Valuing a Caribbean coastal lagoon using the choice experiment method: The case of the Simpson Bay Lagoon, Saint Martin

Sem Duijndam*, Pieter van Beukering, Hanna Fralikhina, Anne Molenaar, Mark Koetse

Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, De Boelelaan 1085, Amsterdam HV 1081, The Netherlands

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ABSTRACT

Like many Caribbean coastal ecosystems, the Simpson Bay Lagoon in Saint Martin suffers from heavy development, wastewater pollution, and overexploitation. These pressures have severely degraded its ecological integrity, causing significant environmental impact as well as negative socio-economic consequences. Local livelihoods depend on important ecosystem services provided by the Simpson Bay Lagoon, such as storm protection and water purification. A major cause for the continued degradation of the Simpson Bay Lagoon is that decision-makers undervalue these ecosystem services. This study conducts an economic valuation of the Simpson Bay Lagoon to solve this undervaluation, providing the first economic valuation of a Caribbean island coastal lagoon.

To estimate the economic value of the Simpson Bay Lagoon, this paper employs a choice experiment, which is embedded in a larger household survey among residents of Saint Martin. The findings of the choice experiment reveal that the Simpson Bay Lagoon in its current environmental state is worth US$12.1 million per year to the residents of Saint Martin. Besides an economic valuation, this paper also scrutinizes the welfare benefits of improved environmental management. Two environmental management scenarios are evaluated: the installation of a sewage treatment plant and mangrove restoration. The installation of a sewage treatment plant would enhance the annual economic value to US$16.5 million, mangrove restoration to US$23.0 million, and the implementation of both measures to US$26.3 million. Hence, ameliorating the ecological integrity of the Simpson Bay Lagoon through improved environmental management proves to be a promising venture for the environment, society, and economy of Saint Martin.

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, Newton, Tett, & Fernandes, 2012; Clara et al., 2018; 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 large 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., 2016).

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). 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; Velasco, Pérez-Ruzafa, Martínez-Paz, & Marcos, 2018). Economic valuation through the ecosystem services approach is often proposed as a solution to this undervaluation, as this method quantifies the benefits of ecosystems for human-wellbeing, and thereby facilitates the embeddedness of the value of nature in decision-making (Franco et al., 2006; Håyhä & Franzese, 2014; Luck et al., 2012). More than 1600 ecosystem service valuation studies have already been published, with the large majority of these studies being conducted in developed countries (Christie, Fazey, Cooper, Hyde, & Kenter, 2012). Although several coastal lagoon valuation studies have been conducted so far (Clara et al., 2018; García-Ayllón, 2019; Martínez-Paz, Perni, & Martínez-Carrasco, 2013; Tuan,
My, Anh, & Toan, 2014; Velasco et al., 2018), these studies remain underrepresented in the literature (Camacho-Valdez, Ruiz-Luna, Ghermandi, & Nunes, 2013; Newton et al., 2018). A recent review article by Newton et al. (2018) on the assessment and valuation of ecosystem services provided by coastal lagoons identified 20 valuation studies targeting coastal lagoons. They find that for coastal lagoons, food provisioning and cultural heritage are the ecosystem services with the highest average monetary value. This is surprising, as de Groot et al. (2012) in a meta-analysis find that, in general, the most valuable services provided by coastal and estuarine ecosystems are regulating services. This contrast might be due to the few and mostly European-based coastal lagoon valuation studies that have been conducted so far. This makes the results sensitive to outliers and less representative for coastal lagoons worldwide. More economic valuation studies of coastal lagoons are therefore needed to enhance the stock of knowledge about the value of these ecosystems.

In this study, we conduct an economic valuation of the Simpson Bay Lagoon, located in the Caribbean island of Saint Martin. This is done by eliciting the lagoon’s value to the local citizens of Saint Martin. To the authors’ knowledge, this study provides the first economic valuation of a Caribbean island coastal lagoon. The Simpson Bay Lagoon (henceforth often called ‘the Lagoon’) is one of the largest coastal lagoons in the Antilles and suffers like many Caribbean coastal ecosystems from heavy development, wastewater pollution, and overexploitation (Burke & Maidens, 2004; Gilders, 2018; Yáñez-Arancibia, Day, Knoppers, & Jiménez, 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 ecosystem services provided by the Lagoon (e.g. for tourism and storm protection). Especially on the Caribbean islands, where many people live in close proximity to coastal lagoons and estuaries, these ecosystems are of vital importance to people (Waite, Kushner, Jungwiwattanaporn, Gray, & Burke, 2015). Fanning et al. (2011) argue 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. Nevertheless, multiple valuation studies of Caribbean coastal ecosystems have already been conducted, illustrating that these ecosystems are of great value for the economy and human wellbeing (Burke, Prager, Cooper, & Greenhalgh, 2008; Cooper, Burke, & Bood, 2009; Mehvar, Filatova, Dastgheib, de Ruiter van Steveninck, & Ranasinge, 2018; Schep, van Beukering, Brander, & Wolfs, 2013; Waite et al., 2015). The fact that economic valuation can indeed be an effective way to improve environmental management of Caribbean coastal and marine ecosystems is demonstrated by Waite et al. (2015). They identified 17 valuation studies of Caribbean coastal ecosystems that directly influenced decision making and led to improved environmental management.

To estimate the economic value of the Simpson Bay Lagoon to the local residents of Saint Martin, this paper employs the choice experiment method. The choice experiment is a hypothetical stated-preference method which can be used to estimate the economic value of ecosystem services by eliciting respondent’s willingness-to-pay (WTP) for these services. 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, Mourato, & Wright, 2002; Koetse, Brouwer, & van Beukering, 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 (Adamowicz, Boxall, Williams, & Louviere, 1998; Hanley et al., 1998; He, Dupras, & Poder, 2017; Koetse et al., 2015; Whittington & Pagiola, 2012). First, a choice experiment provides a more intuitive way to estimate the value of an ecosystem by presenting respondents with different scenarios and by not directly asking them for their WTP. Second, choice experiments have been found to be less prone to strategic response behavior. Third, choice experiments allow for the estimation of individual WTP values for different components of an ecosystem. This aids decision-makers in tailoring their policy efforts towards the most highly valued ecosystem services. Finally, by letting respondents compare different future scenarios, the choice experiment is useful when evaluating alternative management options. This study exploits this latter benefit of the choice experiment method by conducting a scenario analysis of two future environmental management scenarios for the Simpson Bay Lagoon: mangrove restoration and the installation of a sewage treatment plant.

The choice experiment method is well recognized and often employed in the literature on the economic valuation of ecosystem services (Alcon, Albaladejo-García, Zabala, Marín-Miñano, & Martínez-Paz, 2019; Brander, Florax, & Vermaat, 2006; Dupras, Laurent-Lucchini, Revèrét, & DaSilva, 2018; He et al., 2017; Marre et al., 2015; Perez-Verdin et al., 2016; Wright & Eppink, 2016). Nevertheless, the application of the choice experiment method is an innovative approach in the literature on the valuation of ecosystem services provided by coastal lagoons, as previous studies in this field relied predominantly on other methods, such as the contingent valuation or travel cost method. For valuation estimates (Clara et al., 2018; Newton et al., 2018; Tuan et al., 2014; Velasco et al., 2018). Newton et al. (2018) illustrate that due to a great lack of data the economic value of many ecosystem services provided by coastal lagoons remains unclear. One of the main benefits of the choice experiment method is the elicitation of economic values for specific ecosystem services and, consequently, this study provides an important contribution to the existing stock of knowledge.

Although economic valuation allows for the generation of convincing indicators, monetary values are just one source of information and are not meant to replace sociocultural, ethical, intrinsic, and other nonmonetary values (Schröter et al., 2014). To alleviate this drawback of monetary valuation, the choice experiment conducted in Saint Martin was embedded in a larger household survey. This household survey asked respondents multiple questions including questions about the importance of the Simpson Bay Lagoon in their daily lives, their perceptions of the environmental problem, and their acceptance of several envisioned environmental management scenarios.

This study contributes to the existing literature in two ways. First, by applying the choice experiment method to elicit the value of ecosystem services provided by the Simpson Bay Lagoon this research adds to the limited number of economic valuation studies on coastal lagoons (Newton et al., 2018). To the authors’ knowledge, it provides the first valuation study of a Caribbean island coastal lagoon, which is especially important given the proliferation of these ecosystems in the region (Buesa, 2019; European Commission, 2016; Pérez-Villalona, Cornwell, Ortiz-Zayas, & Cuevas, 2015). Second, scientific studies on coastal ecosystems 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. As the Simpson Bay Lagoon suffers from similar pressures as other coastal ecosystems in the Caribbean, the results of this study are wider applicable as well.

The structure of this paper is as follows. Section 2 provides the materials and methods. Section 3 presents the results of the household survey, the economic valuation, and the scenario analysis. Section 4 discusses the main results found in this study. Finally, Section 5 provides a conclusion and gives policy recommendations.
2. Materials and methods

2.1. The case study: Simpson Bay Lagoon, 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 Fig. 1). The island is divided into a Dutch part in the South and a French part in the North. The island comprises an area of 88 km². The Dutch part of the island has a population of 41,109, which makes it the most densely populated country in the Caribbean (World Bank, 2019). The French part of Saint Martin is home to 35,746 people. The number of households on the island is approximately 27,421 (Department of Statistics Sint Maarten, 2019; INSEE, 2016). The economies of both parts of the island are highly dependent on tourism revenues. In 2016, an estimated 1.7 million cruise passengers and around half a million stay-over tourists visited the island (Gilders, 2018). However, the island suffered tremendously from Hurricane Irma, which caused the death of at least eight people and destroyed most of the island’s infrastructure. Restoration efforts are still ongoing and progress is slow (World Bank, 2019).

Fig. 1 shows a map of Saint Martin with the Simpson Bay Lagoon. The Lagoon is situated in the southwest of the island. With a size of approximately 880 ha, it is one of the largest coastal lagoons in the Antilles (Gilders, 2018). Two narrow openings on the Northern and Southern side connect the Lagoon with the ocean. Within the Lagoon lies the Mullet Pond, which is internationally recognized by the Ramsar Convention on Wetlands of International Importance. The Simpson Bay Lagoon is of high ecological value. The presence of mangrove stands and seagrass beds makes the Lagoon an important habitat and nursery ground for many marine species including shrimps, lobsters, conch, turtles and a wide variety of fish species. The mangrove stands further provide an essential habitat and breeding place for birds such as the Green Heron, the Black-winged Stilt and several plovers. The mangroves and seagrasses present in the Simpson Bay Lagoon also prevent terrestrial sediments from reaching nearby coral reefs, thereby protecting these biodiverse ecosystems (Nature Foundation Sint Maarten, 2013).

There is a lot of human activity in and around the Lagoon. The land surrounding the Lagoon is covered with houses, hotels, restaurants and other infrastructure. Furthermore, the Lagoon is home to many marinas where boats can anchor and seek shelter during adverse weather conditions. The Lagoon is also an important part of the tourism sector of both sides of the island, with many people’s employment depending on it. A number of businesses also provide recreational activities on the Lagoon such as kayaking, sailing and jet skiing. Historically, the Lagoon was a popular place for artisanal fishing, but this is hardly practiced anymore (Gilders, 2018; Nature Foundation Sint Maarten, 2013; Vermeij & van den Brink, 2010).

Nevertheless, this proliferation of human activity has a shadow side. Like many Caribbean coastal ecosystems, the Lagoon suffers from heavy development, mangrove destruction, wastewater pollution and over-exploitation (Gilders, 2018; Yáñez-Arancibia et al., 2011). Over the past two decades, the Lagoon has decreased with 23 % in size due to land reclamation for infrastructural projects (Vermeij & van den Brink, 2010). Furthermore, sewage inflow is common due to lacking sewage treatment facilities. These pressures have deteriorated the ecological integrity of the Lagoon and threaten to impair the capacity of the Lagoon to provide essential ecosystem services for the local population. The bad water quality of the Lagoon resulting from human activities also has detrimental impacts on the nearby coral reefs, which are of high ecological and economic value (DCNA, 2018; DeGeorges, Goreau, & Reilly, 2010). Due to the strong conflicts between human development and the natural environment, the Simpson Bay Lagoon can be seen as a microcosm of other Caribbean coastal ecosystems, which makes it a highly relevant case to study.
Table 1
Ecosystem services provided by the Simpson Bay Lagoon.

| Ecosystem | Category  | Service          | Specification                              |
|-----------|-----------|------------------|-------------------------------------------|
| Wetland   | Provisioning | Sea food        | Fish                                      |
|           |           | Local climate regulation | Keeps the surrounding area cool           |
|           |           | Carbon sequestration   | The wetland stores carbon                 |
|           |           | Moderation of extreme events | Flood prevention, safe harbor for yachts  |
|           |           | Wastewater treatment  | Purification of wastewater                |
|           |           | Erosion control      | Prevents soil erosion                     |
|           |           | Pollination         | Birds pollinate nearby trees              |
|           |           | 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 people                |
|           |           | Historical         | Historical value for people               |
| Mangroves | Regulating | Erosion control    | Roots prevent soil erosion                |
|           |           | Carbon sequestration | The mangroves store carbon               |
|           |           | Moderation of extreme events | Attenuation of waves and winds            |
|           |           | Wastewater treatment | Purification of wastewater               |
|           |           | Habitat for species  | Birds, juvenile fish, crabs               |
|           | Cultural  | Nursery ground      | Nursery ground for fish and other marine life |
|           |           | 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 for species  | Habitat and foraging place for many species |
|           |           | Nursery ground      | Nursery ground for fish and other marine life |

2.2. Ecosystem services provided by the Simpson Bay Lagoon

The Simpson Bay Lagoon provides many ecosystem services for the local population of Saint Martin such as storm protection, water filtration, habitat services, recreation, and tourism support (Gilders, 2018). In the light of exacerbating climate change impacts on small Caribbean islands such as Saint Martin, the importance of these ecosystem services is expected to become even more significant in the future (Rhiney, 2015). Table 1 provides a summary of all ecosystem services provided by the Simpson Bay Lagoon, and is modified from an earlier study by Gilders (2018). Ecosystem services are shown separately for the wetland, mangrove and seagrass characteristic of the Lagoon to provide a better picture of the range of services provided by the various ecosystems. Table 1 also displays the classification of the ecosystem services as based on the TEEB classification (de Groot et al., 2020). These categories are provisioning, regulating, habitat 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). Habitat services reveal the importance of ecosystems for providing habitat for species and for maintaining gene pools. Cultural services represent non-material benefits people obtain from ecosystems (e.g. recreation).

2.3. Household survey

The choice experiment method employed in this paper was embedded in a larger household survey. The questions in the survey ask respondents about their demographic characteristics, 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. The full questionnaire can be found in Appendix C of the supplementary material. When designing the questionnaire, multiple local stakeholders were consulted (see Table A.1 in the Appendix for an overview of the consulted stakeholders). 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 et al., 2008). To make the survey accessible for most citizens of Saint Martin, the questionnaire had been made available in both English and French.

The household survey on Saint Martin was conducted in the period April–May 2019 by a group of six trained enumerators. In total, 219 households participated in the survey via face-to-face interviews. The total number of respondents from the Dutch and the French side of Saint Martin was 131 and 88, respectively, reflecting the higher number of people living on the Dutch side of the island. The main target population for our study were people living close to the Lagoon (i.e. within 2 km), as they are likely to benefit most from the Lagoon’s ecosystem services. Nevertheless, 33 people living further away from the Lagoon were interviewed to investigate how they value the Lagoon and to see if their WTP values significantly differ from people living close to the Lagoon. This makes it possible to assess potential distance-decay effects (Schaafsma, Brouwer, Gilbert, van den Bergh, & Wagtendonk, 2013). This sub-sample constitutes 15 % of the total sample size. Stratified sampling was applied to ensure that each region was represented in correspondence to its relative number of inhabitants. Within strata, households were selected using a systemic approach in which interviewers walked in opposite directions and interviewed every third household. This sampling approach has been commonly applied in other (developing country) studies as well (Chakraborty et al., 2016; Grimm & Lesorogol, 2012). Preferably, the head of the household was interviewed, or otherwise anyone else living in the household older than 18 years old.

2.4. Design of the choice experiment

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 considered the opinion of many local stakeholders including environmental, industrial, and governmental organizations. An overview of the consulted stakeholders can be found in Table A.1 in the Appendix. The
The attributes and levels used in the choice experiment.

| Attribute                        | Description attribute                        | 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’ household | US$0, US$2, US$5, US$10, US$20 |

Table 2: The attributes and levels used in the choice experiment.

The attributes and levels used in the choice experiment. Five attributes represent the environmental state of the Lagoon. These environmental attributes are: damage from storms, water quality, habitat for species, suitability for recreation, and number of stay-over tourists. These attributes correspond to, respectively, the following ecosystem services provided by the Lagoon: storm protection, water filtration, habitat services, recreation and tourism support. The sixth attribute is the so-called payment vehicle and constitutes a monthly contribution paid by the household of the respondent. This payment vehicle is essential to elicit the monetary WTP for the different ecosystem services.

The attributes damage from storms, habitat for species, and number of stay-over tourists contain four levels constituting a percentage change. Due to a lack of biophysical data and uncertainties in future developments, exact potential percentage changes could not be determined. The choices for these attribute levels were therefore made in close consultation with stakeholders to make them as policy-relevant as possible (see Table A.1 in the Appendix). Depending on environmental management measures such as mangrove restoration or improved sewage management being put in place, or not, improvements or deteriorations in the provision of these ecosystem services can be expected. For the attributes water quality and suitability for recreation there are three levels, both described in terms of ‘low’, ‘moderate’, and ‘high’. Using these types of levels for water quality and recreation attributes is common in the literature (Eppink, Winden, Wright, & Greenhalgh, 2016; Hoyos, Mariel, & Hess, 2015; Tan et al., 2018). The payment vehicle attribute has five levels, which entail payments ranging between zero and twenty US dollars per month.

Fig. 2 displays the example choice card used in the choice experiment. In each choice card of the choice set, Option C referred to the status quo scenario. The status quo reflects the future scenario when no extra management would be put in place (Barreiro-Hurle, Espinosa-Godor, Martinez-Paz, & Perni, 2018). In this status quo scenario, the environmental condition of the Lagoon would deteriorate, but people would not have to pay a monthly contribution. Pictograms were used in each choice card to reveal the attribute levels to the respondents. Pictograms are preferred to text only, as graphics reduce fatigue problems and are often more understandable for the respondent (Ryffel, Rid, & Grét-Regamey, 2014).

2.5. Statistical design and statistical analysis of the choice experiment

The statistical design of the choice experiment 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 were 24 different choice cards. Each card consisted of three scenarios, where scenario three always entailed the expected future without extra management (i.e. the status quo scenario). The four versions of choice sets were equally represented among and randomly assigned to the sample population.

The type of model that is applied to analyze the choice experiment is the mixed logit (MXL) model. The MXL model has several advantages over the often employed multinomial logit (MNL) model (Carlsson, Frykblom, & Liljenstolpe, 2003; Maitra, Ghosh, Das, & Boltze, 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 modelling technique makes it possible to estimate WTP values for each respondent in the sample. The WTP-values obtained from the MXL model are subsequently used to assess the potential welfare benefits of improved environmental management of the Lagoon. The MXL model is estimated with 1000 Halton draws and a triangular distribution of the random parameters (Ghosh, Maitra, & Das, 2013; Hensher, Rose, & Greene, 2015).

3. Results

3.1. Description of the survey sample

Table 3 shows the sociodemographic profile of the 219 survey respondents. It displays descriptive statistics of gender, age, household income per month, country of birth, education, and average household size. The statistics are shown for the whole sample, as well as for the Dutch and French side separately. 47 % of the respondents are female and 53 % male. Most respondents are between 26 and 55 years old. The typical monthly household income of a respondent is between US$1000 and US$3500 per month. Nevertheless, 18 % of the respondents live in a household with a monthly income lower than US$1000 per month. 19 % of the respondents did not know their household income or refused to answer. Regarding country of birth, 35 % of the respondents were born on Saint Martin, 33 % on other Caribbean countries, and 32 % elsewhere. 60 % of the respondents mentioned high school or vocational training as their highest level of completed education. 31 % of the respondents completed higher education, while 6 % of the respondents had no education or finished solely primary school. The average household size in the sample is 3.04 people. The sample has also been tested for representativeness. This was difficult as not much recent sociodemographic data is available for both the Dutch and the French side of the island.

Nevertheless, representativeness could be tested for age, gender and
education. Results from a chi-square test show that the sample is representative in terms of the age distribution and gender ($p > 0.05$) and not representative for education level ($p < 0.05$). People who have secondary school or university as their highest education level are slightly overrepresented whereas people who have primary school, vocational school or university of applied sciences as their highest education level are slightly underrepresented. This could be due to the fact that this study employs a household survey, and the socio-demographics of the head of the households could differ from that of the general population.

### 3.2. Analysis of the survey questions

Appendix B of the Supplementary material provides an extensive summary of the responses to the survey questions accompanying the choice experiment. Many respondents indicate that they regularly undertake recreational activities on or alongside the Lagoon. Popular activities include birdwatching, boating, sport activities and spending time in catering establishments alongside the Lagoon. More than 80% of the respondents have noticed changes in the environmental state of the Lagoon over the past ten years or since they arrived on Saint Martin.
The following socio-economic and demographic variables were analyzed:

### 3.3.1. Results of the mixed logit model

Table 3 shows the results of the MXL regression analysis of the choice experiment data. The MXL model has been estimated assuming a triangular distribution for all parameters. Estimations of the same model with normal and restricted triangular distributions resulted in identical results (in terms of the significance of the parameters), and are not reported. The estimated coefficients portray the slope of the utility function of the respondents. Model A displays the results of the basic model when no interactions are incorporated. The results indicate that less damage from storms, better water quality, more habitat for species, more stay-over tourists and a lower monthly monetary contribution significantly increase the utility of the respondents. The coefficients of these attributes are all significant at the 1% level. The standard deviations of the parameters of all attributes have been found to be statistically significant. The coefficient of the suitability for recreation attribute is negative and non-significant. Consequently, people do not significantly prefer more recreational opportunities on the Lagoon. The coefficient of the alternative specific constant (ASC) is negative and significant. This illustrates that people attach a significant negative utility to the status quo, which in this study entails the ‘business-as-usual’ or ‘no extra environmental management’ future scenario. Hence, a status-quo bias has not been found to be present in this study (Barreiro-Hurle et al., 2018; Meyerhoff & Liebe, 2009). This indicates people’s positive preferences for improved environmental management of the Lagoon.

Model B displays the results when interaction terms are added to the MXL model. Only significant interactions are included in the final model specification. The coefficient of the interaction between the ASC and higher education is negative and significant at the 1% level. This illustrates that people who completed higher education have a significantly higher preference for improved environmental management of the Simpson Bay Lagoon (i.e. leaving the status quo scenario) than people who did not complete higher education. The coefficient of the interaction between the ASC and age is positive and significant at the 5% level. Hence, older people are more inclined to prefer the status quo than younger people. Finally, the coefficient of the interaction between ASC and female is negative and significant at the 10% level, indicating that females have a higher preference for leaving the status quo than males.

Table 4 also displays the WTP values per month for all significant attributes. Model A is used to calculate the WTP values as this model does not suffer from deleted observations as a result of missing socio-economic information, as model B does. Nevertheless, the parameter estimates of both models are similar. WTP values can be calculated by dividing the coefficient of the attribute with minus the coefficient of the payment attribute (in this case the monthly contribution). The mean WTP values in Table 4 are calculated as the means of the individual-specific WTP estimates generated from the MXL model (Sillano & de Dios Ortúzar, 2005). The mean WTP for a one percent decrease in damage from storms to property nearby the Lagoon is US$0.30 per month. The mean WTP to go from low to moderate water quality is US$6.71 per month, and the mean WTP to go from low to high water quality is US$13.42 per month. The mean WTP for a one percent increase in habitat for species in the Lagoon is US$0.36 per month. Finally, the mean WTP for a 1% increase in stay-over tourists is US$0.35 per month.

### 3.3.2. Current economic value of the lagoon

The results of the choice experiment enable the calculation of the current value of the Lagoon to the residents of Saint Martin. The total WTP is calculated for the four attributes that were significant in the MXL model estimation: damage from storms, water quality, habitat for species and number of stay-over tourists. WTP values for each attribute level are calculated relative to the status quo level of the attribute. This status-quo scenario is defined as the future scenario when no extra damage or losses to the Lagoon are expected. The estimates of the economic values of the Lagoon are then calculated by discounting these values at a rate of 3% per annum for 50 years to reflect the present value of future benefits.
environmental management would be put in place, in which sewage and trash pollution, mangrove and seagrass destruction and over-development in the Lagoon will continue. This is expected to increase storm damage to property nearby the Lagoon, further deteriorate the water quality, decrease habitat for species and decrease the number of stay-over tourists coming to Saint Martin. The following attribute levels pertain to the current environmental state of the Lagoon: no change in damage from storms, low to moderate water quality, no change in habitat for species, and no change in stay-over tourists. Table 5 shows that residents attach an annual value of US$12.1 million to the current environmental state of the Lagoon, relative to the status-quo scenario.

**3.3.3. Scenario analysis of alternative future environmental management scenarios**

One of the main benefits of conducting a choice experiment is that its results are particularly useful for evaluating future environmental management scenarios (He et al., 2017; Koetses et al., 2015). The following two environmental management scenarios have been identified for enhancing the provisioning of ecosystem services by the Simpson Bay Lagoon.

**Sewage treatment plant**

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 (DCNA, 2018; DeGeorges et al., 2010). Furthermore, the dirty water and foul smells resulting from the sewage inflow negatively impact the attractiveness of the Lagoon for tourism and recreation. 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).

**Mangrove restoration**

Another envisioned management scenario is the restoration of mangroves in the Lagoon. As Table 1 shows, mangrove ecosystems in the Lagoon 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 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 other ecosystem services such as storm protection, and habitat services (Alongi, 2012; Gilman et al., 2008).

Table 5 shows the results of the scenario analysis. It displays the total WTP of respondents for the different management scenarios. Note that these WTP values reflect the monetary amount people are willing to pay to move away from the status quo scenario. This measured change in welfare is often referred to as the compensating surplus (Alcon et al., 2019). The results in Table 5 reveal that the residents of Saint Martin highly value improved environmental management of the Lagoon. The average per household WTP for the sewage treatment plant scenario, as compared to the status quo scenario, is US$50.23 per month. This leads to a total yearly WTP of US$16.5 million for this scenario. For the mangrove restoration scenario the total yearly WTP is even higher, US$23 million, due to its beneficial impacts on biodiversity and protection against storms. Implementing both a sewage treatment plant and mangrove restoration would lead to the highest welfare benefits. The total WTP for this scenario is US$26.3 million per year.

**4. Discussion**

The previous sections have presented and explained the answers to the survey questions, the results of the choice experiment analysis and the outcomes of the scenario analysis. The outcomes of the survey questions reveal that the large majority of the respondents are aware of the bad environmental state of the Lagoon. Sewage pollution, garbage pollution, and mangrove destruction are perceived as the most important environmental stressors. Most respondents indicated that the benefits provided by the Lagoon are important for their well-being, and that they are in favor of improved environmental management of the

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Table 4

| Mixed logit estimations and WTP. |
|----------------------------------|
| **Model A: MXL model without interactions** | **Model B: MXL model with interactions** |
| | Coefficient | SE | WTP (US$) | Coefficient | SE |
| ASC | −14.109*** | 3.448 |  | −13.741*** | 3.422 |
| Damage from storms (%) | 0.054*** | 0.019 | 0.304 | 0.050*** | 0.010 |
| Water quality | 1.316*** | 0.157 | 6.711 | 1.314*** | 0.158 |
| Habitat for species (%) | 0.062*** | 0.011 | 0.355 | 0.063*** | 0.011 |
| Suitability for recreation | −0.091 | 0.097 | − | −0.054 | 0.099 |
| Stay-over tourists (%) | 0.063*** | 0.019 | 0.349 | 0.059*** | 0.020 |
| Monthly contribution (US$) | −0.264*** | 0.069 |  | −0.282*** | 0.074 |
| ASC x Higher education |  |  |  | −12.565*** | 3.680 |
| ASC x Age (> 45 years old) | 3.698** | 1.706 |  | 3.172* | 1.794 |
| ASC x Female | 12.895*** | 2.854 |  |  |  |
| St. dv. ASC | 0.091*** | 0.018 | 0.084*** | 0.020 |
| St. dv. Water | 2.486*** | 0.420 | 2.468*** | 0.437 |
| St. dv. Habitat | 0.076*** | 0.024 | 0.069** | 0.028 |
| St. dv. Recreation | 1.183** | 0.538 | 1.101** | 0.492 |
| St. dv. Tourists | 0.102* | 0.054 | 0.125** | 0.064 |
| St. dv. Contribution | 0.568*** | 0.112 | 0.479*** | 0.119 |
| N | 1263 |  | 1169 |  |
| Log-Likelihood | −799.55 |  | −732.90 |  |
| LR chi² | 1176.00*** |  | 1102.76*** |  |
| McFadden Pseudo R² | 0.424 |  | 0.429 |  |
| AIC | 1627 |  | 1499.8 |  |
| AIC/N | 1.288 |  | 1.283 |  |

Note: WTP values based on averages of individual specific parameter estimates. The levels of significance are: *p < 0.1, **p < 0.05, ***p < 0.01.
Table 5  Economic value of the Lagoon in current and future environmental management scenarios.

| Attribute                          | Attribute level | Monthly WTP per household | Total yearly WTP in US$ |
|-----------------------------------|----------------|----------------------------|-------------------------|
| Status quo (future with no extra management) |                |                            |                        |
| Storm protection                  | 40% more damage| $12.16                     | $4,001,272              |
| Water quality                     | Low            | $3.36                      | $1,105,615              |
| Habitat for species               | 40% less habitat| $14.19                    | $4,669,248              |
| Stay-over tourists                | 20% less tourists| $6.98                     | $2,296,783              |
| Total                             |                | $36.69                     | $12,072,918             |
| Sewage treatment plant            |                |                            |                        |
| Storm protection                  | No change      | $12.16                     | $4,001,272              |
| Water quality                     | High           | $13.42                     | $4,415,878              |
| Habitat for species               | No change      | $14.19                     | $4,669,248              |
| Stay-over tourists                | 10% more tourists| $10.46                    | $3,441,884              |
| Total                             |                | $50.23                     | $16,528,282             |
| Mangrove restoration              |                |                            |                        |
| Storm protection                  | 40% less damage| $24.31                     | $7,999,254              |
| Water quality                     | Moderate       | $6.71                      | $2,207,939              |
| Habitat for species               | 40% more habitat| $28.38                    | $9,338,496              |
| Stay-over tourists                | 10% more tourists| $10.46                    | $3,441,884              |
| Total                             |                | $69.86                     | $22,987,573             |
| Sewage treatment plant & mangrove restoration | |                         |                        |
| Storm protection                  | 40% less damage| $24.31                     | $7,999,254              |
| Water quality                     | High           | $13.42                     | $4,415,878              |
| Habitat for species               | 40% more habitat| $28.38                    | $9,338,496              |
| Stay-over tourists                | 20% more tourists| $13.95                    | $4,590,275              |
| Total                             |                | $80.06                     | $26,343,903             |

Notes: WTP values are calculated relative to the status quo levels of the choice attributes, representing the compensating surplus. Monthly WTP values per household are multiplied by the number of households on Saint Martin (27,421) and the number of months in a year (12) to obtain the total yearly WTP.

Lagoon. The Lagoon is also a pivotal component of cultural heritage; more than three-quarters of the respondents mentioned that the cultural and historical aspect of the Lagoon is important to them. These findings correspond to the abundant literature that illustrate the importance of the natural environment for cultural heritage and perceived well-being (Daniel et al., 2012; Nisbet, Zelenski, & Murphy, 2011; Tengberg et al., 2012).

The importance of the Lagoon for the well-being of people on Saint Martin was quantified with the use of the choice experiment. The choice experiment was applied to analyze the WTP of the respondents for five of the main ecosystem goods and services provided by the Lagoon: storm protection, water quality, habitat for species, recreation and tourism support. The analysis of the choice experiment data revealed that the storm protection, water quality, habitat services and tourism support provided by the Lagoon are highly valued by the respondents. 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 often regulating services. The importance of better storm protection and good water quality for people’s well-being has also been found in many other choice experiment studies on these topics (Brouwer, Martin-Ortega, & Berbel, 2010; Oleson et al., 2015; Perni & Martinez-Paz, 2017; Petrolia, Interis, & Hwang, 2014). Similarly, the significant positive preferences for more habitat for species found in this study are in correspondence with most of the literature (Meyerhoff, Liebe, & Hartje, 2009; Petrolia et al., 2014). Regarding increases in tourism, previous studies refer to both benefits for the local population in terms of economic development and disadvantages in terms of over-crowdedness, increases in crime and pollution and changes in traditional ways of living (Andereck, Valentine, Knopf, & Vogt, 2005; Kim, Uysal, & Sirgy, 2013). The choice experiment results of this study indicate that the people of Saint Martin have a significant positive attitude towards an increase in stay-over tourists visiting the island. Perhaps, the large economic dependence of Saint Martin on tourism explains this positive attitude. The insignificant results found for recreation are surprising, as most previous studies on coastal and estuarine ecosystems have found high recreational values (Barbier et al., 2011; Clara et al., 2018; Ghermandi & Nunes, 2013). Nevertheless, it could be that concerns about recreation-related overcrowding and environmental harm are an explanation for these findings (Brand, Van Beukering, & Cesar, 2007; Nahueltual, Carmona, Lozada, Jaramillo, & Aguayo, 2013). The results from the interaction analysis revealed that people with higher education levels, younger people and women are more in favor of improved environmental management of the Lagoon. These findings are in accordance with most previous literature on environmental attitudes and behavior (Gifford & Nilsson, 2014; Xiao & Dunlap, 2007).

The results obtained from the scenario analysis also provide for an interesting comparison with the previous literature on the economic valuation of coastal lagoons. This study found that, compared to the status quo scenario, the total yearly economic value of the Lagoon ranges from US$12.1 million in its current environmental state to US$26.3 million in a combined mangrove restoration and sewage treatment plant scenario. The yearly economic values of coastal lagoons found in other studies include 43.3 million euros for the Mar Menor Lagoon in Spain (Velasco et al., 2018), 36.6 million euros for the Coorong in Australia (Clara et al., 2018) and a minimum value of 12.5 million euros for the Ria de Aveira Lagoon in Portugal (Clara et al., 2018). Hence, the values found in this study are relatively similar to the values found in previous research. Differences in economic values are, besides other factors, due to the assessment of different ecosystem services, the application of different valuation techniques and differences in the cultural and socioeconomic context.

Overall, the findings of this study provide an important contribution to the current literature on the valuation of ecosystem services in general and the valuation of coastal lagoon ecosystems in particular. This study has provided the first economic valuation of a Caribbean island coastal lagoon and did this through the application of the choice experiment method, which is a novel approach in the field of coastal lagoon valuation studies (Newton et al., 2018). One of the main benefits of the choice experiment method is that it allows for the estimation of WTP values for different specific ecosystem services (Christie & Azevedo, 2009; Hanley et al., 1998). Newton et al. (2018) show that the value of coastal lagoons for many specific ecosystem services are not well known, such as for habitat services and regulating services. Our study has added important insights to this knowledge gap in the literature. To further reduce this gap, future coastal lagoon valuation studies are encouraged to also consider applying the choice experiment method. The use of the choice experiment method is further warranted by its usefulness for evaluating future environmental management scenarios, which is vital for instigating better environmental management of these precious ecosystems.
5. Conclusion and policy implications

The Simpson Bay Lagoon in Saint Martin is threatened by pollution and degradation, partly 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. In addition, more scientific knowledge is needed about the value and management of coastal lagoon ecosystems in general, and in the Caribbean in particular (Fanning et al., 2011; Newton et al., 2018). Our study responds to this; it has estimated the economic value of the Simpson Bay Lagoon with the use of the choice experiment method and subsequently performed a scenario analysis of future environmental management scenarios. The choice experiment was embedded in a larger household survey which was distributed among 219 residents of Saint Martin. The results of this study indicate that the current economic value of the Lagoon to the residents of Saint Martin is US$121.1 million per year and could rise to US$263.3 million per year with mangrove restoration and the installation of a sewage treatment plant.

The findings of this study provide important insights for decision-makers regarding the environmental management of the Simpson Bay Lagoon. The results show that the annual economic value of the Lagoon would more than double with mangrove restoration and the installation of a sewage treatment plant, due to the beneficial impacts of these measures on highly valued ecosystem services including habitat services, storm protection, water filtration and tourism support. The survey analysis also demonstrates that local communities strongly support both management scenarios. Consequently, local authorities should seriously consider the implementation of these measures which simultaneously benefit the environment, the society, and the economy of Saint Martin.

Like many studies before, the results of this study illustrate the benefits of nature protection (Costanza et al., 2017). 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 current and future climate change impacts, it is of vital importance to have well-functioning ecosystems (Ebi, Lewis, & Corvalan, 2006; Mercer, Kelman, Altham, & Kurvits, 2012). The potential societal and ecological benefits of improved environmental management as found in this study are not only relevant for Saint Martin. The same results are also likely to hold for other Caribbean coastal ecosystems and societies, which suffer from similar environmental pressures as the case study presented here.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jnc.2020.125845.

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