable for scientists, local decision makers, and the general public alike. Third, this study provides a unique picture of the costs and benefits of alternative environmental management scenarios to protect and enhance the ecosystem services provided by the Lagoon. Conducting these cost-benefit analyses aims for the better integration of ecosystem services in the decision-making process. As the Simpson Bay Lagoon suffers from similar pressures as other coastal wetlands in the Caribbean, the results of the cost-benefit analyses might be wider applicable as well. Finally, this study contributes to the academic debate on the effectiveness and efficiency of nature-based versus man-made solutions for enhancing ecosystem service provisioning. It does so by conducting a cost-benefit analysis of a nature-based solution (mangrove restoration) and a man-made solution (construction of a sewage treatment plant).

3. The case study: Simpson Bay Lagoon, Saint Martin

3.1 General introduction of Saint Martin and the Simpson Bay Lagoon

This study focuses on the valuation and management of the Simpson Bay Lagoon in Saint Martin. Saint Martin is a small island that is part of the Lesser Antilles, which is a group of islands in the Eastern Caribbean (see Figure 4). The island is divided into a Dutch part in the South and a French part in the North. Table 2 shows some summary statistics for both sides of the island. Whereas the French part comprises a larger area, the Dutch side is more populous. In fact, Dutch 'Sint Maarten' is the most densely populated country in the Caribbean (World Bank, 2019). The Dutch part also has a higher GDP per capita. The economies of both parts of the island are highly dependent on tourism revenues. In 2016, an estimated 1,668,863 cruise passengers and 528,154 stay-over tourists visited the island (Gilders, 2018). However, the island suffered tremendously from Hurricane Irma, which caused the death of at least 8 people and destroyed most of the island's infrastructure. Restoration efforts are still ongoing and progress is slow (World Bank, 2019).

Figure 4: Maps of Saint Martin (left) and the Simpson Bay Lagoon (right). *Sources: (Guadeloupe, 2009; Lonely planet, 2019)*

Table 2: Summary statistics of the Dutch and French part of Saint Martin

	Dutch side	**French side**
Area	34 km^2	53.2 km^2
Population	41,109	35,746
Households	14,021	13,400
GDP per capita	$25,968 (48,694 ANG)	$16,572 (€14,700)

Sources: (Department of Statistics Sint Maarten, 2017, 2019; INSEE, 2016; World Bank, 2019)

The Simpson Bay Lagoon lies in the southwest of the island and with a size of approximately 880 hectares, it is one of the largest inland lagoons in the Antilles (Gilders, 2018). Figure 4 shows a map of the Lagoon. Within the Lagoon lies the Mullet Pond, which is internationally recognized by the Ramsar Convention on Wetlands of International Importance. The presence of mangrove stands and seagrass beds makes the Lagoon an important habitat and nursery ground for marine life (Nature Foundation Sint Maarten, 2013). However, like many Caribbean coastal wetlands, the Lagoon suffers from heavy development, wastewater pollution and overexploitation (Gilders, 2018; Yáñez-Arancibia et al., 2011). This has deteriorated the ecological integrity of the Lagoon and threatens to impair the capacity of the Lagoon to provide essential ecosystem services for the local population. In this sense, the Simpson Bay Lagoon can be seen as a microcosm of other Caribbean coastal ecosystems, which makes it a highly relevant case to study.

3.2 Ecosystem services provided by the Simpson Bay Lagoon

The Simpson Bay Lagoon provides many ecosystem services. With the use of expert interviews, field visits, community meetings and literature research, an earlier study by Gilders (2018) has identified the main ecosystem services provided by the Lagoon, and to what extent their provisioning is threatened. Table 3 displays the ecosystem services provided by the Lagoon for each ecosystem (wetlands, mangroves, seagrasses, and coral reefs), and includes a specification for each ecosystem service. Table A.1 in the appendix shows the identified importance of the ecosystem services, and to what extent they are threatened. It is important to note that coral reefs are not directly located within the Lagoon. However, due to their close proximity to the Lagoon, some coral reefs are greatly dependent on the ecological state of the Lagoon (e.g. for fish migration and wastewater regulation).

Table 3: Ecosystem services provided by the Simpson Bay Lagoon

Ecosystem	Category	Service	Specification
Wetland	Provisioning	Sea food	Fish
	Regulating	Local climate regulation	Keeps the surrounding area cool
		Carbon sequestration	The wetland stores carbon
		Moderation of extreme evens	Flood prevention, safe harbor for yachts
		Wastewater treatment	Purification of wastewater
		Erosion control	Prevents soil erosion
		Pollination	Birds pollinate nearby trees
	Habitat	Habitat for species	Birds, fish, turtles, rays, crabs, shrimps, etc.
		Genetic diversity	High biodiversity
		Nursery ground	A nursery ground for many species
	Cultural	Recreational	Swimming, sailing, kayaking, birding
		Tourism	Marine industry, hotels, eco-tourism
		Aesthetic	An aesthetically attractive area
		Education	Tours and activities via NGOs and eco-tourism
		Spiritual	Spiritual value for local population
		Historical	Historical value for local population
Mangroves	Regulating	Erosion control	Roots prevent soil erosion
		Carbon sequestration	The mangroves store carbon
		Moderation of extreme evens	Attenuate waves from storms and hurricanes
		Wastewater treatment	Purification of wastewater
	Habitat	Habitat for species	Birds, juvenile fish, crabs
		Nursery ground	Nursery ground for fish and other marine life
	Cultural	Recreation	Kayaking, birding
		Tourism	Eco-tourism through kayaking, birding, etc.
		Education	Tours and activities via NGOs and eco-tourism
Seagrasses	Regulating	Carbon sequestration	The seagrasses store carbon
		Wastewater treatment	Purification of wastewater
	Habitat	Habitat for species	Home and foraging place for many species
		Nursery ground	Nursery ground for fish and other marine life
Coral reefs	Provisioning	Sea food	Fish
	Regulating	Carbon sequestration	The coral reefs store carbon
		Moderation of extreme evens	Attenuate waves from storms and hurricanes
	Habitat	Habitat for species	A vital habitat for a wide variety of species.
	Cultural	Recreation	Swimming, snorkeling, diving, fishing, etc.
		Tourism	Swimming, snorkeling, diving, fishing, etc.
		Aesthetic	It is an aesthetically attractive ecosystem
		Education	Tours and activities via NGOs and eco-tourism
		Historical	Historical artisanal fishing community

Source: modified from Gilders (2018)

3.3 Environmental management scenarios for the Simpson Bay Lagoon

On the basis of the report by Gilders (2018) and a literature review, two environmental management scenarios have been identified as the most feasible and effective for enhancing the provisioning of ecosystem services by the Simpson Bay Lagoon.

3.3.1 Sewage treatment plant

The first management scenario is the construction of a sewage treatment plant, which is a man-made solution for ecosystem service enhancement. A sewage treatment plant is expected to strongly reduce the inflow of wastewater in the Lagoon, as it would replace the often overflowing septic tanks that are currently installed (Gilders, 2018; van der Lely et al., 2013). The current level of wastewater pollution in the Lagoon has detrimental effects on the water quality of the Lagoon, as the capacity of the wetland to filter the wastewater is overwhelmed. The nutrient overload leads to eutrophication and subsequently to the die-off of marine life. Excessive wastewater inflow (mainly due to sewage) is also killing the nearby coral reefs, which are of high ecological and economic value (Daily Herald, 2019). Furthermore, the dirty water and foul smells resulting from the sewage inflow negatively impact the attractiveness of the Lagoon for tourism and recreation. Although a sewage treatment plant would significantly reduce wastewater inflow and hence the afore-described problems, the construction and maintenance of a sewage treatment plant is costly (van der Lely et al., 2013). There have already been plans to build a sewage treatment plant on Saint Martin, but a final decision has not yet been made (Daily Herald, 2016). This research could add vital information to the policy debate by demonstrating if the economic benefits exceed the costs.

3.3.2 Mangrove restoration

The second management scenario is the restoration of mangrove stands in the Lagoon, which is a nature-based solution. As Table 3 shows, mangrove ecosystems provide many important ecosystem services. However, in the past 50 years most of the mangroves in the Lagoon have been removed (Gilders, 2018). Like a sewage treatment plant, the restoration of mangroves is expected to improve the water quality of the Lagoon (albeit perhaps less efficient than a sewage treatment plant), as the roots of mangroves remove nutrients and contaminants from the wastewater (Ouyang & Guo, 2016). In addition, the restoration of mangroves would increase the provisioning of many other ecosystem services such as carbon sequestration, storm protection, and habitat and nursery services (Alongi, 2012; Gilman et al., 2008). Nevertheless, mangrove restoration can also be costly (Bayraktarov et al., 2016). To estimate the potential area of mangroves in the mangrove restoration scenario, the author used methods including mapping, GIS, and aerial photography (see Annex B for a detailed description). In the analysis, the results of both management scenarios are compared to a third scenario, a scenario in which the current management of the Lagoon is unchanged (baseline scenario).

4. Data and methodology

To solve the undervaluation of the Lagoon and to add to the few valuation studies done on coastal lagoons in general, this study conducts an economic valuation of the Lagoon. The methods that are used to estimate the total economic value of the Lagoon are the choice experiment method (complemented with a survey questionnaire) and the value transfer method. Furthermore, a cost-benefit analysis of alternative environmental management scenarios is performed to provide decision makers with hands-on management advice and to shed a light on the economic feasibility of nature-based versus man-made solutions for ecosystem service enhancement. The following paragraphs explain these methods in further detail, as well as the corresponding data collection strategies.

4.1 Choice experiment and survey questionnaire

The following paragraphs explain the choice experiment method, the attributes and levels that are used in the choice experiment, the questions that are used in the survey, the sampling and data collection strategy, and the statistical design and analysis of the choice experiment.

4.1.1 Choice experiment versus contingent valuation

The choice experiment is a stated-preference method which can be used to estimate the economic value of practically any ecosystem good or service. In a choice experiment, respondents are asked to choose between a set of hypothetical alternatives with different attribute levels. These alternatives, attributes, and levels are typically presented to the respondents in the form of a choice card. A key part of the choice experiment is the inclusion of a payment vehicle as a choice characteristic (e.g. price of the alternative). This makes it possible to estimate the economic value (WTP) for changes in attribute levels (Hanley et al., 2002; Koetse et al., 2015). The choice experiment is related to but different than the contingent valuation method. In a contingent valuation study, respondents are asked directly about their WTP (e.g. for environmental management). Although both are hypothetical stated-preference methods, a choice experiment has several advantages over a contingent valuation study. A choice experiment is more intuitive for respondents, it generates separate WTP values for different environmental attributes, and it is less prone to strategic response behavior (Adamowicz et al., 1998; Koetse et al., 2015). Furthermore, by letting respondents compare different future scenarios, the choice experiment is useful when assessing alternative future management scenarios, as is done in this study. However, the choice experiment often leads to (even) more overestimated WTP values than a contingent valuation study (Ryan & Watson, 2009; Stevens et al., 2000). Consequently, the results from the contingent valuation study can serve as a useful robustness check for the choice experiment and might provide a lower bound for the WTP values. Therefore, in addition to the choice experiment, the survey also includes a contingent valuation component.

4.1.2 Attributes and levels used in the choice experiment

In this study, the choice experiment is used to elicit the local, recreational, and cultural value of the Simpson Bay Lagoon. Table 4 shows the attributes and levels that are used in this choice experiment. Figure 5 displays the example choice card. Pictograms are used in the choice

Table 4: The attributes and levels used in the choice experiment

Attributes	Description attributes	Levels
Damage from storms	Damage from storms to properties nearby the Lagoon	40% more damage
		No change
		20% less damage
		40% less damage
Water quality	Quality of the water, related to smell and water clarity	Low quality
		Moderate quality
		High quality
Habitat for species	Habitat for species in the Lagoon	40% less habitat
		No change
		20% more habitat
		40% more habitat
Suitability for recreation	The suitability of the Lagoon for doing recreational activities	Low
		Moderate
		High
Stay-over tourists	The number of stay-over tourists that come to Saint Martin	20% less stay-over tourists
		No change
		10% more stay-over tourists
		20% more stay-over tourists
Monthly contribution	The monthly contribution paid by the respondents and all other households of Saint Martin in US $	$0
		$2
		$5
		$10
		$20

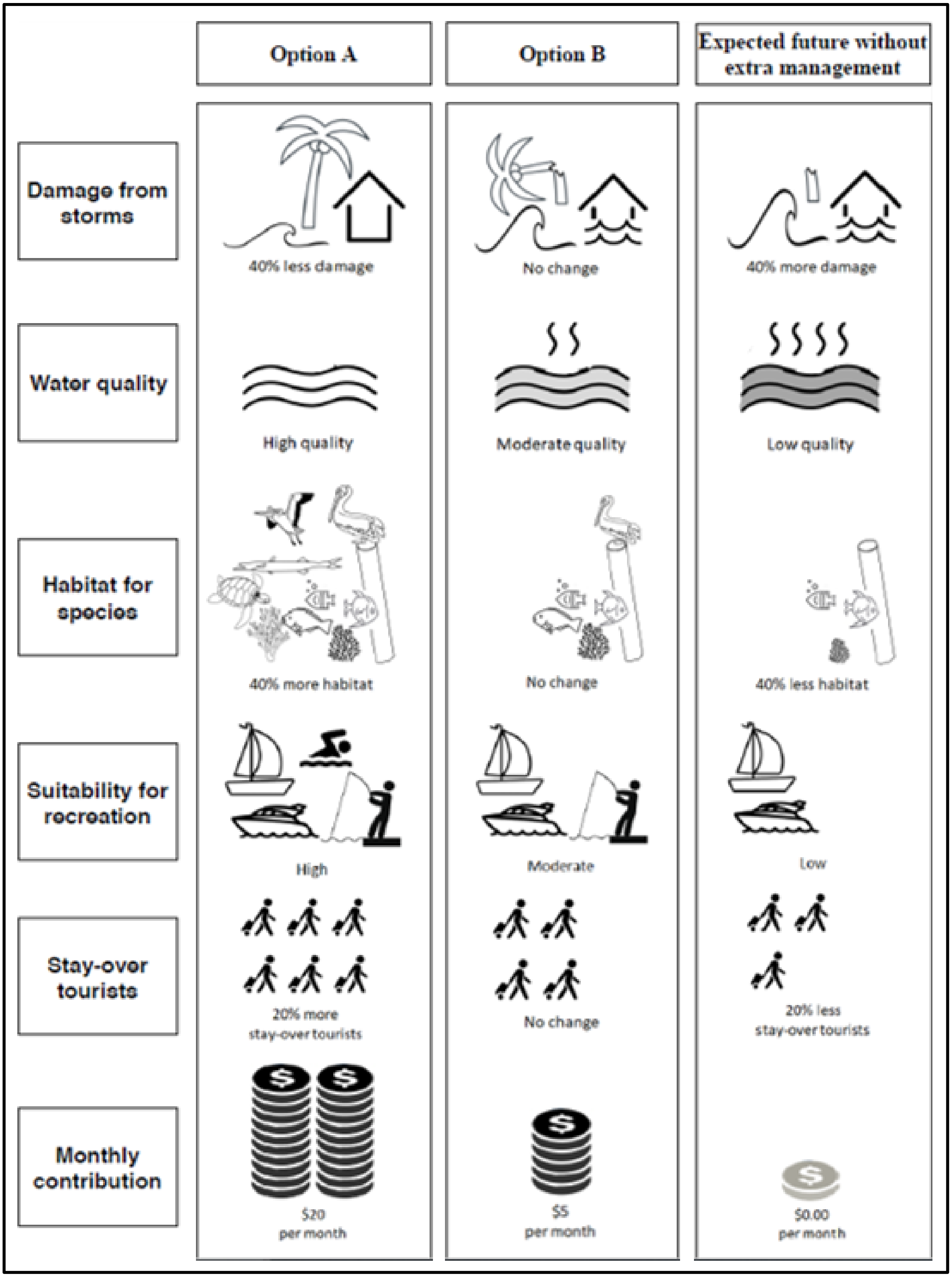

Figure 5: Example choice card

card to reveal the attribute levels to the respondents. Pictograms are preferred to text, as graphics reduce fatigue problems and are often more understandable for the respondent (Ryffel et al., 2014). The choice of the attributes and levels is one of the most important aspects of designing a choice experiment (Louviere, Flynn, & Carson, 2010). When deciding on the attributes and levels, this study took into account the opinion of many stakeholders, as to ensure that the attributes and levels were relevant and understandable for the local population of Saint Martin. This is especially important when there are potential cultural and language differences between the researchers and the local population, as was the case for this study (Mangham, Hanson, & McPake, 2009). Table A.2 provides a non-exhaustive overview of the stakeholders that have been consulted during the design stage of the choice experiment and survey questionnaire, including stakeholders from both the Dutch and the French side of the island. Part of the design phase was the pre-testing of the choice experiment and survey questionnaire among the local population. In the pilot study, an extensive debriefing was held with the respondents to hear their opinion on the survey questions and the attributes and levels of the choice experiment. The pilot study was held among 11 respondents.

A previous study by Gilders (2018) has identified that storm surge protection, wastewater regulation, habitat services, recreation, and tourism support are experienced by the citizens of Saint Martin as important ecosystem services provided by the Lagoon. This was further confirmed during an expert meeting with government officials of the Environment Ministry of Saint Martin and when piloting the choice experiment under the local population of Saint Martin. Hence, these ecosystem services are included in the choice card as attributes. The choice of the attribute levels is based on an expert meeting with government officials, meetings with other stakeholders, close consultation with the thesis supervisor, the pre-test results of the choice experiment, and previous studies (see Brouwer et al., 2014; van der Lely et al., 2013). A thorough explanation of and motivation for the chosen attributes and levels are provided in Annex C.

4.1.3 The survey questionnaire

The choice experiment is complemented with a survey questionnaire. This is useful to obtain the background characteristics of the respondents, and to know the respondents' attitudes towards the Lagoon and the proposed management scenarios. The total survey questionnaire can be found in Annex G. The questions in the survey ask respondents about their relationship with the

Lagoon, their perception of the current environmental state of the Lagoon, their attitude towards future environmental management scenarios, and their general environmental perceptions and behavior.

When deciding on the survey questions, many local stakeholders were consulted, and several of the initial questions were changed to make them more appropriate for the local context of Saint Martin. Many survey questions were derived or inspired from previous similar surveys held on Caribbean islands (see Fenkl et al., 2014; Laclé et al., 2012). For all questions, it was made sure that they were understandable and unambiguous, as inadequate survey questions can significantly reduce the reliability and validity of the survey results (de Leeuw, Hox, & Dillman, 2008). To make the survey accessible for most citizens of Saint Martin, the questionnaire has been made available in both English and French.

4.1.4 Sampling strategy and data collection

Initially, the target population of the survey was all resident households of Saint Martin (both the French and Dutch part). However, during stakeholder consultations we were repeatedly notified that it would be better to focus on people that live close to the Lagoon, as they depend much more on the ecosystem services provided by the Lagoon, and their environmental behavior also has a larger impact on the Lagoon's ecological integrity. Hence, it was decided that the largest

Figure 6: Lagoon area, enclosed by the mountain ridges

part of our sample would constitute households located close to the Lagoon. The area close to the Lagoon, or simply ‘the lagoon area’, is defined as the area consisting of the Lagoon, and enclosed by the mountain ridges (see Figure 6).

Nevertheless, to investigate how people outside the Lagoon area value the Lagoon, and to see if their WTP values significantly differ from people living close to the Lagoon, 33 people outside the Lagoon area were interviewed. 21 people in this sub-sample were from the Dutch side of the island, and 12 from the French side. This is around 15% of the total sample size of 219 respondents. Although, generally, 400 respondents is assumed to be a golden rule for choice experiment studies (de Bekker-Grob et al., 2013), this number was unattainable due to time constraints. The total number of respondents from the Dutch side of Saint Martin is 131, and from the French side 88. The reason for collecting more responses from the Dutch side is twofold. First, the Dutch side has a higher total population number (40,535 compared to 35,746). Second, for the French part, this study partly relied on external French-speaking interviewers. It was not known beforehand how many surveys they would be able to do. Still, respondents from both sides of the island are well represented in the sample.

Within the lagoon area, stratified sampling was applied. The strata are different regions within the lagoon area, as to ensure that each region is represented in correspondence to its relative number of inhabitants. This was done for the Dutch and French side separately. Five regions have been identified as strata, three at the Dutch side, and two at the French side. Table 5 shows that for the Dutch side of the lagoon area, the percentage of respondents from each region closely corresponds to the percentage of people that live in that region. For the French side, the representativeness is lower in terms of the geographical distribution of the respondents.

Table 5: Comparing the percentage of respondents from each region with the actual percentage of people living in each region

	Number of respondents	**Percentage of respondents**	**Population**	**Percentage of population**
Inside lagoon area, Dutch side				
Cole Bay	89	80.91%	7,194	79.54%
Simpson Bay	13	11.82%	1,142	12.63%
Low Land	8	7.27%	708	7.83%
Total	110	100%	9,044	100%
Inside lagoon area, French side				
Sandy Ground – Les Terres Basses	43	56.58%	4,627	25.56%
Marigot area	33	43.42%	13,405	74.34%
Total	76	100%	18,032	100%

Source: Population statistics from INSEE (2019) *and the Department of Statistics Sint Maarten* (2019)

When approaching households, the sampling strategy was to interview every third household. However, in some neighborhoods it was very difficult to adhere to this sampling strategy. The reason for this is that many houses were unapproachable (due to gates, aggressive dogs, etc.), people were not at home, or people refused to participate. Strictly adhering to interviewing every third household would not have provided us with enough respondents for some strata. Hence, in this case, convenience sampling was used, which implies that within neighborhoods each household could be targeted and interviewed if willing to participate. If possible, the head of the household was interviewed. Otherwise, anyone else living in the household and older than 18 was interviewed.

4.1.5 Statistical design and statistical analysis of the choice experiment

For the statistical design of the choice experiment, this study relied on the kind help of Mark Koetse. The statistical design that is used in this study is a D-efficient design, with priors based on theoretical expectations of the signs of the coefficients of each attribute. An efficient, instead of an orthogonal, design is used to exclude dominant alternatives. The design is generated using the software Ngene version 1.1.1. In the choice experiment, four versions of each six choice cards are employed. Hence, in total there are 24 different choice cards. Each card consists of three scenarios, where scenario three always entails the expected future without extra management.

The type of model that is applied to analyze the choice experiment results is the random parameter logit (RPL) model. The RPL model has several advantages over the often employed multinomial logit (MNL) model (Carlsson, Frykblom, & Liljenstolpe, 2003; Maitra et al., 2013). It does not exhibit the independence of irrelevant alternatives property, it captures heterogeneity in preferences by estimating individual parameters, and it often has a higher explanatory power. This more advanced modelling technique makes it possible to estimate WTP values for each respondent in the sample, and to subsequently conduct further (regression) analyses on these individual parameters. The estimation of an RPL model is time intensive, and the time needed for estimation increases with the number of random draws taken. When deciding on the number of draws, the author followed the recommendation of Bhat (2001) by employing 1000 Halton draws. Respondents who answered none of the choice questions or only one choice question are excluded from the RPL model estimation, as including them would lead to unreliable individual parameter estimates.

4.2 Value transfer

The local, recreational, and cultural value of the Lagoon obtained from the choice experiment should be supplemented with additional value estimates to obtain the total economic value of the Lagoon. These include the carbon sequestration, fishery, and tourism value. These values are estimated with the use of the value transfer method. Value transfer entails the transfer of existing valuation information to new study sites where valuation data is limited or non-existent (Plummer, 2009). Previous studies have estimated the value of mangroves and seagrasses for carbon sequestration and fisheries (Alongi, 2012; Salem & Mercer, 2012). These values can be used to estimate the carbon sequestration and fishery value of the mangroves and seagrass beds in the Lagoon. The tourism value, on the other hand, can be determined by utilizing the results of tourism surveys held on other Caribbean islands. These specific value transfer strategies are further elaborated upon in the results chapter. Value transfer is a popular method in ecosystem service valuation studies, as it can provide reliable value estimates even when stringent time and budget constraints are in place (Troy & Wilson, 2006). Nevertheless, large transfer errors can occur, especially when the site to be valued and the original study site are strongly dissimilar (Koetse et al., 2015). Hence, this should be carefully considered when conducting and interpreting the value transfer.

4.3 Cost-benefit analysis

To assess the economic rationale for the three environmental management scenarios (i.e. business as usual, sewage treatment plant, and mangrove restoration), this study employs a cost-benefit analysis. As this decision-support tool is able to present the various costs and benefits of a project in one single monetary figure, it is often used and decisive in the prioritization of alternative management scenarios (Martinez-Harms et al., 2015). The annual benefits of the management scenarios are calculated based on the valuation exercise. The annual costs are derived from literature research and/or local insights. The annual benefits and costs are subsequently converted to a single unit: the present value. To calculate the present value, the choice of the time period and the discount rate is crucial. This study uses a time period of 30 years, as this is long enough for the management scenarios to have an impact on the provisioning of ecosystem services, and short enough to provide reasonable economic predictions (van der Lely et al., 2013). Setting the discount rate, which reflects time preferences and the opportunity costs of capital, is a contentious enterprise.

Economists often argue for widely diverging discount rates (see Nordhaus, 2007; Stern, 2007), while at the same time present value estimates are highly sensitive to the choice of the discount rate. Therefore, discount rates ranging from 0% to 15% are applied in this study.

When the present value of the costs and benefits have been calculated, the net present value (NPV) can be obtained by subtracting the present value costs from the present value benefits. If the NPV>0 the management scenario will improve social welfare. Another useful metric is the benefit-cost ratio, which is the ratio of the present value benefits and costs. A BCR>1 indicates that the benefits exceed the costs. Besides the NPV and BCR, the final decision on the preferred alternative should also consider how the benefits and costs are distributed across different groups in society, as some groups might be disproportionally affected by the measure (Brander & van Beukering, 2015).

5. Results

The Lagoon's ecological integrity is threatened by pollution and degradation due to its undervaluation by decision makers. At the same time, only little is known about the value and management of coastal lagoon ecosystems in general, and in the Caribbean in particular. Hence, an analysis of the Lagoon's economic value and the economic feasibility of future environmental management scenarios is desperately needed. This chapter provides and explains the results of such an analysis. The first part of this chapter entails estimating the economic value of the Lagoon, including both the choice experiment and the value transfer estimates. The second part presents the outcomes of the cost-benefit analysis, as to elicit what is economically the most favorable environmental management scenario for enhancing ecosystem service provisioning by the Lagoon.

5.1 The economic value of the Simpson Bay Lagoon

To estimate the total economic value of the Lagoon, four types of value are calculated: the local, recreational and cultural value, the carbon sequestration value, the fishery value, and the tourism value. To estimate the local, recreational, and cultural value a choice experiment is conducted. Value transfer is used to estimate the carbon sequestration, fishery, and tourism value.

5.1.1 The local, recreational, and cultural value of the Lagoon

Description of the survey sample

Table A.3 in the appendix shows the sociodemographic profile of the 219 survey respondents. It displays descriptive statistics of gender, age, household income per month, country of birth, and average household size. The statistics are shown for the whole sample, as well as for the Dutch and French side separately. In the sample, males are slightly overrepresented. This can be due to the fact that, in Saint Martin, a male might be more often regarded as the head of the household than a female. For age, most respondents are between 26 and 55 years old. Most respondents indicate that the monthly income of their household is between 1,000 and 3,500 US dollars per month. Nevertheless, a considerable number of respondents, especially at the French side of the island, live in a household with a monthly income lower than $1,000 per month. Almost 20% of the respondents did not know their household income or refused to answer. Regarding country of birth, more than 35% of the respondents were born on Saint Martin, while almost 33% of the respondents were born elsewhere in the Caribbean. Looking at education, we can observe that more than 44% of the respondents mentioned high school as their highest level of completed education. Only few respondents completed no education or solely primary education. 30.14% of the respondents completed higher education. Finally, the average household size in the sample is 3.04 people. In Annex D.1, the sociodemographic representativeness of the sample is analyzed and explained. The results show that the sample is representative for gender and age and unrepresentative for country of origin and education.

Analysis of survey questions, WTP-preparedness, and the contingent valuation study

Due to word limitations, the analysis of the survey questions, the WTP-preparedness of respondents, and the contingent valuation study are provided in Annex D.2 and D.3. This section summarizes the results. The analysis of the survey questions reveals that most respondents have noticed the degradation of the ecological integrity of the Lagoon, and that they find the government most responsible for this. When being asked about their attitudes towards environmental management scenarios for the Lagoon, a large majority of the respondents indicated to be in favor of both mangrove restoration and the construction of a sewage treatment plant. Regarding WTP-preparedness, 76.71% of the respondents are in principle willing to pay for environmental management of the Lagoon. The average WTP per household is $13.76 per month. To test the relationship between WTP and population characteristics, several regression models have been estimated. Most model estimates indicate that the WTP values of males, higher educated people, and people with a high household income are significantly higher than those of females, lower educated people, and people with a low household income. Furthermore, respondents born on the French mainland have a significantly lower WTP than respondents born on Saint Martin. No significant differences in WTP have been found between people living on the French side and people living on the Dutch side of the island, or between people living inside and outside the lagoon area. With these results, the total WTP for environmental management of the Lagoon, of the households of Saint Martin, can be calculated. Together, the in total 27,421 households of Saint Martin are willing to pay $4,527,756 per year for environmental management of the Lagoon.

Survey questions related to the choice experiment

The choice experiment consisted of four versions of choice sets. For a proper statistical analysis on the WTP values, it is important that each version is equally represented. Figure D.13 in the appendix shows that this is the case for this study; versions 2 to 4 are used 55 times, while version 1 is used 54 times. After making their choices, respondents were asked which attributes they found most important when they made a choice. Figure 7 displays that water quality and habitat for species are considered most important by the respondents. Suitability for recreation and the monthly contribution were of lower importance. When making a choice decision, most

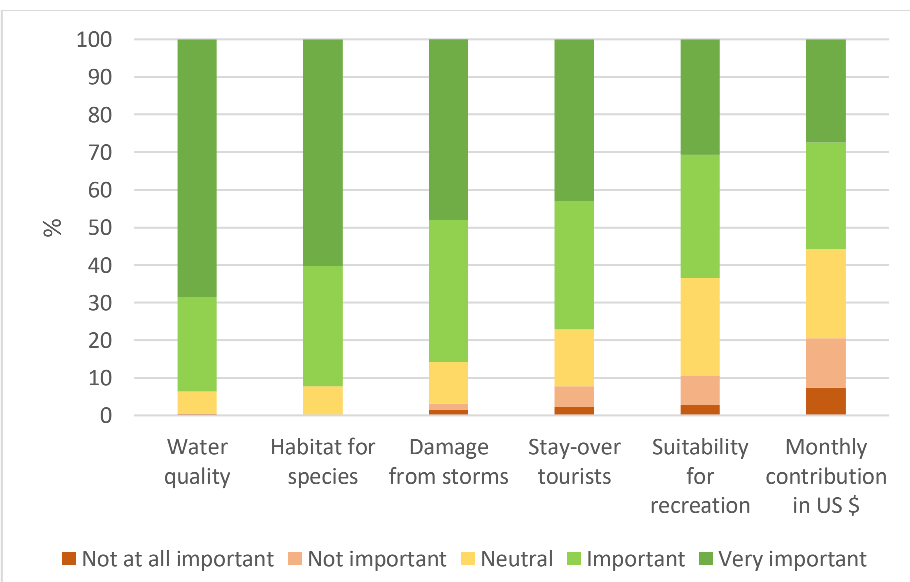

Figure 7: Importance of the attributes to the respondents when making a choice

respondents considered all attributes on the choice card (see Figure D.14). Furthermore, more than 75% of the respondents were certain or very certain about the choices they made, while only less than 5% of the respondents were uncertain about this.

Model estimates and WTP

As explained in the methodology section, the main model that is used to analyze the choice data is the RPL model. The RPL model generates individual parameter estimates for each respondent, which subsequently can be used to estimate the WTP for all attributes. 212 respondents made more than one choice decision and are therefore included in the analysis.

Table 6 shows the results of the RPL model. The estimated coefficients portray the slope of the utility function. For instance, a one percent decrease in storm damage increases utility by 0.0405. The results indicate that less damage from storms, better water quality, more habitat for species, and a lower monthly contribution significantly increase the utility of the respondents. Surprisingly, the coefficient of the suitability for recreation attribute is negative, and significant at the 5% level. In Figure 7, we already saw that suitability for recreation was perceived as a less important attribute. Nevertheless, a negative sign is still unforeseen. It might be that people fear that too much recreation would lead to overcrowding on the Lagoon, or that it would harm the environment. In the model, recreation is modeled as a continuous, instead of a discrete variable. The reason for this, is that the type of choice experiment design does not allow for multiple discrete

Table 6: Results of the random parameter logit model

	Coefficient	Standard error	P-value	WTP (US $)
Damage from storms (%)	0.0405	0.0054	0.0000	0.2799
Water quality (baseline: low quality)				
Moderate water quality	2.3451	0.3297	0.0000	16.4109
High water quality	3.7271	0.3593	0.0000	25.6634
Habitat for species (%)	0.0471	0.0060	0.0000	0.3275
Suitability for recreation	-0.3161	0.1283	0.0138	-
Stay-over tourists (%)	0.0192	0.0121	0.1134	-
Monthly contribution ($)	-0.1501	0.0232	0.0000	-
N	1263			
Adjusted Pseudo R^2	0.3462			
AIC	1.4477			
BIC	1.4925			

Note: WTP values based on averages of individual parameter estimates attributes in the model specification. This also explains why the constant term is not included. Nonetheless, this does not distort the reliability of the model estimates. When including recreation, instead of water quality, as a discrete variable, the coefficients for recreation are still negative, although insignificantly so. As will be explained later, when estimating an MNL model, the coefficient for the recreation attribute is also insignificant. Hence, it can be assumed that people do not attach a significant negative value to recreation. The coefficient for stay-over tourists is positive, but insignificant. This is also surprising, as the economy of Saint Martin is largely dependent on tourism. Again, overcrowding and environmental harm might be explanations for this finding.

Table 6 also shows the WTP per month for all significant attributes. WTP values can be calculated by dividing the coefficient of the attribute (level) with minus the coefficient of the payment attribute (in this case the monthly contribution). The average WTP values in the table are calculated as the average of the 212 individual WTP estimates. Although the results do not differ much compared to calculating the WTP directly from the general model estimates, calculating averages from individual data is more accurate. The average WTP for a one percent decrease in damage from storms is $0.2799 per month. The average WTP for a one percent increase in habitat for species in the Lagoon is $0.3275 per month. The higher WTP for percentage changes in habitat compared to storm damage corresponds well with the findings in Figure 7, which showed that habitat was perceived as a more important attribute than damage from storms. Finally, the WTP to go from low to moderate water quality is $16.41, whereas the WTP to go from low to high water quality is $25.66. Figure D.15 in the appendix shows kernel density plots of the individual WTP estimates, which reveals the distribution of WTP values among the 212 respondents. For all attributes, quite some variability in WTP values is visible. For the recreation and tourism attribute, as would be expected from the general model estimates, a reasonable number of people display negative WTP values.

As a robustness check, this study has also estimated an MNL model, in addition to the RPL model. The results are shown in Table D.9 in the appendix. The number of observations for this model is slightly higher than that for the RPL model, as respondents who answered only one choice card can be included in this model. Again, storm damage, water quality, habitat for species, and the monthly payment significantly influence the utility of the respondents. The coefficient for recreation is still negative, but not significant anymore at the 5% level. The tourism attribute remains insignificant. These mostly similar findings enhance the robustness of the results found by the RPL model. Striking, though, are the much higher WTP estimates of the MNL model compared to the RPL model. As a choice experiment already often leads to an overestimation of the WTP values (Stevens et al., 2000), this study relies on the lower WTP estimates of the RPL model. The lower AIC and BIC values of the RPL model further support the choice for this model.

Sociodemographic variation in WTP

As for the contingent valuation study, it is interesting to see how WTP for the choice attributes differs across population groups. To assess this, the individual WTP values for each attribute can be regressed on sociodemographic variables. The results of this exercise are shown in Table 7. Regressions are only conducted on the significant attributes: storm damage, water quality, and habitat for species. To address heteroskedasticity, robust standard errors are applied. The variables included in the regression specifications are the same as those in the contingent valuation study (see Table D.7). This is useful for comparing the results of both studies. As almost 20% of the respondents did not provide their household income, the results with and without income are displayed separately. Hence, for each attribute (level), two models are estimated. The first model shows the results when gender, age, higher education, geographical location, and country of birth are included in the regression, while the second model also incorporates household income.

The model results indicate that sociodemographic variables are not able to explain much of the variation in WTP for each attribute. The R^2 of all models is lower than 0.10, and the F-statistic is often insignificant. Only one variable seems to significantly influence WTP. People who completed higher education have a significantly higher WTP for less storm damage, for more habitat for species, and for going from low to moderate water quality, compared to people who did not complete higher education. Only for model 6, which regresses WTP for high water quality, the coefficient for higher education is not significant. Another interesting finding of the regression models is that people living outside the lagoon area are not significantly willing to pay less for improving the environment of the Lagoon than people living inside the lagoon area. This was also found when analyzing the WTP estimates obtained from the contingent valuation study. In addition, the WTP of people living on the French side of the island is not significantly different from that of people living on the Dutch side of the island.

Table 7: Regression models explaining WTP for the significant attributes in the choice experiment

	WTP damage from storms		WTP moderate water quality		WTP high water quality		WTP habitat for species	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Gender (1=female)	0.002	0.013	-0.417	0.047	0.314	1.390	-0.016	-0.003
	(0.011)	(0.012)	(0.569)	(0.620)	(0.834)	(0.885)	(0.012)	(0.013)
Age	-0.008	-0.009*	-0.247	-0.297	-0.410	-0.568	-0.003	-0.005
	(0.004)	(0.005)	(0.208)	(0.224)	(0.300)	(0.336)	(0.004)	(0.004)
Higher education	0.039**	0.029*	2.273**	2.153**	2.813**	1.344	0.045**	0.041**
	(0.012)	(0.013)	(0.595)	(0.691)	(0.843)	(0.964)	(0.013)	(0.016)
French side	0.005	0.010	0.425	0.907	-0.819	-0.833	0.013	0.017
	(0.012)	(0.013)	(0.599)	(0.636)	(0.894)	(0.940)	(0.013)	(0.014)
Outside lagoon area	-0.001	-0.005	-0.372	-0.694	0.713	0.797	0.008	0.000
	(0.016)	(0.017)	(0.774)	(0.771)	(1.167)	(1.199)	(0.018)	(0.018)
Country of birth (baseline: Saint Martin)								
Caribbean	0.024	0.013	1.412*	1.109	0.834	0.469	0.023	0.019
	(0.014)	(0.015)	(0.705)	(0.754)	(0.977)	(1.066)	(0.014)	(0.014)
French mainland	-0.006	0.002	-1.200	-0.459	0.107	1.093	0.009	0.027
	(0.018)	(0.020)	(1.033)	(1.186)	(1.533)	(1.517)	(0.023)	(0.026)
Elsewhere	0.005	0.008	0.458	0.861	-0.107	-0.454	0.010	0.011
	(0.017)	(0.018)	(0.797)	(0.858)	(1.170)	(1.235)	(0.018)	(0.019)
High income		0.002		-0.651		1.780		-0.007
		(0.012)		(0.707)		(1.029)		(0.016)
Constant	0.281**	0.285**	16.162**	16.113**	26.020**	26.263**	0.315**	0.320**
	(0.016)	(0.017)	(0.781)	(0.827)	(1.226)	(1.311)	(0.018)	(0.020)
N	203	168	203	168	203	168	203	168
R^2	0.079	0.076	0.094	0.093	0.065	0.083	0.076	0.087
F-statistic	1.94	1.41	3.05**	2.32*	1.89	2.09*	2.27*	1.88

*Note: Robust standard errors in parentheses. The levels of significance are: *p<0.05, **p<0.01*

As the number of variables in the regression specification is substantial, it is important to test for multicollinearity. To evaluate multicollinearity, a Variance Inflation Factor (VIF) analysis is employed. VIF values higher than 5 indicate worrisome levels of multicollinearity (Hair, 2010; Rogerson, 2001). The results in Table D.10 show that for all the variables in the regression, the VIF values are well below 5. Consequently, multicollinearity is not likely to have posed a problem for the parameter estimations.

The local and cultural value of the current environmental state of the Lagoon

With the just derived results, it is possible to calculate the annual local and cultural value of the Lagoon. Figure 8 shows the monthly WTP for different levels of water quality. This attribute exhibits diminishing marginal utility. The WTP for going from low to moderate quality is higher than the WTP for going from moderate to high quality. Diminishing marginal utility for attribute levels is also found in many other choice experiment studies (Brouwer et al., 2014; Laclé et al., 2012; Remoundou et al., 2015). Assuming that this non-linearity holds across the whole spectrum of water quality levels, a polynomial function of the order 2 is estimated. Both the linear and the non-linear function are shown in Figure 8. As the attribute for water quality exhibits diminishing marginal utility, one would expect that this also holds for the storm damage and habitat attribute. Consequently, the same non-linear shape for the water quality attribute is assumed for habitat and storm damage. The monthly WTP for percentage changes in storm damage and habitat are shown in Figure 9 and 10, including both the linear and the non-linear functions. Note that the linear functions show the WTP when one assumes that the WTP estimates in Table 6 are constant for each percentage increase, while the non-linear functions assume decreasing marginal WTP.

This section calculates the local and cultural value of the current environmental state of the Lagoon; the future values under the different management scenarios will be discussed in the cost-benefit analysis later on. For the WTP calculations, the estimated non-linear functions are used, as they are deemed most realistic. Currently, the water quality in the Lagoon can be designated as low to moderate (VROMI, 2014). In the non-linear model, the monthly WTP for low to moderate water quality is $9.10, assuming that this attribute level is in between low and moderate quality. The current value of storm protection is the value for 'no change' in storm damage. The monthly WTP for no change compared to a 40% increase in storm damage is $14.32. As for storm protection, the

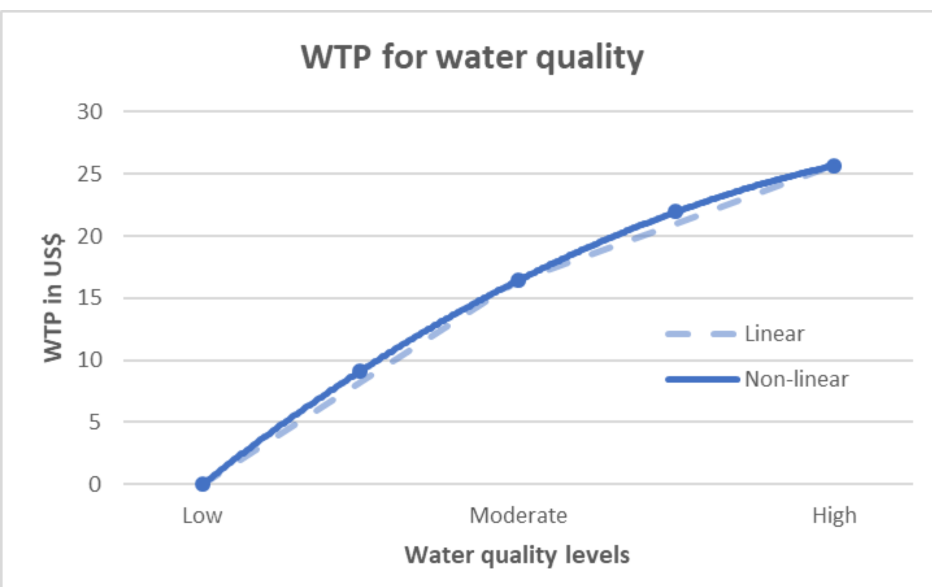

Figure 8: WTP for different water quality levels (in US $ per month)

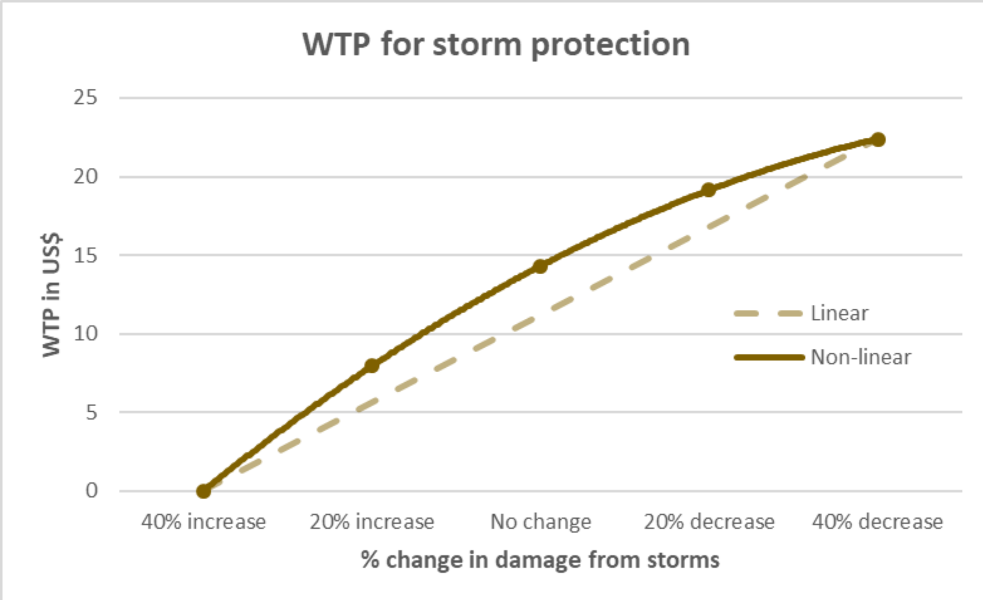

Figure 9: WTP for a decrease in storm damage (in US $ per month)

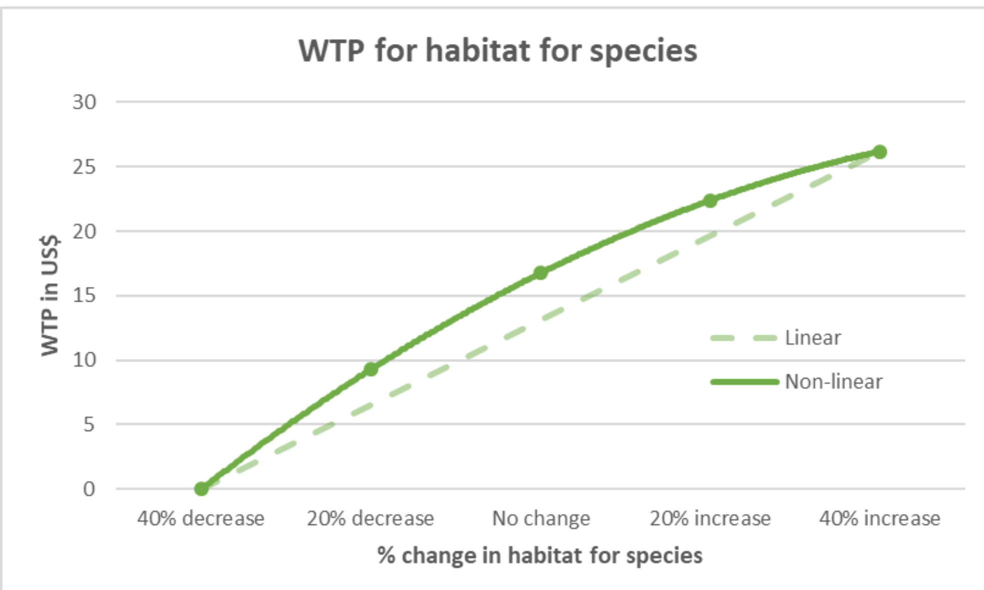

Figure 10: WTP for an increase in habitat for species (in US $ per month)

current value of habitat for species equals the WTP for 'no change' in habitat, which is $16.75. The assumed percentage changes in storm protection and habitat might seem somewhat arbitrary. However, these are the changes we presented to the residents of Saint Martin in the choice experiment, based on the insights from scientific literature and local stakeholders. As the exact percentage changes in storm protection and habitat for species cannot be accurately determined, sensitivity analyses will be conducted to see how using different values influences the outcomes of the cost-benefit analysis.

Table 8: Local and cultural value of the current state of the Lagoon, assuming the non-linear functions hold

Attribute	Attribute level	Monthly WTP per household	Months	Number of households	Total yearly WTP
Storm protection	No change	$14.32	12	27,421	$4,711,926
Water quality	Low to moderate	$9.10	12	27,421	$2,994,702
Habitat for species	No change	$16.75	12	27,421	$5,513,102
Total	**-**	**-**	**-**	**-**	**$13,219,730**

Note: Shown are rounded numbers. Calculations are based on non-rounded numbers.

Table 9: Local and cultural value of the current state of the Lagoon, assuming the linear functions hold

Attribute	Attribute level	Monthly WTP per household	Months	Number of households	Total yearly WTP
Storm protection	No change	$11.20	12	27,421	$3,684,066
Water quality	Low to moderate	$8.21	12	27,421	$2,700,020
Habitat for species	No change	$13.10	12	27,421	$4,310,581
Total	**-**	**-**	**-**	**-**	**$10,694,667**

Note: Shown are rounded numbers. Calculations are based on non-rounded numbers.

To obtain the total annual WTP of all households on Saint Martin, the monthly WTP estimates are multiplied by 12, and by the number of households on Saint Martin (27,421). This leads to a yearly WTP of $13,219,730. The calculations are summarized in Table 8. Table 9 shows the results when instead of the non-linear, the linear functions are used. The annual value would then be $10,694,667. This is considerably lower. Sensitivity analyses will assess if this influences the cost-benefit outcomes. The local and cultural value found for the Simpson Bay Lagoon is higher than that found on other Caribbean islands, such as Bonaire and Sint Eustatius (Fenkl et al., 2014; Laclé et al., 2012). This is mainly due to the much higher number of households on Saint Martin.

5.1.2 Value transfer results

This section provides the results of the value transfer analysis, which elicits the tourism, fishery, and carbon sequestration value of the Lagoon. The author would like to restate that transferring value estimates from other study sites to the Lagoon does probably not provide a fully accurate picture of the true value of the Lagoon. To prevent overestimated values, this study tends to depend on conservative lower-bound value estimates. Consequently, the values presented here are more likely an underestimation than an overestimation of the true value. To obtain the fishery and tourism value of the Lagoon, multiple value transfer strategies could be employed. This study has chosen for value transfer strategies which make it possible to assess how economic values change under the different management scenarios. For instance, using WTP values from contingent valuation questions might be useful to obtain a holistic view of people's WTP for ecosystem services, but it does not allow this value to change under different management scenarios. This is, however, vital for properly applying a cost-benefit analysis of future environmental management scenarios.

The carbon sequestration value of the Lagoon

Mangroves and seagrasses are the most prominent ecosystems in the Lagoon, and they play an important role in carbon sequestration. A review study by Mcleod et al. (2011) shows that mangroves and seagrasses, respectively, sequester on average 2.26 and 1.38 tons of carbon per hectare per year. In order to estimate the carbon sequestration value of the mangroves and seagrasses present in the Simpson Bay Lagoon, information on the total area of mangroves and seagrasses is needed. Unfortunately, this information was largely non-existent. The methods that were employed by the author to estimate the total area of mangroves and seagrasses included mapping, GIS, aerial photography and expert judgements. Annex B provides a detailed description of how the area of mangroves and seagrasses was estimated.

The estimated total area of mangroves in the Lagoon is 1.04 hectares and that of seagrasses is 264 hectares. Although mangroves were once flourishing in the Lagoon, the area of seagrasses now overshadows that of mangroves. For the value per ton of sequestered carbon, this study uses the market price of carbon instead of the social cost of carbon. The reason for this is that this value gives important practical insights to policy makers, as it shows the amount of money that the Lagoon might yield on the carbon market (van Beukering & Wolfs, 2012). In addition, there is no consensus among scientists on the value of the social cost of carbon (Anthoff & Tol, 2013; Nordhaus, 2017; Stern, 2007). The market price of carbon in the EU carbon market is currently €27.17 ($30.43) per ton of carbon. Consequently, as the calculations in Table 10 show, the total current carbon sequestration value of the Lagoon is $11,158 per year.

Table 10: Current carbon sequestration value of the Lagoon

Ecosystems	Yearly carbon sequestration per hectare	Market price/t	Value per hectare	Surface area in the Lagoon	Carbon sequestration value
Mangroves	2.26 t/ha/y	$30.43	$68.77	1.04 ha	$71.52/y
Seagrasses	1.38 t/ha/y	$30.43	$41.99	264 ha	$11,086/y
Total	**-**	**-**	**-**	**-**	**$11,158/y**

The tourism value of the Lagoon

To obtain the tourism value of the Lagoon, one would ideally conduct a tourism survey. In a tourism survey, one could reveal the WTP of tourists for environmental management of the Lagoon or for changes in the levels of attributes (water quality, habitat, etc.). This would yield the consumer surplus of the tourism value. In the tourism survey, one could also ask tourists about the expenditures they made on activities that depend on the ecosystem services provided by the Lagoon (e.g. kayaking and boat rental). This information would make it possible to calculate the producer surplus of the tourism value. However, due to time and other resource constraints, it was not possible to conduct a tourism survey on Saint Martin and, hence, value transfer is used.

The tourism value: consumer surplus

For value transfer, it is important to use observations from study sites that are similar to the case at hand. Therefore, to obtain the consumer surplus of the tourism value of the Lagoon, this study makes use of the results of a tourism survey held on two Caribbean islands that are near to Saint Martin: Sint Eustatius and Saba. For these islands, the willingness to pay of tourists for coastal water quality has been estimated (van de Kerkhof, Schep, van Beukering, & Brander, 2014; van de Kerkhof et al., 2014). The attribute 'coastal water quality' in these studies included both water quality and coral reef quality. The beaches and coral reefs of Saint Martin are the main attraction for tourists for doing activities such as diving, snorkeling and fishing. As the water quality of the Lagoon directly affects the water quality and the reef quality of nearby coastal waters, this attribute is highly relevant for estimating the economic value of the Lagoon for tourists.

Currently, the water quality of the coastal waters surrounding the Lagoon can be designated as moderate. Although the poor to moderate water quality of the Lagoon is already impacting the quality of the nearby coastal waters and coral reefs (Daily Herald, 2019), in most areas tourists can still enjoy beach and reef recreation. The study on Sint Eustatius found that tourists' WTP per day of stay for moderate coastal water quality instead of poor coastal water quality is $1.97. For going from poor to good coastal water quality the WTP is $3.21, while for going from poor to excellent quality it is $3.47. For Saba, higher WTP values were found. To be conservative, the WTP values for Sint Eustatius are applied in this study. In addition, the studies on Saba and Sint Eustatius were about the coastal water quality of the coastline of the whole island. The Simpson Bay Lagoon affects the coastal water quality of only about 25% of the coastline of Saint Martin (based on measurements in Google Earth). Consequently, the WTP values are multiplied by 0.25. The resulting WTP values for each level of coastal water quality are shown in Figure 11.

As currently the coastal water quality can be designated as moderate, the WTP per day of stay for the current situation is $0.4925 ($1.97*0.25). The average number of days that stay-over tourists stay on Saba and Sint Eustatius are 8.69 and 12.3 days, respectively. Again, the conservative value, which is 8.69 days, is assumed for Saint Martin. Cruise passengers are assumed to stay on average one day. For tourism numbers, this study uses data from 2016. In 2016, an estimated 1,668,863 cruise passengers and 528,154 stay-over tourists visited the island (Gilders, 2018). With this information, the current tourism value of the Lagoon can be calculated. These calculations are shown in Table 11. Based on the aforedescribed methodology, the yearly consumer surplus of the tourism value of the Lagoon is $3,082,322.

Figure 11: WTP of tourists for different levels of coastal water quality

Table 11: The consumer surplus of the tourism value of the Simpson Bay Lagoon, related to the Lagoon's impact on coastal water quality

Type of tourist	Number of tourists per year	WTP per day of stay	Number of days stayed	Tourism value per year in US $
Cruise	1,668,863	$0.4925	1	$821,915
Stay-over	528,154	$0.4925	8.69	$2,260,407
Total	-	-	-	**$3,082,322**

The tourism value: producer surplus

Obtaining the producer surplus of the Lagoon directly from tourist expenditures on other islands is prone to lead to unreliable results. The reason for this is that these expenditures are based on the services of multiple (non-lagoon) ecosystems, while at the same time tourists are not asked about how their expenditures would change as a result of changes in the environment. This makes it particularly hard to estimate the producer surplus under different environmental management scenarios. Consequently, in order to estimate the producer surplus of the tourism value of the Lagoon, this study looks at the ratios of producer/consumer surplus that were found in other studies on Caribbean islands. In Sint Eustatius, the producer surplus was 2.96 times as high as the consumer surplus (Fenkl et al., 2014). For Bonaire the ratio was 1.08 (Schep at al., 2013), while for Saba the ratio was 3.79 (van de Kerkhof et al., 2014). To be conservative, the ratio of 1.08 is used. As the yearly consumer surplus was estimated as being $3,082,322, the producer surplus is estimated to be $3,082,322*1.08=$3,328,907.

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Total tourism value of the current environmental state of the Lagoon

The consumer and producer surplus of the tourism value of the current environmental state of the Lagoon are $3,082,322 and $3,328,907, respectively. This leads to a total tourism value of $6,411,229. As this result relies on some heavy assumptions, and is likely to be a conservative estimate, sensitivity analyses on the tourism value will be conducted to see how this influences the cost-benefit outcomes.

The fishery value of the Lagoon

At the moment, the Simpson Bay Lagoon might not be identified as a location that is of high value for fisheries, mainly due to its polluted waters. However, the Lagoon has an enormous potential for both recreational and commercial fisheries. Seagrasses and mangroves in the Lagoon provide a suitable reproductive habitat and nursery ground for many fish species. Many of these

Table 12: Fishery value of the Lagoon in its current environmental state

Ecosystems	Fishery value per unit/time	Surface area in Simpson Bay Lagoon	Fishery value per year in US $
Mangroves	$627/ha/y	1.04 ha	$652
Seagrasses	$38/ha/y	264 ha	$10,032
Total	**-**	**-**	**$10,684**

fish species migrate to Saint Martin's nearby coral reefs when they are grown up (Gilders, 2018). Several studies have investigated the economic value of mangroves and seagrasses for fisheries. Based on 51 valuation studies, Salem and Mercer find that the mean yearly fishery value (commercial and recreational) of a hectare of mangroves is $23,613. The median value is $627. As a conservative estimate, the median instead of the mean value is used, as the mean is much higher than the median due to a few outliers. There have also been some studies done on the recreational and commercial fishery value of seagrasses. Studies by Jackson et al.(2015), Samonte-Tan et al. (2007), and Unsworth et al. (2010) find, respectively, that the fishery value of seagrasses is $36.36, $38, and $63 per hectare. Again, the median value of $38 is used in this study. The current area of mangroves and seagrasses in the Lagoon is 1.04 and 264 hectares, respectively (see Annex B for a description). This leads to a total annual fishery value of $10,684, as shown in Table 12.

To test the robustness of this finding, a second methodology is employed. This method assesses the WTP of local residents for recreational fishing on other Caribbean islands and is described in Annex D.5. Utilizing this second method leads to an annual fishery value that is close to the $10,684 found when applying the first method, and therefore enhances the robustness of this finding. As the first method encompasses both recreational and commercial fisheries, and because it is more straightforward to relate the environmental management scenarios to changes in mangroves and seagrasses, solely this method will be applied in the remainder of this study.

5.1.3 The total economic value of the Lagoon in its current environmental state

Table 13 provides the yearly economic value of the ecosystem services provided by the Simpson Bay Lagoon when in its current environmental state. Currently, the local and cultural value, the carbon sequestration value, the tourism value and the fishery value together have an

Table 13: Total yearly economic value of the ecosystem services provided by the Lagoon in its current environmental state

Value	**Attribute levels / relevant indicators**	**Yearly value in US $**
Local and cultural	-	-
Storm protection	No change in damage from storms	$4,711,926
Water quality	Low to moderate water quality	$2,994,702
Habitat for species	No change in habitat for species	$5,513,102
Carbon sequestration	1.04 ha mangroves, 264 ha seagrasses	$11,158
Tourism	Moderate coastal water quality	$6,411,229
Fishery	1.04 ha mangroves, 264 ha seagrasses	$10,684
Total	**-**	**$19,652,801**

economic value of $19,652,801 per year. By far the largest part of this economic value comes from the local and cultural value, and the tourism value.

5.2 Cost-benefit analysis of future environmental management scenarios for the Lagoon

The following sections present the cost-benefit analysis of the environmental management scenarios for the Simpson Bay Lagoon. To practically execute a cost-benefit analysis, certain assumptions have to be made. These assumptions are summarized in Annex E.1. All the expected effects of the management scenarios are assumed to occur in 30 years, and in between these years the ecosystem services linearly move towards their envisaged long-term levels.

5.2.1 Costs and benefits of the baseline scenario

In the baseline scenario, the ecological integrity of the Lagoon deteriorates further. Sewage pollution will continue, and this will not be counterbalanced with mangrove restoration. This will lead to detrimental water quality. This subsequently will result in the massive die-off of seagrasses because of algae blooms, thereby decreasing habitat for species. The bad ecological state of the Lagoon also reduces the resilience of the Lagoon to provide storm protection. Hence, in this scenario, after 30 years, no local or cultural value can be attached to the Lagoon. In fact, the Lagoon is more likely to become a plague than a blessing for the population of Saint Martin. The bad water quality of the Lagoon will also deteriorate the water quality of the surrounding coastal waters, making it of no value to tourists. Following the methods used in this study, there will still be a low fishery and carbon sequestration value, as not all seagrasses and mangroves will disappear (see Annex B). Table 14 shows that this will lead to a TEV of merely $7,763. An explanation of this calculation is provided in Annex E.2. As in the baseline scenario there will be no extra management, the costs of this scenario are zero. Figure 12 shows the non-discounted annual TEV for the period 2020-2050 in the baseline scenario. Although currently the annual TEV is still $19.7 million, it will decline to near zero in 2050.

5.2.2 Costs and benefits of the sewage treatment plant scenario

Constructing and maintaining a sewage treatment plant will strongly reduce sewage inflow into the Lagoon, which currently is the main reason for the poor water quality of the Lagoon. Hence, in this scenario the water quality will be high. The improved water quality is expected to

Table 14: The annual total economic value of the ecosystem services provided by the Simpson Bay Lagoon in 30 years under the baseline, sewage plant, and mangrove restoration scenario

Value	Attribute levels / relevant indicators	Total economic value
	Baseline scenario	
Local and cultural	-	-
Storm protection	40% more storm damage	$0
Water quality	Low water quality	$0
Habitat for species	40% less habitat	$0
Carbon sequestration	1.04 ha mangroves, 88 ha seagrasses	$3,767
Tourism	Poor coastal water quality	$0
Fishery	1.04 ha mangroves, 88 ha seagrasses	$3,996
Total	**-**	**$7,763**
	Sewage treatment plant scenario	
Local and cultural	-	-
Storm protection	No change in storm damage	$4,711,926
Water quality	High water quality	$8,444,791
Habitat for species	20% more habitat	$7,367,803
Carbon sequestration	1.04 ha mangroves, 440 ha seagrass	$18,549
Tourism	Good coastal water quality	$10,446,724
Fishery	1.04 ha mangroves, 440 ha seagrass	$17,372
Total	**-**	**$31,007,164**
	Mangrove restoration scenario	
Local and cultural	-	-
Storm protection	40% less storm damage	$7,368,429
Water quality	Moderate water quality	$5,400,401
Habitat for species	40% more habitat	$8,621,327
Carbon sequestration	54.565 ha mangroves, 440 ha seagrass	$22,230
Tourism	Moderate coastal water quality	$6,411,229
Fishery	54.565 ha mangroves, 440 ha seagrass	$50,932
Total	**-**	**$27,874,548**

lead to an increase in the area of seagrasses from 264 hectares now to 440 hectares in 30 years (see Annex B). This increases the habitat for species in the Lagoon. As the increase in habitat will not be as much as in the mangrove restoration scenario, an increase of 20% is assumed. Better water quality does not lead to better storm protection. However, the resulting increase in seagrasses improves the resilience of the lagoon ecosystem to continue providing ecosystem services such as storm protection (Guannel et al., 2016). Hence, no change in damage from storms is expected. The increase in seagrasses will also boost the carbon sequestration and fishery value of the Lagoon. Finally, the high water quality of the Lagoon will allow the coastal water quality to go from moderate to good. This strongly enhances the tourism value. The coastal water quality will not be excellent, as other pollution sources as well as climate change affect the coastal water quality. Table 14 displays that in this scenario, the annual TEV will be $31,007,164 in 30 years. The exact calculation of this value is presented in Annex E.3. Figure 12 shows the annual TEV for the period 2020-2050, assuming that the plant will be built in 2020. The TEV gradually increases from around $19.7 million in 2020 to $31 million in 2050. The increase in the TEV is non-linear due to the decreasing marginal WTP of the households of Saint Martin for improving ecosystem service provisioning.

The construction of a sewage treatment plant is costly. The costs of building a sewage treatment plant in the lagoon area are estimated at $15,820,000. Besides these initial construction costs, there are also yearly operation and maintenance costs. The yearly operation and maintenance costs are estimated at $1,582,000. An explanation and motivation for these cost figures are provided in Annex E.4. Figure 13 displays these costs graphically.

5.2.3 Costs and benefits of the mangrove restoration scenario

In the mangrove restoration scenario, more than 50 hectares of mangroves will be planted, leading to a total mangrove area of 54.565 hectares (see Annex B). This strong increase in mangroves will enhance many of the ecosystem services provided by the Lagoon. First of all, mangroves are very important for storm protection, as their root systems attenuate wave energy, and thereby weaken the force of storms and hurricanes (Barbier, 2015). Hence, in this scenario storm damage is expected to decrease with 40% (the sensitivity of the results to these exact percentage estimates are tested in the sensitivity analyses). Mangroves also have an important water filtering function, which will improve the water quality. The water quality is expected to improve from ‘low to moderate’, to moderate. The reason why no higher water quality is assumed, is that sewage pollution will continue in this scenario. The increase in mangrove stands and the improvement in water quality also have a positive effect on seagrasses, of which the area is expected to increase to 440 hectares (see Annex B). Both mangroves and seagrasses provide important habitats for species, and therefore habitat for species is expected to increase with 40% in this scenario. The increase in the area of mangroves and seagrasses in the Lagoon also leads to a higher carbon sequestration and fishery value. Lastly, the increase in the water quality of the Lagoon to a moderate quality will halt the deterioration of the nearby coastal waters, so that the coastal water quality remains moderate. Table 14 shows that in this scenario, the annual TEV is $27,874,548. Annex E.5 presents the exact calculation of this value. Figure 12 shows the annual

TEV for the period 2020-2050 in the mangrove restoration scenario. Over time, the TEV increases from $19.7 million now to almost $28 million in 2050.

In the mangrove restoration scenario, 53.525 hectares of mangroves are planted and maintained. This requires substantial investments in mangrove seeds, labor, and equipment. The total cost figures related to these investments are provided, explained, and justified in Annex E.6. This study has found that the total initial costs of mangrove restoration are expected to be $319,883 ($5,976/ha). Besides these initial costs, there are also yearly maintenance and monitoring costs. These costs decrease linearly from $10,812 in the first year to $736 in the thirtieth year. These cost figures are presented in Figure 13.

5.2.4 Comparing the TEV, NPV, and BCR of the management scenarios

Figure 12 shows the TEV of the ecosystem services provided by the Lagoon under the baseline, mangrove restoration, and sewage plant scenario. The TEV is highest in the sewage plant scenario, although there is not much difference compared to the mangrove restoration scenario. The added benefits of these environmental management scenarios compared to the baseline scenario are substantial and are rising over time. The costs of the management scenarios are shown in Figure 13. As the costs of a sewage treatment plant are much higher than the costs of mangrove restoration, the costs are shown on a logarithmic scale.

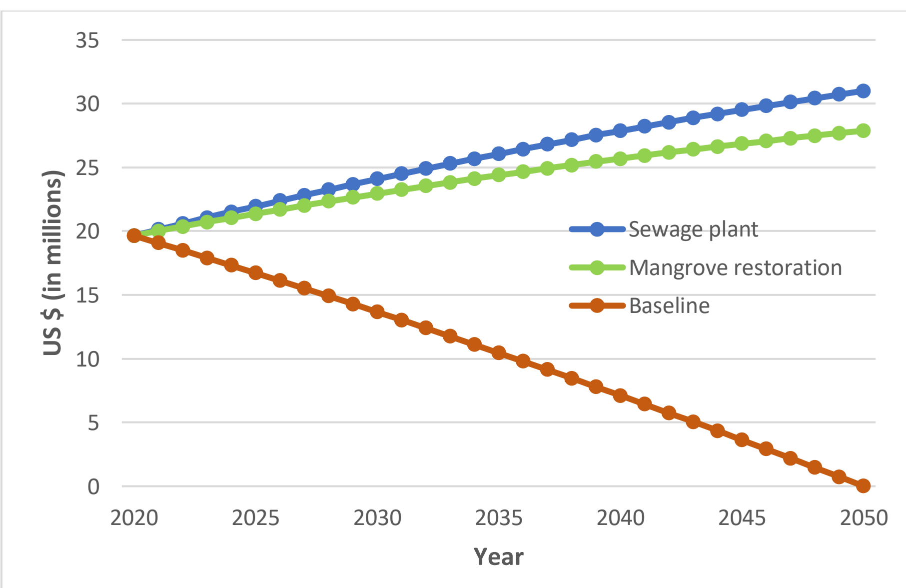

Figure 12: Comparing the TEV of the baseline, mangrove restoration, and sewage plant scenario

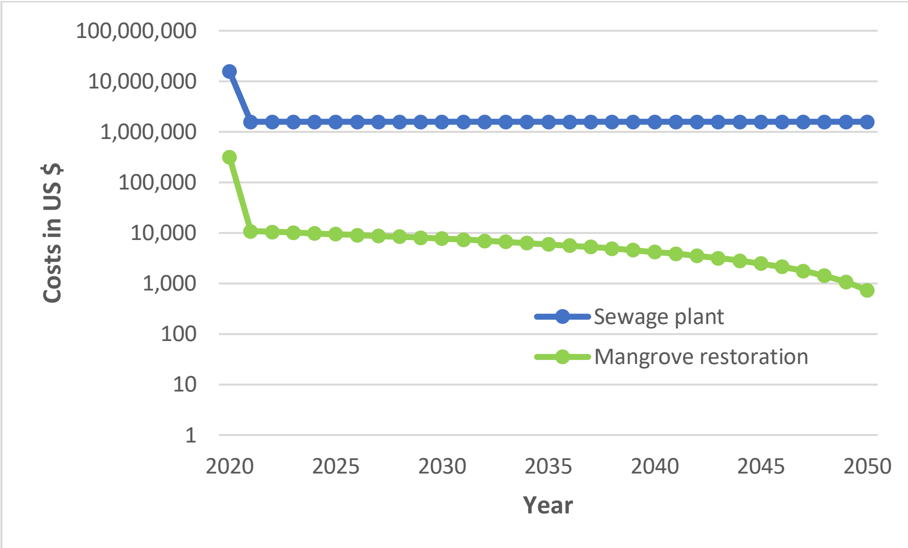

Figure 13: Yearly costs of the environmental management scenarios

To measure if the added benefits compensate for the costs of the management scenarios, the net present value (NPV) and the benefit-cost ratio (BCR) are two useful metrics. Figure 14 shows the NPV of the sewage plant and the mangrove restoration scenario for different discount rates. Naturally, the NPV decreases when the discount rate increases. Even though the TEV is higher in the sewage plant scenario, the NPV is higher in the mangrove restoration scenario. This is due to the much higher costs of the sewage plant compared to mangrove restoration. Nevertheless, for both scenarios the NPV is high, ranging from around $425 million at a discount rate of 0% to $50 million for mangrove restoration and $25 million for the sewage plant scenario at a discount rate of 15%. As the NPV for both scenarios is always higher than zero, both the restoration of mangroves and the construction of a sewage treatment plant would be economically more beneficial than the baseline scenario. This also follows from the benefit-cost ratios displayed in Figure 15. For both scenarios, the BCR>1, indicating that the present value benefits exceed the present value costs. For the sewage plant scenario, the BCR ranges from 7.63 at a discount rate of 0% to 1.88 at a discount rate of 15%. These BCR's are very similar to the BCR's found in a similar study on Bonaire, where also the costs and benefits of constructing a sewage plant were assessed (van der Lely et al., 2013). For the mangrove restoration scenario, the BCR is very high. The low costs of this measure are the main reason for this. For instance, at a 3% discount rate, the present value benefits are around $250 million whereas the present value costs are less than $0.5 million. Although certainly striking, finding such high BCR values for low-cost measures is not unusual. Van der Lely et al. (2013), for instance, find a BCR of 227 for a 'conservation' scenario on Bonaire.

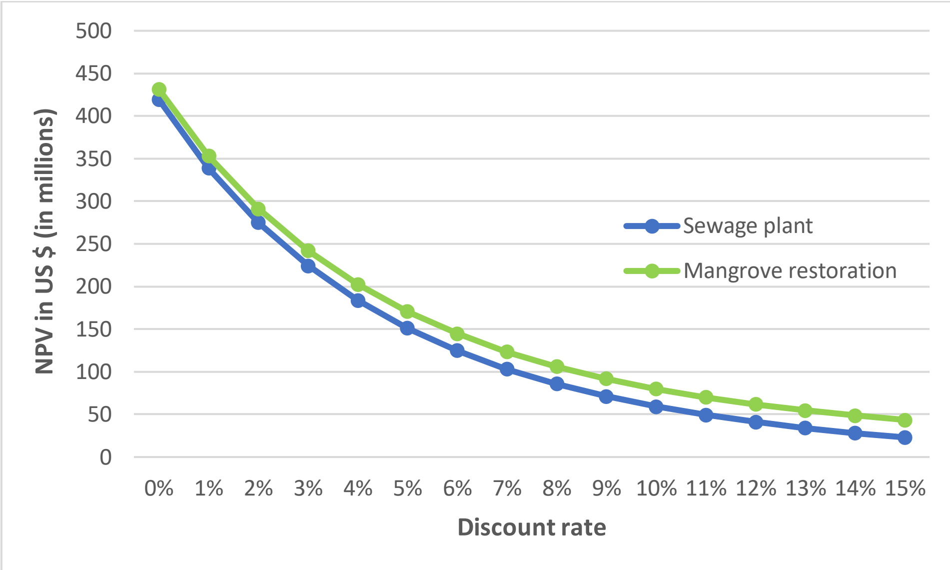

Figure 14: Comparison of the NPV of the mangrove restoration and sewage plant scenario

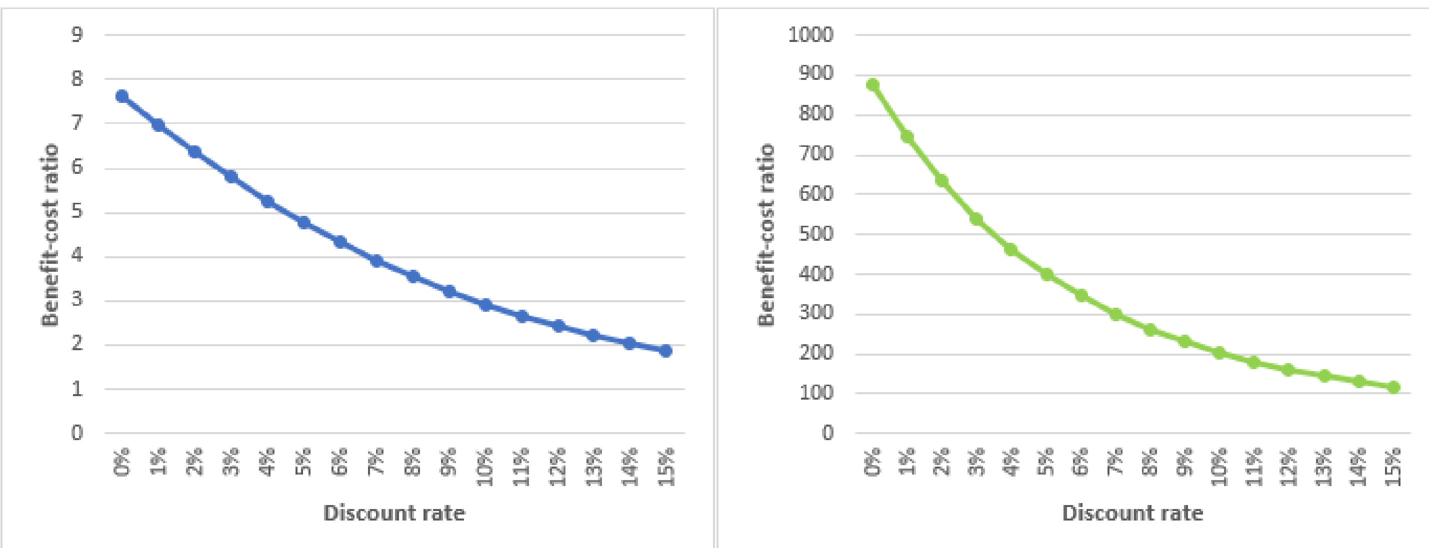

Figure 15: Benefit-cost ratio of the sewage plant (left) and mangrove restoration scenario (right)

Overall, the findings seem to indicate that mangrove restoration would economically be the most beneficial environmental management scenario. However, some critical assumptions have been made along the way. The extent to which the previous findings withstand changes in these assumptions is tested in the upcoming sensitivity analyses.

5.2.5 Sensitivity analyses

This section executes five sensitivity analyses, which scrutinize the sensitivity of the main results to changes in critical assumptions underlying the economic valuation and cost-benefit analysis. Sensitivity to the following changes was assessed: halving the effects of the environmental management scenarios on storm damage and habitat for species, assuming linear instead of non-linear WTP functions, including solely households living close to the Lagoon in the WTP calculation, assuming higher tourism values, and assuming 50% higher costs of the management scenarios. A comprehensive explanation of and motivation for these sensitivity analyses can be found in Annex F. Table 15 displays the results. It shows the NPV and BCR of mangrove restoration and the construction of a sewage plant for each sensitivity analysis, and for four different discount rates. Graphs of the TEV, NPV, and BCR can be found in Annex F.

The sensitivity analyses reveal two important findings. First, for each sensitivity analysis NPV>0 and BCR>1 for both mangrove restoration and the sewage plant, for all discount rates. Hence, even when one assumes that the costs of the management scenarios are 50% higher than expected, or that only people living close to the Lagoon attach a value to the Lagoon, the benefits of environmental management still exceed the costs. Second, the BCR, and in most cases the NPV, is higher for mangrove restoration than for the sewage plant scenario. Only when one assumes higher tourism values or lower impacts on storm damage and habitat, the NPV of a sewage plant is higher than that of mangrove restoration, although only for low discount rates.

Table 15: Sensitivity of the cost-benefit outcomes to changes in core assumptions

	NPV (in million $)				**BCR**			
	0%	*5%*	*10%*	*15%*	*0%*	*5%*	*10%*	*15%*
Lower percentage changes in storm damage and habitat								
Mangrove restoration	387	152	71	38	786	357	180	103
Sewage plant	405	145	56	22	7.40	4.62	2.84	1.82
Linear WTP functions								
Mangrove restoration	431	170	80	44	876	400	203	117
Sewage plant	399	145	57	22	7.31	4.60	2.85	1.85
Including only households in the lagoon area								
Mangrove restoration	208	82	38	21	422	193	98	56
Sewage plant	203	65	19	0.96	4.21	2.63	1.61	1.04
Higher tourism value								
Mangrove restoration	523	207	97	53	1062	485	247	141
Sewage plant	569	210	87	38	9.99	6.24	3.83	2.46
Higher costs of management scenarios								
Mangrove restoration	431	170	80	43	584	267	136	78
Sewage plant	388	131	44	10	5.08	3.18	1.95	1.25

6. Discussion

The previous sections have presented and explained the total economic value of the Lagoon, and the cost-benefit analysis of future environmental management scenarios. The outcomes of the cost-benefit analysis reveal that mangrove restoration and the construction of a sewage treatment plant improve social welfare more than a business-as-usual scenario. Nevertheless, the NPV's and BCR's of mangrove restoration are almost always higher than those of the sewage plant scenario. This is due to the low investment and maintenance costs of mangrove restoration, which is exemplary for nature-based solutions for ecosystem service enhancement (Temmerman et al., 2013). This finding provides support to H1, which states that a nature-based solution (mangrove restoration) is economically more favorable than a man-made solution (sewage plant) for enhancing ecosystem service provisioning. Consequently, this study provides further empirical evidence that the favorability of nature-based solutions does not only hold in theory, but also in practice (Eggermont et al., 2015; Keesstra et al., 2018; Nesshöver et al., 2017). Nevertheless, the sensitivity analyses indicated that for low discount rates, the NPV of the sewage plant is sometimes higher than that of mangrove restoration, especially if we assume higher tourism values. Hence, Keesstra et al.'s (2018) notion of 'superior' nature-based solutions might not hold here.

Besides adding to the discussion on nature-based solutions, this study also contributes to the literature on the valuation of ecosystem services. It has namely provided the first economic valuation of a Caribbean coastal lagoon, which increases the, in general, small stock of knowledge about the economic value of coastal lagoons (Newton et al., 2018). In the choice experiment, the attributes significantly of value to respondents were storm protection, water quality, habitat for species, and monthly contribution. The high values attached to storm protection and water quality correspond well with de Groot et al. (2012), who find that the most valuable services provided by coastal and estuarine ecosystems are regulating services (e.g. storm protection and wastewater treatment). The insignificant results for recreation and tourism are surprising, as previous studies on coastal and estuarine ecosystems have found high recreational values (Barbier et al., 2011; Ghermandi & Nunes, 2013), while at the same time the economy of Saint Martin is highly dependent on tourism. Nevertheless, it could be that concerns about tourism- and recreation-related overcrowding and environmental harm have taken the overhand on Saint Martin (Brander et al., 2007; Nahuelhual et al., 2013).

This study also provides two important insights on the methodologies often employed in valuation exercises. First, the MNL model predicted much higher WTP values than the RPL model. This supports the finding that the type of model used for analyzing the choice data can strongly influence the results (Hensher, Rose, & Greene, 2015). Therefore, future studies are encouraged to apply multiple types of models when conducting WTP estimates. Second, this study again shows that choice experiments lead to higher WTP estimates than contingent valuations (Ryan & Watson, 2009; Stevens et al., 2000). The average WTP from the contingent valuation study was $13.76, while in the choice experiment the WTP for high water quality already exceeded $25. This is problematic, as valuation studies often utilize solely one of these methods (Mahieu et al., 2015). Employing both methods is recommended, as it can provide a more balanced picture of the WTP.

Despite its contributions, this study certainly has some limitations. First, as discussed earlier, the choice experiment method often leads to inflated WTP estimates. Second, when random sampling was not possible, convenience sampling was used for the household surveys. Using convenience sampling as a sampling strategy increases self-selection bias, and might lead to the overrepresentation of some parts of the population (Costigan & Cox, 2001; de Leeuw et al., 2008). For instance, people committed to the environment might have been more likely to participate in the survey, which could have led to a further overestimation of the average WTP of the population of interest. Third, the value transfer results probably do not provide a fully accurate picture of the true value of the Lagoon. Although useful and necessary in this case, the generalizations of the value transfer method ignore many of the case-specific complexities involved (Costanza et al., 2014). Nevertheless, the conservative estimates used for the value transfer might have compensated for the inflated WTP values of the choice experiment. Finally, this study only appraises the economic value of the Lagoon, and does not shed a light on ecological, ethical, intrinsic and other non-monetary values (Schröter et al., 2014). These alternative values are surely not subordinate to economic values and considering these values would likely make an even stronger case for the ecological restoration of the Lagoon.

Overall, like many studies before, the results of this study illustrate the benefits of nature protection. In an era of rapid demographic changes, looming climate change, and the proliferation of environmental threats, it is imperative to cherish the natural capital that is still left on this planet. Especially for small island states, such as Saint Martin, which are highly vulnerable to (future) climate change impacts, it is of vital importance to have well-functioning ecosystems (Ebi et al., 2006; Mercer et al., 2012). The societal and ecological benefits of more active (nature-based) environmental management as found in this study are not only relevant for Saint Martin. The same results would likely hold for other Caribbean coastal wetlands and societies, which suffer from similar problems as the case study presented here (Yáñez-Arancibia et al., 2011).

7. Conclusion

The Simpson Bay Lagoon in Saint Martin is threatened by pollution and degradation due to its undervaluation by decision makers. This has detrimental impacts on the ecological integrity of the Lagoon and on the local livelihoods that depend on the Lagoon's provisioning of ecosystem services. At the same time, there is only little scientific knowledge about the value and management of coastal lagoon ecosystems in general, and in the Caribbean in particular. Therefore, this study aimed to answer the following research question: "*What is economically the most favorable environmental management scenario for enhancing ecosystem service provisioning by the Simpson Bay Lagoon?"* It has done so by scrutinizing two sub-research questions.

The first sub-research question was: *"What is the total economic value of the ecosystem services provided by the Simpson Bay Lagoon?"* The second sub-research question asked: *"What are the economic costs and benefits of the environmental management scenarios for enhancing ecosystem service provisioning by the Simpson Bay Lagoon?"* This study held a choice experiment under local households to estimate the local, recreational and cultural value of the Lagoon, and conducted value transfer to evaluate the carbon sequestration, tourism and fishery value. The choice experiment data were analyzed with the use of an RPL model. The choice experiment results revealed that only the Lagoon's storm protection, water quality, and habitat services are of significant value to the residents of Saint Martin. Parameter estimates for recreation and the number of stay-over tourists were insignificant. Overall, the findings show that the current annual TEV of the Lagoon is $19,652,801. The major share of this value comes from the local and cultural value, and the tourism value of the Lagoon. However, the continued provisioning of valuable ecosystem services by the Lagoon is in danger. If current pollution and degradation continue, the expected TEV of the Lagoon is expected to be near zero in 30 years. Constructing a sewage treatment plant or mangrove restoration, on the other hand, would increase the TEV to $31,007,164 or $27,874,548, respectively. The cost-benefit analysis has shown that the added benefits of these two environmental management scenarios outweigh their costs and that they are therefore economically more beneficial than the business-as-usual scenario. This even held for high discount rates and stringent sensitivity analyses. Nevertheless, the BCR's and the NPV's of mangrove restoration were higher than those of the sewage treatment plant under almost all conditions. Consequently, the overall answer to the main research question is that mangrove restoration is economically the most favorable environmental management scenario for enhancing ecosystem service provisioning by the Simpson Bay Lagoon.

These findings are not only academically relevant by providing empirical evidence for the economic favorability of nature-based solutions, such as mangrove restoration, for enhancing ecosystem service provisioning; they also have important practical implications. The rehabilitation of the Lagoon's ecosystem through mangrove restoration, or to a lesser extent the construction of a sewage treatment plant, would improve the livelihoods of many people on Saint Martin. Hence, decision makers from both the Dutch and the French side of Saint Martin should overcome their disagreements and work together to improve the ecological integrity of the Lagoon. However, the assessed management scenarios are not standalone measures. A proper mooring system should also be put in place, such that anchoring boats cannot destroy the seagrass habitats in the Lagoon. Furthermore, the dumping of wastewater in the Lagoon by boats should be prohibited, and to facilitate this, sufficient facilities such as pump-out services should be provided. Finally, stronger enforcement of environmental regulations is needed. On the whole, the reputation of the Lagoon as a free haven and dumping location should shift towards that of a pristine environment that must be protected. This does not only apply to the Simpson Bay Lagoon, but also to other Caribbean coastal wetlands which face similar hardships.

Although this study provides important academic and practical insights, there are still many promising avenues for further research on nature valuation and management. First, regarding research on (Caribbean) coastal lagoons, future studies are encouraged to collect primary data on the tourism and fishery value of these ecosystems. In the present study, these values were estimated with value transfer, by using values obtained from studies on non-lagoon ecosystems. These value estimates probably do not fully reflect the unique characteristics of coastal lagoons. Second, future inquiries are recommended to apply multiple methodologies when conducting environmental valuation. This study has shown that the choice for a valuation technique (e.g. choice experiment or contingent valuation) can strongly influence the results. Furthermore, when analyzing choice experiment data, the choice for a multinomial logit or random parameter logit model can be decisive for the final outcomes. Finally, this study encourages more holistic research projects on the valuation of nature that consider both economic and other (non-monetary) values, such as intrinsic and ecological values. Often, both strands of research work in isolation of each other (Schröter et al., 2014). Bundling strengths would lead to a more interdisciplinary and complete picture of the motivations for nature protection.

On a final note, this study has provided further scientific evidence that both society and nature greatly benefit from the protection and restoration of our ecosystems. Although there are still many knowledge gaps that ask for more scientific knowledge generation on this ever so important topic, the real challenge is a political and not a scientific one. A sustainable future is only within reach if political decision makers stand up and put into practice what the large majority of the scientific community tries to tell them for a long time already.

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Appendix

Annex A: Miscellaneous tables

Table A.1: Important and threatened ecosystem services provided by the Simpson Bay Lagoon

		Wetland	Mangroves	Seagrasses	Coral reefs
Provisioning	Sea food (fisheries)	x			x
Regulating	Climate and air regulation	x	x		
	Carbon sequestration	x	x	x	x
	Extreme events	x	x		x
	Wastewater regulation	x	x	x	
	Erosion and soil fertility	x	x		
	Nutrient regulation	x			
	Pollination	x	x		
	Biological control				x
Habitat	Habitat for species	x	x	x	x
	Genetic diversity	x			x
	Nursery ground	x	x	x	
Cultural	Recreational	x	x		x
	Tourism	x	x		x
	Aesthetic	x	x		x
	Education	x	x		x
	Spiritual	x			
	Historical	x			

Note: A green box means that the ecosystem service is identified as important, an orange box means that the ecosystem service is highly threatened, and a red box means that the ecosystem service is important and highly threatened. Source: modified from Gilders (2018)

Table A.2: Stakeholders consulted during the design phase of the choice experiment and survey

Stakeholder	Type of stakeholder	Persons
Environmental Protection in the Caribbean	Environmental organization	Rueben Thompson
Environment Ministry of Dutch Saint Martin	Government	Ildiko Gilders, Johann Sidial, Melissa Peterson, Ruud van Diepen
La Réserve Naturelle de Saint-Martin	Environmental organization	Aude Berger, Julien Chalifour, and two interns
Les Fruits De Mer	Environmental organization	Jennifer Yerkes, Mark Yokoyama
Marine Trade Association Saint Martin	Industry	Brian Deher, Norina Edelman, Robbie Ferron
Nature Foundation Saint Martin	Environmental organization	Tadzio Bervoets
Local residents of Saint Martin	The public	11 local residents, during the pre-test of the choice experiment and survey

Table A.3: Sociodemographic profile of the survey respondents

	Whole sample	Dutch Side	French Side
Number of respondents	219	131	88
Gender (%)			
Female	47.49%	48.09%	46.59%
Male	52.51%	51.91%	53.41%
Age (%)			
18-25	11.42%	10.69%	12.5%
26-35	20.55%	18.32%	23.86%
36-45	21.92%	22.14%	21.59%
46-55	21.00%	23.66%	17.05%
56-65	15.53%	13.74%	18.18%
66+	7.31%	9.16%	4.55%
Refused to answer	2.28%	2.29%	2.27%
Household income per month			
<$500	8.22%	4.58%	13.64%
$500-$900	10.05%	11.45%	7.95%
$1000-$1599	18.72%	17.56%	20.45%
$1600-$2499	13.24%	12.98%	13.64%
$2500-$3499	15.07%	15.27%	14.77%
$3500-$4999	7.31%	6.11%	9.09%
$5000-$6999	3.65%	5.34%	1.14%
$7000-$9999	2.28%	2.29%	2.27%
>$10000	2.28%	2.29%	2.27%
Did not know/refused	19.18%	22.14%	14.77%
Country of birth			
Saint Martin	35.16%	34.35%	36.36%
Elsewhere in the Caribbean	32.88%	38.17%	25.00%
Elsewhere in Latin America	4.57%	5.34%	3.41%
Netherlands mainland	3.20%	4.58%	1.14%
French mainland	12.79%	3.82%	26.14%
North America	4.11%	5.34%	2.27%
Other	6.85%	7.63%	5.68%
Refused	0.46%	0.76%	0.00%
Highest level of education			
No education or primary school	6.39%	4.58%	9.09%
High school	44.29%	47.33%	39.77%
Vocational/technical school	16.89%	14.50%	20.45%
Higher education	30.59%	31.30%	29.55%
Did not know/refused/other	1.83%	2.29%	1.14%
Average household size	3.04 people	2.93 people	3.19 people

Annex B: Estimating the area of mangroves and seagrasses in the Lagoon

Annex B.1: The current area of mangroves and seagrasses in the Lagoon

Mangroves and seagrasses are two of the most important ecosystems present in the Simpson Bay Lagoon. Both ecosystems play an important role in carbon sequestration and the support of fisheries. Previous studies have analyzed the carbon sequestration and fisheries value of mangroves and seagrasses in monetary terms. Hence, by knowing the area of the mangroves and seagrasses present in the Simpson Bay Lagoon, the carbon sequestration and fisheries value of the Lagoon can be estimated. Unfortunately, no official data records on the area of mangroves on the French side of the Simpson Bay Lagoon are available. Furthermore, no studies have identified suitable areas for mangrove restoration in the Lagoon. In addition, there are no official records on the total area of seagrasses for both the Dutch and the French side of the Lagoon. Information on this is essential to properly conduct a value transfer.

To estimate the area of mangroves on the French side of the Lagoon, and to identify suitable areas for mangrove restoration on the whole lagoon, fieldwork by the author was needed. Three

Figure B.1: The author mapping the location and area of mangroves in the Lagoon and potential sites for mangrove restoration (left); the drone used to make aerial photographs of the mangrove stands (right). *Pictures made by Anna Fralikhina (left) and the author (right).*

methods were used for this. First, during a field study, the areas where mangroves are present and the potential sites for restoration were identified (see Figure B.1). Potential areas for mangrove restoration are only those areas where there is currently no development present (e.g. houses, marina's restaurants). Furthermore, there should still be abundant space for vessels in the Lagoon. Second, by mapping out where mangroves are or could be present, it was possible to obtain the total length of the mangrove stands with the use of measurements in Google Earth. To obtain the total area of mangroves, the width of the mangrove stands is also very important. To calculate the average width of the mangrove stands, aerial photos of the mangrove stands were taken with a drone (see Figure B.1). By taking into account that the length of the boat from which the drone was launched was 8 meters, the width of the mangrove stands could be approximated (as both the mangroves and the boat were present on the pictures).

To obtain information on the area of seagrasses in the Lagoon, dive trips should be undertaken. Unfortunately, conducting these dive trips was not feasible for this research project. Hence, to obtain approximations of the current and potential future area of seagrasses in the Lagoon, this study depended on expert judgements by Tadzio Bervoets. Bervoets is the manager of Nature Foundation Saint Martin and the author of many ecological studies on the Simpson Bay Lagoon. He has also done many diving trips in the Lagoon and is, therefore, well aware of the ecological state of the seagrasses in the Lagoon.

By mapping out the presence of mangrove stands during a fieldtrip, by subsequently estimating the length of the mangrove stands in Google Earth, and by approximating the average width of the mangrove stands with the use of aerial photographs, the total area of mangroves present on the French side of the Lagoon could be estimated. The total length of the mangrove stands on the French side of the Lagoon is estimated as 3,047 meters. The average width of the mangrove stands is approximately 3 meters (much wider stands are accompanied with small sporadic stands). This means that the total area of the mangroves that are currently present on the French side of the Lagoon is around 3*3,047=9,141 square meters. For the Dutch side of the Lagoon, already a study has been done on the approximate area of mangroves. Bervoets (2011) finds that the area of mangroves in the Mullet Pond section of the Simpson Bay Lagoon is 880 square meters, and that this equals, approximately, 70% of the total area of mangroves on the Dutch side of the Lagoon. Hence, the total area of mangroves is roughly 1,257 square meters. This area is substantially lower than on the French side of the Lagoon, as on the French side much less development is present.

Hence, the total area of mangroves in the Lagoon is around 10,398 square meters, or 1.04 hectares. Regarding the area of seagrasses, Tadzio Bervoets states that around 30% of the Lagoon is covered with seagrass beds. Given that the Simpson Bay lagoon has an area of 880 hectares, the total area of seagrasses is around 264 hectares. Although mangroves were once flourishing in the Lagoon, the area of seagrasses now overshadows that of mangroves.

Annex B.2: The area of mangroves and seagrasses in the mangrove restoration scenario

Figure B.2 shows the areas in the Lagoon that can potentially be designated for mangrove restoration. These areas are chosen based on on-site observations and aerial photographs. Only areas where currently no development is present are chosen. The total length of the designated area is 10,913 meters (as measured in Google Earth). Mangrove stands can potentially have a width of hundreds of meters (Alongi, 2008). However, this is not realistic for the Simpson Bay Lagoon, as this would seriously hinder boats and would likely imply the destruction of already existing development. Assuming an average potential width of the mangrove stands of 50 meters is more realistic. Currently, there are already mangrove stands at the French part of the Lagoon that have a width of more than 10 meters (as measured by aerial photographs).

Figure B.2: Map of the Simpson Bay Lagoon, where the red lines indicate the areas that could be used for mangrove restoration and/or conservation. *Map created with Google Earth.*

Figure B.3: Small mangrove restoration site on Little Key Island in the Simpson Bay Lagoon. *Picture made by the author.*

Hence, the total area in the Simpson Bay Lagoon that can be restored with mangroves is around 50*10,913=545,650 square meters, or 54.565 hectares. In areas near large-scale development, such as the islands in the Southeast part of the Lagoon, the potential width of the mangrove stands might be lower than 50 meters. Nevertheless, there are also many areas where the potential width could be higher, such as on the long stroke of land on the right part of the Lagoon (see Figure B.2). As 55 hectares of mangroves is not even 10% of the total area of the Lagoon, it is not expected that this would seriously hinder the boats and industry on the Lagoon, if managed wisely. Currently, no large-scale mangrove restoration is taking place in the Lagoon. There is only a very small restoration site at Little Key island, which is maintained by volunteers. Figure B.3 displays a picture of this restoration site.

A larger area of mangroves in the Lagoon will improve the water quality, and will subsequently reduce algae blooms that kill the seagrasses in the Lagoon. Furthermore, there is a symbiotic relationship between seagrasses and mangroves (Bosire, Okemwa, & Ochiewo, 2012; Guannel et al., 2016), in which both ecosystems depend on each other (e.g. for nutrient filtering and wave dissipation). Hence, an increase in the area of mangroves will have a positive effect on the seagrasses in the Lagoon. According to Tadzio Bervoets, in the mangrove restoration scenario the area of seagrasses present in the Lagoon could increase to 50% of the total area of the Lagoon, which equals 0.5*8.8=4.4 square kilometers, or 440 hectares.

Annex B.3: The area of mangroves and seagrasses in the sewage treatment plant scenario

In the sewage treatment plant scenario, the area of mangroves is expected to remain the same. According to Tadzio Bervoets, the bad water quality in the Lagoon does not affect the mangroves in the Lagoon. Hence, an improvement in the water quality due to the construction of a sewage treatment plant is not expected to increase the number of mangroves. According to Tadzio, the area of seagrasses in this scenario is expected to increase to 50% of the total area of the Lagoon, which equals 440 hectares. The reason for this is that the construction of a sewage treatment plant will have the most beneficial effect on the water quality. This will strongly reduce the occurrence of algae blooms that are currently having a devastating effect on the seagrasses.

Annex B.4: The area of mangroves and seagrasses in the baseline scenario

In the business-as-usual scenario, the area of mangroves is expected to remain unchanged. As explained earlier, the bad water quality of the Lagoon does not seem to adversely affect the mangroves in the Simpson Bay Lagoon. According to Tadzio Bervoets, the area of seagrasses is expected to decrease to 10% of the total area of the Lagoon. This equals an area of 0.10*880=88 hectares. The rationale for this is that when no extra management will be put in place, the water quality in the Lagoon will deteriorate further. This will strongly increase the incidence of algae blooms. By smothering the seagrass beds, and by depleting the oxygen levels in the Lagoon, these algae blooms will likely kill most of the remaining seagrasses.

Annex C: Explanation of the chosen attributes and levels

Storm surge protection is extremely relevant for the population of Saint Martin, especially considering the devastating consequences of Hurricane Irma. The mangroves in the Simpson Bay Lagoon provide important storm protection for properties nearby the Lagoon. The massive root systems of mangroves are efficient in attenuating wave energy, so that the force of storms and hurricanes is severely weekend when it reaches the shore (Barbier, 2015). Hence, increasing or decreasing the area of mangroves in the Lagoon leads to respectively less or more damage from storms to property nearby the Lagoon. The attribute levels were decided upon in consultation with stakeholders, and by taking into account the envisaged effects of the management scenarios. This led to the following attribute levels: 40% more damage, no change in damage, 20% less damage, 40% less damage.

Water quality is also highly relevant. In the last decades, the water quality of the Lagoon has deteriorated significantly due to pollution and the destruction of mangroves. To keep the choice tasks simple, the levels that were chosen for this attribute were low, moderate and high. To make the attribute more familiar to the local population, water quality is related to the smell and clarity of the water. This is also depicted in the pictograms on the choice card.

The third attribute in the choice card is **habitat for species**. Seagrasses and mangroves in the Lagoon provide important habitat for many species, such as birds, turtles and fishes. Habitat for species in the Lagoon will either decrease, stay the same, or increase in the future depending on the development of seagrasses and mangroves. The percentage changes are again decided upon by stakeholder consultations, and by considering the anticipated effects of the management scenarios: 40% less habitat, no change in habitat, 20% more habitat, 40% more habitat.

Recreation has also been identified as being important for the local population of Saint Martin. Due to its bad ecological state, much less recreational activities are currently practiced on the Lagoon. To keep choices simple and understandable, the levels of the suitability for recreation attribute are low, moderate and high. The pictograms in the choice card depict familiar recreational activities such as sailing, fishing, and swimming. Swimming is only shown when suitability for recreation is depicted as high.

The fifth attribute relates to the number of **stay-over tourists** visiting Saint Martin. Most local people on both the French and the Dutch side of Saint Martin are dependent on tourism for their income. Stay-over tourists are expected to be more likely to come or return to Saint Martin when the island's environment is in a pristine state. As the Simpson Bay Lagoon does not affect the whole natural environment of Saint Martin, it was decided that the levels for this attribute should not include drastic changes in the number of stay-over tourists. Consequently, the chosen levels were: 20% less stay-over tourists, no change in stay-over tourists, 10% more stay-over tourists, and 20% more stay-over tourists.

Finally, a **monthly contribution** was chosen as the payment vehicle. A contribution implies that payment is mandatory, but it does not have the negative connotation of a fee or tax. The levels for the payment vehicle are set at 0, 2, 5, 10 and 20 US dollars per month. Although initially it was expected that $20 per month would be too much money for the local population of Saint Martin, the pre-test results indicated that this was not the case.

Annex D: Chapters related to the survey, choice experiment, and value transfer results

Annex D.1: Sociodemographic representativeness of the sample

To test the sociodemographic representativeness of the sample, chi-square tests are conducted. In order to test the representativeness, it is vital that official statistics are available with which the sample statistics can be compared. For both the Dutch and the French side of Saint Martin it was very hard to find statistics that fulfilled this requirement. Fortunately, for the Dutch side of the island, the statistician Joy-Ann van Arneman had access to individual-level census data from 2011. As legislation prohibits the public sharing of these data, Joy-Ann did the representative tests for us. Representativeness for the Dutch side could be tested for gender, country of origin, age, and education. For the French side, unfortunately, we were only able to test representativeness for gender and born on Saint Martin. Data on the French side of Saint Martin were obtained from INSEE (2016) for the year 2012. For both the Dutch and the French side, the population statistics are already quite outdated, which might affect the outcomes of the representativeness tests. However, more recent reliable data were not available.

Figure D.1 shows the gender distribution of both the French and the Dutch sample. It compares this data with data from official statistics for both sides of the island. The chi-square test tests if the distribution of the sample is significantly different from that of the population. For both the Dutch and the French side, the results of the chi-square test show that the sample is representative for the population in terms of gender ($p>0.05$). As we can see from Figure D.1, males are slightly overrepresented. The reason for this might be that males are more likely to be the head of the household on Saint Martin.

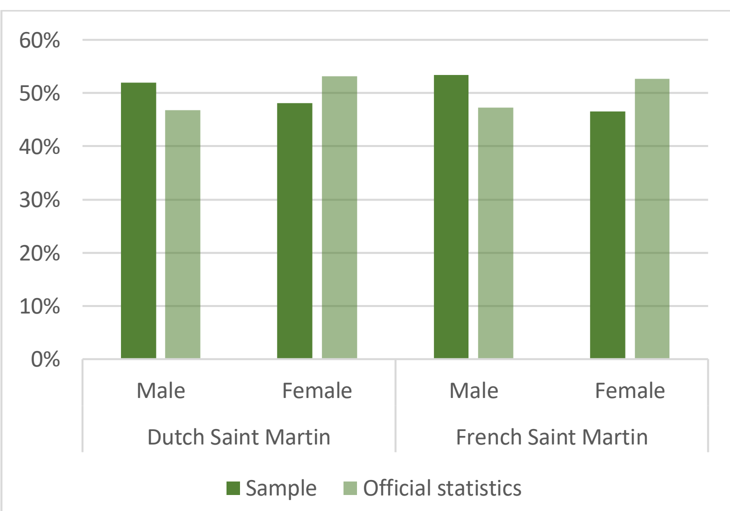

Figure D.1: Gender distribution of sample compared to official statistics

Figure D.2 compares the sample population that stated to be born on Saint Martin with the true population of interest. The results of the chi-square test indicate that for both the Dutch and the French side, the sample is not representative in terms of local origin ($p<0.05$). As Figure D.2 shows, people born on Saint Martin were overrepresented in the sample. The reason for this might be that people who were not able to speak English or French, were not able to fill in the survey. People who do not master any of these two languages are less likely to originate from Saint Martin.

Figure D.3 compares the country of origin of the sample respondents with that of the population for the Dutch side of Saint Martin. The chi-square test indicates that the sample is not representative in terms of origin ($p<0.05$). As the figure shows, people born on Saint Martin are overrepresented, while people born elsewhere in the Caribbean are underrepresented. Again, language issues might be a reason for this.

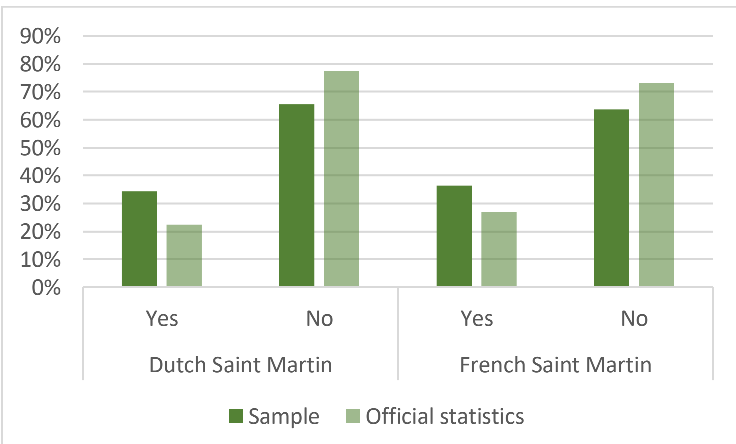

Figure D.2: Distribution of sample compared to official statistics for being born on Saint Martin (yes/no)

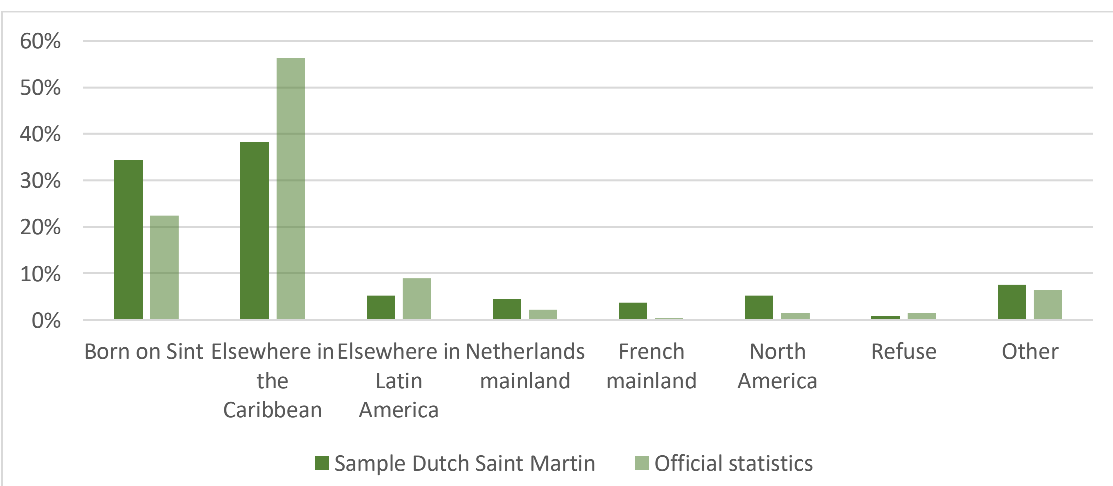

Figure D.3: Distribution of sample compared to official statistics for country of origin

Figure D.4 compares the age distribution of the sample with that of the population for the Dutch side of Saint Martin. The chi-square test indicates that the sample is representative in terms of age ($p>0.05$). Although the age distribution for the sample is not significantly different from that of the population, we can still observe that younger people are slightly underrepresented and older people slightly overrepresented. Perhaps this can be explained by the fact that older (retired) people are more likely to be at home to fill in the surveys.

Finally, Figure D.5 compares the education level distribution of the sample with that of the population for the Dutch side of Saint Martin. The chi-square test shows that the sample is not representative in terms of education level ($p<0.05$). The figure indicates that people who just finished primary education are underrepresented, while those who finished high school or university are overrepresented. Possibly, this can be explained by the fact that the head of the household is more likely to be higher educated than other household members.

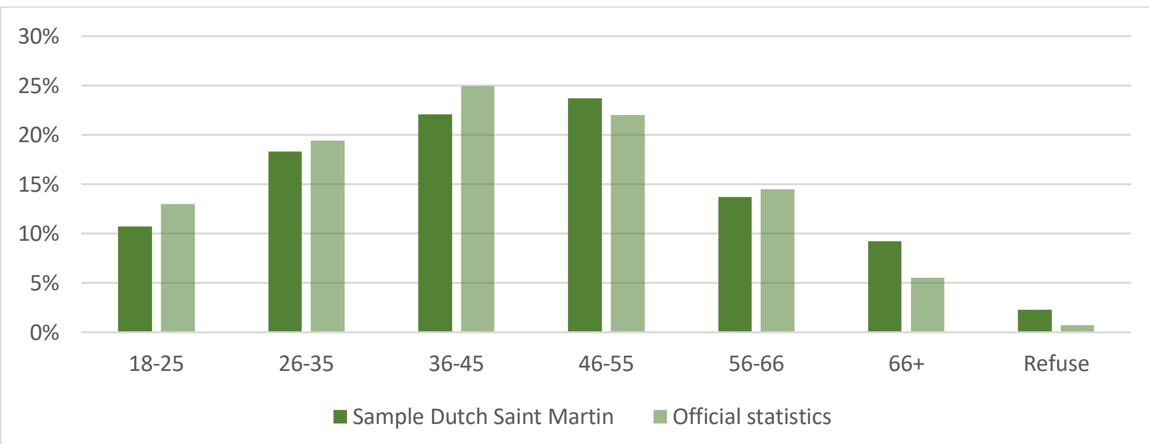

Figure D.4: Age distribution of sample compared to official statistics

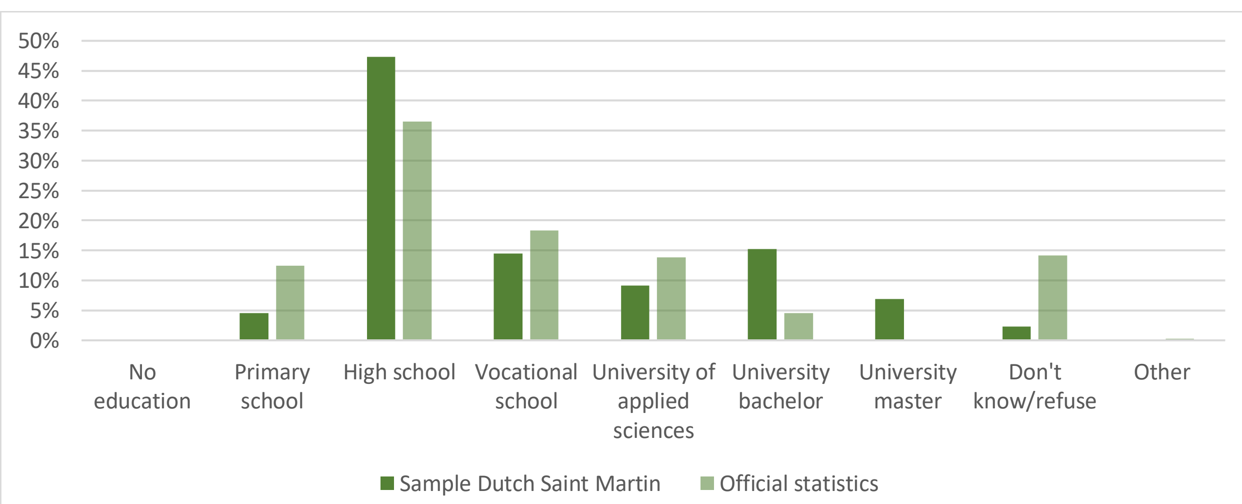

Figure D.5: Education level distribution of sample compared to official statistics

Annex D.2: Descriptive statistics of the survey questions

Table D.1 shows how often respondents do certain recreational activities on the Simpson Bay Lagoon. Many respondents often spend time near the Lagoon, such as on terraces and in bars and restaurants. Walking, jogging and cycling near the Lagoon is also a popular recreational activity. However, for all other recreational activities, such as swimming and fishing, more than half of the respondents indicate that they never undertake them. Figure D.6 shows the responses to the question if respondents noticed any changes in the environmental condition of the Simpson Bay Lagoon in the past 10 years or since they arrived on Saint Martin. More than three fourth of the respondents indeed noticed changes in the Lagoon's environmental condition. If respondents said to have noticed changes in the environmental condition of the Lagoon, they were asked which changes they have noticed. The results of this question are shown in Figure D.6. Trash and plastic

Table D.1: Recreation on the Simpson Bay Lagoon

	Never	Once a year	Once a month	Once a week	More than once a week
Boating/Sailing	64.38%	16.44%	9.59%	2.74%	6.85%
Spending time near the Lagoon (terraces, bars, restaurants, etc.)	23.74%	13.24%	26.03%	20.09%	16.89%
Kayaking/Paddle boarding	83.11%	10.96%	2.74%	2.28%	0.91%
Swimming	81.28%	5.48%	6.39%	3.65%	3.20%
Walking/Jogging/Cycling	47.49%	5.48%	16.44%	11.87%	18.72%
Fishing	85.84%	2.28%	6.39%	3.20%	2.28%
Bird/Wildlife watching	61.64%	6.39%	10.96%	11.42%	9.59%

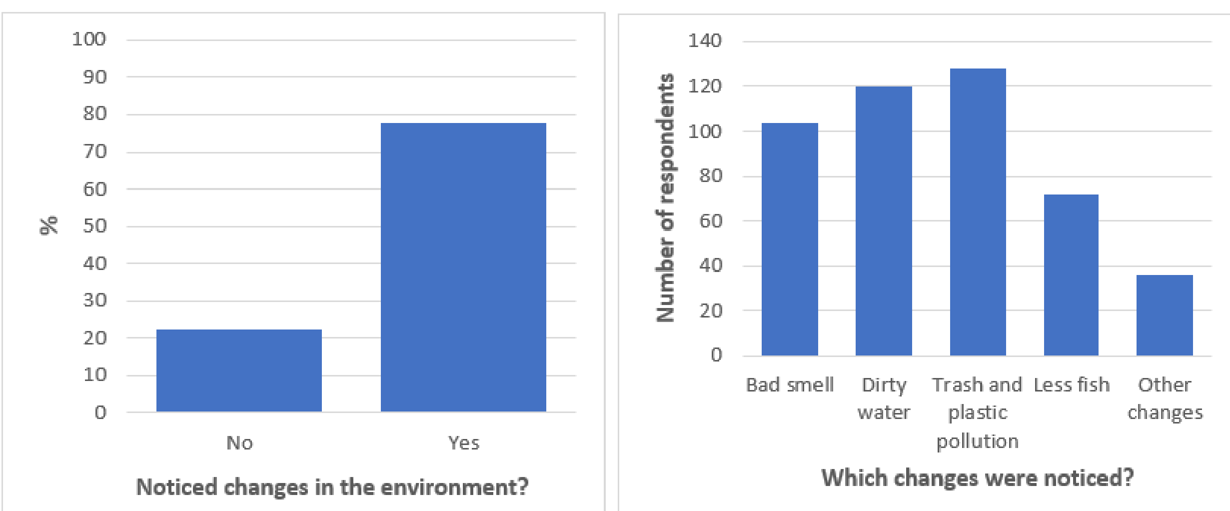

Figure D.6: If respondents noticed changes in the environmental condition of the Simpson Bay Lagoon (left), and which changes they noticed (right)

Pollution, and dirty water were most often mentioned. Many respondents also noticed bad smell coming from the Lagoon and a reduced amount of fish in the Lagoon. Some people also noticed other changes, and often they referred to the ship wrecks in the Lagoon.

Respondents were also asked about what they considered to be important reasons for the poor environmental condition of the Lagoon. The results of this question are shown in Table D.2 Sewage pollution, garbage pollution, ship wrecks, and mangrove destruction are considered to be most important for the poor environmental condition of the Lagoon. Construction and development, and invasive species are less often mentioned as being important. When being asked about who is most responsible for the poor environmental condition of the Lagoon, a striking percentage of respondents mentioned the government as being most responsible (see Figure D.7). Some respondents stated that businesses and local people are most responsible, while only very few find tourists most responsible. Related to this was a question about future management scenarios to improve the environmental condition of the Simpson Bay Lagoon (see Table D.3). Except for restricting development, more than half of the respondents are strongly in favor of each

Table D.2: Perceived importance of several reasons for the poor environmental condition of the Lagoon

	Not at all important	Not important	Neutral	Important	Very important
Sewage pollution	3.65%	3.20%	7.31%	19.63%	66.21%
Construction and development	3.20%	10.96%	20.55%	30.14%	35.16%
Garbage pollution	2.74%	5.94%	5.94%	21.46%	63.93%
Ship wrecks	2.74%	3.65%	11.87%	27.85%	53.88%
Mangrove destruction	1.83%	2.28%	14.16%	27.85%	53.88%
Invasive species	4.57%	6.39%	37.44%	21.46%	30.14%

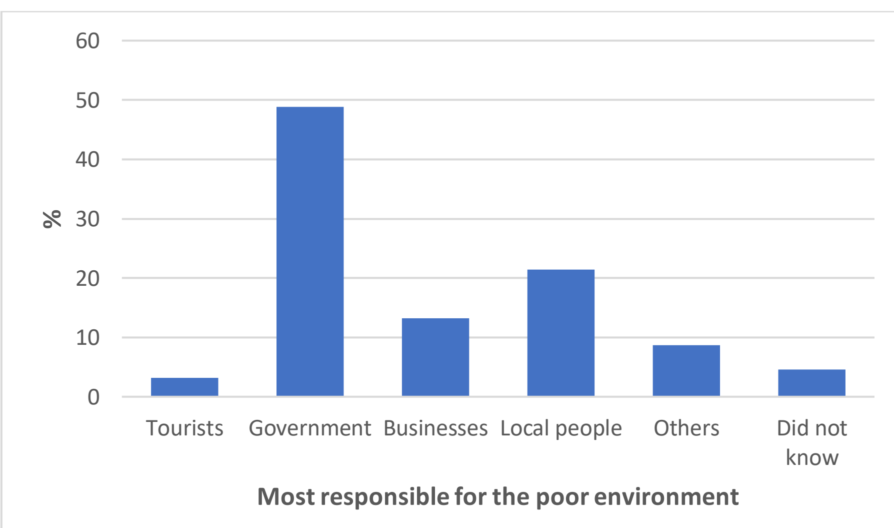

Figure D.7: Perceived responsibility for the poor environmental condition of the Lagoon

Table D.3: Favorability of management scenarios to improve the environment of the Lagoon

	Not at all in favor	Not in favor	Neutral	In favor	Strongly in favor	Did not know
Sewage treatment plant	2.28%	1.37%	9.13%	26.48%	56.62%	4.11%
Mangrove restoration	0.91%	2.28%	9.13%	25.11%	59.82%	2.74%
Better enforcement of regulations	1.37%	0.91%	6.39%	22.37%	67.12%	1.83%
Removing shipwrecks	0.46%	3.20%	6.39%	20.55%	66.21%	3.20%
Restricting development	3.20%	8.22%	24.66%	21.92%	37.90%	4.11%
Environmental awareness raising	0.91%	0.00%	2.28%	13.70%	79.00%	4.11%

of the management scenarios. As this thesis assesses the costs and benefits of mangrove restoration and the construction of a sewage treatment plant, it is important to see that a large majority of the respondents is in favor of both management scenarios. Solely less than 5% of the respondents mentioned not to be in favor of either of these management options.

Respondents were also asked about their environmental behavior. Table D.4 shows that a majority of the respondents mentions that they avoid littering and properly dispose of hazardous chemicals. Only few respondents often attend environmental meetings, donate money to an environmental cause, or do voluntary environmental work. Finally, respondents were asked about their environmental awareness and how their well-being is related to the Lagoon (see Table D.5). The table reveals many interesting results. First, more than 80% of the respondents considers themselves environmentally aware, and most respondents mention that Hurricane Irma has increased their awareness about the environment. Second, a large majority of the respondents mentions that the Lagoon is important for their well-being, and the well-being of other people on Saint Martin. Third, more than one third of the respondents believes that the pollution of the Lagoon has a negative effect on their health. Finally, many respondents do not feel involved in the decision-making process of the management of the Lagoon.

Table D.4: Environmental behavior of respondents

	Never	Rarely	Sometimes	Often	Very often
Look for environmental information	15.98%	19.18%	36.99%	15.53%	12.33%
Attend environmental meetings or events	62.56%	14.61%	15.98%	3.65%	3.20%
Donate money to an environmental cause	57.53%	14.61%	18.72%	5.48%	3.65%
Do any voluntary environmental work	38.36%	16.44%	23.74%	14.16%	7.31%
Purchase environmentally friendly products	19.18%	9.13%	25.11%	25.11%	21.46%
Walk or bike instead of driving	17.81%	11.87%	22.83%	25.11%	22.37%
Recycle your waste	32.42%	13.24%	17.35%	18.72%	18.26%
Avoid littering, and encourage other people not to litter	4.11%	4.11%	8.68%	18.72%	64.38%
Properly dispose of hazardous chemicals	11.42%	8.68%	16.89%	21.92%	41.10%

Table D.5: Statements on environmental awareness and respondent's relation to the Lagoon

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I consider myself environmentally aware	0.91%	3.65%	10.96%	48.86%	35.62%
Hurricane Irma has increased my awareness about the natural environment	4.57%	11.42%	12.33%	35.16%	36.53%
Compared to other people, I was less affected by Hurricane Irma	18.72%	20.09%	14.16%	25.11%	21.92%
The pollution of the Lagoon has a negative effect on my health	10.05%	24.66%	27.4%	20.55%	17.35%
The area around the Lagoon is an important place to meet other people	4.57%	6.85%	15.53%	43.38%	29.68%
I feel involved in the decision-making process of the management of the Lagoon	22.83%	22.37%	29.22%	19.63%	5.94%
The benefits provided by the Lagoon are important for my own well-being	3.65%	4.57%	19.63%	42.47%	29.68%
The benefits provided by the Lagoon are important for the well-being of other people on Saint Martin	1.37%	0.91%	6.85%	45.21%	45.66%
The benefits provided by the Lagoon are important for my income	23.74%	16.89%	21.92%	18.72%	18.72%
The cultural and historical aspect of the Lagoon is important to me	1.83%	4.57%	17.81%	40.64%	35.16%

Annex D.3: Analysis of WTP-preparedness and the contingent valuation study

In addition to the choice experiment, the survey also included a contingent valuation component. Prior to the contingent valuation question, respondents were asked if they were in principle willing to pay for environmental management of the Lagoon. The results, shown for the whole sample and for different population groups, are presented in Table D.6. In total, 76.71% of the respondents are in principle willing to pay for environmental management. Nevertheless, there are some notable differences among population groups. Males, people who completed higher education, and people with a high income were more likely to be willing to pay than, respectively, females, lower educated people, and people with a low income. Striking is the relatively low percentage of people born on the French mainland that are willing to pay. The location where people live also seems to play a role. A much higher percentage of people living on the Dutch side are willing to pay. Furthermore, people living in the lagoon area were more often willing to pay

Table D.6: Percentage of respondents in principle willing to pay for environmental management and average WTP values, for different population groups

	% willing to pay	Average WTP	Observations
Gender			
Female	75.00%	$10.53	104
Male	78.26%	$16.69	115
Age			
18-25	72.00%	$14.38	25
26-35	82.22%	$14.07	45
36-45	62.50%	$9.02	48
46-55	91.30%	$16.70	46
56-65	73.53%	$16.87	34
66+	68.75%	$13.44	16
Education			
Higher education	79.10%	$18.57	67
No higher education	77.03%	$11.89	148
Income			
High income (>$2500/m)	86.57%	$21.63	67
Low income (<$2500/m)	75.45%	$10.87	110
Country of birth			
Saint Martin	77.92%	$14.53	77
Elsewhere in Caribbean	76.39%	$13.82	72
French mainland	60.71%	$8.61	28
Elsewhere	85.37%	$15.83	41
Location			
Dutch side	82.44%	$15.26	131
French side	68.18%	$11.53	88
Inside lagoon area	78.49%	$13.99	186
Outside lagoon area	66.67%	$12.45	33
Overall average	76.71%	$13.76	219

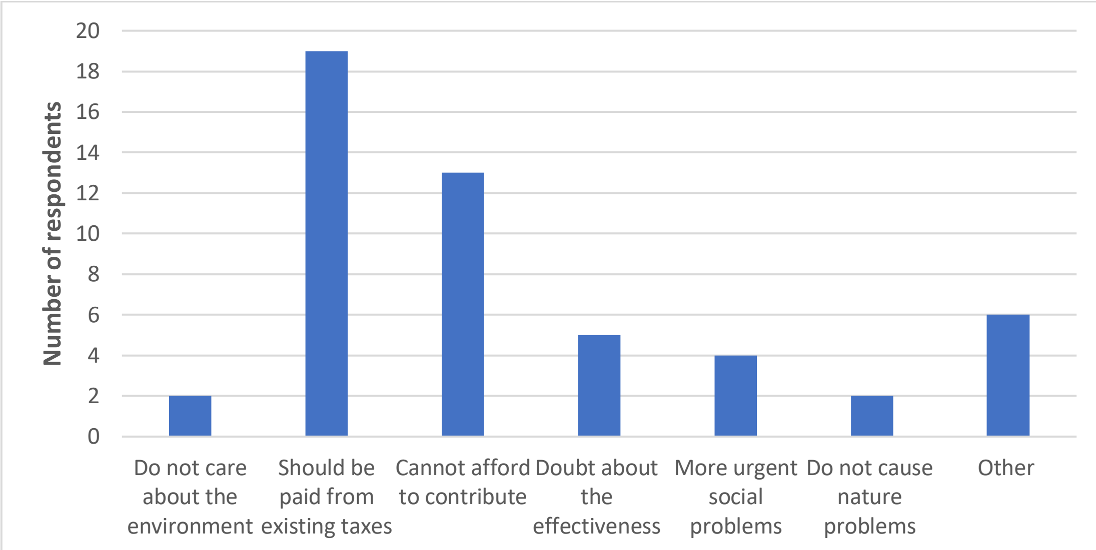

Figure D.8: Reasons for not willing to pay for environmental management of the Lagoon

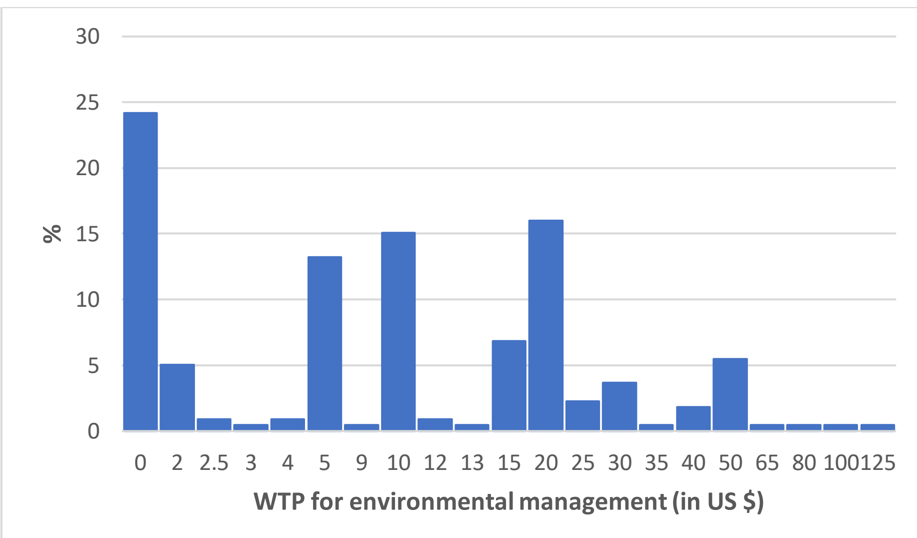

Figure D.9: Respondent's stated WTP for environmental management of the Simpson Bay Lagoon

than people living outside the lagoon area. Respondents who did not want to pay often stated not to be able to afford a contribution or that protection should be paid from existing tax revenues (see Figure D.8).

When a respondent was in principle willing to pay for environmental management of the Lagoon, he/she was asked what maximum amount of monthly contribution his/her household was willing to pay. Figure D.9 shows the distribution of WTP values for the whole sample, while Figure D.10 and D.11 show the WTP values for the Dutch and French side, respectively. A WTP of 0 is

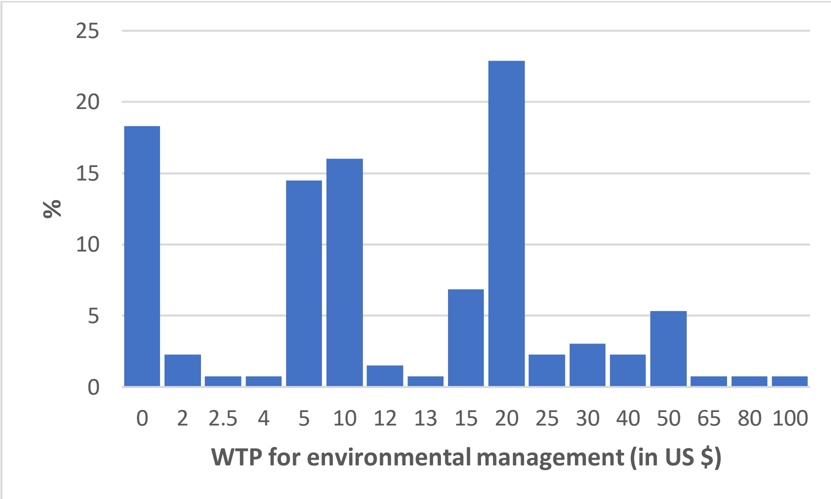

Figure D.10: Respondent's stated WTP for environmental management of the Simpson Bay Lagoon, for the Dutch side of Saint Martin

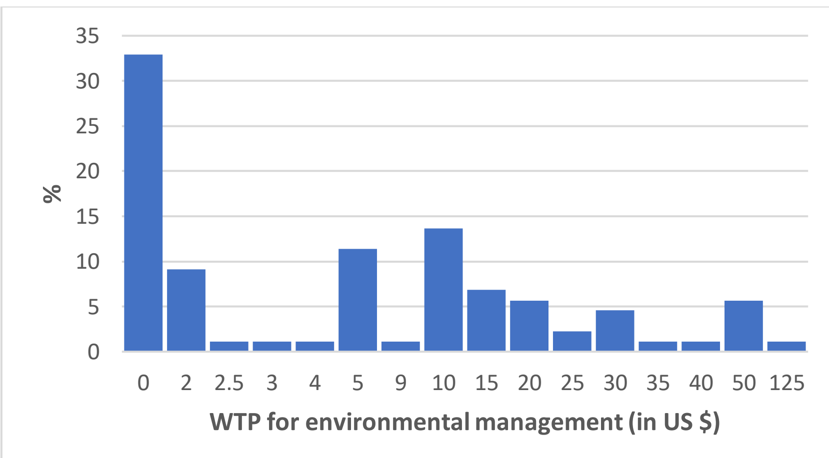

Figure D.11: Respondent's stated WTP for environmental management of the Simpson Bay Lagoon, for the French side of Saint Martin

assumed for people who were not willing to pay, or who did not answer the question. The most often mentioned WTP values are 20, 10, and 5 US dollars per month. Some outliers are visible at the high end of the WTP spectrum, with $125 being the highest mentioned WTP value. Table D.6 shows the average WTP values for the whole sample, and for different population groups. The average per household WTP for environmental management of the Lagoon is $13.76 per month. Looking at different population groups, similar patterns can be observed as for the WTP-preparedness question. For instance, people with a high income are on average willing to pay almost double as much as people with a low income. Remarkable is also the small difference in WTP values for people living inside compared to outside the lagoon area. An independent samples

Table D.7: Regression models explaining WTP for environmental management of the Simpson Bay Lagoon

	Linear regression models <u>including outliers</u>		**Linear regression models <u>excluding outliers</u>**	
	Model 1	Model 2	Model 3	Model 4
Gender (1=female)	-6.785**	-5.509*	-5.358**	-3.914
	(2.339)	(2.607)	(1.888)	(2.075)
Age	0.996	1.090	0.522	0.509
	(0.905)	(1.056)	(0.755)	(0.862)
Higher education	8.364*	3.268	5.440*	0.504
	(3.363)	(3.383)	(2.425)	(2.577)
French side	-1.956	-0.102	-2.811	-1.350
	(3.114)	(3.717)	(2.129)	(2.443)
Outside lagoon area	-2.030	-1.658	-3.759	-3.492
	(4.161)	(4.382)	(2.476)	(2.546)
Country of birth (baseline: Saint Martin)				
Caribbean	-0.773	0.692	-0.078	1.414
	(2.834)	(3.187)	(2.433)	(2.710)
French mainland	-8.770*	-11.530*	-5.847	-7.412*
	(4.125)	(4.994)	(3.281)	(3.609)
Elsewhere	-1.979	-2.512	-1.636	-1.810
	(4.344)	(4.774)	(3.162)	(3.383)
High income		10.596**		8.979**
		(2.830)		(2.505)
Constant	14.272**	11.155*	15.235**	12.832**
	(4.208)	(4.868)	(3.138)	(3.454)
N	209	173	209	173
R^2	0.102	0.147	0.095	0.144
F-statistic	2.48*	3.12**	2.96**	3.69**

*Note: Robust standard errors in parentheses. The levels of significance are: *p<0.05, **p<0.01*

t-test shows that indeed the mean WTP for people living inside the lagoon area does not significantly differ from that of people living outside the lagoon area (p>0.05).

To formally test the relationship between WTP and population characteristics, regression analyses are conducted. The results are shown in Table D.7. As the Breusch-Pagan/Cook-Weisberg test for heteroskedasticity has shown that heteroskedasticity is significantly present in the regressions, robust standard errors are applied. Model 1 shows the results when gender, age, higher education, geographical location, and country of birth are included in the regression. The results indicate that the WTP values of males and people who completed higher education are significantly higher than those of females and lower educated people. Furthermore, respondents born on the French mainland are willing to pay significantly less than those born on Saint Martin. Model 2 includes income in the regression specification. As almost 20% of the respondents did not provide their household income, the results with and without income are displayed separately. When adding the income variable, the number of observations naturally drops considerably. The results show that people with a high household income (i.e. >$2500/month) are willing to pay significantly more for environmental management of the Lagoon than people with a low household income. Adding the income variable makes the coefficient for higher education insignificant.

In the exploratory analysis (see Figure D.9), we have identified a few very high WTP values. Although these are also valid observations, outliers can seriously influence the regression outcomes (Casson & Farmer, 2014). Therefore, models 3 and 4 show the results of the same regression specification as models 1 and 2, except for the fact that the four WTP values higher than $50 are coded as $50. Table D.7 shows that excluding these outliers considerably influences the parameter estimates. It even renders gender insignificant in model 4, while being born on the French mainland is not significant anymore in model 3. To test for multicollinearity, Table D.8 shows the outcomes of a Variance Inflation Factor (VIF) analysis. As the VIF values for all variables are considerably lower than 5, the parameter estimates have likely not suffered from worrisome multicollinearity levels (Hair, 2010; Rogerson, 2001).

With the results of the contingent valuation exercise, the total WTP for environmental management of the Lagoon, of the households of Saint Martin, can be calculated. The results of the t-test and the regression analyses have indicated that the mean WTP for people inside the lagoon area does not significantly differ from that of people living outside the lagoon area. Furthermore, no significant differences are found for the French compared to the Dutch side of the island.

Table D.8: VIF values for the independent variables in the linear regression models depicted in Table D.7

	VIF
Gender (1=female)	1.09
Age	1.12
Higher education	1.33
High income	1.35
French side	1.25
Outside lagoon area	1.03
Caribbean	1.41
French mainland	1.52
Elsewhere	1.40

Note: VIF values estimated based on model specification 2 in Table D.7

Therefore, we can assume that the mean WTP per household ($13.76) holds for the whole island. Nevertheless, generalized results should always be treated with caution. The number of households on the Dutch side of Saint Martin was last measured during a Household Listing Survey in 2014, and equaled 14,021 (Department of Statistics Sint Maarten, 2019). The number of households on the French side was last measured in 2012, and equaled 13,400 (INSEE, 2016). Hence, the total number of households is 27,421. Although at present, 2019, the number of households is most likely higher, a specific number cannot be assumed. The likely underestimation of the number of households might counterbalance the possible overestimation of WTP values. All in all, the results suggest a total WTP for environmental management of the Lagoon, of all households of Saint Martin, of $377,313 (27,421*$13.76) per month, or $4,527,756 per year. When asking respondents who should manage the funds for environmental management, 'local environmental organizations' was by far the most popular answer option (see Figure D.12).

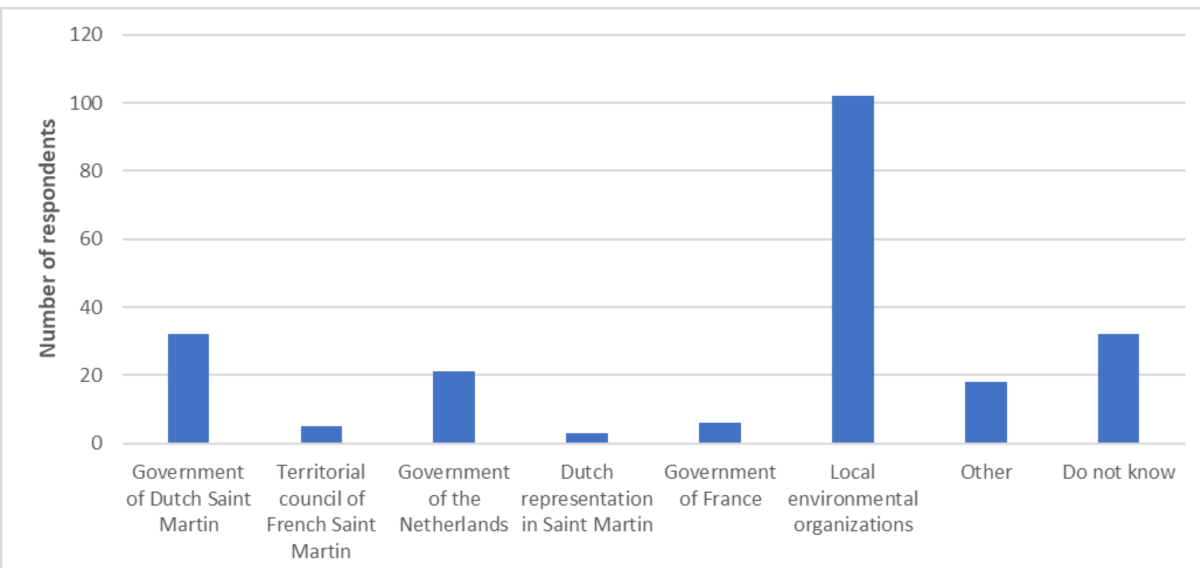

Figure D.12: Which organization should manage the funds for environmental management of the Lagoon

Annex D.4: Tables and figures related to the choice experiment analysis

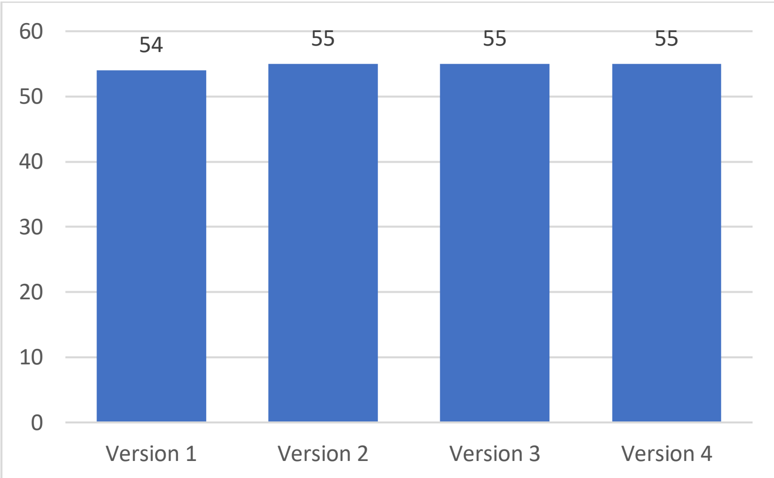

Figure D.13: Number of times each choice experiment version is used

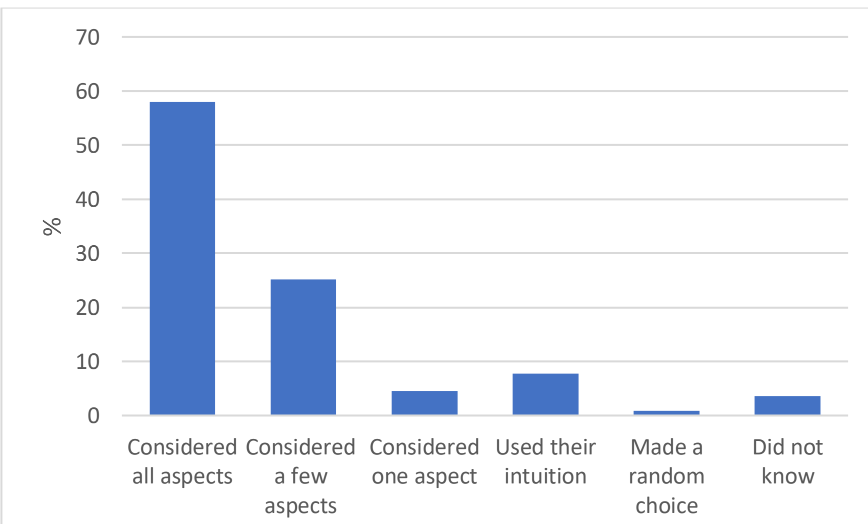

Figure D.14: How respondents made their choice

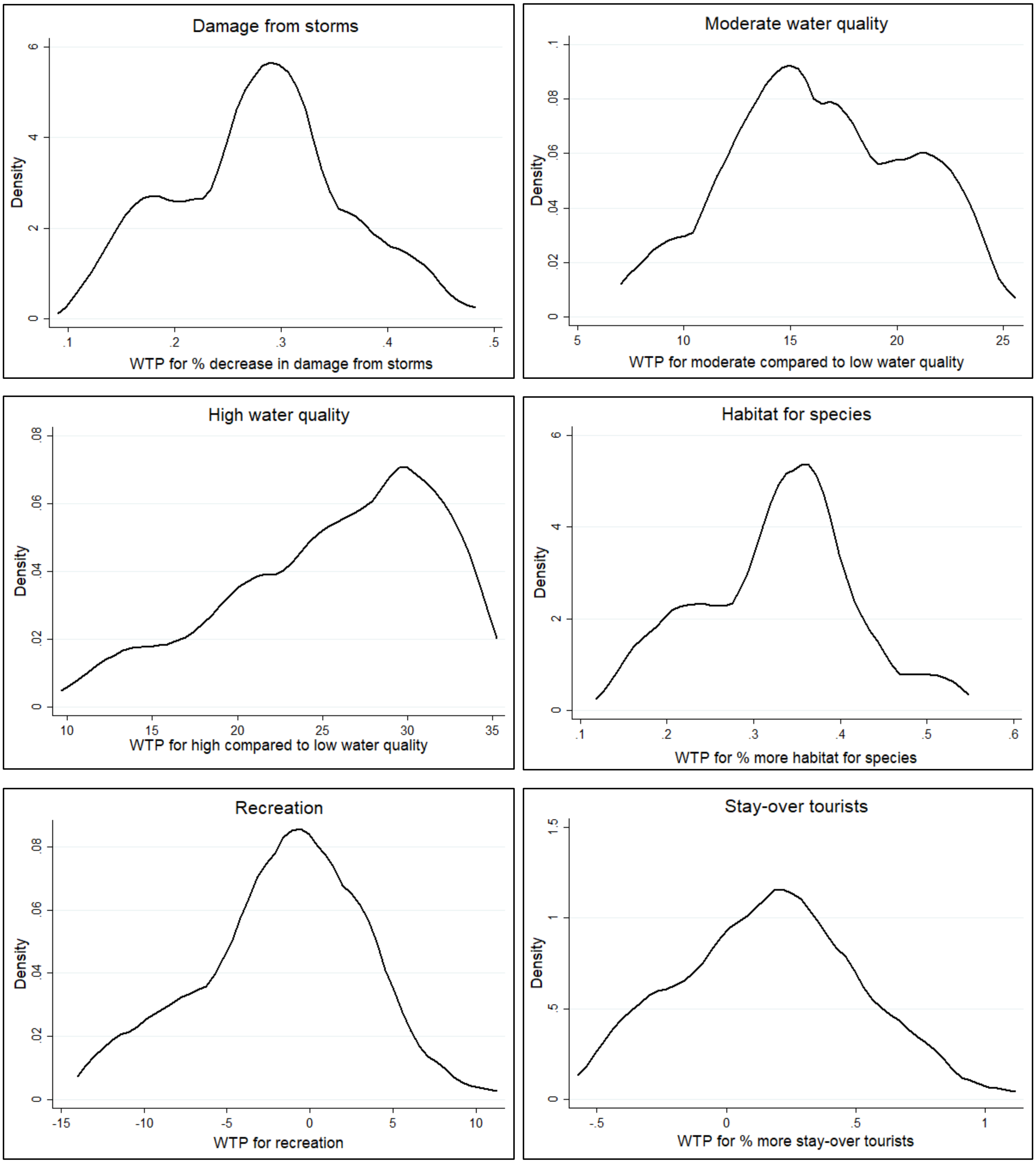

Figure D.15: Kernel density plots displaying heterogeneity in WTP values for all attributes

Table D.9: Results of the Multinomial Logit model

	Coefficient	Standard error	P-value	WTP (US $)
Damage from storms (%)	0.0140	0.0032	0.0000	0.3842
Water quality (baseline: low quality)				
Moderate water quality	1.0156	0.1781	0.0000	27.8224
High water quality	1.8154	0.1734	0.0000	49.7314
Habitat for species (%)	0.0226	0.0034	0.0000	0.6182
Suitability for recreation	-0.1072	0.0648	0.0980	-
Stay-over tourists (%)	-0.0017	0.0072	0.8110	-
Monthly contribution ($)	-0.0365	0.0156	0.0221	-
N	1265			
Adjusted Pseudo R^2	0.1018			
AIC	1.6622			
BIC	1.6906			

Table D.10: VIF values for the independent variables in the linear regression models depicted in Table 7

	VIF
Gender (1=female)	1.10
Age	1.13
Higher education	1.32
High income	1.34
French side	1.23
Outside lagoon area	1.03
Caribbean	1.41
French mainland	1.50
Elsewhere	1.40

Note: VIF values estimated based on model specifications 2, 4, 6, and 8 in Table 7

Annex D.5: Alternative method to estimate the fishery value of the Simpson Bay Lagoon

A second method to obtain the fishery value of the Lagoon is to assess the WTP of local residents for recreational fishing. On Aruba and Bonaire, choice experiments have been held under the local population to reveal the value of recreational fishing. These studies have looked at how much local people are willing to pay for the status quo or for an increase in fish catch, compared to a decrease in fish catch. The increase or decrease in fish catch was either 20% (Bonaire), or 50% (Aruba). The study from Bonaire finds that households are on average willing to pay $6.18 for no change in fish catch compared to a 20% decrease in fish catch (Laclé et al., 2012). The study on Aruba finds that there is no significant increase in WTP for going from 50% less fish catch to the no change scenario. The insignificant results for the Aruba study show that a high recreational fishery value is not self-evident. Hence, as a conservative estimate, this research assumes that the average annual WTP per household within the 'lagoon area' of Saint Martin is equal to the lower bound of the 95% confidence interval for the Bonaire study. This equals a yearly WTP of $1.81 (Laclé et al., 2012). In total, around 27,076 people live in the lagoon area (see Table 5). Data on the number of households in the lagoon area is, unfortunately, unavailable. Assuming that the average number of people per household found in our survey, 3.04, is representative for the lagoon area, around 8,907 households live in this area.

This leads to a total annual recreational fishery value of $16,122 (8,907*1.81). This value is close (in absolute terms) to the value of $10,684 found when applying the first methodology and, therefore, enhances the robustness of this result. As the first methodology encompasses both recreational and commercial fisheries, and because it is more straightforward to relate the management scenarios to changes in mangroves and seagrasses, solely the first methodology is used to estimate the fishery value of the Simpson Bay Lagoon in the remainder of the study.

Annex E: Calculations of the costs and benefits of the management scenarios

Annex E.1: Assumptions made in the cost-benefit analysis

1. The time period of the cost-benefit analysis is 30 years. The envisaged long-term effects of the management scenarios are expected to occur after 30 years. The reason for this is that the ecosystems in the Lagoon, and those of the coastal waters surrounding it, need time to recover from the heavy pollution that is currently occurring. In addition, the mangroves and seagrasses need time to grow before they can fully provide their ecosystem services.

2. Over the 30 years, the provisioning of ecosystem services linearly moves towards the envisaged long-term level. For instance, when habitat for species is expected to increase with 40%, the annual increase in habitat for species is 1.33 percentage point. Previous studies find both decreasing and increasing marginal improvements over time, which makes the assumption of linear improvements a relatively safe bet (van der Lely et al., 2013; van der Lely et al., 2014).

3. The number of households (27,421) on Saint Martin is assumed to stay the same over the 30-year period.

4. The number of cruise and stay-over tourists that come to Saint Martin is assumed to stay the same over the 30-year period (1,668,863 and 528,154, respectively).

Annex E.2: Calculations of the benefits in the baseline scenario

The calculations of the benefits in the baseline scenario are summarized in Table G.1. In the baseline scenario, the TEV of the Simpson Bay Lagoon will be very low. The local and cultural value of storm protection, water quality and habitat for species will be zero, as in this scenario the lowest levels of each of these attributes will be reached. The same holds for the tourism value, as this value depends on the WTP of tourists for coastal water quality, which is zero for poor coastal water quality. The zero value does not only follow from the employed methodology, but also from common sense. It would be peculiar to assign a monetary value to an ecosystem that is in such a bad shape that it will more likely pose a threat to tourists and local people, than that it will provide benefits.

Only a fishery and a carbon sequestration value can be attached to the Lagoon, as not all mangrove stands and seagrass beds will disappear. In the baseline scenario, the area of seagrasses will drop to 88 hectares, while the area of mangroves will remain unchanged at 1.04 hectares. The

Table G.1: Calculation of the total yearly economic value of the ecosystem services provided by the Simpson Bay Lagoon under the baseline scenario

Value	Attribute levels / relevant indicators	Calculation of the annual economic value	Annual economic value
Local and cultural			
Storm protection	40% more storm damage	-	$0
Water quality	Low water quality	-	$0
Habitat for species	40% less habitat	-	$0
Carbon sequestration	1.04 ha mangroves 88 ha seagrasses	Mangroves: $68.77/ha Seagrasses: $41.99/ha Value=1.04*68.77+88*41.99	$3,767
Tourism value	Poor coastal water quality	-	$0
Fishery value	1.04 ha mangroves 88 ha seagrasses	Mangroves: $627/ha Seagrasses: $38/ha Value=1.04*627+88*38	$3,996
Total		**Adding al components**	**$7,763**

carbon sequestration value per hectare of seagrasses is $41.99, while that of mangroves is $68.77 (see Table 10). This leads to a total carbon sequestration value of 1.04*68.77+88*41.99 =$3767. The fishery value per hectare of seagrasses is $38, while that of mangroves is $627 (see Table 12). Consequently, the total fishery value in this scenario is 1.04*627+88*38 =$3996. Adding the carbon sequestration and fishery value leads to an annual TEV of $7,763.

Annex E.3: Calculations of the benefits in the sewage treatment plant scenario

The calculations of the benefits in the sewage treatment plant scenario are summarized in Table G.2. In the sewage treatment plant scenario, there will be no change in damage from storms. The non-linear function in Figure 9 shows that the WTP for no change in damage from storms is $14.32 per month per household. The total number of households on Saint Martin is 27,421. This leads to a total yearly value of $14.32*27,421*12=$4,711,926. The water quality in this scenario will be high. From Figure 8 we can see that the monthly WTP for high water quality compared to low water quality is $25.66 per household. The total yearly value for high water quality is therefore 25.66*27,421*12= $8,444,791. In this scenario, habitat for species in the Lagoon is assumed to increase with 20%, due to an increase in seagrass beds. Figure 10 shows that the monthly WTP for a 20% increase in habitat for species is $22.39 per household. Hence, this entails a yearly value of 22.39*12*27,421=$7,367,803. When a sewage treatment plant will be installed, the area of seagrasses is expected to increase to 440 hectares while the area of mangroves will remain 1.04 hectares. The carbon sequestration value per hectare of seagrasses is $41.99, while that of mangroves is $68.77 (see Table 10). This leads to a total carbon sequestration value of 1.04*68.77+440*41.99=$18,549. The fishery value is also calculated based on the area of seagrasses and mangroves present in the Lagoon. The fishery value per hectare of seagrasses is $38, while that of mangroves is $627. Hence, the total fishery value in this scenario is 1.04*627+440*38=$17,372

This thesis looks at the WTP of tourists for coastal water quality to obtain the consumer surplus of the tourism value of the Lagoon. In the sewage treatment plant scenario, the coastal water quality will be good. The WTP of tourists for good coastal water quality is $3.21 per day of stay. This WTP estimate is obtained from a tourism survey conducted on Sint Eustatius (see Section 5.1.2 for an explanation). As the Simpson Bay Lagoon affects the water quality of only about 25% of the coastline of Saint Martin, this WTP estimate is multiplied by 0.25, equaling $0.8025.

Table G.2: Calculation of the yearly total economic value of the ecosystem services provided by the Simpson Bay Lagoon under the sewage treatment plant scenario

Value	Attribute levels / relevant indicators	Calculation of the annual economic value	Annual economic value
Local and cultural			
Storm protection	No change in storm damage	$14.32 WTP per month 27,421 households Value=14.32*12*27,421	$4,711,926
Water quality	High water quality	$25.66 WTP per month 27,421 households Value=25.66*12*27,421	$8,444,791
Habitat for species	20% more habitat	$22.39 WTP per month 27,421 households Value=22.39*12*27,421	$7,367,803
Carbon sequestration	1.04 ha mangroves 440 ha seagrasses	Mangroves: $68.77/ha Seagrasses: $41.99/ha Value=1.04*68.77+440*41.99	$18,549
Tourism value	Good coastal water quality	$0.8025 WTP per day of stay (0.25*3.21) 1,668,863 cruise, 528,154 stay-over tourists Cruise stay 1 day, stay-over 8.69 days Producer surplus=1.08*consumer surplus Value=(0.8025*1,668,863+0.8025*8.69*528,154)*(1+1.08)	$10,446,724
Fishery value	1.04 ha mangroves 440 ha seagrasses	Mangroves: $627/ha Seagrasses: $38/ha Value=1.04*627+440*38	$17,372
Total		**Adding all components**	**$31,007,164**

The yearly number of cruise tourists and stay-over tourists arriving on Saint Martin are, respectively, 1,668,863 and 528,154. Cruise tourists stay on average one day, while stay-over tourists are assumed to stay 8.69 days. Hence, the total consumer surplus equals 0.8025*1,668,863 +0.8025*8.69*528,154=$5,022,463. The producer surplus is (conservatively) estimated as being 1.08 times as large as the consumer surplus (see Section 5.1.2), and hence equals 1.08*5,022,463.31=$5,424,260. This makes a total tourism value of $10,446,723. Adding all these components leads to an annual TEV of $31,007,164.

Annex E.4: Calculation of the costs in the sewage treatment plant scenario

Although there is still no official agreement on the construction of a sewage treatment plant in the lagoon area, already a concrete plan has been made for the construction of a sewage treatment plant in this area (Technopolis Group, 2014). This sewage treatment plant would serve 17,000 residents in the lagoon area, with 50% of them residing on the Dutch side and 50% on the French side. The overall construction costs of the plant have been estimated to be €13,000,000. These costs include the network connections for the French side but exclude the network connections for the Dutch side. The costs of the network connections for the French side have been projected to be €1,000,000. As the station serves an equal amount of people at the French side and the Dutch side, it is assumed that the network connection costs for the Dutch side will also equal €1,000,000. Hence, the total construction costs are estimated to be €14,000,000. When using the prevailing exchange rate of $1.13/€, the total construction costs in US dollars equals $15,820,000.

Besides construction costs, there are also yearly operation and maintenance costs. Unfortunately, information on these costs is not available for the proposed plant in Saint Martin. A study on the cost-effectiveness of building a sewage treatment plant on the Caribbean island of Bonaire has found that the yearly operation and maintenance costs equal about 10% of the construction costs (Gijzen & van der Steen, 2004). Assuming that this will also hold for the proposed plant on Saint Martin, the yearly operation and maintenance costs are $1,582,000.

Annex E.5: Calculations of the benefits in the mangrove restoration scenario

The calculations of the benefits in the mangrove restoration scenario are summarized in Table G.3. In the mangrove restoration scenario, damage from storms will decrease with 40%. As the non-linear function in Figure 9 shows, the WTP for a 40% decrease in damage from storms is

$22.39 per month per household. This leads to an annual WTP by all households of Saint Martin of 22.39*12*27,421=$7,368,429. In this scenario the water quality will increase from 'low to moderate' to moderate. The monthly WTP per household for moderate compared to low water quality is $16.41, as can be observed in Figure 8. This makes a total annual water quality value of 16.41*12*27,421=$5,400,401. The increase in mangroves and seagrasses in this scenario will increase habitat for species with 40%. Figure 10 shows that the monthly WTP for a 40% increase in habitat for species is $26.20 per household. Hence, the total annual value of habitat for species in this scenario is 26.20*12*27,421=$8,621,327. In the mangrove restoration scenario, the area of mangroves is expected to increase to 54.565 hectares and the area of seagrasses to 440 hectares. The carbon sequestration value per hectare of seagrasses is $41.99, while that of mangroves is $68.77 (see Table 10). Consequently, the total annual carbon sequestration value in this scenario

Table G.3: Calculation of the yearly total economic value of the ecosystem services provided by the Simpson Bay Lagoon under the mangrove restoration scenario

Value	Attribute levels / relevant indicators	Calculation of the annual economic value	Annual economic value
Local and cultural			
Storm protection	40% less storm damage	$22.39 WTP per month 27,421 households Value=22.39*12*27,421	$7,368,429
Water quality	Moderate water quality	$16.41 WTP per month 27,421 households Value=16.41*12*27,421	$5,400,401
Habitat for species	40% more habitat	$26.20 WTP per month 27,421 households Value=26.20*12*27,421	$8,621,327
Carbon sequestration	54.565 ha mangroves 440 ha seagrasses	Mangroves: $68.77/ha Seagrasses: $41.99/ha Value=54.565*68.77+440*41.99	$22,230
Tourism value	Moderate coastal water quality	$0.4925 WTP per day of stay (0.25*1.97) 1,668,863 cruise, 528,154 stay-over tourists Cruise stay 1 day, stay-over 8.69 days Producer surplus=1.08*consumer surplus Value=(0.4925*1,668,863+0.4925*8.69*528,154)*(1+1.08)	$6,411,229
Fishery value	54.565 ha mangroves 440 ha seagrasses	Mangroves: $627/ha Seagrasses: $38/ha Value=54.565*627+440*38	$50,932
Total		**Adding all components**	**$27,874,548**

is 54.565*68.77+440*41.99=$22,230. The fishery value is also calculated based on the area of seagrasses and mangroves present in the Lagoon. The fishery value per hectare of seagrasses is $38, while that of mangroves is $627. Hence, the total fishery value in this scenario is 54.565*627+440*38= $50,932.

This study looks at the WTP of tourists for coastal water quality to obtain the consumer surplus of the tourism value of the Lagoon. In the mangrove restoration scenario, the coastal water quality will be moderate. The WTP of tourists for moderate coastal water quality is $1.97 per day of stay. This WTP estimate is obtained from a tourism survey conducted on Sint Eustatius (see Section 5.1.2 for an explanation). As the Simpson Bay Lagoon affects the water quality of only about 25% of the coastline of Saint Martin, this WTP estimate is multiplied by 0.25, equaling $0.4925. The yearly number of cruise tourists and stay-over tourists arriving on Saint Martin are, respectively, 1,668,863 and 528,154. Cruise tourists stay on average one day, while stay-over tourists are assumed to stay 8.69 days. Hence, the total consumer surplus equals 0.4925*1,668,863 +0.4925*8.69*528,154=$3,082,322. The producer surplus is (conservatively) estimated as being 1.08 times as large as the consumer surplus (see Section 5.1.2), and hence equals 1.08*3,082,321.72=$3,328,907. This leads to a total tourism value of $6,411,229. When adding all these components, one arrives at an annual TEV of $27,874,548.

Annex E.6: Calculations of the costs in the mangrove restoration scenario

First of all, the author would like to note that the costs of mangrove restoration on Saint Martin are unknown. The author has tried to compile the best estimate possible with the available information, obtained from local environmental organizations and the scientific literature. The cost data are compared to that of other studies to ensure that they are realistic. To account for the uncertainty in the estimation, sensitivity analyses are conducted to see how different cost figures influence the results.

The type of mangrove that is planted in the Simpson Bay Lagoon is Rhizophora Mangle (red mangrove). For the small mangrove restoration project at Little Key Island in the Lagoon (see Annex B), 200 red mangrove seeds were bought for $470, including $240 for the costs of the seeds ($1.20 per unit) and $230 for the transportation costs. Typically, red mangroves are planted with a 1.5 meter spacing between each plant, requiring around 4500 mangrove seeds per hectare (Duke & Allen, 2005). In the mangrove restoration scenario, 54.565-1.04=53.525 hectares of mangroves need to be planted. Hence, this requires the purchase of a total of 240,863 seeds. Ordering this large amount of seeds will substantially lower the purchase and especially the transportation costs per seed. Hence, it is assumed that the unit price per seed will drop with 50% to $0.60. This leads to a total purchase cost of $144,518. Transportation to Saint Martin is costly, as seeds have to be transported from another country to the island. Transportation costs are assumed to equal 20% of the purchase costs, or $28,904. This leads to a total cost of $173,421, or $3,240 per hectare. A recent study by Brander et al. (2018) in Vietnam finds that the seedling costs per hectare of restored mangroves equal $2,583. The $3,240 per hectare found for this study is deemed realistic as transportation to Saint Martin is likely to be more expensive, while at the same time the island might have to deal with higher mangrove seed prices.

Regarding the labor costs of mangrove restoration, a study by Marchand (2008) finds that you need around 10 persons working a full workday to plant one hectare of mangroves. Hence, to plant 53.525 hectares, around 535 working days are needed. Assuming that a working day consists of 8 hours, in total 4,280 working hours are needed to plant the mangroves. The labor costs of mangrove restoration depend very much on the amount of work that is done by volunteers and the amount of work done by paid workers. On both the Dutch and the French side of Saint Martin, there are a considerable number of environmental volunteers. However, it would be unrealistic to assume that they are capable and/or willing to restore more than 50 hectares of mangroves. Hence, it is assumed that 25% of the work will be done by volunteers and 75% by paid workers. This means that of the 4280 hours required for mangrove restoration, 1,070 hours are occupied by volunteers and 3,210 by paid workers. There is uncertainty about how to value the time that volunteers spend on work. Therefore, to calculate the total labor costs of mangrove restoration, this study makes use of a formula proposed by Hagedoorn and van Beukering (2019). This study states that an hour of paid work is valued at the hourly wage rate, unpaid work at two thirds of the hourly wage rate and leisure time at one third of the hourly wage rate. Volunteer work is by definition unpaid work (Bierhoff, 2002), and an hour of volunteer work is therefore valued as two thirds the hourly wage rate. The assumed average hourly wage rate for mangrove restoration is the minimum wage on Sint Maarten. Currently, many people are unemployed while statistics show that even people who do work, often earn less than the minimum wage (Social Economic Council Sint Maarten, 2015). Hence, the use of the minimum wage as the average wage rate for mangrove restoration is deemed appropriate. The minimum wage on Sint Maarten in 2017 was 8.83 ANG per hour, or around $5 per hour (Department of Statistics Sint Maarten, 2017). Hence the total labor costs of mangrove restoration are estimated as being 3,210*5+1,070*⅔*5=$19,617.

Besides labor and seed costs, there are also other costs such as equipment, maintenance, and monitoring costs. No case-specific data are available for Saint Martin to estimate these costs. Therefore, this study makes use of a study by Brander et al. (2018), that finds that these 'other costs' amount to 65.71% of the labor and seed costs. For Saint Martin, this means that these costs equal 0.6571*($173,421.36+19,616.67)=$126,845. Hence the total costs of mangrove restoration on Saint Martin are expected to be $319,883. All components of the total initial investment costs are summarized in Table G.4. Besides these initial costs, there are also some monitoring and maintenance costs that occur after the first year in which restoration takes place. These costs are generally low. Brander et al. (2018) find that these costs are 3.38% of the initial investment costs in the first year after restoration, and 0.23% in the thirtieth year. For this study, this implies monitoring and maintenance costs of $10,812 (0.0338*319,883.32) in the first year after restoration, and $736 in the thirtieth year. In between these years, a linear reduction in costs is assumed.

The total initial costs of mangrove restoration on Saint Martin found in this exercise equal $319,883, or $5,976 per hectare. Bayraktarov et al. (2016) find, based on 107 case studies, that the average restoration costs per hectare of mangroves are $8,961. This value comes close to the value found for Saint Martin, and hence supports the reliability of this finding. The somewhat lower costs per hectare for Saint Martin might be explained by the fact that 59 of the 107 case studies used in the study by Bayraktarov et al. were about mangrove restoration projects in developed countries. The labor costs for planting, monitoring, and maintenance are expected to be much higher in a typical developed country compared to Saint Martin. Nevertheless, sensitivity analyses will assess how the cost-benefit outcomes change when we assume that the costs of mangrove restoration will be 50% higher

Table G.4: Total initial investment costs of mangrove restoration in the Lagoon

	Costs in US $
Mangrove seeds	$173,421
Planting (labor)	$19,617
Other costs (equipment, monitoring, maintenance, etc.)	$126,845
Total costs	**$319,883**

Annex F: Sensitivity analyses

Annex F.1: Lower percentage changes in damage from storms and habitat

In the main results, we assume that mangrove restoration increases habitat for species with 40% and decreases storm damage with 40%. Constructing a sewage treatment plant increases habitat with 20%. Although these were the levels used in the choice experiment, it is unclear what the exact effects of the measures will be. Hence, as a robustness check, this section presents the results if one assumes that mangrove restoration leads to just a 20% increase in habitat and a 20% decrease in storm damage, while a sewage plant increases habitat with just 10%. This leads to TEV's for each management scenario as presented in Figure F.1. Figure F.2 and Figure F.3 display

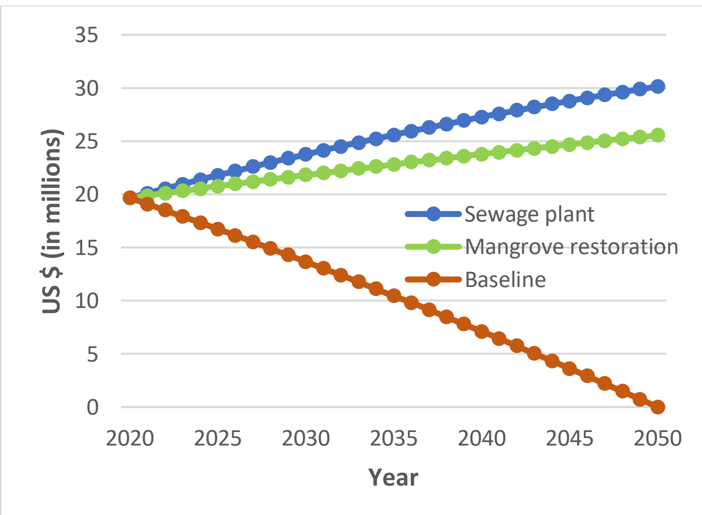

Figure F.1: The TEV of the baseline, mangrove restoration, and sewage plant scenario when assuming lower % changes in storm damage and habitat

Figure F.2: NPV when assuming lower % changes in storm damage and habitat

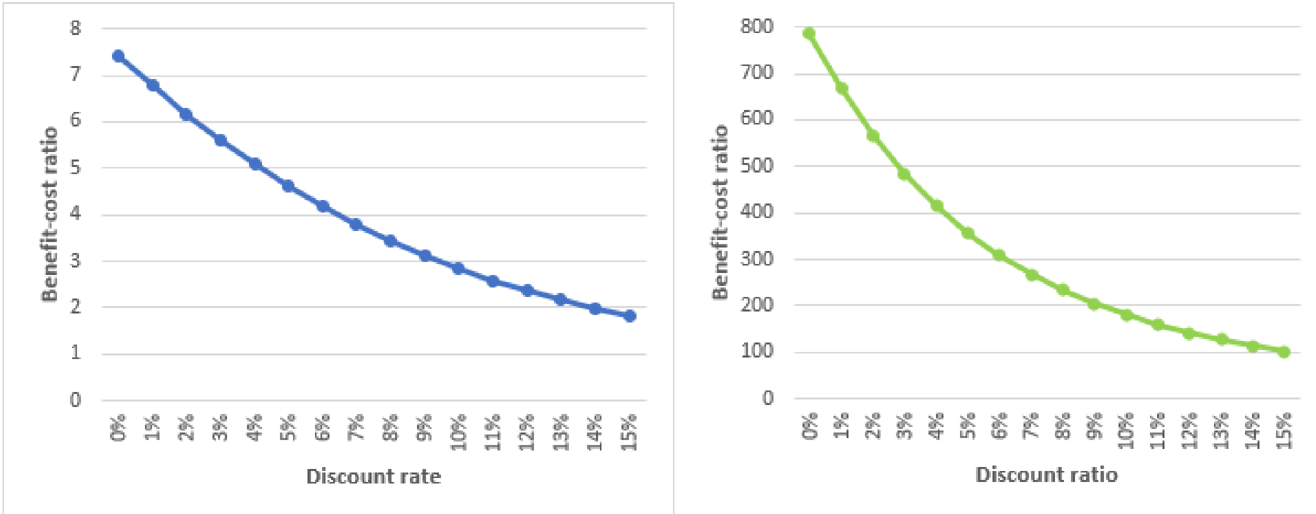

Figure F.3: Benefit-cost ratio of the sewage plant (left) and mangrove restoration scenario (right) when assuming lower % changes in storm damage and habitat

that even in this case, both management scenarios pay off economically. For discount rates below 3%, the sewage plant scenario has a higher NPV than the mangrove restoration scenario. Otherwise, the NPV and BCR of mangrove restoration are higher.

Annex F.2: Linear WTP functions

To calculate WTP for all attribute levels, this study used a non-linear function exhibiting decreasing marginal WTP. It is interesting, methodologically and content-wise, to see how the results would have changed if we would have assumed linear WTP functions. Figure F.4 shows that this lowers the TEV of all three management scenarios. As the TEV also decreases for the

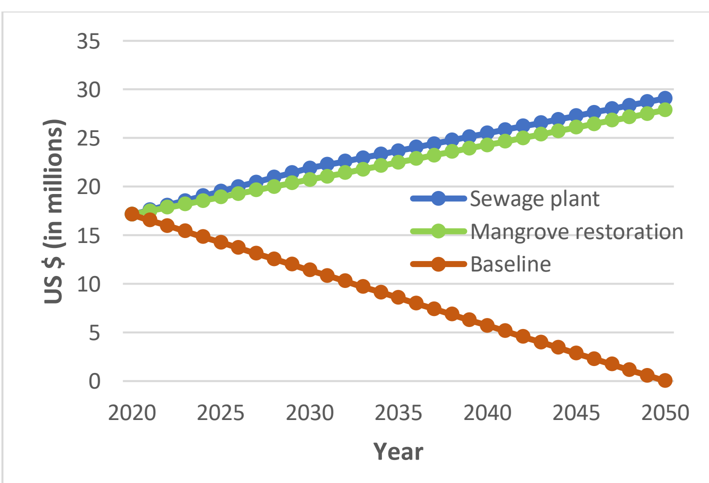

Figure F.4: The TEV of the baseline, mangrove restoration, and sewage plant scenario when utilizing linear WTP functions

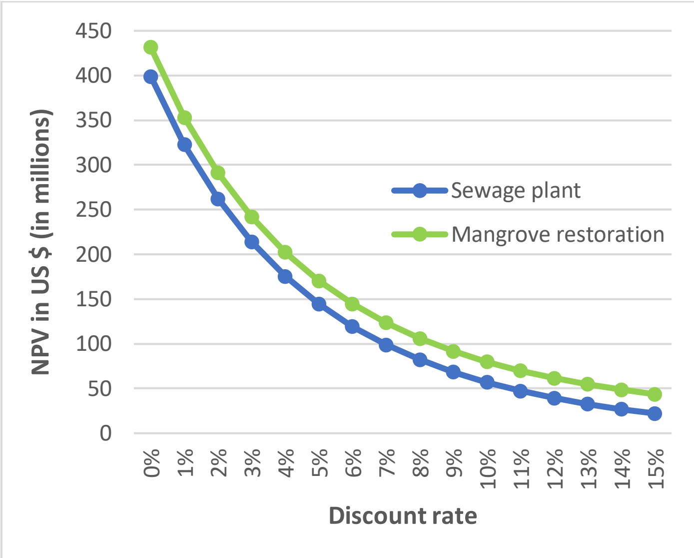

Figure F.5: NPV when assuming linear WTP functions

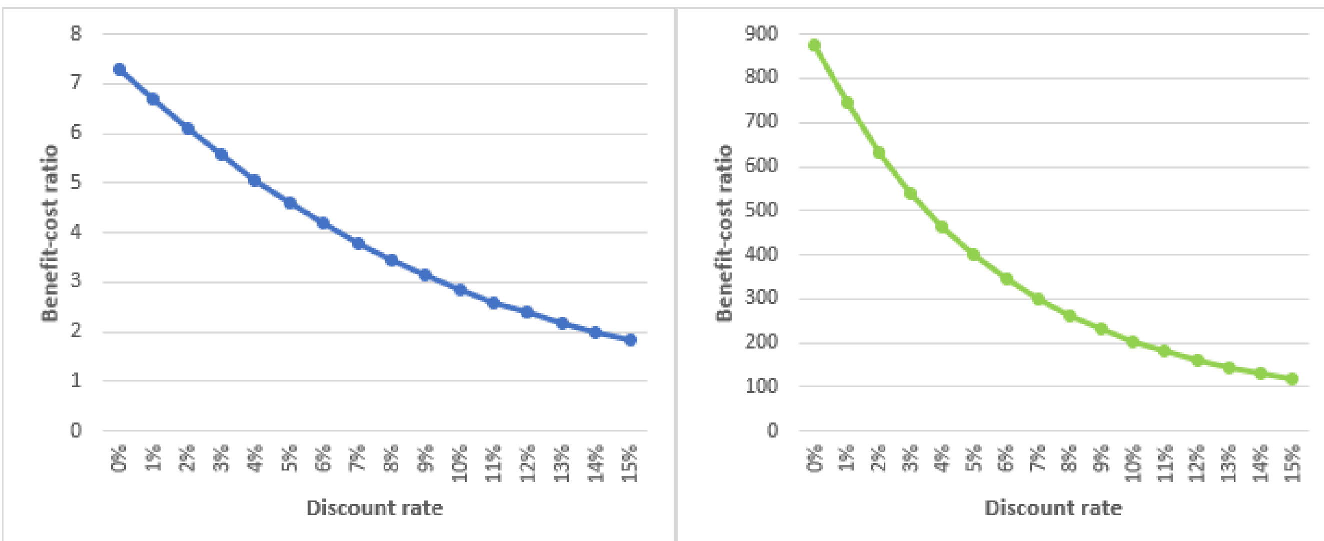

Figure F.6: Benefit-cost ratio of the sewage plant (left) and mangrove restoration scenario (right) when utilizing linear WTP functions

baseline scenario, this does not much affect the added value of the mangrove restoration and sewage plant scenario compared to the baseline. Hence, Figure F.5 and Figure F.6 display no marked changes in the NPV and BCR of both scenarios.

Annex F.3: Including only households living close to the Lagoon

When calculating the local and cultural value of the Lagoon, the per household WTP values were multiplied by the total number of households on Saint Martin, as no significant differences in

WTP were found for people living inside compared to outside the lagoon area. However, one might still wonder if WTP values are truly uniform across the island. Therefore, as an extreme case, this section calculates the results when one assumes that the found WTP values only hold for people living inside the lagoon area, implying that people outside the lagoon area attach no value to the Lagoon. In the lagoon area live around 8,907 households, compared to 27,421 on the whole island.

Obviously, this substantially lowers the TEV of all scenarios (see Figure F.7). However, Figure F.8 and F.9 show that even with this drastic assumption, the NPV and BCR of the sewage plant and mangrove restoration scenario are still higher than 0 and 1, respectively. This holds for all discount rates, although only slightly so for the sewage plant scenario for higher discount rates.

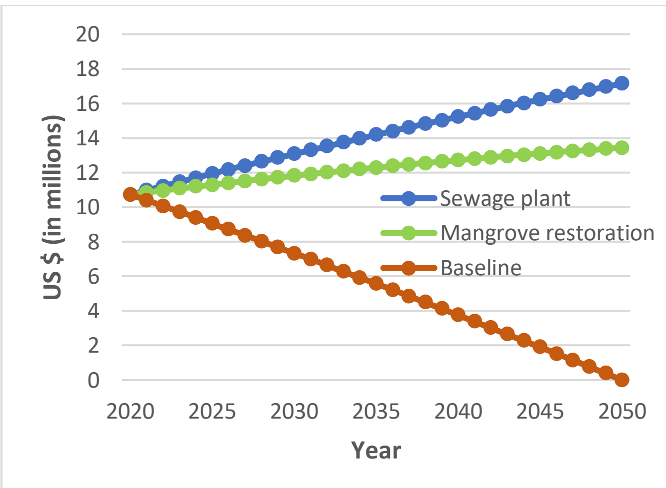

Figure F.7: The TEV of the baseline, mangrove restoration, and sewage plant scenario when only including households living in the lagoon area

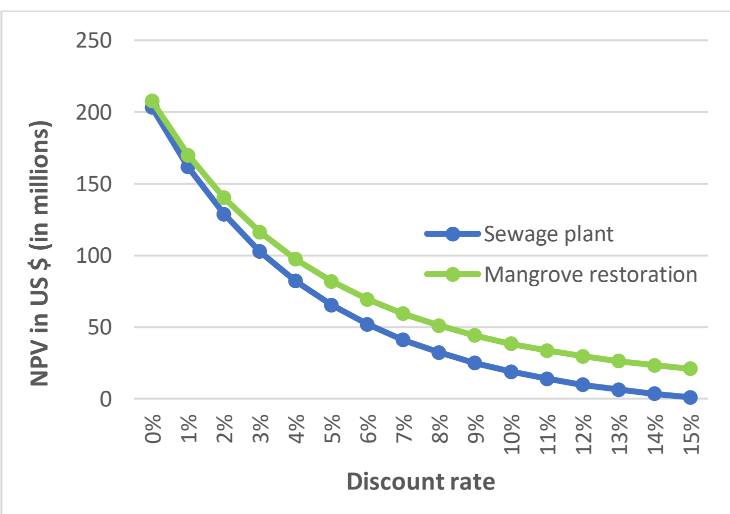

Figure F.8: NPV when only including households living in the lagoon area

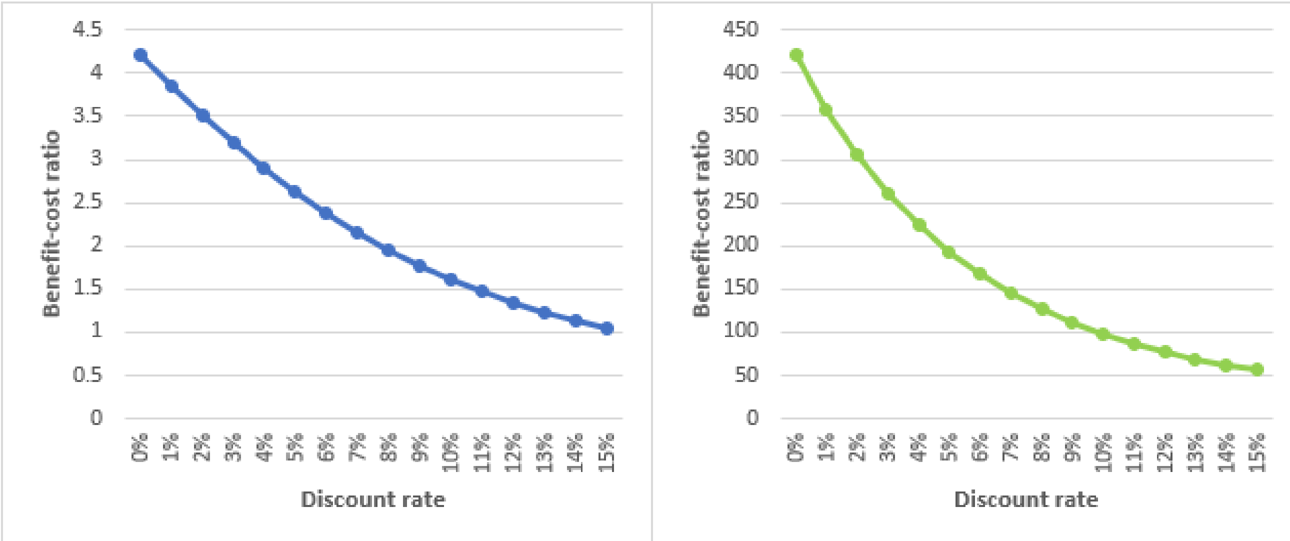

Figure F.9: Benefit-cost ratio of the sewage plant (left) and mangrove restoration scenario (right) when only including households living in the lagoon area

Annex F.4: Higher tourism value

When calculating the tourism value of the Lagoon, this study depended on the conservative estimate that the producer surplus of the tourism value is 1.08 that of the consumer surplus (see Section 5.1.2). However, for Saba and Sint Eustatius the producer surplus was, respectively, 3.79 and 2.96 that of the consumer surplus. This section shows the results when we assume that the ratio producer/consumer surplus for Saint Martin is 3 instead of 1.08. This is not unreasonable, as more than 80% of Saint Martin's economy depends on tourism. Figure F.10 shows that this increases the

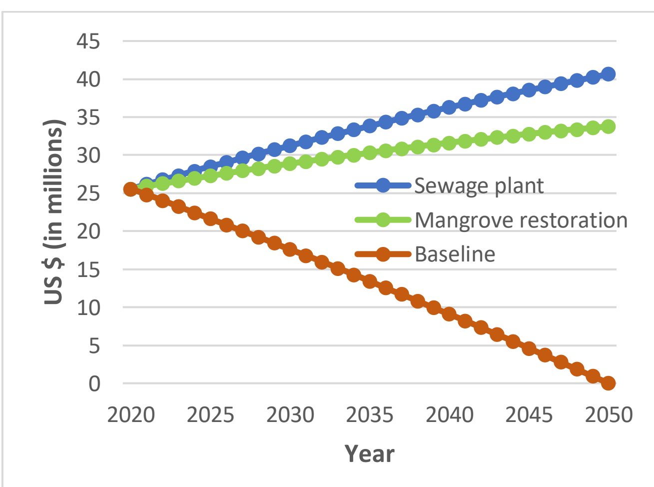

Figure F.10: The TEV of the baseline, mangrove restoration, and sewage plant scenario when assuming a higher tourism value

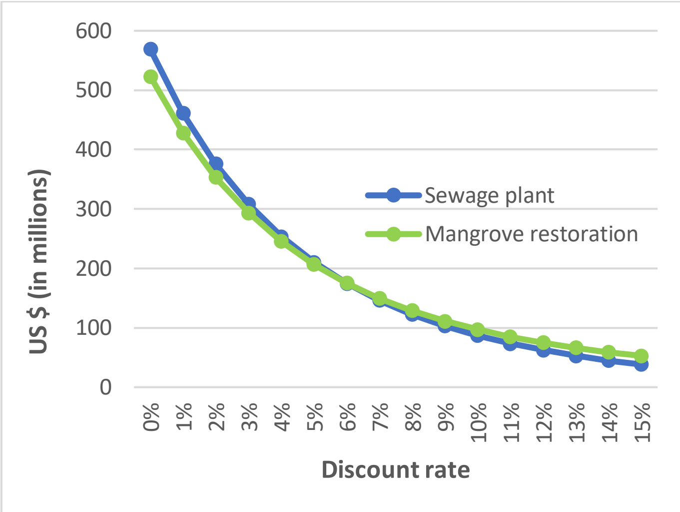

Figure F.11: NPV when assuming a higher tourism value

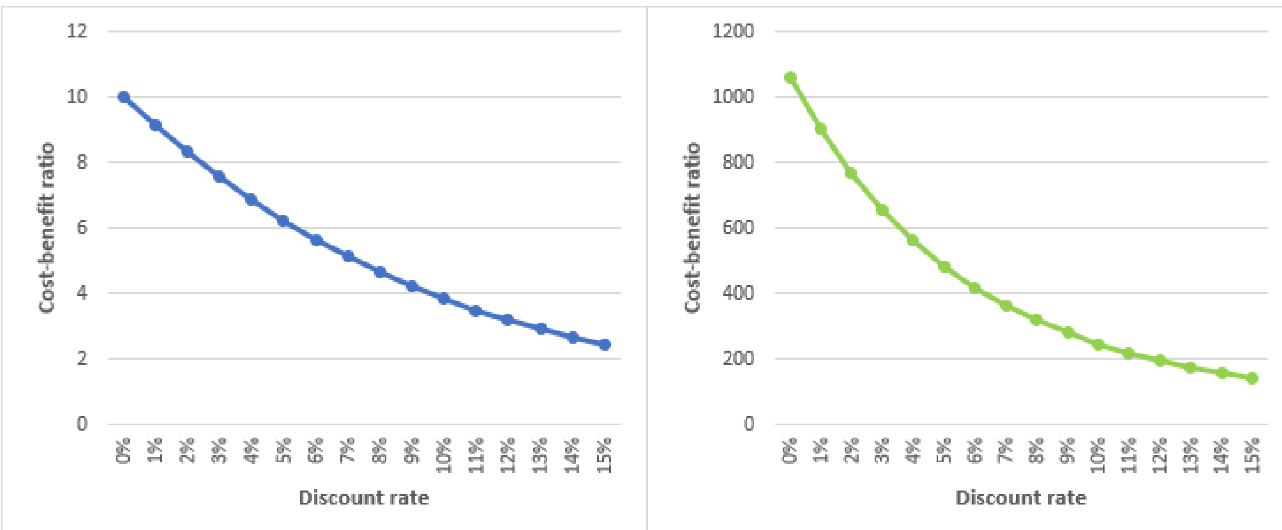

Figure F.12: Benefit-cost ratio of the sewage plant (left) and mangrove restoration scenario (right) when assuming a higher tourism value

TEV of both scenarios. Figure F.11 illustrates that this mostly benefits the sewage plant scenario, which now has a higher NPV than the mangrove restoration scenario until a discount rate of 6%. Nevertheless, the BCR of mangrove restoration still far exceeds that of the sewage plant (see Figure F.12).

Annex F.5: Higher costs of management scenarios

Although the author believes that this study provides accurate cost figures of the management scenarios, projects can always be costlier due to unforeseen circumstances. This section presents the results if for both mangrove restoration and the sewage plant the investment and yearly operation and maintenance costs are 50% higher than expected. Figure F.13 shows the resulting yearly costs of the management scenarios, on a logarithmic scale. Figure F.14 and F.15 illustrate that even when costs are 50% higher, for all discount rates the mangrove restoration and sewage plant scenario are economically more beneficial than the baseline scenario, as NPV>0 and BCR>1.

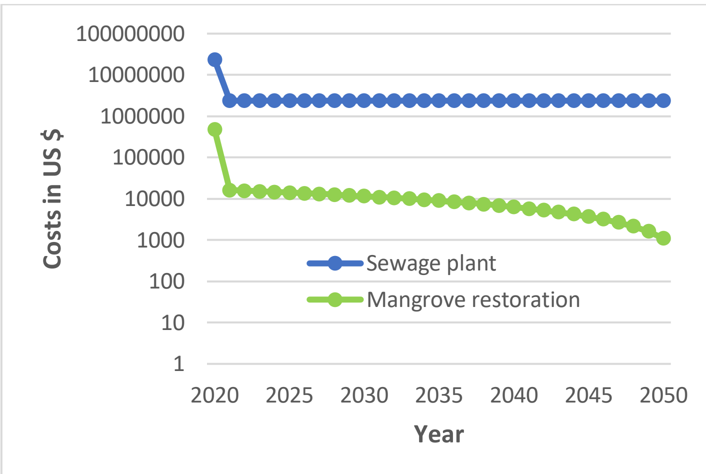

Figure F.13: Yearly costs of management scenarios when increasing costs with 50%

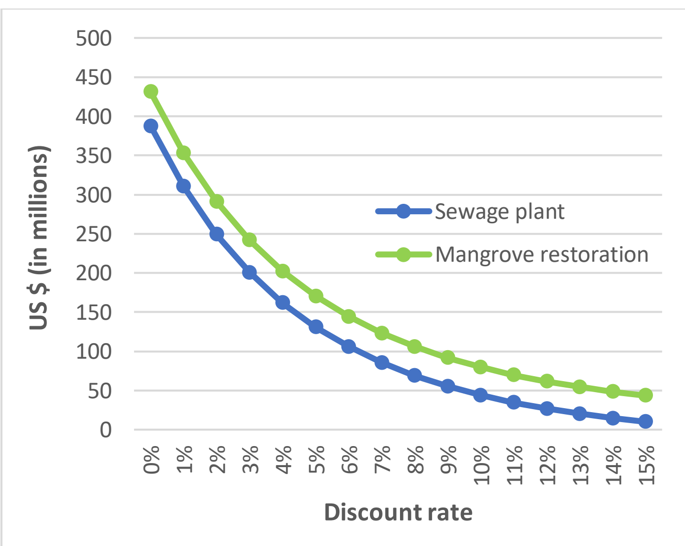

Figure F.14: NPV when assuming higher costs of the management scenarios

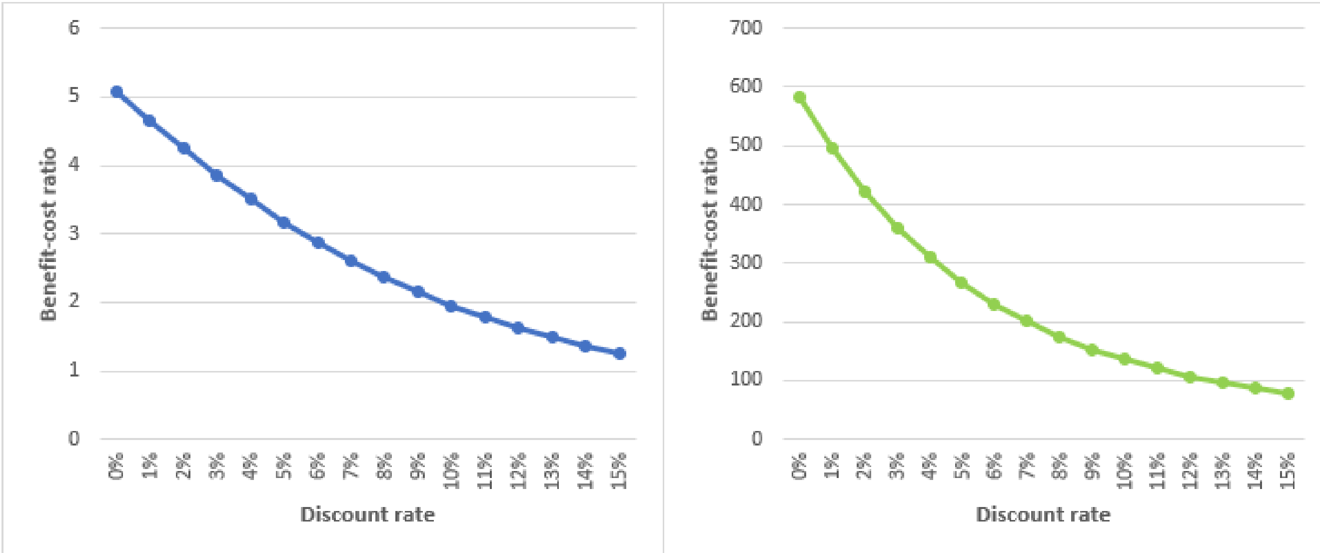

Figure F.15: Benefit-cost ratio of the sewage plant (left) and mangrove restoration scenario (right) when assuming higher costs of the management scenarios

Annex G: Survey questionnaire

Questions filled in by interviewer

Name interviewer	
Location interview (French or Dutch side)	
Date of interview	
Time of interview	From:……. To:………

Introduction at the house

Hello my name is.......... I am contributing to a study of Environmental Protection in the Caribbean (EPIC). We are conducting a survey on the importance of the environmental condition of the Simpson Bay Lagoon for the community of Saint Martin. We would like to hear your opinion about this topic. Everything that you tell us will be kept strictly confidential and the results will be analyzed anonymously.

Would you be willing to participate in the survey?

[No], thank you for your time and have a good day. (Continue to next address)

[Yes], Thank you very much for cooperating. I will tell you a little bit more about the study.

Introduction of the study

Thank you for participating in this survey. This survey is part of a research project of Environmental Protection in the Caribbean and VU University Amsterdam. The aim of this study is to show the benefits of improving the environmental condition of the Simpson Bay Lagoon for the community of Saint Martin. This study is partly about the benefits that the Simpson Bay Lagoon provides to the people of Saint Martin. Examples of these benefits are food provisioning (in the case of the lagoon this could be fishing), recreational opportunities, tourism, biodiversity, storm protection, etc. We would like to hear your opinion about this topic. Everything that you tell us will be kept strictly confidential and the results will be analyzed anonymously. The survey will start with some general questions.

I. General questions

Question 1: What is your gender?

a. Male	
b. Female	

Question 2: Were you born on Saint Martin? If yes, go to question 5.

a. Yes	
b. No	

Question 3: If not, where are you from?

a. Elsewhere in the Caribbean		e. North America	
b. Elsewhere in Latin America		f. Other, please specify:	
c. Netherlands mainland		g. Refuse to answer	
d. French mainland			

Question 4: How many years have you been living on Saint Martin

Number of years	

Question 5: How many people live in your household?

Number of people	

II. Recreational activities on the Lagoon

Question 6: Please indicate in the table below how often you do the following activities near or on the lagoon.

	Never	Once a year	Once a month	Once a week	More than once a week
a. Boating/Sailing					
b. Spending time near the lagoon (terraces, bars, restaurants, etc.)					
c. Kayaking/Paddle boarding					
d. Swimming					
e. Walking/Jogging/Cycling					
f. Fishing					
g. Bird/Wildlife watching					

III. The environmental condition of the Lagoon

Question 7: Did you notice any changes in the lagoon's environmental condition in the past 10 years or since you arrived on Saint Martin?

a. Yes	
b. No	

Question 8: Which changes have you noticed? You can pick multiple answers.

a. Bad smell coming from the lagoon	
b. Dirty water	
c. Trash and plastic pollution in the water/on the shores	
d. Less fish in the water	
e. Other, please specify:	

Question 9: How important do you consider the following reasons for the poor environmental condition of the Simpson Bay Lagoon?

	Not at all important	Not important	Neutral	Important	Very important
a. Sewage pollution					
b. Construction and development					
c. Garbage pollution					
d. Ship wrecks					
e. Mangrove destruction					
f. Invasive species					

Question 10: Who do you think is most responsible for the poor environmental condition of the lagoon? Please choose only one answer.

a. Tourists	
b. Government	
c. Businesses (restaurants, boat repair shops, etc.)	
d. Local people	
e. Other, please specify:	
f. I don't know	

Question 11: Are you in favor or not in favor of the following management activities to improve the environmental condition of the Simpson Bay Lagoon?

	Not at all in favor	Not in favor	Neutral	In favor	Strongly in favor	I don't know
a. Sewage treatment plant						
b. Mangrove restoration						
c. Better enforcement of regulations						
d. Removing shipwrecks						
e. Restricting development						
f. Environmental awareness raising						

Question 12: Do you think nature should be protected from human pollution (i.e. garbage, sewage, overdevelopment, etc.)?

a. Yes	
b. No	

Question 13: If yes, why? Choose the answer that best fits your opinion. Nature should be protected...

a. For its own sake, it has an important value of its own	
b. So humans can benefit from it (i.e. for recreation, etc.)	
c. Because of its cultural and historical value	
d. I don't know	

IV. Choice experiment and contingent valuation

Question 14: What is the version number used?

Version number	

Following the interview protocol, respondents are explained how the choice experiment works. The interviewer explains the choice experiment with the use of an example choice card. In each choice card, the scenarios are described in terms of the following aspects:

1. *Damage from storms* refers to the damage from storms to properties nearby the lagoon. Mangroves around the lagoon provide important protection from storms.
2. *Water quality* refers to the quality of the water in the Simpson Bay Lagoon. This takes into account the clarity of the water and the smell of the water.
3. *Habitat for species* refers to the extent to which the lagoon can provide a habitat for species (e.g. fish, turtles, birds). Many species find a habitat in the seagrass beds and mangrove stands that are present in the lagoon.
4. *Suitability for recreation* refers to the suitability of the lagoon for recreational activities (fishing, sailing, swimming, barbecuing, bird watching, etc.).
5. *Stay-over tourists* refers to the number of stay-over tourists that come to the island of Saint Martin.
6. The *contribution per month* that would be contributed financially by all households of Saint Martin and would be used strictly for the environmental management of the Simpson Bay Lagoon.

The options in the example card of the choice experiment are explained as follows, where option C refers to the scenario when no additional environmental management would be put in place:

- In **Option A** the damage from storms to properties nearby the lagoon will reduce with 40%. The water quality will be high, with clear water and no bad smell. Habitat for species will increase with 40%. Suitability for recreation will be high. The number of stay-over tourists will increase with 20%. Your household pays $20 per month.
- In **Option B** the damage from storms to properties nearby the lagoon will stay the same as it is now. The water quality will be moderate, with occasional bad smell and areas of clear and unclear water. Habitat for species will stay the same as it is now. Suitability for recreation will be moderate. The number of stay-over tourists will stay the same as it is now. Your household pays $5 per month.
- In **Option C** the damage from storms to properties nearby the lagoon will increase with 40%. The water quality will be low, with bad smell and unclear water. Habitat for species will decrease with 40%. Suitability for recreation will be low. The number of stay-over tourists will decrease with 20%. You do not have to pay a monthly contribution.

It is stressed to the respondents that they have to make trade-offs, and that there are no wrong answers. When respondents do not understand the choice experiment, the interviewer explains the protocol again with the use of the example choice card.

Question 15: The responses of the respondents to the six choice cards

Choice card	Option A	Option B	Option C	Refused to answer
Choice card 1				
Choice card 2				
Choice card 3				
Choice card 4				
Choice card 5				
Choice card 6				

Question 16: How certain are you about the choices you just made?

a. Very uncertain	b. Uncertain	c. Neutral	d. Certain	e. Very certain

Question 17: In making your choices, how important were the following aspects to you?

	Not at all important	Not important	Neutral	Important	Very important
a. Storm surge protection					
b. Water quality					
c. Biodiversity					
d. Suitability for recreation					
e. Tourism					
f. Monthly contribution is US $					

Question 18: How did you make your choices? Did you:

a. Consider all aspects	
b. Consider a few specific aspects	
c. Only consider one specific aspect	
d. Use your intuition	
e. Make a random choice	
f. I don't know	

Question 19: Are you in principle willing to pay for environmental management of the Simpson Bay Lagoon?

a. Yes	
b. No	

Question 20: If no, what is the main reason you are not willing to pay for environmental management of the Simpson Bay Lagoon?

a. I do not care enough about the environment	
b. I am in favor of more protection, but this should be paid from existing tax revenues	
c. I can't financially afford to contribute	
d. I doubt the effectiveness of nature protection	
e. Other social problems are more urgent	
f. I do not cause nature problems and therefore I am not responsible for solving them	
g. Other, please specify:	

Question 21: If yes, what is the maximum amount of MONTHLY contribution your household is willing to pay for environmental management of the Simpson Bay Lagoon? You can pick any amount from the payment card or come up with your own amount. In making a choice, carefully take into account whether your household actually can and is willing to pay this amount given your current income level.

Amount willing to pay in US $ per month	

Payment card:

$0	$2	$4	$8	$15	$30	$65	$125
$1	$2.50	$5	$10	$20	$40	$80	More than $125
$1.50	$3	$6	$12.50	$25	$50	$100	Don't want to say

Question 22: How certain are you about the choice you just made?

a. Very uncertain	b. Uncertain	c. Neutral	d. Certain	e. Very certain

Question 23: Which organization should manage the funds for the environmental management of the Simpson Bay Lagoon?

a. Government of Dutch Saint Martin	
b. Territorial council of French Saint Martin	
c. Government of the Netherlands	
d. Government of France	
e. VNP Saint Maarten (Dutch representation Sint Maarten)	
f. Local environmental organizations (e.g. EPIC, Nature Foundation, Reserve Naturelle, Les Fruits des Mer)	
g. Other, please specify:	
h. Don't know/no preference	

V. Environmental perceptions and behavior

Question 24: Please indicate in the table below how often you do the following activities near or on the lagoon:

	Never	Rarely	Sometimes	Often	Very often
a. Look for environmental information (on the internet, TV, newspaper, radio, etc.)					
b. Attend public meetings or events related to the environment					
c. Donate money to an environmental cause (e.g. Nature Foundation/ EPIC)					
d. Do any voluntary environmental work (e.g. clean up of beach/nature)					
e. Purchase environmentally friendly products (reusable bags, etc.)					
f. Walk or bike instead of driving					
g. Recycle your waste (plastic, carton, glass, etc.)					
h. Avoid littering, encourage other people not to litter					
i. Properly dispose of hazardous chemicals (oil, paint, etc.) that should not be poured down the drain					

Question 25: To what extent do you agree or disagree with the following statements? Please indicate below:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a. I consider myself environmentally aware					
b. Hurricane Irma has increased my awareness about the natural environment					
c. Compared to other people on Saint Martin, I was less affected by Hurricane Irma					
d. The pollution of the lagoon has a negative effect on my health					
e. The area around the lagoon is an important place to meet other people for social interaction					
f. I feel involved in the decision-making process of the management of the lagoon					
g. The benefits provided by the lagoon are important for my own well-being					
h. The benefits provided by the lagoon are important for the well-being of other people on Saint Martin					
i. The benefits provided by the lagoon are important for my income					
j. The cultural and historical aspect of the lagoon is important to me					

VI. Demographics

Question 26: How old are you?

a. 18-25		e. 56-65	
b. 26-35		f. 66+	
c. 36-45		g. Refuse to answer	
d. 46-55			

Question 27: In which field are you employed?

a. Retail		i. Healthcare	
b. Hotels, restaurants and other hospitality services		j. Care and social work	
c. Government		k. Tour activities (e.g. diving, jeep tours, etc.)	
d. Construction		l. Retired	
e. Electricity, gas and water		m. Not employed	
f. Transportation and storage services		n. Other, please specify:	
g. Education		o. Don't know / refuse	
h. Rental and leasing activities			

Question 28: What is the highest level of education that you have completed?

a. No education		f. Higher education: University bachelor	
b. Primary school		g. Higher education: University master	
c. High school		h. Other, please specify:	
d. Vocational school / technical school (MBO, CFA)		i. Don't know / refuse	
e. Higher education: University of applied sciences (HBO)			

Question 29: May I ask your gross household income in US $ from the last month?

a. <500		f. 3500-4999	
b. 500-999		g. 5000-6999	
c. 1000-1599		h. 7000-9999	
d. 1600-2499		i. >10000	
e. 2500-3499		j. Don’t know / refuse	

Question 30: Are there any other issues or suggestions that you would like to share related to the environment of the Simpson Bay Lagoon?

Thank you very much for participating in this survey. Your participation will contribute to the improvement of the environment of the Simpson Bay Lagoon.