The Economics of Enhancing the Marine Protected Areas of the Cayman Islands

December 2017

WOLFS COMPANY
NATURE BY NUMBERS

IVM VU
Institute for Environmental Studies

IVM
Institute for Environmental Studies
VU University Amsterdam
De Boelelaan 1087
1081 HV, AMSTERDAM
The Netherlands
T: +31-20-598 9555
F: +31-20-598 9553
E: info.ivm@vu.nl

Wolfs Company
Sarphatistraat 370
1018 GW, Amsterdam
The Netherlands
T: +3120 520 6993
E: info@wolfscompany.com

Authors: Amílcar Guzmán, Stijn Schep, Boris van Zanten, Pieter van Beukering, Elena Palacios Nieto, Romy Hoogeveen, Anette Luna Stangl, Marleen Schutter, Gina Ebanks-Petrie and Timothy Austin.

This report was commissioned by the Department of Environment of the Cayman Islands Government.

Summary

The challenge

Healthy marine ecosystems, such as coral reefs and mangrove forests, are critical to the economy and wellbeing of the residents of the Cayman Islands. In the last decades, local and global pressures have resulted in serious threats to these fragile ecosystems, potentially jeopardising the foundations of the local economy. To protect the marine environment from these looming threats, the Cayman Islands Department of Environment (DoE) has developed a proposal to enhance its marine protected areas (MPAs). To support well-founded decision-making around the proposed plans, it is crucial to understand how the marine environment contributes to the economy and human wellbeing.

Therefore, this study aimed to assess the economic value and the societal importance of the marine ecosystems of Grand Cayman, Cayman Brac and Little Cayman. By estimating the potential changes in the value of ecosystems over time, the socioeconomic effects of the proposed MPA enhancement were assessed. The results of this study will support the development of long- term policies that promote sustainable economic development in the Cayman Islands.

Tools

From the outset of the study, stakeholders participated by facilitating the data collection process and this provided opportunities to simultaneously create support for the concept of ecosystem services. The study addressed the most relevant marine ecosystems and ecosystem services in the Cayman Islands and applied a variety of economic valuation tools to estimate their value. A wide range of existing economic data was used to assess the importance of natural capital for the public and private sectors. Furthermore, by surveying over 800 visitors and residents of the Cayman Islands, the study estimated the willingness to pay (WTP) of individuals to conserve ecosystem services provided by the marine environment. The WTP estimates obtained in this study represent the maximum amount that individuals are willing to sacrifice to enhance the protection of marine and coastal ecosystems, thereby avoiding a future decrease in the supply of ecosystem services. Based on the valuation results, the change in ecosystem services was modelled in a scenario analysis to assess the costs and benefits of the proposed MPA enhancement.

Economic value of marine ecosystems

To assess the importance of marine and coastal ecosystems for human wellbeing in the Cayman Islands, the economic value of each key ecosystem service was estimated. The analysis focused on services obtained from coral reefs, mangroves, seagrasses and beaches. Together, the ecosystem services identified provide a total economic value (TEV) of at least **US$179 million (CI$147 million) per year**. It should be noted that this value

reflects the services provided by the ecosystems as a whole. No benefits related to individual species are estimated.

The ecosystem services that support the tourism industry contribute most to the TEV. Although tourism arrivals vary over time, approximately 380,000 stay-over tourists and 1,600,000 cruise tourists visit the Cayman Islands each year. Many of these tourists choose the islands as their holiday destination because of the beautiful marine environment (i.e. beaches, coral reefs and mangroves). As the natural environment adds value to the Cayman Islands as a tourism destination, this can be seen as an essential resource for the prosperity of the tourism industry. This study shows that around 40% of the added value that is created in the entire tourism industry (US$180 million, or CI$148 million, per year) can be attributed to the marine environment; this contribution amounts to US$69 million (CI$57 million) per year. Additional to this, the results of the survey used for the study indicate that tourists have an aggregate WTP for nature conservation of US$94 million (CI$77 million) per year.

The high WTP of visitors for nature conservation suggests that the current environmental fees could be re-evaluated without having a substantial effect on the number of tourists visiting the islands. Together, the financial value and the WTP add up to a total economic value of nature for tourism of US$163 million (CI$134 million) per year.

Many residents on the Cayman Islands engage in recreational activities, such as swimming, going to the beach and diving. Furthermore, a pristine natural environment is important to the cultural identity of Caymanians. To quantify the value of the marine environment to the residents of the Cayman Islands, the WTP for an enhancement of the MPAs was estimated through a household survey. Results indicate that, per year, local households would be willing to contribute a total of US$5.6 million (CI$5 million) for enhancing protected areas and thereby conserving the ecosystem services provided by the marine environment. The results of the household survey conducted in 2014, in support of this study, indicate that the enhancement plans are supported by at least 58% of the population on Grand Cayman, 63% of the population on Cayman Brac and 85% of the population on Little Cayman.

Other ecosystem services covered in the study are coastal protection to storms and hurricanes, fisheries that depend on fish stocks in the coastal waters, carbon sequestration, the pharmaceutical application of environmental products and the value of marine ecosystems as amenity to real estate. Together, these ecosystem services amount to an annual value of over US$16 million per year.

Economic effects of enhancing Marine Protected Areas

If current environmental degradation continues, the value of these ecosystem services will decrease. To prevent further degradation of, and conserve the benefits provided by, the marine environment, the DoE proposes to expand the coverage of and enhance the Marine Protected Areas (MPAs) in the Cayman Islands. These changes would result in an overall

increase in coastal marine area under protection of 15%. Furthermore, by restructuring the different user zones within the MPAs, the total area classified as “no take” marine reserves would increase substantially. To analyse the socioeconomic effects of these plans, future changes in the ecosystem service values obtained in this study were compared in two policy scenarios: 1) maintaining the current network of MPAs; 2) expanding and restructuring the MPAs according to the plans proposed by the DoE.

Considering the factors that were included in the economic valuation, the analysis of changes in ecosystem services over 25 years indicates that enhancing the MPAs leads to the highest economic value (Scenario 1 < Scenario 2; see Figure 6). In the last year of the analysis, the total net benefits are likely to be at least 7% higher in Scenario 2, with the MPA enhancement (US$149 million, or CI$122 million), than in Scenario 1, with existing MPAs (US$139 million or CI$114 million). The stakeholders that benefit most from improved ecosystem services in Scenario 2 (MPA enhancement) are those involved in the tourism industry and local households. Also, the benefits from fisheries and coastal protection are expected to increase.

Most importantly, none of the ecosystem services analysed in the study is expected to decrease in the scenario with the MPA enhancement. A sensitivity analysis indicates that, even if MPA management proves to be ineffective in reversing the current rates of environmental degradation, the MPA enhancement is unlikely to lead to a loss in human wellbeing in the Cayman Islands (based on the ecosystem services analysed in this study). In other words, the society as a whole only stands to gain in overall economic benefits if the MPA enhancement is implemented. In addition, the DoE has stated that minimal funds are required to realise the enhancement plans.

Given this information, it can be concluded that the proposed MPA enhancement is a low-cost and low-risk investment with the opportunity to substantially improve overall wellbeing in the Cayman Islands.

List of acronyms

CBA	Cost-Benefit Analysis
CIDOT	Cayman Islands Department of Tourism
DoE	Department of Environment of the Cayman Islands
EEZ	Exclusive Economic Zone
GDP	Gross Domestic Product
MA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
NPV	Net Present Value
TEEB	The Economics of Ecosystems and Biodiversity
WTP	Willingness to Pay

Table of Contents

CHAPTER 1: INTRODUCTION 9

1.1 RESEARCH QUESTIONS 11

CHAPTER 2: THEORETICAL BACKGROUND 12

2.1 TEEB APPROACH 12
2.2 STUDY FRAMEWORK 13
2.3 DATA COLLECTION PROCESS 15

CHAPTER 3: ECONOMIC VALUE OF ECOSYSTEM SERVICES 16

3.1 ECOSYSTEM SERVICE VALUATION 16
3.2 FISHERIES 18
3.2.1 METHODS 18
3.2.2 RESULTS 20
3.3 PHARMACEUTICAL VALUE 21
3.3.1 METHODS 21
3.3.2 RESULTS 22
3.4 COASTAL PROTECTION 23
3.4.1 METHODS 23
3.4.2 RESULTS 27
3.5 CARBON SEQUESTRATION 28
3.5.1 METHODS 28
3.5.2 RESULTS 29
3.6 AMENITY VALUE 31
3.6.1 METHODS 31
3.6.2 RESULTS 35
3.6.3 ECONOMIC VALUE 38
3.6.4 VALUE MAP 39
3.7 TOURISM VALUE 40
3.7.1 METHODS 40
3.7.2 RESULTS 43
3.7.3 TOTAL TOURISM VALUE 46
3.8 CULTURAL AND RECREATIONAL VALUE 49
3.8.1 METHODS 49
3.8.2 RESULTS 50
3.9 OVERVIEW OF THE ECONOMIC VALUE OF ECOSYSTEM SERVICES IN THE CAYMAN ISLAND 53

CHAPTER 4: COSTS AND BENEFITS OF ENHANCING THE MARINE PROTECTED AREAS OF THE CAYMAN ISLANDS 55

4.1 CURRENT MPAS AND MPA ENHANCEMENT 55
4.1.1 GENERAL BACKGROUND 55
4.1.2 CURRENT MPAS 58

4.1.3 MPA ENHANCEMENT 59
4.2 METHODOLOGY 60
4.2.1 SCENARIOS AND PARAMETERS 60
4.2.2 CHANGES IN ECONOMIC VALUE 62
4.2.3 NET PRESENT VALUE 64
4.3 RESULTS OF THE EXTENDED COST-BENEFIT ANALYSIS 65
4.3.1 OVERVIEW OF MAIN CHANGES IN THE VALUE OF ECOSYSTEM SERVICES 68
4.3.2 CHANGE IN NET BENEFITS IN THE CASE OF EFFECTIVE MANAGEMENT (MPA MANAGEMENT SCENARIO B) 71
4.3.3 CHANGE IN NET BENEFITS IN THE CASE OF INEFFECTIVE MANAGEMENT (MPA MANAGEMENT SCENARIO A) 75

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS 80

5.1 ECOSYSTEM SERVICES ON THE CAYMAN ISLANDS 80
5.1.1 TOURISM 80
5.1.2 LOCAL CULTURE AND RECREATION 81
5.1.3 AMENITY VALUES 81
5.1.4 FISHERIES 81
5.1.5 PHARMACEUTICAL PRODUCTS 81
5.1.6 REGULATING SERVICES 82
5.2 COST-BENEFIT ANALYSIS OF MPA ENHANCEMENT 82
5.2.1 LIMITATIONS 83
5.2.2 RECOMMENDATIONS 84

REFERENCES 85

ANNEXES 91

ANNEX 1 – DESCRIPTIVE STATISTICS OF SOLD HOUSES 91
ANNEX 2 – BASELINE REGRESSION FOR CORAL REEFS AND MANGROVES 92
ANNEX 3 – REGRESSION WITH DISTANCE TO CORAL REEFS AND DISTANCE TO MANGROVES 93
ANNEX 4 – SENSITIVITY TEST ON SEPARATED DISTRICTS 94
ANNEX 5 – SENSITIVITY TEST ON SEPARATED PRICE RANGES 95
ANNEX 6 – CHARACTERISTICS OF COAST FOR RELATIVE REEF CONTRIBUTION 96
ANNEX 7 – DESCRIPTION OF REGULATIONS CONSIDERED IN THE EXISTING MPA FRAMEWORK IN THE CAYMAN ISLANDS 97
ANNEX 8 - SENSITIVITY OF THE RESULTS TO DIFFERENT RATES OF ECOSYSTEM DEGRADATION 98

Chapter 1: Introduction

Despite the dependence of human life and well-being on the health of marine ecosystems (Reuchlin-Hugenholtz and McKenzie, 2015), there is no single area of the ocean that has not faced the impacts of our development (Halpern et al., 2008). Anthropogenic drivers of change derived from pollution, climate change, fishing and a wide variety of other human activities threaten marine biodiversity worldwide and impair the capacity of marine ecosystems to provide mankind with the services that support our own existence (Halpern et al., 2008; Reuchlin-Hugenholtz and McKenzie, 2015).

To deal with local and global threats to marine biodiversity, properly designed Marine Protected Areas (MPAs) are widely recognized as an essential management tool (Watson et al., 2014; Halpern et al., 2010; Halpern, 2003; Roberts and Hawkins, 2000). MPAs can help preserve the composition of natural communities, maximize ecosystem resilience, prevent loss of species, restore species abundance, and maintain reproductive, nursery and feeding areas (Angulo-Valdés and Hatcher, 2010). Furthermore, no-take MPAs have resulted in an increase in fish size, density and biomass within and beyond their boundaries in different latitudes (Lester et al., 2009).

Although the development of MPAs was originally guided by ecological goals (UNEP, 1992; Agardy, 1994), this approach has shifted towards a combination of conservation, social and economic objectives (Watson et al., 2014; Brander et al., 2015; Potts et al., 2014). Through this paradigm shift, it has been acknowledged that protecting marine ecosystems entails protecting fisheries, genetic resources, natural hazard barriers, climate regulation, and tourism, recreation, education and research opportunities (Potts et al., 2014; Angulo-Valdés and Hatcher, 2010). Consequently, the concept of ecosystem services, which stands for the benefits that people obtain from ecosystems (MA, 2005), has become an important driver for the creation of MPAs.

Due to global concerns in relation to marine and coastal ecosystems, MPAs have significantly expanded in the last century and in recent years, but this increase in area has not yet been sufficient to achieve international policy targets regarding marine protection (Watson et al., 2015; Boonzaier and Pauly, 2016). Between 2008 and 2013, the area of MPAs increased fivefold, and by 2015 around 6,000 MPAs were estimated to cover approximately 3.3% of the oceans (Boonzaier and Pauly, 2016). However, the Aichi target 11 adopted by the Parties to the Convention on Biological Diversity in 2010 demands participating countries in the convention to expand the existing protected area network to cover at least 10% of coastal and marine areas by 2020 (CBD, 2010). In addition to this, the IUCN World Parks Congress (WPC, 2014) has more recently recommended a specific target of strictly protected areas that cover at least 30% of each marine habitat and address both biodiversity and ecosystem services.

Although MPAs are not the only management option, their creation and expansion certainly represent key steps for the implementation of comprehensive ecosystem based approaches to address threats to biodiversity as much as other socioeconomic concerns (Halpern et al., 2010). Furthermore, the global coverage of MPAs is a simple, comprehensible and quantifiable metric to encourage international conservation (Boonzaier and Pauly, 2016). In line with this approach, research has shown that the benefits of expanding MPAs according to the international policy targets for marine protection would significantly outweigh the global costs of achieving this expansion (Brander et al., 2015).

In the Caribbean, MPAs have shown positive results in terms of coral loss prevention (Selig and Bruno, 2010), the improvement of biological measures of fish populations in general (Lester et al., 2009) and the recovery of particularly beneficial fish populations for the resilience of coral reefs (Jackson et al., 2014). Considering the benefits that local inhabitants might obtain from this type of improvements in the health of marine ecosystems, the Department of the Environment (DoE) of the Cayman Islands has developed plans to modify and expand their existing MPA network. The changes proposed aim to secure local well-being by improving the protection of relevant ecosystems and their services against pressures such as tourism growth, overfishing, population growth, coastal development and pollution.

Box 1 - General overview of the Cayman Islands (Bettencourt and Imminga-Berends, 2015; Trading economics, 2016)

The Cayman Islands correspond to the Caribbean United Kingdom Oversea Territory formed by Grand Cayman, Cayman Brac and Little Cayman. The following facts and figures provide a general overview of the socioeconomic and biophysical context of this territory:

Land area:	262 km^2	*Total population (2012):*	56,732 inhabitants
Sea exclusive economic zone (EEZ):	119,137 km^2	*Population density:*	210 inhabitants/km^2
Main Ecosystems:	Lowland mangrove swamps	*GDP (total):*	US$3.48 billion
	Dry subtropical forests	*GDP (per capita):*	US$57,827
	Sea grass beds Coral reefs	*Unemployment rate:* *Illiteracy rate:*	5.6% 0.3%

Local inhabitants of the Cayman Islands are in many aspects dependent on services provided by marine and coastal ecosystems. These ecosystems provide opportunities for recreation and fishing, while the marine life offers diving and snorkeling conditions that boost the local tourism industry every season (Schutter et al., 2014). At the same time,

marine and coastal ecosystems of the Cayman Islands serve as habitat and breeding grounds for endemic and endangered species (Bettencourt and Imminga-Berends, 2015). All these benefits reflect part of the contribution that MPAs and their proposed enhancement can offer to the economy of the Cayman Islands.

To gain insight into the added value of the proposed MPA enhancement, the DoE has commissioned Wolfs Company and the VU University Amsterdam, to investigate the economic value of the benefits provided by marine and coastal ecosystems to different stakeholders in the Cayman Islands.

1.1 Research questions

To provide insight into the added value of the MPA enhancement proposed by the DoE of the Cayman Islands, the study follows the research questions described below.

1. What are the relevant ecosystem services in the Cayman Islands?
2. What is the current contribution of relevant ecosystem services to the economy of the Cayman Islands?
3. How would the socioeconomic benefits of local ecosystem services be affected by the enhancement of MPAs in the Cayman Islands?

To answer the first question, a preliminary subset of ecosystem services that could be relevant in the local context was selected by the research team and validated with the DoE and local stakeholders (see Chapter 2). The results of the economic valuation, presented in Chapter 3 of this report, show how relevant these ecosystem services are and answers the second questions by determining their contribution to the local economy. To answer the third research question, the previous results are used as a baseline and potential changes in economic value over a 25-year timeframe are estimated in scenarios of current MPAs and MPA enhancement (including MPA expansion and improvement of zone designation). The economic value obtained in these scenarios is finally compared to determine the effect of the MPA enhancement (Chapter 4).

Chapter 2: Theoretical Background

2.1 TEEB approach

The ecosystem service valuation conducted in this study is based on the Economics of Ecosystems and Biodiversity (TEEB). This approach follows the Millennium Ecosystem Assessment (MA, 2005) and defines ecosystem services as the benefits people obtain from ecosystems and biodiversity (MA, 2005; De Groot et al., 2010). Ecosystems and biodiversity therefore benefit societies through the provision of ecosystem services, which ultimately contribute to improve human wellbeing (Figure 1). The capacity to provide ecosystem services is given by the biophysical components of ecosystems and their function in relation to the regulation of processes (de Groot et al., 2010; Haines-Young and Potschin, 2013).

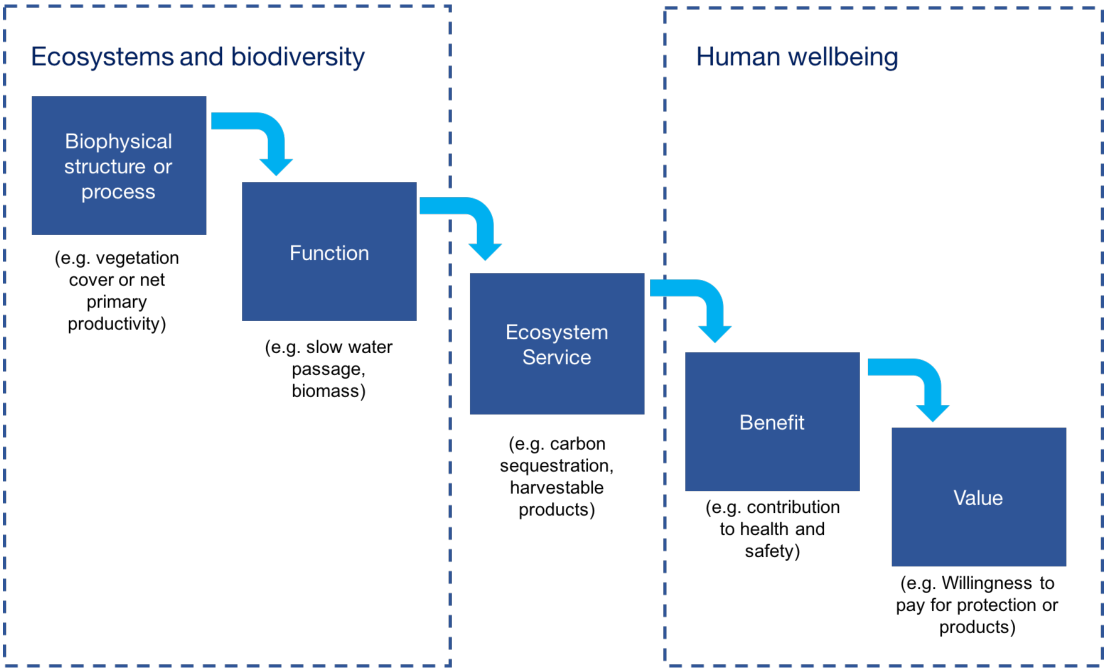


Figure 1 - The ecosystem service cascade that depicts the pathway from ecosystem structure and processes to human well-being. Adapted from de Groot et al. (2010) and Haines-Young and Potschin (2013)

According to this overarching framework, societies benefit from the following three categories of ecosystem services: provisioning, regulating, and cultural services (MA, 2005; De Groot et al., 2010). Provisioning ecosystem services are material outputs such as water and timber. Regulating services help society deal with processes such as coastal erosion and changes in water flows, and with extreme events such as floods and storms. Cultural services relate to the non-material benefits of ecosystems, including spiritual and recreational values (MA, 2005; De Groot et al., 2010). The contribution of these services to human wellbeing is expressed in different types of values (Figure 1), which are defined and analysed for the Cayman Islands in Chapter 3 of this report.

2.2 Study framework

In order to assess the value of ecosystem services in the governance setting of the Cayman Islands, the theoretical framework proposed by Daily et al. (2009) has been adapted to this study. This framework is based on TEEB and represents an iterative process in which the state of ecosystems, the value of ecosystem services and the wellbeing of stakeholders are indirectly affected by governance decisions to deal with pressures on ecosystems (Figure 2, upper part).

Based on the framework shown in Figure 2, the local setting of the Cayman Islands can be summarized as follows:

- On the Cayman Islands, **pressures** such as overfishing, coastal development, ship groundings and recreational activities have direct impacts on the state of marine and coastal ecosystems.
- Due to these pressures, the **ecosystems** gradually degrade over time, thereby becoming less resilient and capable of providing ecosystem services.
- The **ecosystem services** provided by marine and coastal ecosystems are likely to decrease in value if ecosystems do.
- Benefits for **stakeholders,** such as local residents, fishermen and the tourism industry, will decrease if ecosystem services decrease in value.
- This would result in a decrease in the **wellbeing** of many residents on the Cayman Islands.
- To address this potential loss and secure the wellbeing of residents, **governance decisions** can be made in order to address pressures on and improve the state of ecosystems.

To guide the decision-making process, the Department of Environment (DoE) of the Cayman Islands commissioned Wolfs Company and the VU University Amsterdam to conduct research on the value of ecosystem services provided by marine and coastal ecosystems in the territory.

Relevant ecosystem services to be included in the study were firstly identified by the research team and then validated in consultation with the DoE of the Cayman Islands and local stakeholders. Previous research in the Caribbean was used as a reference to identify ecosystem services that could be potentially important in the local context. A preliminary list of important ecosystem services was further refined based on the availability of data and the feasibility of their valuation. As a result, seven ecosystem services are described and valued in this report, two of them from the provisioning category, two regulating services and three cultural services (Figure 2).

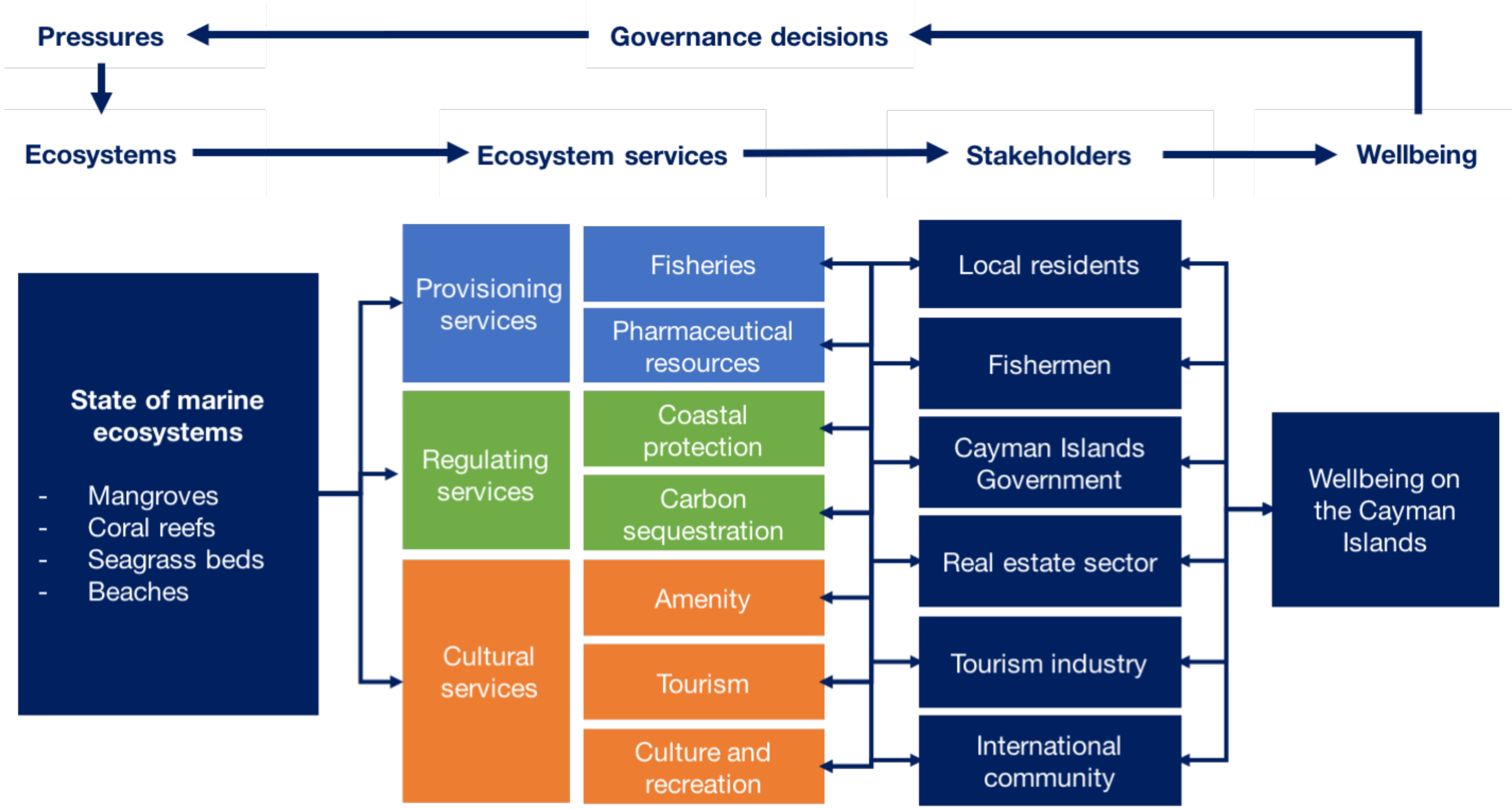


Figure 2 – Framework of this study. Based on the framework of analysis proposed by Daily et al. (2009).

In 2014, the research team studied the economic value of marine and coastal ecosystems for tourism, local culture and recreation. The results of such research are included in this report and complemented by the valuation of the remaining ecosystem services from the list presented in Figure 2. Further details on the information used to conduct this analysis is provided in the next section.

2.3 Data collection process

The study is based on both secondary and primary data sources. Between December 2015 and June 2016, a wide variety of stakeholders was contacted on the Cayman Islands to support the research with existing data. Many government departments, public and private organizations agreed to support.

In terms of primary data collection, two surveys were conducted:

1) A tourism survey in 2013-2014 to create insight in tourism behaviour, expenditures and willingness to pay (WTP) of tourist for additional nature conservation efforts. Almost 400 visitors responded to the survey (Van Beukering et al., 2014).

2) A survey in 2014 among households on Grand Cayman, Cayman Brac and Little Cayman to create insight in the relevant ecosystem services for local residents, the support for the MPA enhancement plans and the WTP for conservation of the marine environment. In total, 380 households responded to the survey (Schutter et al. 2014).

In addition, a wide range of experts and stakeholders have been interviewed to validate research results.

Chapter 3: Economic value of ecosystem services

Marine and coastal ecosystems of the Cayman Islands support local livelihoods in multiple ways, provide several opportunities for recreation, protect important natural resource stocks and contribute to the success of important economic sectors. The economic value of the main marine and coastal ecosystem services estimated in this chapter illustrates the importance of these benefits to the Cayman Islands economy and the well-being of their inhabitants.

The following subsections describe the general approach to the economic valuation and provide detailed descriptions of the methods and results of the valuation of each ecosystem service included in the analysis. The economic values estimated in this chapter provide the basic information to compare MPA scenarios through the extended cost-benefit analysis (CBA) described in Chapter 4 of this report.

3.1 Ecosystem service valuation

The economic value of an ecosystem service can be classified in use or non-use value. Use values are divided into direct use and indirect use values (Figure 3). The first category corresponds to values derived from the direct harvesting or extraction of ecosystem products, such as food or water. Indirect use values, on the other hand, correspond to benefits obtained from the regulating capacity of ecosystems without entailing an active extraction of ecosystem products (Waite et al. 2014; van Beukering et al., 2007).

Non-use values include the existence value (i.e. the value humans place on the knowledge that a resource or species exists), bequest value (i.e. the value of guaranteeing the existence of a resource or ecosystem for the future generation), and option value of ecosystems (i.e. the value humans place on having the option to use or visit the resource or ecosystem in the future). Figure 3 presents the Total Economic Value (TEV) framework and the different use and non-use values that can be assigned to ecosystem services.

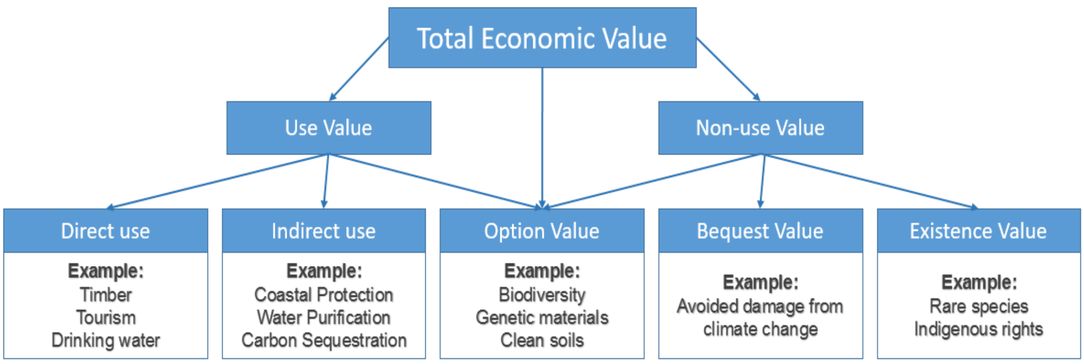


Figure 3 - The Total Economic Value (TEV) framework for the valuation of ecosystems services. Adapted from Waite et al. (2014)

Table 1 – Valuation techniques used in this study (van Beukering et al., 2007; Waite et al., 2014)

Type of technique	Valuation technique	Description
Market-based techniques	Market price	Market prices are used as an indicator of the economic benefits obtained from using an ecosystem good or service.
	Avoided damage	This technique focuses on the costs of potential damage avoided by regulating processes of ecosystems.
	Net factor income	Technique based on the revenue from sales of goods or services obtained from ecosystems. Costs of other inputs are subtracted.
Non-market techniques	Hedonic pricing	Technique based on the influence of specific ecosystem features on the price of marketed goods, e.g. real estate.
	Contingent valuation	Survey-based technique in which respondents are asked directly about their willingness to pay for the supply of ecosystem services.
	Choice modelling	Survey-based technique in which the willingness to pay of respondents is elicited by asking them to trade off different ecosystem attributes, goods or services.

In this study, the different values of ecosystem services are quantified according to the TEV framework and expressed in monetary values. This type of analysis can be conducted through the application of different valuation techniques, which are classified in market-based techniques, non-market techniques and benefit transfer (Table 1). In this study, each valuation technique is chosen according to its suitability to analyze specific ecosystem services, as well as on the availability of data and time.

Table 2 – Ecosystem services addressed and valuation techniques used in this study

Type of ecosystem service	Ecosystem service	Value	Valuation technique
Provisioning	Fisheries	Direct use value	Market based: net factor income
	Pharmaceutical	Direct use value	Market based: net factor income
Regulating	Coastal Protection	Indirect use value	Market based: avoided damage
	Carbon Sequestration	Indirect use value	Market based: market price
Cultural	Amenity	Indirect use value	Non-market based: hedonic pricing
	Tourism	Direct use value	Market based: net factor income Non-market based: contingent valuation and choice modelling
	Culture and Recreation	Existence and direct use value	Non-market based: contingent valuation

The ecosystem services analyzed in this study are selected in consultation with stakeholders and the Department of Environment of the Cayman Islands (DoE). Table 2 presents the type of ecosystem services, type of value, and techniques adopted for the valuation. The next subsections of this chapter provide further details on the methodological steps that are specifically carried out to value each ecosystem service and the results of the valuation.

3.2 Fisheries

3.2.1 Methods

To support the analysis of potential benefits arising from the MPA enhancement in the Cayman Islands, this section examines the economic value of the fish catch that relates to local coral reef ecosystems. Since no major commercial fishing activities exist on the Cayman Islands (Meier et al., 2011; Henshall, 2009), this section focuses on artisanal fishing for recreation, subsistence and small-scale commercial purposes.

Based on questionnaires applied to local residents, expatriates, tourists, charter boats operators and migrant workers in 2011, Figure 4 illustrates the fishing effort (or pressure) for pelagic and reef fish in Grand Cayman (Meier et al., 2011). Areas such as North West Point, the entrance to the North Sound, South Sound and Jackson Point were identified as popular ones among the reef fishers that participated in the questionnaire (Meier et al., 2011).

As this study aims to estimate the economic value that is associated with local marine ecosystems, only reef fish are considered in the analysis. The share of the catch that consists of pelagic species is considered out of scope, since these fish species rely on foreign ecosystems for most of their lives.

The economic value of reef fisheries is estimated through the net factor income approach (van Beukering et al., 2007). This market-based approach assumes that the value of fishing is determined by the availability of fish and the costs of other production factors required for fishing (labor, boats and fishing gear). The value of the ecosystem service is defined as the value of fish as a production factor in this process. This implies that the value of the fish needs to be isolated from the other production factors, which can be done by estimating the difference between the fishing revenue and the costs of fishing, i.e. the added value of fishing. As labor costs are considered a benefit to the society of the Cayman Islands, these are included in the total value of the ecosystem service.

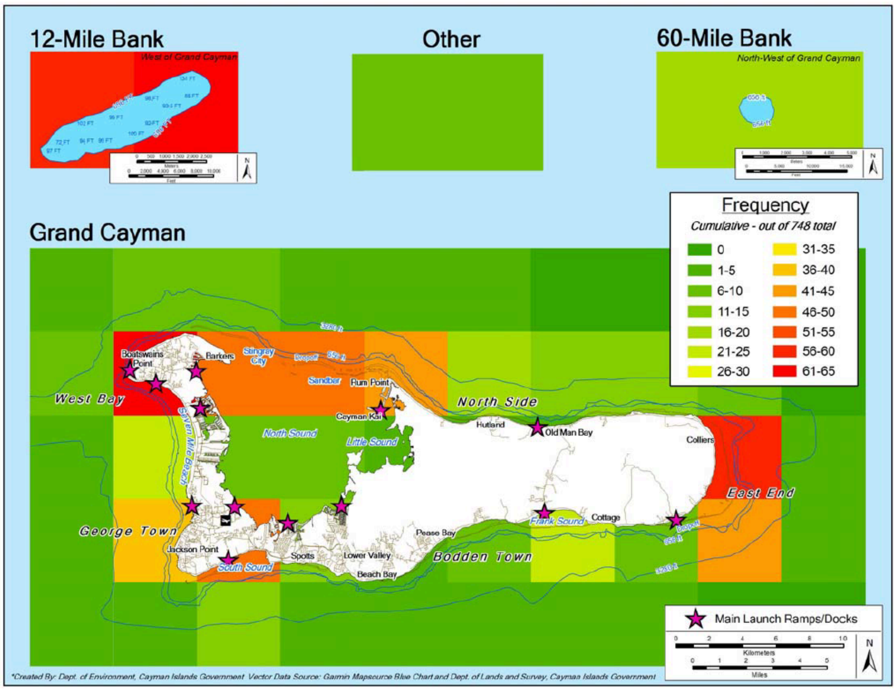


Figure 4 - Spatial distribution of fishing effort over a monthly period in Grand Cayman, based on information collected through socioeconomic questionnaires conducted in February and March 2011 (Meier et al., 2011)

Estimates of the number of reef fish caught in the Cayman Islands are obtained from Henshall (2009) and Meier et al. (2011). Both studies focus on the impact of artisanal and recreational fisheries on coral reef ecosystems. Based on the information presented in these studies and the answers of artisanal fishermen interviewed for our study in April 2016, the estimates associated to artisanal fisheries are considered to include fish catch for subsistence and small-scale commercial purposes (i.e. local market). The estimates associated to recreational fisheries, on the other hand, refer to recreational charter boat fishing. For the latter, only the value of the fish catch is incorporated in the calculations for the fisheries value. Recreational values related to charter boat fishing are incorporated in the calculations for the tourism value. According to Meier et al. (2011), there is no major commercial fishing on reef ecosystems in the Cayman Islands.

Henshall (2009) provides figures of the number of reef fish caught in Grand Cayman in 2009 and Meier et al. (2011) estimate the number of reef fish caught in each of the three islands in 2011. To obtain an indication of the current reef fish catch, the annual percent increase in reef fish catch in Grand Cayman between these two studies is extrapolated to the whole Cayman Islands over the period between 2012 and 2016.

The total revenue from local reef fish catch is subsequently estimated by multiplying the amount of reef fish caught in 2016 by the average weight of reef fish and the local fish price per unit of weight. The average weight of reef fish is obtained from Williams and Ma (2013),

while the fish price is estimated based on consultation meetings with local fishermen held in the Cayman Islands in April 2016.

Fishing costs are assumed to represent 44% of the total annual revenue, as estimated in previous research on artisanal fishing in Caribbean coral reef ecosystems (Schep et al., 2012).

3.2.2 Results

As explained in the methods, the net factor income approach assumes that the economic value of coral reef to fisheries is the net benefit obtained from fishing, which is calculated through subtracting the total costs of fishing (except for labor costs) from the fisheries total revenue. Table 3 presents the total annual revenue, total annual costs, and annual net income (or benefit) associated to reef fish caught for recreational, subsistence and small-scale commercial purposes.

The calculation of the total annual revenue of fishing is based on the following parameters:

- The average price of reef fish species in the Cayman Islands, estimated at US$5.85 per pound according to the information provided by local fishermen interviewed in April 2016.
- The average fish weight of the most common reef fish species caught in Cayman Islands waters according to existing literature (Williams and Ma, 2013), estimated at 1.8 pound/fish.
- A reef fish catch of around 390,000 individuals in 2016, estimated through the extrapolation of data from Henshall (2009) and Meier et al. (2011).

The total annual fishing costs, which are estimated at 44% of the total revenue, represent around US$1.8 million per year. Thus, the total economic value of coral reef fishing for recreational, subsistence and small-scale commercial purposes is valued in around US$2.3 million per year (Table 3).

Table 3 - Total annual value of recreational, subsistence and small-scale commercial fishing on coral reefs

Total annual value		
Total annual revenue	$	4,109,889
Total annual costs	$	1,808,351
Annual net benefit	**$**	**2,301,538**

As described in the methods, no large scale commercial fishing is reported to exist in Cayman Islands waters (Meier et al., 2011) and only a small part of the artisanal fish catch is reported to be sold in the local market[1].

3.3 Pharmaceutical value

3.3.1 Methods

In this study, based on the main existing classifications of ecosystem goods and services (De Groot et al., 2002; MA, 2005; De Groot et al., 2010; Haines-Young and Potschin, 2013), the pharmaceutical value refers to the contribution of the biotic materials and chemical substances available in local ecosystems to the economy of the Cayman Islands. Through an exceptional five-year agreement, the Government of the Cayman Islands allows the extraction of Caribbean Sea Whip (*Plexaura homomalla*) by the company Maxey Lash as of 2016. The extracted coral is processed by the company to obtain black-sea red oil (BSRO), which is subsequently used to produce a cosmetic eyelash maintaining serum.

The legal license established in the agreement with the Cayman Islands Government is given under specific conditions to ensure that the extraction is done sustainably. To allow the coral colony to regrow, the harvesting is restricted to specified locations and to a maximum of 10 kg of raw coral tips per year. Furthermore, the company is required to pay a royalty fee that will go into the Environmental Protection Fund of the Cayman Islands. The conditions that determine the royalty fee that is to be paid by the company are presented in Table 4, below.

Table 4 – Royalty structure for the extraction of wet coral for cosmetic purposes

Royalty structure
Per kilogram of wet coral harvested, a royalty of CI$25,000 is payed, or per gram of BSRO extracted from the coral, a royalty of CI$500 is payed, whichever is greater
A royalty of 10% on the Net Sales of BSRO to third parties is payed to the Cayman Islands Government
A 10% royalty of the Net Sales of Maxey Cosmetics Products (MC Products) which contain BSRO are payed to the Cayman Islands Government

In this study, the pharmaceutical value is estimated through the net factor income technique (van Beukering et al., 2007), a market based approach that focuses on the net income obtained from the extraction of coral for the cosmetic purpose described above. The total economic value of this ecosystem service therefore includes the potential income

[1] As reported by artisanal fishermen interviewed for this study in April 2016.

obtained from sales by Maxey Lash and the royalty that could be collected by the government as an outcome of the coral extraction.

Since the extraction rates of wet coral were not made available at the time of this study, the estimation of Maxey Lash's income relies on the assumption that the current extraction of wet coral corresponds to the legal maximum of 10 kg per year. The average extraction rates of the active ingredient of BSRO (i.e. Prostaglandin A2 15 acetate methyl ester) from wet coral are estimated in the range between 0.3% and 3% (Bhakuni and Rawat, 2005).

As described during personal communication with Maxey Lash, part of the BSRO obtained from coral is directly sold to third parties and the rest is utilized for developing cosmetics. For calculations conducted in this study, it is assumed that the total harvest is sold in Maxey cosmetics, since this provides an indication of the maximum income that can be potentially obtained from the extraction of coral for this purpose.

The royalty fee that could be collected by the Cayman Islands Government is estimated according to the license conditions stipulated in the agreement with the company. It is therefore important to note that both, the company's net income and the royalty fee collected by the government, are most likely upper-bound estimates of the economic value of this product.

3.3.2 Results

With average extraction rates ranging from 0.3% to 3%, the maximum permitted harvest of 10 kg of wet coral can provide between 30 g and 300 g of BSRO per year. Maxey cosmetic products are sold for a price of around US$75 per piece and contain 0.5 mg of BSRO. Due to lack of specific data on the annual financial results of the company, the net margin of Maxey Lash, after subtracting royalties, taxes and production costs, is assumed at 20%[2]. The net-income potentially obtained by Maxey Lash from the maximum allowed extraction of 10 kg of wet coral per year is thus estimated in the range between US$0.9 and US$9 million.

Based on the extraction rates considered in this analysis and the assumption of all the BSRO being sold in cosmetic products, royalties should be collected only in relation to the amount of wet coral extracted and the net sales of cosmetic products containing BSRO (Table 4). If 10 kg of wet coral were annually extracted, the government of the Cayman Islands would collect a royalty fee of approximately US$0.3 million per year. Additionally, between US$0.4 and US$4.3 million in royalties can be associated to the annual net sales of the company (Table 5).

---

[2] Based on various sources, including market analysis websites and datasets (e.g. CSImarket and online databases compiled by the Stern School of Business of the New York University), publicly available financial reports of cosmetic companies (e.g. Loreal) and financial news (e.g. Bloomberg).

Table 5 - Royalty fees potentially collected in relation to coral extraction for the production of cosmetic products (US$ millions per year)

	Value	Royalty fees
Wet coral extraction	10 kg	US$0.3
Net annual sales*	$4.3 - $42.8	$0.4 - $4.3
Total	**-**	**$0.7 – $4.6**

**Estimation based on average BSRO extraction rates and 5% of sales discounts, returns and allowances.*

The total pharmaceutical value is estimated as the sum of the potential net profit from cosmetic products with BSRO produced by Maxey Lash and the potential income from royalty fees paid to the Cayman Islands Government. As shown in Figure 5, this results in an annual total economic value in the range between US$1.6 and US$13.6 million.

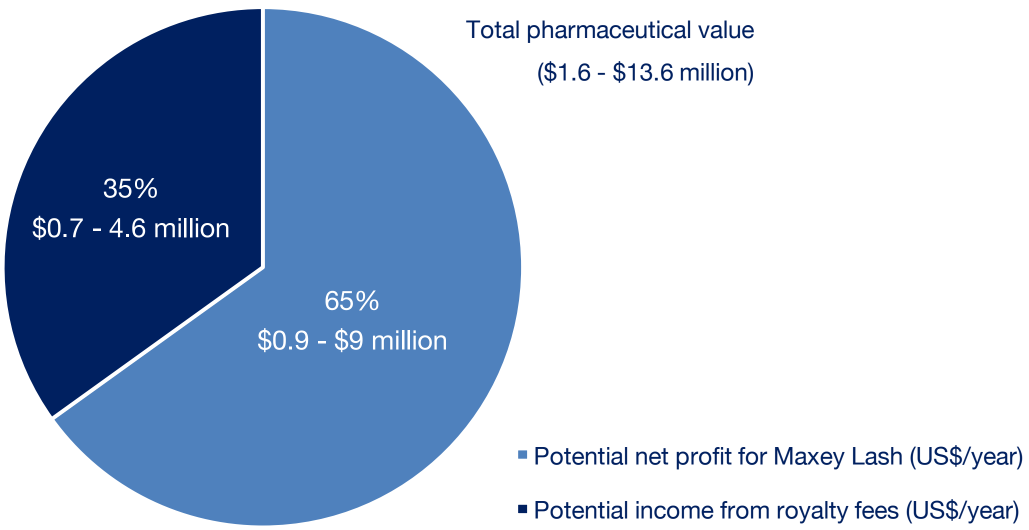


Figure 5 - Total economic value associated to pharmaceutical coral extraction (US$ millions per year)

3.4 Coastal protection

3.4.1 Methods

Coral reef structures serve as buffers against waves, floods and storms, preventing loss of life, erosion and property damage. For this study, the coastal protection value of coral reefs in the marine protected areas (MPAs) of the Cayman Islands is estimated using the avoided-damage approach[3]. To estimate the coastal protection value of coral reefs, we apply a GIS-based method to calculate the total flood damages that occur during a 1/25-year return time storm as well as the share of these damages that would be prevented by

[3] The approach used to conduct this analysis is adapted from Hoogeveen (2016).

the presence of nearby coral reefs. This percentage (the relative reef contribution – RRC – that mitigates storm damages) is calculated per coastal transect using a methodology developed by Burke et al. (2008).

The benefits from coastal protection considered in the analysis are direct avoided damages to properties (Cesar and van Beukering, 2004; Constanza et al., 1997; Waite et al., 2014; van Zanten et. al 2014), meaning the economic effect of the avoided physical damages to buildings as a result of wave impact and flooding. Avoided damages to infrastructure and indirect benefits of coastal protection such as avoidance of business interruption are not accounted for in this analysis. Therefore, the estimation of the value of coastal protection by coral reefs is assumingly a lower-bound estimate of the actual economic value of this service.

The characteristics of a 1/25-year return-period event are supported by empirical information from hurricane Ivan (2004) provided by the DoE. This analysis is innovative as it relies on detailed data that enables the estimation of avoided damages on individual building level.

3.4.1.1 Relative reef contribution (RRC)

To value the coastal protection of properties by coral reefs, the relative reef contribution (RRC) to this service needs to be determined per coastal transect. The RRC is a coefficient that, multiplied with the total economic damages during a storm, defines the avoided damages that can attributed to the presence of nearby coral reefs (Burke et al, 2008).

Per coastal transect, the RRC is obtained using equation 1: The RRC is the scaled percentage of the reef's contribution to protecting coastline in relation to all the factors that contribute to the relative total coastal protection (RTCP). The RTCP is calculated by averaging the value of nine factors that define the level of protection of properties along the coast: geomorphology (e.g. cliffs or beaches), coastal exposure, wave energy, storm frequency, coral reef characteristics, coastal vegetation, coastal elevation, coastal slope, and the presence of erosive anthropogenic activities (Annex 6). These factors are scored on a scale between 0 and 4 representing the level of coastal protection (0 means no coastal protection and 4 very high coastal protection). The RRC is calculated by taking the square root of the ratio of the Coral Reef Index (CRI) – which is one the factors that define coastal protection – over the sum of all coastal protection factors divided by the RTCP for each coastal transect.

$$RRC = \sqrt{\frac{CRI/\Sigma_1^N\ CoastalProtectionFactors}{RTCP}} \qquad (1)$$

The CRI is estimated according to the equation below, where *n* is the number of coastal protection factors included in the analysis. The reef index factors are 1) reef type, 2) reef

distribution (e.g. in case of patch reef, the distribution of patches) and 3) distance of reef to the coast.

$$CRI = \frac{\Sigma ReefIndexFactors}{4 * n} \quad (2)$$

3.4.1.2 Storm regime

The analysis of storms' threat is based on observed inundation depth data of hurricane Ivan (2004) on Grand Cayman provided by DoE. This was a category 4 hurricane with an approximate once per 25-year return time. As this was a severe hurricane, the probability of higher inundation depths is relatively low (Taramelli et al., 2014). As an illustration for the situation on Grand Cayman, Figure 6 shows the inundation depth map as was recorded during hurricane Ivan and the location of buildings. For the sister islands, an inundation model as shown in Figure 6 is not available. For Little Cayman and Cayman Brac, an inundation map was created using the difference between the mean surge height from the Grand Cayman inundation model (7.25ft) and a digital elevation model.

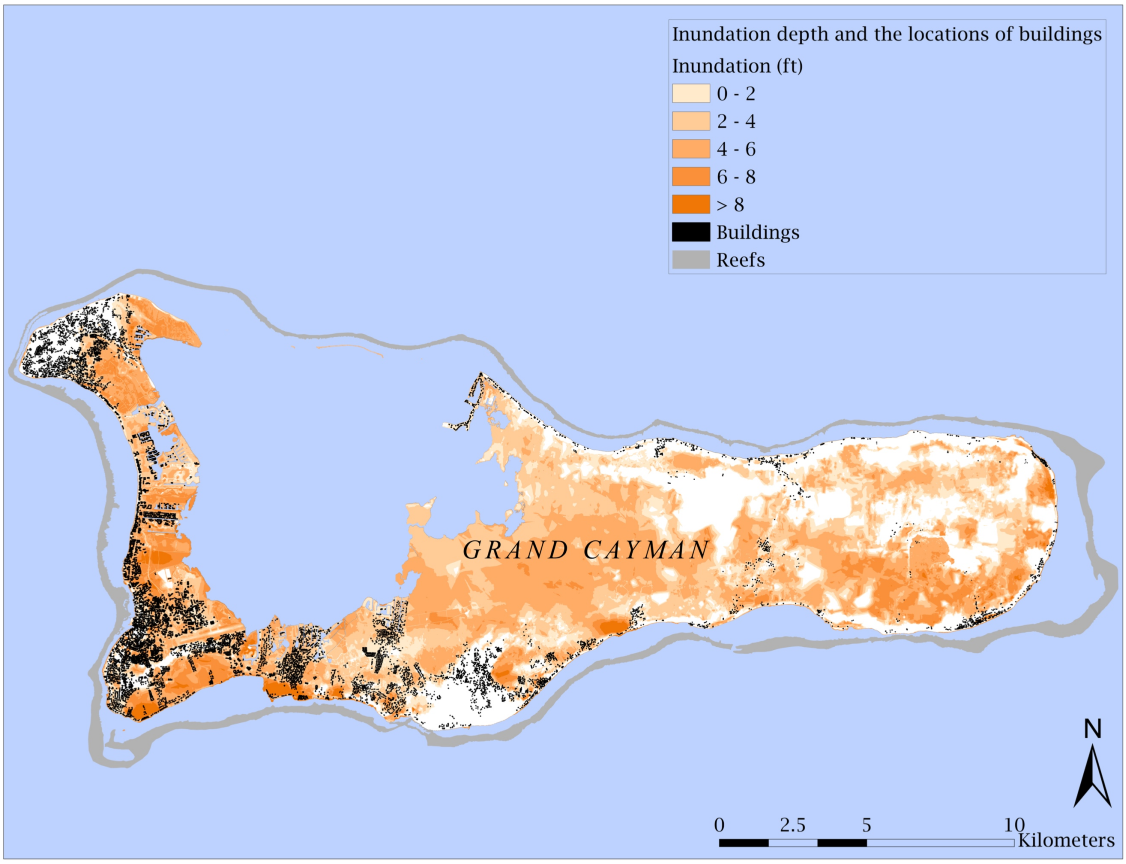


Figure 6 – Inundation depth and property locations in Grand Cayman

3.4.1.3 Vulnerable lands and properties

Vulnerable lands are considered to be those areas that are situated below the maximum storm surge of hurricane Ivan; as for example the inundated areas in Figure 6 on Grand Cayman. Vulnerable lands and buildings were identified by overlaying a storm surge map and the cadastral building map provided by the Lands and Survey Department for the three Cayman Islands in a geographic information system (GIS).

3.4.1.4 Property values

Intersecting the inundation map with the locations of the buildings included in the 2016 cadastral dataset of the Lands and Survey Department for the Cayman Islands gives us the inundation per building. The value that is lost during a storm is not the same for all properties. Relative damages (the % of its initial value that is lost) to properties vary as a result of the type of structure (i.e. one or two stories or commercial), but also depend on inundation level. The US-based Federal Emergency Management Agency (2000) has established the relation between flood depth and relative damage for three different types of building structures (Figure 7): A-zone residential one story, A-zone residential two stories and V-zone. These relative damage estimates are based on empirical data from numerous coastal floods in the US. The x-axis in Figure 7 indicates the depth of the flood in feet, whereas the y-axis shows the percentage of value that is lost during the flood. For example, during a shallow flood, below 5 feet of inundation depth, single floor homes suffer the highest relative damage. During more severe floods, around 10 feet of inundation depth, the difference in relative damage between one and two story buildings evens out a bit. The absolute property values were obtained from the 2016 cadastral dataset – provided by the Lands and Survey Department – with appraised value. This dataset for the Cayman Islands enables a detailed, building level, storm damage estimation procedure. In contrast to A-zones, V-zone depth damage curves apply in areas with high wave impact. In this analysis, it is assumed that high wave impacts occur where the inundation is higher than five feet.

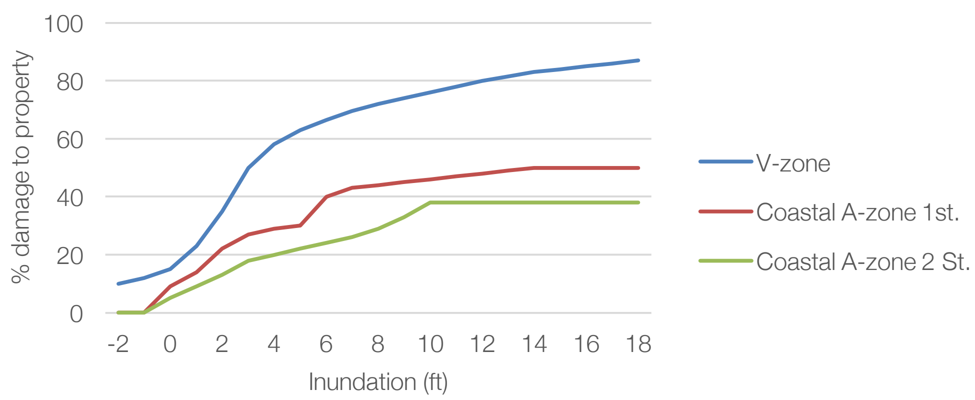


Figure 7 – Relative damage to different building types according to inundation depth (FEMA, 2000)

3.4.1.5 The coastal protection value

The next step requires that the surface area of the Islands is allocated to the coastal transects that have an assigned RRC. For this step, a Euclidean allocation analysis is used in a GIS. This analysis relates coastal transects to buildings on land as well as the assigned RRC of the nearest coastal transect.

Once the inundation depth as well as the RRC per building is determined, the total damage per house is calculated using depth damage relations presented in Figure 7 for the two building categories. To estimate the coastal protection value, as an approximation of the avoided damages because of the presence of nearby coral reefs, we multiply to the total expected damages with the RRC. We obtain an annual coastal protection value by dividing the total coastal protection value of coral reefs during an event comparable to hurricane Ivan (with a return time of 1/25 years) by 25.

To develop a coral reef value map for the ecosystem service of coastal protection, the sum of the coastal protection value attributed to each coastal transect is calculated. This value is then spatially allocated to the spur and groove reefs[4] adjacent to the coastal transects and displayed as an annual value per hectare of coral reef. The value is allocated to spur and groove reefs because they are formed by wave energy exposure and located in the zones where most wave energy dissipation takes place.

3.4.2 Results

The annual coastal protection value by coral reefs in the Cayman Islands is estimated at US$5.1 million. This number is derived from the total coastal protection value of coral reefs during an event with an estimated 25-year return time: US$128 million. During such an event, comparable to hurricane Ivan, the expected total damages are estimated at US$1.25 billion. Approximately 98% of the coastal protection value attributed to coral reefs is located in Grand Cayman, 1.6% in Cayman Brac and 0.1% in Little Cayman.

Figure 8 displays the annual coastal protection value per hectare of coral reef in Grand Cayman. The values that are presented in the maps correspond to the avoided damages to residential and commercial properties due to the presence of nearby coral reefs. The value maps for Little Cayman and Cayman Brac are not presented here because the coastal protection value of coral reefs around these islands is very limited, due to the low level of development in flood prone areas.

The per hectare coastal protection value of coral reefs, as shown in Figure 8, depends on a number of factors. First, the sum of property values in inundated areas in the neighborhood along a coastal transect determines the value at risk. Second, the type of

[4] Obtained from the spatial classification of benthic areas in the Cayman Islands made available through the DoE of the Cayman Islands.

building as well as the inundation depth determine the extent of damage to properties. Third, the relative contribution of coral reefs to the protection of the coast against wave energy determines the relative reef contribution (RRC) as an approximated percentage of the total expected damages. The importance of these factors can be observed in Figure 8. Figure 8 indicates high values in places with a high concentration of expensive properties located in low-lying areas, such as the developments Cypress Pointe between West Bay and George Town. Also, the coral reefs nearing the Patrick's island neighborhood in south-eastern George Town have a high value due to the high concentration vulnerable properties.

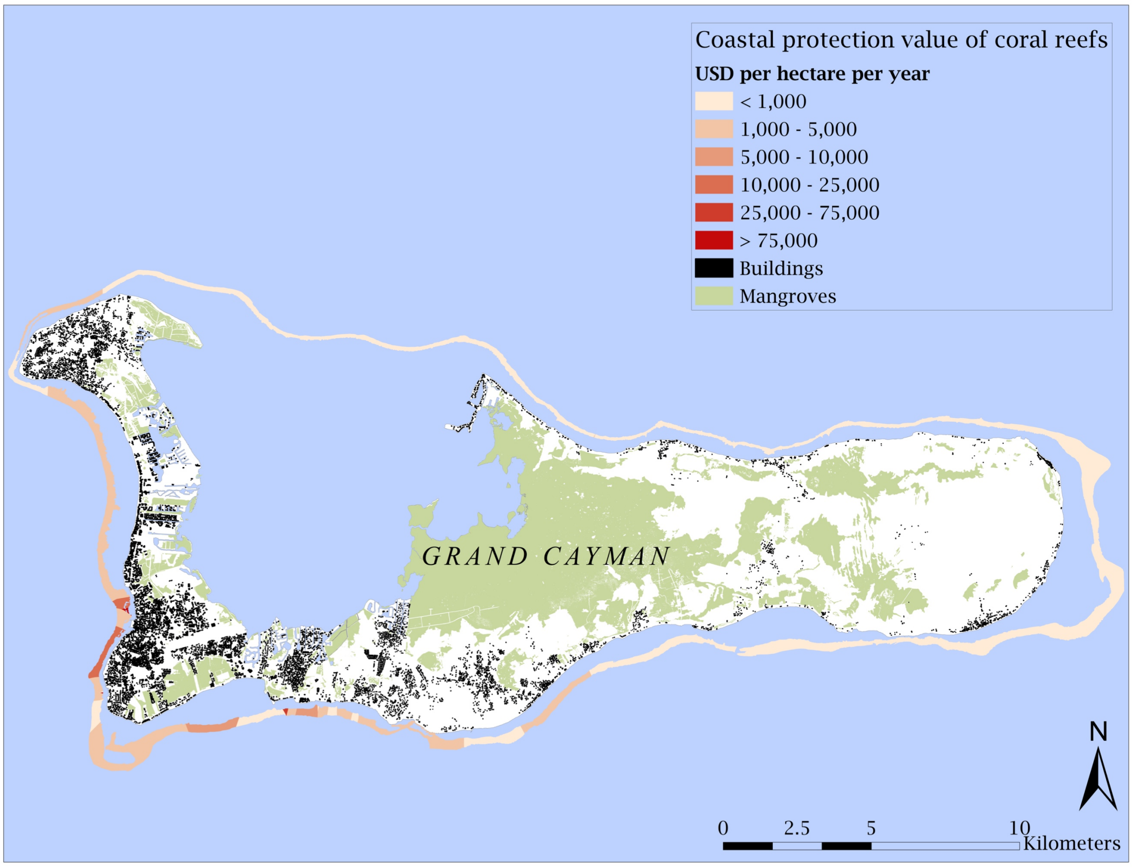


Figure 8 - Annual coastal protection value per hectare of coral reef in Grand Cayman

3.5 Carbon sequestration

3.5.1 Methods

In this study, the economic value of carbon sequestration is estimated through the market price technique (van Beukering et al., 2007; Waite et al., 2014). The economic value of this service therefore represents the potential market value of annual flows of carbon from the atmosphere to coastal carbon pools, given the actual extent of mangroves and seagrass beds in the Cayman Islands.

The total economic value of annual carbon gains in the present (EVt) is estimated as the product of the carbon sequestration potential (Cseq) and the price (P) per ton of carbon dioxide that could be compensated through a hypothetical carbon market. This is summarized in the following formula:

$$EVt = 3.67 \cdot Cseq \cdot P \tag{3}$$

The conversion factor included in the formula (i.e. 3.67) corresponds to the ratio of the molecular weights of carbon and carbon dioxide. This ratio is used for estimating the equivalent carbon dioxide that can be produced if the carbon stored in the system is released to the atmosphere (Howard et al., 2014).

The selection of the price for estimating the economic value of the carbon sequestration service is based on the mechanisms established by the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. It is important to note that emission reductions related to oceanic carbon are not currently guaranteed under these mechanisms, and hence, the price used in this analysis provides only a reference of a hypothetical market that is not currently in place.

In this study, we use the price assigned to 1 metric ton of carbon dioxide in emission trading systems as the measure to monetize carbon fluxes in coastal ecosystems. Approximately 70% of the global carbon dioxide emissions are priced through emission trading systems in a range that varies from around US$1 to US$9 per Mg[5] of carbon dioxide emissions (Kossoy et al., 2015). Since this price range has remained relatively stable in absolute terms during the past two years (Kossoy et al., 2015; World Bank and Ecofys, 2016), this is used as a representative measure of price for the estimation of the economic value of carbon. For the sake of simplicity, the price used in the calculations is the median of the range selected, estimated at US$5 per Mg of carbon dioxide emissions.

3.5.2 Results

In this study, the estimation of the economic value of carbon sequestration focuses on seagrass and mangroves, since these are the main carbon pools identified in the Cayman Islands. Global average values of carbon stock (Howard et al., 2014; IPCC, 2006; IPCC, 2014) suggest that the carbon potentially stored in seagrass and mangroves could reach approximately 3.5 million Mg in the Cayman Islands. Of this amount, approximately 65% is stored in mangrove areas in Grand Cayman. Existing MPAs comprise around 20% of the total carbon stock (Table 6).

[5] 1 megagram (Mg) = 1 Metric ton (tonne). Mg is commonly used in carbon sequestration literature.

Table 6 - Carbon stock in the Cayman Islands (Mg)

Ecosystem	Grand Cayman		Cayman Brac		Little Cayman		Total
	MPAs	Outside MPAs	MPAs	Outside MPAs	MPAs	Outside MPAs	
Seagrass	419,500	346,300	100	1,500	12,300	7,500	787,300
Mangroves	266,000	2,270,500	-	6,700	300	184,500	2,727,900
Total	**685,500**	**2,616,900**	**100**	**1,500**	**12,600**	**192,000**	**3,515,200**

To estimate the annual economic value of the carbon sequestration service provided by coastal ecosystems, the carbon sequestration potential is estimated based on global average value of annual accumulation of carbon (Laffoley and Grimsditch 2009). The obtained results suggest that the highest carbon sequestration potential is found in mangrove ecosystems in Grand Cayman (Table 7).

Table 7 - Carbon sequestration potential in coastal ecosystems in the Cayman Islands (Mg/year)

Ecosystem	Grand Cayman	Cayman Brac	Little Cayman	Total
Seagrass	5,900	<100	200	6,100
Mangroves	9,100	<100	700	9,800
Total	**15,000**	**<100**	**800**	**15,900**

To assign a monetary value to the carbon sequestration potential, the results presented in Table 7 are firstly converted to carbon dioxide units based on the ration of the molecular weights of carbon and carbon dioxide (i.e. 3.67). Considering a price of US$5 per Mg of carbon dioxide (based on Kossoy et al., 2015; World Bank and Ecofys, 2016), the total economic value of this service is estimated at around US$ 291,300 per year (Table 8). As shown in Figure 9, most of the economic value of the carbon sequestration service estimated in the Cayman Islands originates from mangroves in Grand Cayman, given the large area of this ecosystem type in the central swamp of the island.

Table 8 - Economic value of the carbon sequestration service per year (US$)

Ecosystem	Grand Cayman	Cayman Brac	Little Cayman	Total
Seagrass	$108,000	$200	$2,800	$111,000
Mangroves	$167,600	$500	$12,200	$180,300
Total	**$275,600**	**$700**	**$15,000**	**$291,300**

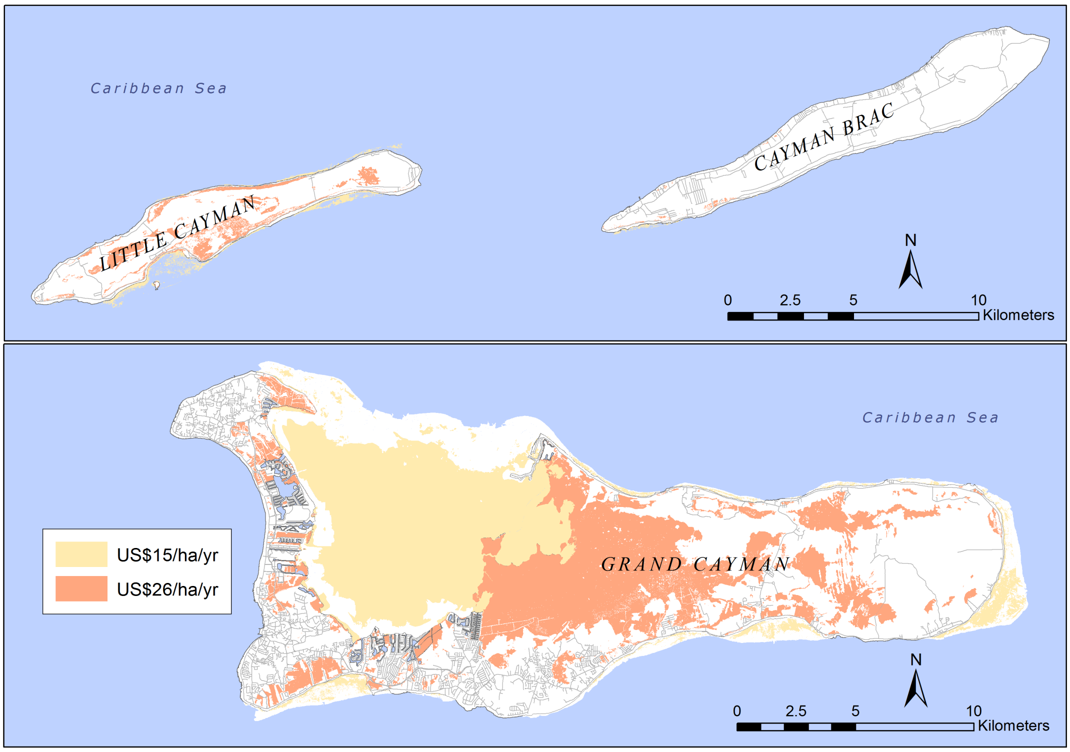


Figure 9 - Spatial representation of the economic value associated with carbon sequestration in the Cayman Islands (US$/ha/year)

3.6 Amenity value

3.6.1 Methods

In this study, the amenity value refers to the value that ecosystems such as coral reefs and mangroves potentially add to real estate prices on the Cayman Islands. This value is estimated by using the hedonic pricing method[6], a revealed preference approach used to obtain the economic value of a variable, such as any specific environmental feature, that is implicitly part of the price of houses (i.e. residential building).

The hedonic pricing analysis has the underlying assumption that the price of every house or building can be explained by its individual characteristics (Rosen, 1974). The method uses multiple regression analysis to quantify the relative importance of different variables for the price of a good. Each independent variable has its own implicit price and its own importance for the overall price of the property (Dunse and Jones, 1998).

As part of the many variables that define the price of houses, this study examines the importance of their proximity to coral reefs and mangroves. The amenity value is therefore calculated as the difference between the total price of houses and the distance to natural amenities that have been found to influence the price significantly. Hence, the relation

---

[6] The approach used to conduct this analysis is adapted from Hoogeveen (2016).

between property values and the distance to reefs and mangroves is assessed to establish the hedonic price of these habitats as an ecosystem service. The total amenity value for Grand Cayman is estimated by extrapolating the mean amenity value per house over the total number of residential buildings in Grand Cayman.

This analysis focuses on the amenity value for residents, and hence, it only considers house transactions. Although environmental amenities can influence the price of lands bought for future residential use, this might not be the case for land transactions with other purposes, e.g. commercial use, agricultural use, investment, etc. Since the purpose of individual land transactions in the Cayman Islands is unknown, these are not included in the estimation of the amenity value.

3.6.1.1 Variable construction

The variables in the dataset provided by the Cayman Islands Real Estate Brokers Association (CIREBA, 2016) present structural, neighborhood and spatial characteristics. Although the dataset contains 4,830 observations, 1,861 can be georeferenced and linked to a specific parcel on Grand Cayman. A large part of the georeferenced observations, however, do not contain any information about the square feet, bedrooms or bathrooms and further inspection shows that most of these cases turned out to be parcels. Consequently, only 686 data points are usable observations, all located in Grand Cayman.

The descriptive statistics of the variables considered in the analysis are shown in Table 9. The structural characteristics of sold houses included in the hedonic pricing model are price, surface area land, number of bedrooms, number of bathrooms, surface area house and view.

Table 9 - Descriptive statistics of sold houses in the dataset that were considered for the hedonic pricing model.

	Mean	St. deviation	Min	Max
Dependent variable				
House price (US$)	879,813	929,004	2,996	9,453,780
Housing features				
Surface area house/apartment (ft.^{2})	3,188	1,780	384	13,804
Surface area land (ft.^{2})	17,460	12,537	4,356	184,694
Bedrooms (count)	3.61	1.31	1	10
Bathrooms (count)	3.13	1.92	0.5	10
Environmental amenities				
Distance to canals (ft.)	7,928	10,385	30	64,038
Distance to mangroves (ft.)	1,314	1,545	0	6,821
Distance to reefs (ft.)	3,660	2,554	95	12,120
Distance to coast (ft.)	1,307	1,551	30	8,184
Beach view (cat.)	0.13	0.33	0	1
Waterfront view (cat.)	0.06	0.24	0	1

The average house price in the dataset is US$879,813 with a maximum of US$9.5 million. The houses are on average 3,188 ft^2 and contain on average 3.6 and 3.1 bed and bathrooms respectively. View is particularly relevant for the analysis due to its correlation to the coast and coral reefs, and it is expected that ocean view has a positive correlation with property prices (Sarkis et al., 2010). 13% of the houses in the database have beach view and 6% of the houses was categorized as waterfront view. Spatial features are analyzed using GIS and include the distance of properties to ecosystems such as mangroves and reefs, and to green infrastructure such as canals.

3.6.1.2 Empirical framework

The hedonic pricing method is based on regression analysis, which uses the following specification to estimate the factors influencing the house prices:

$$logpi = \alpha Ei + \beta Hi + \epsilon \tag{4}$$

Where log p_i is the logarithmic transformation of the sold price at location i, Ei is the effect of the environmental amenities of the property or parcel at location i, H_i are the property characteristics and ϵ is the error term. α and β are the parameters to be estimated. The house price (dependent variable) and several explanatory variables have been log-transformed to conform to a normal distribution.

The regression uses robust standard errors to reduce the heteroscedasticity in the error terms. Variation might occur due to the spatial relationship within the data in a spatial dataset. For example, an attractive neighborhood might have higher house prices so the observed price in that neighborhood is higher. To account for this effect, locational fixed effects are tested in the analysis. The locational fixed effects are based on the districts that the observations correspond to. This results in the following regression equation, where θi are the district fixed effects:

$$logpi = \alpha Ei + \beta Hi + \theta i + \epsilon \tag{5}$$

Spatial autocorrelation among observations is often found when working with spatial data. It is possible that observations close to each other are correlated. When this is the case, the Ordinary Least Square (OLS) regression should be adapted to consider this effect. To test whether OLS is the right model, Moran's I spatial dependence test can be conducted. If there is spatial dependency, the following models are appropriate to use. A spatial lag model based on the distance between observations can be used to correct for the dependency. A spatial error model corrects for the dependency of the error terms of the observations (Dekkers an Koomen, 2008).

Using the software GeoDa, a row standardized spatial weights matrix is constructed, based on the distance from every observation to every other observation. Moran's I can be

calculated based on this spatial weight matrix. The formal notation of the spatial error model is:

$$p = \alpha Ei + \beta Hi + \rho Wp + \varepsilon \quad (6)$$

$$\varepsilon = \lambda W\varepsilon + u \quad (7)$$

Where p is the price, W the spatial weight matrix, and ε is the independent error term. ρ and λ are econometric coefficients that describe the importance of the spatial lag and spatial error terms (Dekkers and Koomen, 2008).

3.6.1.3 Mapping the amenity value of ecosystems

A value map is developed to visualize the spatial variation of the amenity value of environmental location characteristics. The mapping method uses statistically significant effects of the environmental location characteristics (e.g. distance to mangroves and reefs) to determine the amenity value of these ecosystems per hectare, by calculating the cumulative added value to house prices in a neighborhood around the particular patch of mangrove or reef. The value mapping analysis consists of the following steps:

Step 1: Develop raster layers in GIS that describe the effect on house price based on the distance to the nearest ecosystem types (e.g. mangroves and reefs) per grid cell. Scale the value of the Euclidean distance grid by using log-transformation and then multiplying the log-transformed values by the coefficients obtained by the hedonic model. If the effects of the environmental location characteristics are added up, the combined effect of these coefficients on the modeled house price are calculated. Because both the dependent and the independent variables are log-transformed, the coefficients should be interpreted as follows: if the independent variable increases by 1%, the dependent variable increases with the coefficient*1%. Thus, if a coefficient of distance to reef is -0.03, we know that a 100% increase would lead to a 3% decrease in the house price.

Step 2: The hedonic pricing model is estimated based on the 686 observations selected from the dataset of the Cayman Islands Real Estate Brokers Association (CIREBA). In order to have a representative view of the spatial distribution of houses on Grand Cayman, spatial cadastral information on building locations is used. From the 2016 cadastral spatial dataset provided by the Cayman Islands Lands and Survey Department (shapefile), all residential properties on Grand Cayman are selected (n = 11,272). We noticed, however, that a significant amount of recently sold houses were not present in the cadastral shapefile with residential properties. The cadastral file has been therefore updated with houses from the CIREBA dataset and then converted to a raster layer, which indicates the count of houses per 90*90 feet grid cell.

Step 3: This step links the house values to the ecosystem types. To obtain the amenity value of ecosystem types per grid cell, the layers prepared in step 1 are multiplied by the

layer prepared in step 2. Then, the total amenity value of ecosystem types (e.g. reefs or mangroves) is added up by conducting a neighborhood analysis in a specific radius (given by the maximum values from dataset used for the hedonic pricing model) around each grid cell. Following this step, the results of the neighborhood analysis are intersected with each ecosystem type. This final dimensionless index layer indicates the relative amenity value that can be used to distribute the total simulated amenity value across ecosystems on Grand Cayman.

3.6.2 Results

Figure 10 shows the locations of houses in the dataset and in Figure 11 we explore the correlations among variables that are considered for the hedonic pricing analysis. A set of structural variables, such as number of bedrooms and bathrooms, size of the house and house plot, are directly obtained from the CIREBA dataset. Also, the type of view from the house is included in the dataset. In this analysis, we include categorical variables for houses with beach- and waterfront view. The other mutually exclusive view categories (canal, garden, pool) represent the reference category in this analysis. The location variables that describe the distance to ecosystem types and habitats, such as mangroves, canals, reefs and the coast were obtained through spatial analysis and added to the dataset (Annex 1).

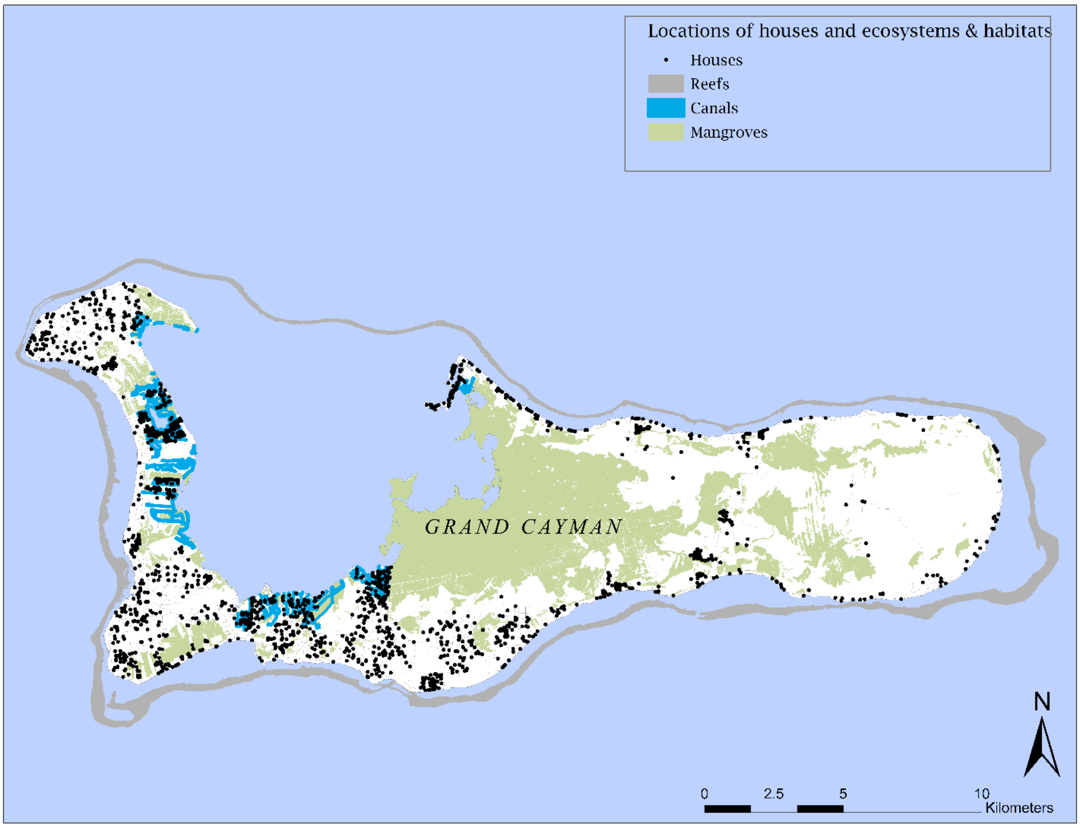


Figure 10 - Locations of houses in the CIREBA dataset and the locations of mangroves, coral reefs and canals on Grand Cayman.

Prior to the correlation analysis, collinearity tests indicated that districts and population density are highly correlated. Hence, districts are excluded from the dataset. This means that the model does not include district fixed effects. In Figure 11, the blue dots indicate a positive relation between variables, a red dot indicates a negative relation. Not surprisingly, strong positive correlations are observed between structural characteristics, such as house area and number of bathrooms and also between number of bathrooms and number of bedrooms.

Distance to the coast is positively correlated to distance to canals (as canals are an open system and thus part of the coastline) and negatively correlated to house area and beach view: when distance to the coast increases houses tend to get smaller and beach view rare (Figure 11). Besides the correlation with distance to coast, distance to canals is negatively correlated to distance to reefs.

Based on the correlation analysis, distance to coast is excluded from the analysis because it is a highly collinear 'container variable', which most likely combines the effects of distance to canals, beach view and waterfront view. Bedrooms and bathrooms are not considered either because of their strong correlation with house area. This is confirmed by high variance inflation factors (> 3) when these variables are included in the model estimates.

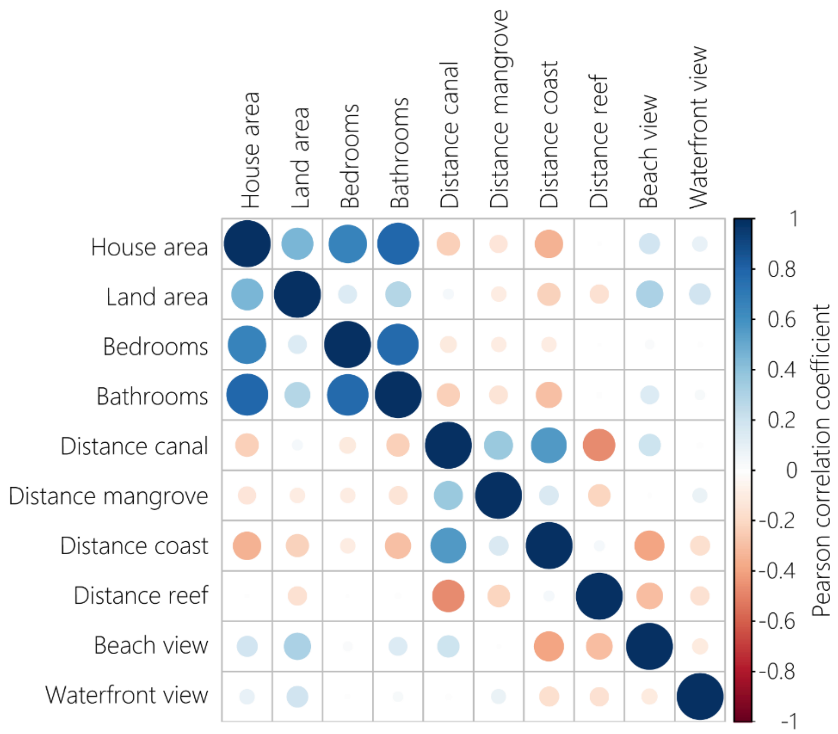


Figure 11 - Correlation plot between independent variables considered for the hedonic pricing model.

Table 10 shows the estimates of the hedonic pricing model. It is specified as a log-log linear regression model, where the dependent variable (house price), as well as the

continuous independent variables, are log-transformed (using the natural logarithm). First, a set of models is estimated with the environmental location variables (distance to reef, distance to mangroves, distance to canals) as sole independent variable. Distance to reef has no significant effect on the house price and is therefore excluded from the full model. Distance to mangroves and distance to canals are significant in all models, also in combination with each other. This means that, even when holding the distance to canals constant for all houses, an increasing distance to mangroves has a negative effect on house prices. The full model has an adjusted R2 of 0.75, which indicates that the variance of the natural logarithm of house prices that is explained by the independent variables in the model is 75%.

All models are estimated using R statistics software. For log-log models, a 1% increase of an independent variable yields a change of the coefficient*1% of the dependent variable. For example, Table 10 shows that house area has a strong positive effect on house price, as a 1% increase in house area leads to a 0.94% increase in house price.

The overall statistically insignificant relation between house prices and distance to coral reefs was further explored in a sensitivity analysis (Annex 4 and 5). Annex 4 shows model estimates for subsets of the data per district; Annex 5 shows estimates for subsets with low and high real estate.

Table 10 - Log-log OLS estimate for the hedonic pricing model.

	Canals		**Mangroves**		**Full model**	
	Coefficient	St. error	Coefficient	St. error	Coefficient	St. error
Intercept	14.17***	0.11	14.24***	0.18	5.25***	0.40
Housing features						
Surface area house/apartment (log sq.ft.)					0.94***	0.36
Surface area land (log sq.ft.)					0.15***	0.04
Environmental amenities						
Distance to canals (log ft.)	-0.14***	0.01			-0.10***	0.01
Distance to mangroves (log ft.)			-0.17***	0.03	-0.04**	0.02
Beach view (cat.)					0.86***	0.05
Waterfront view (cat.)					0.24***	0.07
n	686		686		686	
Goodness of fit statistics						
Adjusted R2	0.11		0.05		0.75	

The most important conclusion that can be drawn from the sensitivity analysis using separate districts and different segments of house prices is that the distance to reefs is not significant for any of them.

3.6.3 Economic value

To calculate the amenity value of the two significant environmental location variables (distance to mangroves and distance to canals), we apply the hedonic pricing function (Table 10). This model is used to predict the sum of house values in the dataset for the current situation and for a scenario where the mangrove ecosystem has retreated by 1,000 feet until a maximum of 6,800 feet (i.e. for each house, the distance to the nearest patch of mangroves has increased by 1,000 feet), while holding all other variables in the hedonic pricing function constant. The column 'predicted sum house values' shows the estimates per scenario. The difference between the predicted sum and the predicted sum of the baseline is the amenity for the mangrove scenarios. In comparison to the 'Less mangroves' scenario, the current stock of mangroves on Grand Cayman yields an amenity value of almost US$26.5 million for houses in the CIREBA dataset.

Table 11 - The modelled amenity value of mangroves for houses in the dataset following the hedonic pricing function (US$)

CIREBA dataset	Observed sum house values	Predicted sum house values	Amenity mangrove distance + 1000 ft.
Baseline	$612,945,424	$557,849,803	
Less mangroves		$531,346,815	$26,502,988

The next step in the analysis is to extrapolate the results and quantify the amenity value of mangroves to all houses on Grand Cayman. The total population in 2016 is estimated at 63,816 based on the extrapolation of 2012 data from the Economics and Statistics Office (2016). By dividing the total population by the average number of people per household (i.e. 2.11; Schutter, 2014), it is estimated that there are 30,244 households in Cayman Islands. Because 4.5% of the households is located on the sister islands and the hedonic pricing model only applies to houses on Grand Cayman, the number of houses used for extrapolation is 28,883 (95.5% of all houses in the Cayman Islands). Hence, the estimates presented in Table 11 are divided by 686 to obtain the amenity value per house, and subsequently multiplied by 28,883 to obtain the amenity for all houses on Grand Cayman (Table 12). The amenity value of mangroves is estimated at approximately US$1.1 billion[7].

Table 12 - Quantified estimates of the amenity value of mangroves for houses on Grand Cayman

Quantification	Observed sum house values	Predicted sum house values	Amenity mangrove distance + 1000 ft.
Baseline	$25,807,147,000	$23,487,428,000	
Less mangroves		$22,371,560,000	$1,115,869,000

[7] Because real estate transactions are subject to a stamp fee of 7.5% of purchase price (or higher, depending on the property house), changes in the amenity value of properties are directly linked to government revenue created through this duty.

3.6.4 Value map

A value map was developed by a spatially explicit application of the hedonic pricing function for mangroves. The effect of the distance to mangroves on house prices is estimated by assuming that the structural housing characteristics are evenly distributed across houses on Grand Cayman. If a location on the map is further away from mangroves, the negative effect on the house price increases.

The final step is to distribute the estimated amenity value of mangroves for Grand Cayman (Table 12) over the dimensionless raster layer. The result is presented in Figure 12. The amenity value per hectare on Grand Cayman ranges from less than US$200,000 to over US$1,500,000. The highest values are assigned to mangrove patches in Georgetown and to a lesser extent in West Bay.

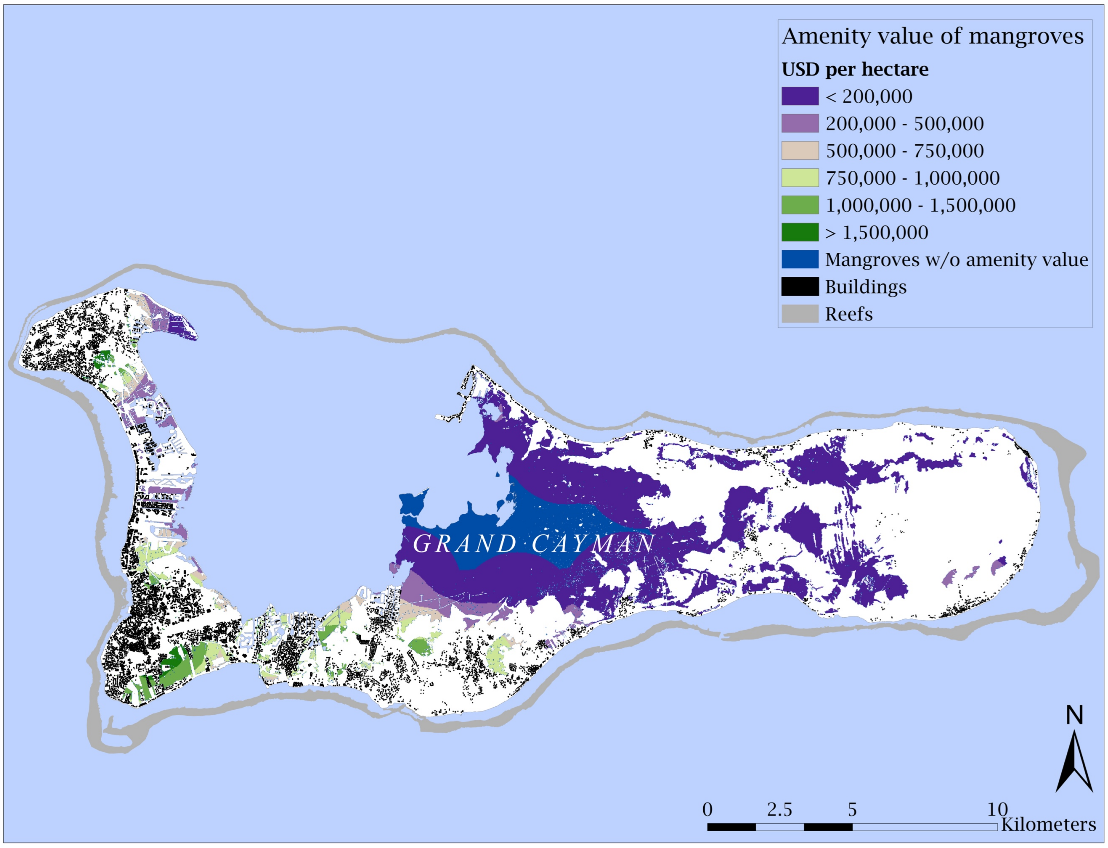


Figure 12 - Amenity value of mangroves on Grand Cayman per hectare. Source data for mangroves is obtained from the DoE habitat map

3.7 Tourism value

3.7.1 Methods

Tourism is one of the main industries in the Cayman Islands (Cayman Islands Government, 2011). Tourists are strongly attracted by the white beaches, coral reefs, fish diversity and other attributes of the marine environment of the islands. As an illustration, the exit survey conducted by the Cayman Islands Department of Tourism (CIDOT) between July 2015 and June 2016 reveals that 87.9% of visitors in the country go to the beach (CIDOT, 2016).

The services provided by marine ecosystems to tourism can be classified as direct and indirect values. Direct tourism values are created by services that depend directly on natural ecosystems, such as diving and snorkelling (Schep et al., 2012). Direct values to tourism are a result of activities in which tourists directly interact with the natural environment, such as diving, recreation on the beach, etc. Indirect values to tourism are values that result from other economic activities that facilitate the interaction of tourists with the natural environment, such as accomodation, car rental and food suppliers.

The approach adopted to assess the value of marine and coastal ecosystems to tourism in the Cayman Islands is based on the economic surplus of consumers and producers. The economic surplus is the total net benefit generated, in this case, from tourism activities. The consumer surplus is the net benefit that tourists obtain from visiting the Cayman Islands and the producer surplus represents the net benefits for the local tourism industry when considering its total revenue and costs. For the purpose of this study, the analysis focuses on the part of the producer and consumer surpluses that originates from local ecosystems.

The total tourism value of local ecosystems in the Cayman Islands is calculated as the sum of the total consumer surplus and the total producer surplus.

3.7.1.1 Consumer surplus

The consumer surplus is calculated based on the willingness to pay (WTP) of tourists to prevent the decline in quality of coral reefs. To estimate the WTP, Van Beukering et al. (2014) applied a choice experiment among 326 visitors and concluded that, on average, one tourist would be willing to pay US$23.2 per day in order to prevent decline in quality of coral reefs from medium to low levels.

The average WTP per tourist per day is multiplied by the total number of visitors in a year and by the average length of stay for both cruise and stay-over tourists according to data from the visitor exit survey (CIDOT, 2016). This results in the total annual consumer surplus of tourism in the Cayman Islands.

3.7.1.2 Producer surplus

The estimation of the producer surplus is based on the tourism expenditure, which is the total amount tourists spend when visiting the Cayman Islands. For the purpose of this analysis, it is assumed that this value also represents the total revenue for the local tourism industry. The producer surplus is therefore estimated through the net factor income technique (van Beukering et al., 2007) and corresponds to the total revenues minus the costs of production.

The total number of and average daily expenditure by stay-over and cruise tourists is obtained from the visitor exit survey (CIDOT, 2016). Although this survey provides specific information about spendings on recreational activities, it does not provide a complete breakdown of the total daily expenditure. This analysis is therefore based on the following expenditure categories investigated by van Beukering et al., (2014) among visitors to the Cayman Islands: airfare, accommodation, local transportation, diving, snorkelling, fishing, other water-based activities, land-based activities, food and beverage, shopping and donations.

To estimate the expenditure on each of the categories mentioned above and according to the most recent figures, the percentage of expenditure on each category estimated by van Beukering et al. (2014) is extrapolated to the average daily estimates from the visitor exit survey (CIDOT, 2016). This extrapolation is conducted by firstly stratifying the sample of the visitor exit survey according to the four sub-groups defined in the former study. Thus, the stay-over and cruise tourist groups are each divided in subgroups of diver and non-diver tourists.

The visitor exit survey was applied only to stay-over tourists and 13% of them were divers (CIDOT, 2016). To make the stratification possible, it is therefore assumed that this percentage is similar among the cruise tourists. It is however expected that this assumption results in an overestimation of the number of divers among cruise tourists.

Once the total number of tourists per subcategory is obtained, the average daily expenditure from the exit survey (US$209 for stay-over tourists and US$118 for cruise tourists) is distributed according to the percentage of expenditure allocated to each activity by the corresponding type of tourist, as defined by van Beukering et al. (2014).

Afterwards, the added value of tourism per person per day is calculated for each expenditure category. Because information on the costs structure in the tourism industry in Cayman Islands is scarce, it is assumed that 25% of the total expenditures corresponds to the added value of the tourism industry. This estimate is based on average margins within the tourism sector and estimates presented by Schep et al. (2012). In other words, it was assumed that 75% of the tourists' expenditure (i.e. the gross revenue for the tourism industry) is used to cover the costs involved in the majority of the analyzed spending categories. Only donations given by tourists were assumed to have an added value of

100%. The total producer surplus is estimated as the sum of the added values of the different expenditure categories.

In order to assess how much of the total producer surplus corresponds to benefits obtained from marine ecosystems, the sum of the added value was multiplied by a factor of ecosystem dependence per activity. This percent factor used for this analysis is based on values determined by expert judgement in previous studies (Schep et al., 2012; van de Kerkhof et al., 2014a; van de Kerkhof et al., 2014b). By multiplying the added value by the factor of ecosystem dependence for each expenditure category, the total producer surplus related to local ecosystems is finally obtained; i.e., the net benefit of the tourism industry obtained from local ecosystems.

3.7.1.3 Value map

A value map is generated to illustrate the spatial distribution of the value of the marine environment for tourism in the Cayman Islands. This is done by allocating the consumer and producer surplus previously estimated to those ecosystems that support these values.

In this study, available data restricts the spatial allocation of economic value only to coral reefs. Available willingness to pay data refer explicitly to this ecosystem, and therefore, the economic value associated to the consumer surplus is entirely allocated to it. The expenditure data that support the estimation of the producer surplus, on the other hand, relate to several ecosystem types. Of these ecosystems, coral reef is the only one to which some of the analyzed expenditure categories, such as diving, can be entirely attributed. The value map, therefore represents the consumer surplus and a part of the producer surplus estimated in previous sections. The part of the producer surplus that cannot be associated to any specific ecosystem type is not spatially represented.

The area and boundaries of the coral reefs in the Cayman Islands is obtained from the benthic classification of the DoE. All coral types are included in the map, as well as hardbottom, rubble and backreef areas connecting coral reef patches.

The consumer surplus, i.e. total WTP, is evenly allocated to all coral reef areas, since this value does not relate to any specific location in the Cayman Islands. The part of the producer surplus that is associated to diving activities is added to the coral reef areas, but in this case, the value is distributed in proportion to the visits to different dive areas. This is done by firstly obtaining the percentage of visitors and number of dives per visitor to the different areas of analysis utilized by van Beukering et al. (2014) (see Figure 13). Then, the economic value associated to diving in coral reefs is distributed among these different areas proportionally to the annual number of dives per area.

Within each area of analysis (Figure 13), the corresponding economic value is distributed over a 300-meter buffer area around the existing dive spots and within the boundaries defined for the coral reef area. It is assumed that 300 m is the maximum radius that a diver would be able to reach around each mooring site under normal conditions.

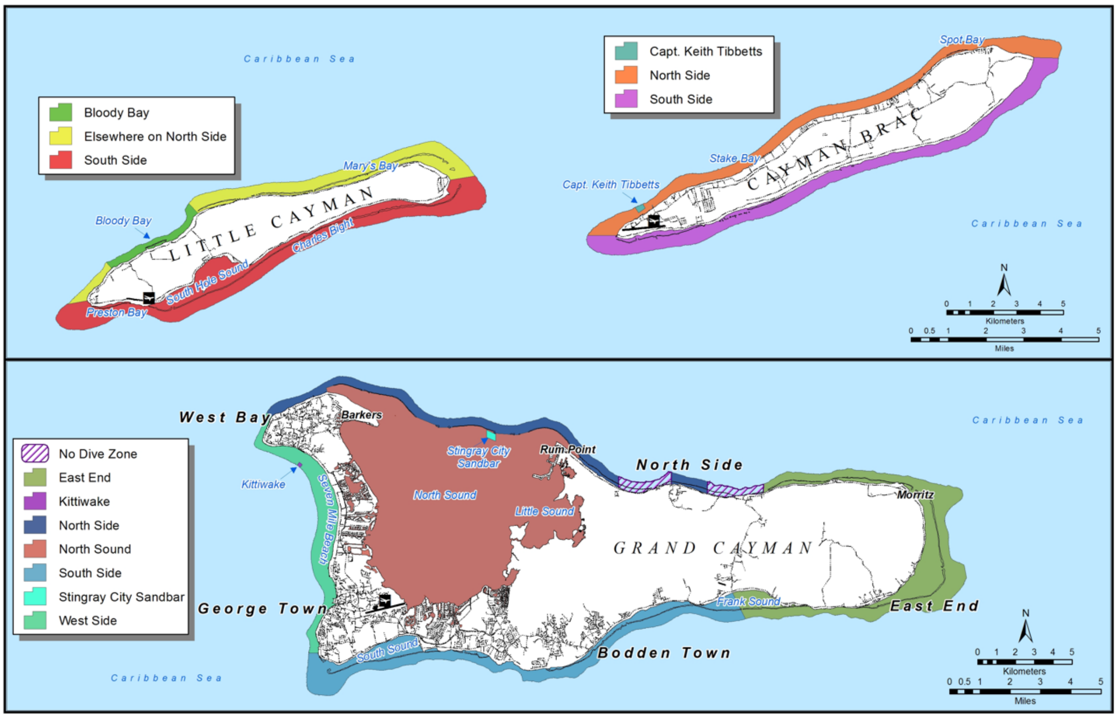


Figure 13 - Different areas of Cayman Islands (van Beukering et al., 2014)

3.7.2 Results

The estimation of the total economic value of the marine and coastal ecosystems of the Cayman Islands for the tourism industry is based on the consumer and producer surplus results presented below.

3.7.2.1 Consumer surplus

The consumer surplus is calculated on the basis of the WTP of tourists to prevent coral reef quality to decline from medium to low levels. This value can be interpreted as an estimate of the value that tourists derive from their appreciation of local ecosystems, but do not actually pay for through organized activities or travel costs required to get to the Cayman Islands. This value is therefore additional to the monetary expenditures already done by tourists.

The average WTP of stay-over and cruise tourists is estimated at US$23.2 per person per day by (van Beukering et al., 2014). The average length of stay is estimated at 6.4 days for stay-over tourists based on the latest visitor exit survey (CIDOT, 2016) and it is assumed as 1 day for cruise tourists. Based on the exit survey, approximately 382,000 stay over tourists and 1,603,000 cruise tourists arrive in the Cayman Islands per year.

Table 13 - Total willingness to pay to prevent the decline of coral reefs from medium to low levels

	Stay over tourists	Cruise tourists
WTP (US$/day; van Beukering et al., 2014)	$23.2	$23.2
Average length of stay (DoT, 2016)	6.4	1
Number of visitors (July 2015 – June 2016; DoT, 2016)	382,374	1,603,112
Total WTP (US$/year)	**$56,863,602**	**$37,192,198**

The total annual WTP to prevent reef quality decline is around US$ 57 million for stay-over tourist and around US$37 million per year for cruise tourists. The consumer surplus is thus estimated at approximately **US$94 million per year.**

3.7.2.2 Producer surplus

Table 14 shows the percentage of the average daily expenditure allocated to different categories by the four types of tourists (Cruise and stay-over; diver and non-diver) investigated by van Beukering et al. (2014). To obtain a detailed indication of the expenditure of all the visitors to the Cayman Islands, the percent allocation of expenditure presented in the table is applied to the total daily spending of US$209 per day for stay-over tourists and US$118 per day for cruise tourists, obtained from the visitor exit survey in the Cayman Islands (CIDOT, 2016).

Table 14 - Expenditure allocation based on the survey conducted by van Beukering et al. (2014)

Expenditure category	Stay over tourist		Cruise tourist	
	diver	Non-diver	diver	Non-diver
1. Airfare	36%	37%	0%	0%
2. Accommodation	22%	28%	0%	0%
3. Transportation	2%	2%	2%	3%
4. Diving	11%	0%	53%	2%*
5. Snorkeling	4%	0%	5%	7%
6. Fishing	0%	3%	0%	0%
7. Other water-based activities	0%	0%	4%	10%
8. Land based activities	0%	1%	2%	10%
9. Food and beverage	19%	25%	12%	28%
10. Shopping	6%	3%	17%	38%
11. Donations	0%	0%	4%	3%
Total	**100%**	**100%**	**100%**	**100%**

**Respondents who did not identify themselves as divers, but spent money in diving activities.*

Table 15 - Added value and net ecosystem benefit from stay-over tourists in the Cayman Islands (US$)

Expenditure by stay-over tourists (including taxes)	Factor of ecosystem dependence	Added value		Net ecosystem benefit	
		Diver	Non-diver	Diver	Non-diver
1. Airfare	30%	$18.7	$19.1	$5.6	$5.7
2. Accommodation	50%	$11.6	$14.7	$5.8	$7.3
3. Transportation	50%	$1.1	$1.1	$0.6	$0.5
4. Diving	100%	$5.5	$0.2	$5.5	$0.2
5. Snorkeling	100%	$2.0	$0.2	$2.0	$0.2
6. Fishing	50%	$-	$1.7	$-	$0.9
7. Other water-based activities	50%	$0.1	$0.2	$-	$0.1
8. Land based activities	50%	$0.1	$0.3	$-	$0.2
9. Food and beverage	25%	$10.1	$13.2	$2.5	$3.3
10. Shopping	25%	$3.1	$1.6	$0.8	$0.4
11. Donations	50%	$-	$-	$-	$-
Total per person per day	**-**	**$52.2**	**$52.2**	**$22.8**	**$18.8**
Total per year (total number of tourists times average length of stay)	**-**	**$16.6 million**	**$111.4 million**	**$7.3 million**	**$40.1 million**

Table 16 – Added value and net ecosystem benefit from cruise tourists in the Cayman Islands (US$)

Expenditure by cruise tourists (including taxes)	Factor of ecosystem dependence	Added value		Net ecosystem benefit	
		Diver	Non-diver	Diver	Non-diver
1. Airfare	30%	$-	$-	$-	$-
2. Accommodation	50%	$-	$-	$-	$-
3. Transportation	50%	$0.7	$0.9	$0.4	$0.4
4. Diving	100%	$15.7	$0.6	$15.7	$0.6
5. Snorkeling	100%	$1.5	$2.0	$1.5	$2.0
6. Fishing	50%	$-	$-	$-	$-
7. Other water-based activities	50%	$1.0	$2.9	$0.5	$1.4
8. Land based activities	50%	$0.5	$3.0	$0.3	$1.5
9. Food and beverage	25%	$3.6	$8.1	$0.9	$2.0
10. Shopping	25%	$5.0	$11.1	$1.2	$2.8
11. Donations	50%	$5.2	$3.0	$2.6	$1.5
Total per person per day	**-**	**$33.3**	**$31.6**	**$23.1**	**$12.3**
Total per year (total number of tourists times average length of stay)	**-**	**US$6,9 million**	**US$44,1 million**	**US$4,8 million**	**US$17,2 million**

The added value, or net benefit obtained by the tourism industry from the tourists' spending, is assumed to be equivalent to 25% of all the expenditure categories, except for donations, on which the added value is assumed to equal 100%. The net benefit that relates specifically to local ecosystems is furthermore estimated by using a factor of ecosystem dependence per expenditure category.

To obtain the added value and net ecosystem benefit for the entire tourism industry, the results presented in Table 15 and Table 16 are multiplied by the average length of stay of the different tourist types (i.e. 6.4 days for stay-over and 1 for cruise tourists) and by the number of visitors per year (as presented in Table 13).

In total, the added value derived from stay-over tourists is estimated at US$128 million per year (Table 15), while the added value associated to the expenditure of cruise tourists is estimated at US$51 million (Table 16). If these figures are aggregated, the added value that is created by the entire tourism industry in the Cayman Islands can be estimated at almost US$180 million per year.

When applying the factor for ecosystem dependence, the net ecosystem benefit associated to stay-over tourists is calculated at around US$47 million per year and the total net ecosystem benefit linked to cruise tourists results in approximately US$22 million per year. In total, the producer surplus for the tourism industry from local ecosystems is estimated to be around **US$69 million per year (**Table 17**)**. These results suggest that almost 40% of the US$180 million created as added value by the tourism industry every year in the Cayman Islands can be attributed to local ecosystems.

Table 17 – Net ecosystem benefits in the tourism industry (US$ per year)

	Stay over tourists	Cruise tourists
Diver	$7,277,900	$4,811,500
Non-diver	$40,058,000	$17,160,400
Total producer surplus	**$47,335,900**	**$21,971,800**

3.7.3 Total tourism value

Table 18 presents the main results of the economic value of marine and coastal ecosystems for tourism in the Cayman Islands. Based on the producer surplus and consumer surplus previously estimated, the total tourism value of local ecosystems results in approximately US$163 million per year. The table below presents the results for stay-over and cruise tourists, revealing that stay-over tourist create almost twice as much value in the tourism industry as cruise tourists when it comes to nature-related activities.

Table 18 - Total annual value of local ecosystems for tourism in the Cayman Islands (US$ per year)

	Stay-over tourists	Cruise tourists	Total
Consumer surplus (total WTP)	$56,863,600	$37,192,200	$94,055,800
Producer surplus	$47,335,900	$21,971,800	$69,307,700
Total annual tourism value	**$104,199,500**	**$59,164,000**	**$163,363,500**

Table 19 presents the tourism value that relates to coral reefs, which correspond to the only ecosystem type on which a part of the economic value for tourism can be spatially allocated with the available data. As mentioned in the methods, the total value of the consumer surplus (around US$94 million per year) is attributed to coral reefs because the WTP used for the consumer surplus relates specifically to this ecosystem type. From the producer surplus, only the economic value that comes from the tourists' expenditure in diving (around US$6 million per year) is directly allocated to coral reef areas. Therefore, only around 60% (approximately US$100 million) of the total economic value of local ecosystems for tourism has an explicit spatial representation.

Table 19 - Spatial allocation of the tourism value of marine and coastal ecosystems in the Cayman Islands (US$ per year)

Spatial unit	Consumer surplus (WTP)	Producer surplus
Coral reef area	$94,055,800	$6,247,500 *

** Economic value associated to diving by tourists.*

As previously described, the value associated to the consumer surplus is evenly distributed over the coral reef area. The value related to the producer surplus, on the other hand, is proportionally distributed according to the number of dives by stay-over and cruise tourists across a buffer area around existing dive-spots and within the coral reef boundaries. Based on the percentage of divers derived from the visitor exit survey (CIDOT, 2016), it is estimated that approximately 50,000 stay-over and 200,000 cruise visitors dive every year in the Cayman Islands.

Table 20 shows the number of dive spots obtained from the dataset of the DoE, classified into the focus areas defined by van Beukering et al. (2014). The average number of dives per spot per year, in each of these focus areas, is extrapolated from the results of the tourist survey conducted by van Beukering et al. (2014) to the total number of stay-over and cruise diver tourists derived from the visitor exit survey (CIDOT, 2016)[8]. The resulting value is used to proportionally allocate the producer surplus value to each focus area.

[8] As described in the methods section, the number of cruise tourists that dive in the Cayman Islands is likely overestimated due to lack of specific data on this group.

Table 20 - Number of dive spots per area and average number of dives per spot per year, based on estimates of stay-over and cruise visitors that dive in the Cayman Islands

Island	Areas	Number of dive spots per area	Average number of dives per spot per year*
Grand Cayman	East End	50	793
	North Side (incl. stingray city sandbar and north sound)	61	781
	South Side	46	446
	West Side (incl. Kittiwake)	87	5.464
Little Cayman	Bloody Bay	26	516
	Elsewhere on North Side LC	15	521
	South Side LC	25	112
Cayman Brac	North Side CB (incl. Capt. Keith Tibbets)	40	-
	South Side CB	28	-

** The West Side of Grand Cayman holds a substantially higher number of dives than other areas because, according to the survey (van Beukering et al., 2014), this is the most visited diving area among cruise tourists.*

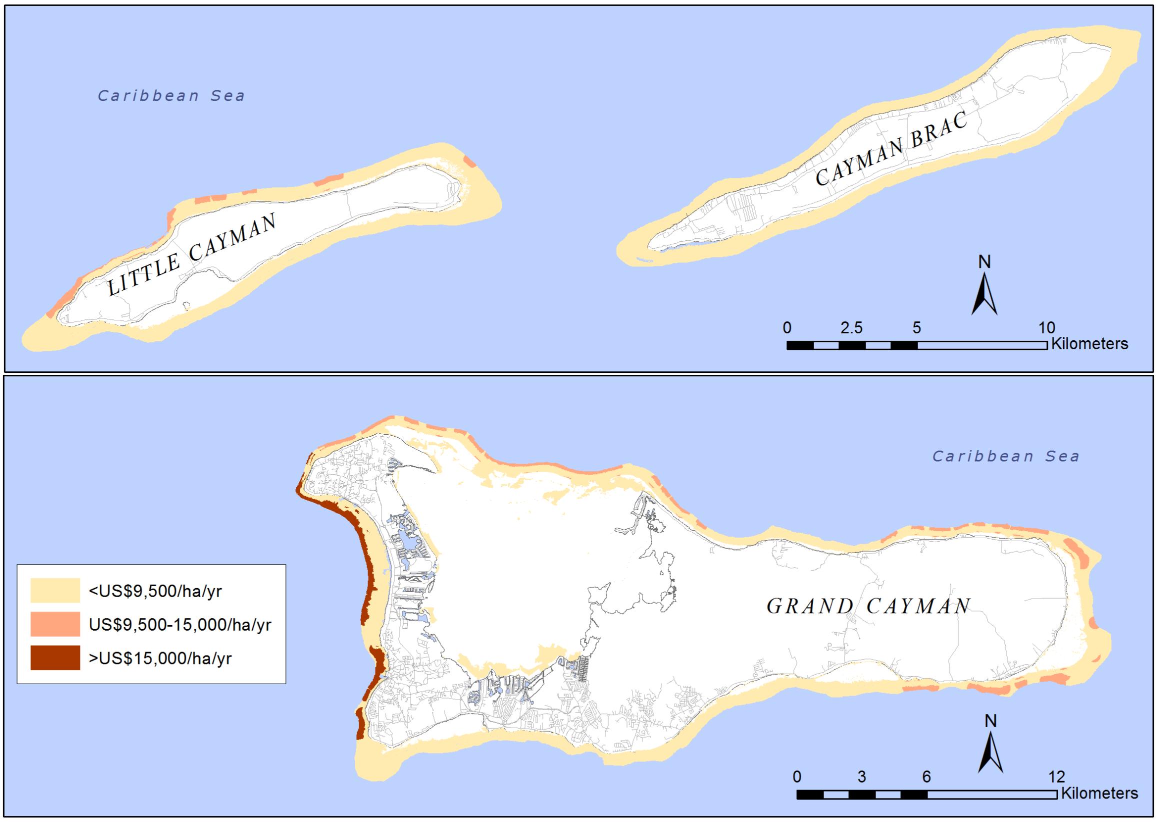


Figure 14 - Spatial representation of the tourism value in coral reef areas in the Cayman Islands (approximately 60% of the total tourism value is spatially represented)

The areas of coral reef with the highest number of dives per spot are located on the West Side of Grand Cayman, where approximately 67% of stay-over diver tourists and 92% of cruise diver visitors go diving (van Beukering et al., 2014). As a result, the highest tourism value per hectare in all the Cayman Islands is also observed in this area of Grand Cayman (Figure 14). In Little Cayman, the areas with the highest monetary value per hectare are in the North Side of the Island, e.g. dive spots in Bloody Bay.

3.8 Cultural and recreational value

3.8.1 Methods

Cultural ecosystem services correspond to "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences" (MA, 2005, p. 10). In this study, we focus on the local benefits from recreational and cultural services provided by marine and coastal ecosystems in the Cayman Islands.

The valuation of cultural and recreational services conducted in this study builds upon the results of previous research conducted by Schutter (2014), which estimates the willingness to pay (WTP) of residents for better enforced and expanded MPAs in the Cayman Islands. Therefore, the results obtained through this analysis are only limited to a scenario of MPA enhancement and, in contrast with the baseline values estimated for other services, the value of cultural and recreational services does not represent the current situation in the Cayman Islands. Despite the lack of data to reflect the current situation in relation to recreational and cultural benefits, this analysis is useful to represent potential changes in value between the scenarios compared in the CBA described in the next chapter.

To estimate the WTP for better enforced and expanded MPAs, Schutter (2014) uses two stated preference approaches, namely: contingent valuation and choice modelling. However, since Schutter (2014) concludes that the WTP results obtained through the choice experiment are unrealistically high due to the extrapolations of the model, the valuation presented in this report only uses the WTP obtained from the contingent valuation. The choice experiment still provides relevant information, such as the relative importance of different natural aspects in relation to the WTP of respondents, but in this report, these findings are used only for descriptive purposes.

In total, the contingent valuation study by Schutter (2014) surveyed 384 households. In the survey, respondents were asked whether they were willing to pay for a better enforcement and expansion of MPAs in the Cayman Islands or not. If the answer was positive, they were asked about their maximum monthly WTP for such an improvement. The WTP was asked in an open question, so the interviewees could answer freely the amount they were willing to pay considering their income.

The WTP estimates obtained through the contingent valuation are consistent with the topics inquired in the context of the survey. Therefore, these results refer specifically to the influence of a protected marine environment on the enjoyment of local recreational and cultural activities such as fishing, going to the beach, sailing, swimming, diving and snorkeling. Although the average WTP was positive on each of the three islands, an ANOVA test applied by Schutter (2014) shows that there is significant difference between the WTP among residents in the three islands. The WTP used for this study is the average WTP for the Cayman Islands.

To estimate the total cultural and recreational value of the improved enforcement and expansion of the MPAs of the Cayman Islands, the per capita values derived from the study conducted by Schutter (2014) are extrapolated to the entire population in the territory. The total population in the Cayman Islands in 2016 is calculated with data from the Economics and Statistics Office of the Cayman Islands Government (2016). The total population in 2016 is obtained from 2012 estimates, which are extrapolated by using the average population increase of 4% per year observed during the period between 1980 and 2012. Finally, the total population estimated for 2016 is multiplied by the average WTP per person derived from the study conducted by Schutter (2014).

3.8.2 Results

The recreational activities included in the household survey conducted by Schutter (2014) to assess the cultural and recreational value of marine ecosystems are fishing, going to the beach, boating, sailing, kayaking, swimming, wading, diving and snorkelling. Figure 15 shows the average number of times per year that people living the Cayman Islands participate in each activity and reveals that the most common recreational activities related to marine ecosystems in Cayman Islands are swimming/wading and going to the beach.

From the respondents to the survey performed by Schutter (2014), approximately 62% answered “yes” when asked whether they were willing to pay for better enforcement and expansion of MPAs in the Cayman Islands. The analysis per island illustrated in Figure 16 suggests that the percentage of respondents willing to pay is the highest in Little Cayman (85% of 34 respondents), which is followed by Cayman Brac (63% of 97 respondents) and Grand Cayman (58% of 109 respondents). Statistical tests applied by Schutter (2014) show significant differences between the answers of respondents in Grand Cayman and Little Cayman, and Cayman Brac and Little Cayman ($p<.001$). However, no significant differences are observed between Grand Cayman and Cayman Brac.

From the respondents that stated that they would not be willing to pay for better enforcement and expansion of MPAs, the majority (65%) specified that they could not financially afford such contribution, and a further 16% indicated that this should be paid from existing tax revenues (Schutter, 2014).

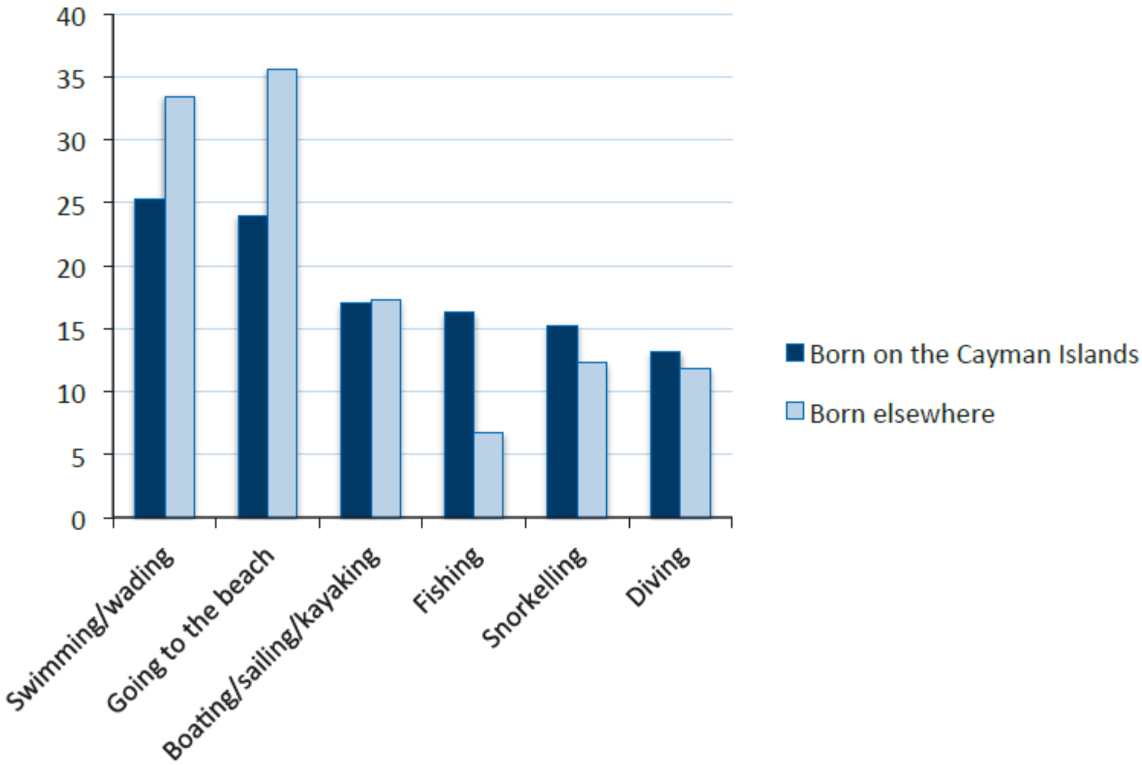


Figure 15 – People's participation in recreational activities in the Cayman Islands (Schutter, 2014)

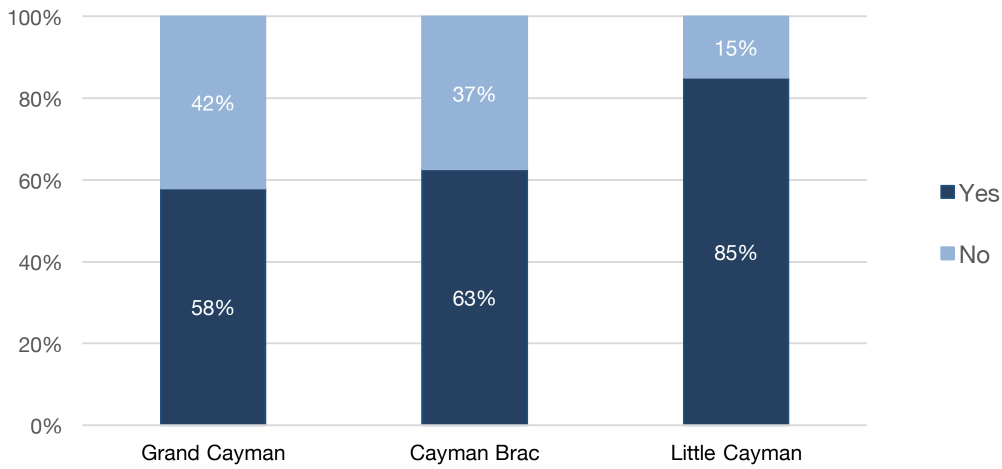


Figure 16 - Answers to the question: Are you willing to pay for better enforcement and expansion of MPAs in the Cayman Islands? (Schutter, 2014)

Considering all the respondents to the survey, the contingent valuation conducted by Schutter (2014) estimates an average monthly WTP for better enforcement and expansion

of MPAs of approximately US$15.46[9] per household in the Cayman Islands. The statistical analysis of this value per island shows that the monthly amount that people are willing to pay is significantly different in the three islands, being Little Cayman the one with the highest WTP ($p<.001$).

To estimate the total WTP for better enforcement and expansion of MPAs, we use the total population in the Cayman Islands in 2016 and an average number of people per household of 2.11 (Schutter, 2014). The total population in 2016 is estimated at 63,816, based on the extrapolation of available data from 2012 (Economics and Statistics Office, 2016). By dividing the total population by the average number of people per household, the total number of households in the Cayman Islands is estimated at 30,244. Finally, by multiplying the number of households by the average WTP per household, the total WTP in the Cayman Islands is estimated at approximately **US$5.6 million per year** (Table 21). In this study, this estimate represents the value associated with recreational and cultural ecosystem services of strengthened MPAs, through further enforcement and expansion.

As explained in the methods, the choice modelling approach applied by Schutter (2014) reveals the WTP of residents for each attribute of marine ecosystems. According to the panel error correction and logit model for the 'attributes only model' and 'complete model' applied, the attribute that households are willing to pay more for is the good quality of coral reefs.

Table 21 - Annual Recreational and Cultural Value

Recreational and cultural ecosystem services	
Population in Cayman Islands	63.816
Average number of people per household	2.11
Average monthly WTP per household	$15.46
Total annual value	**$5.612.189**

It should be noted that double counting in the estimation of the economic value of recreational fishing (estimated in section 3.2) and total cultural and recreational value could be expected to occur. However, the model constructed by Schutter (2014) shows that the fish catch has a significant effect on the WTP of residents only in Cayman Brac, and in this case, it has a weak influence on the logit transformation compared with other explanatory variables. This suggests that the economic value of better enforcement and MPA expansion accounts mainly for cultural and recreational activities, other than fishing.

[9] Conversion rate: US$1= CI$0.82 (XE, 2016).

3.9 Overview of the economic value of ecosystem services in the Cayman Island

The previous sections present the monetary valuation of the services provided by local ecosystems to coastal protection, carbon sequestration, tourism, amenity, pharmaceutical products, fisheries, and culture and recreation. All the estimated values correspond to the current supply of ecosystem services on an annual basis, except for the cultural and recreational value and the amenity value. The cultural and recreational value stands for the potential value allocated by households to local ecosystems under better MPA enforcement conditions and expanded MPAs. The amenity value, on the other hand, corresponds to an absolute value that is not expressed on a yearly basis.

While some of the evaluated services are provided by a broad range of marine and coastal ecosystems, there are others that can be delivered exclusively by one type of ecosystem (Table 22). The value of fisheries refers to coral reef fish, but is at the same time influenced by other ecosystems that provide food and shelter or serve as nursery for fish populations. The tourism and the cultural and recreational values can be attributed to a broad range of ecosystems, including coral reefs, beaches and mangroves. The amenity value is completely associated to mangroves. Carbon sequestration can be allocated to mangroves and seagrass beds. The coastal protection and the pharmaceutical values estimated in this study are exclusively linked to coral reefs.

As a summary of the economic valuation, Table 22 presents the total annual value of the current supply of the ecosystem services considered in the study. In total, these services currently contribute at least US$179 million[10] per year to the Cayman Island's economy.

As shown in Table 22 the tourism value of nature represents, by far, the largest contribution of marine and coastal ecosystems to the economy of the Cayman Islands at present. This value corresponds to 91% of the total economic value of ecosystem services analyzed under the current situation. A further 8% of the economic value of marine and coastal ecosystems is given by the coastal protection capacity of coral reefs, 4% by the pharmaceutical use of products derived from coral reefs (of which 65% corresponds to the private income of a foreign company), 1% by fisheries and <1% by the carbon sequestration potential of mangroves and seagrass.

---

[10] This can be considered a lower bound estimate of the total annual value of ecosystem services, since this figure excludes the amenity value of mangroves (for which an annual value is not estimated in this chapter) and the cultural and recreational value of marine and coastal ecosystems (for which the annual value is not estimated in the current situation).

Table 22 - Overview of the economic value of the current supply of the ecosystem services assessed in this study (millions US$ per year)

Ecosystem service or value	*Relevant ecosystems*	*Total annual value of current supply (millions US$)*
Fisheries	*All marine and coastal ecosystems*	*$2*
Pharmaceutical value	*Coral reefs*	*$2 - 14*
Coastal protection	*Coral reefs*	*$6*
Amenity value	*Mangroves*	*n.a.**
Carbon sequestration	*Mangroves and seagrass*	*< $1*
Tourism value	*All marine and coastal ecosystems*	*$163*
Cultural and recreational value	*All marine and coastal ecosystems*	*n.a.***
Total annual economic value of marine and coastal ecosystem services		**$179**

** The amenity value (US$1.1 billion) is not estimated on an annual basis and therefore is not considered in the calculation of the total annual value of ecosystem services.*

*** The recreational and cultural value estimated in this chapter (US$5.6 million per year) represents the value of better MPA enforcement and MPA expansion. Therefore, this value is not included as part of the total annual value of the current supply of ecosystem services.*

All the values estimated in this chapter serve as input for the cost-benefit analysis of the MPA enhancement. This analysis compares the value of ecosystem services under different scenarios, namely current MPAs and enhanced MPAs, over a specific timeframe. Except for the cultural and recreational value, all the values presented above represent the current provision of ecosystem services. These values are common for the first year of the analysis of all the scenarios. The cultural and recreational value is considered only in the MPA enhancement scenario, as of the second year of analysis. In this chapter, the amenity value (US$1.1 billion) is not estimated on an annual basis and therefore it is not considered in the calculation of the total annual value of ecosystem services. However, for the purpose of the calculations conducted in the cost-benefit analysis, this absolute value is divided by the number of years under analysis. Further details on the changes in ecosystem service provision considered in the cost-benefit analysis are presented in the next chapter

Chapter 4: Costs and benefits of enhancing the Marine Protected Areas of the Cayman Islands

The main purpose of this cost-benefit analysis (CBA) is to evaluate the costs and benefits related to an enhancement of the Marine Protected Areas (MPAs) in the Cayman Islands in comparison with the current situation. In addition to the direct economic values included in traditional CBAs, this extended CBA also considers possible changes in indirect use and non-use values that are provided by ecosystem services.

Differences in costs and benefits are analyzed in four scenarios, i.e. 1A, 2A, 1B and 2B, which are defined by alternative MPA boundaries and effectiveness of MPA management in the Cayman Islands. The analysis considers changes in the value of ecosystem services and costs of MPA management over a 25-year timeframe. The results of the ecosystem service valuation are used as a starting point for the first year of the analysis (year 0). Changes in the values of ecosystem services during subsequent years are estimated in relation to changes in the marine environment under the various scenarios.

Once the expected changes in value have been outlined for all the ecosystem services, the total annual economic value per scenario is estimated by firstly adding all the values per ecosystem service and then subtracting the management costs. Thereafter, the net present value (NPV) is calculated for the entire timeframe by using a discount rate to reflect time preference.

The comparison of the scenarios is based on the NPV and the trends in annual value. Differences in economic value (NPV and trends in annual value) serve to identify monetary costs and benefits that the MPA enhancement would create to different stakeholders. It should be noted that the MPA enhancement considers expansion of MPAs, a more precise contouring and changes in zone designation.

Further details on the MPA enhancement plans, the methodology of the scenario analysis and relevant parameters, and the results of the CBA are provided in the following subsections.

4.1 Current MPAs and MPA enhancement

4.1.1 General background

The current MPA framework of the Cayman Islands was established in 1986 through the Cayman Islands Marine Conservation Law of 1978. This framework defines marine zones with different degrees of protection. However, the periodical monitoring of the conservation status of the Islands' marine resources has provided continued evidence of their degradation (Richardson et al., 2013).

Given the increasing threats to marine and coastal ecosystems, and after extensive discussions with stakeholders on the Cayman Islands, the Department of Environment (DoE) has developed plans to adapt the existing MPA framework (Richardson et al., 2013). The proposed framework, which involves the enhancement of the MPAs, is expected to be more effective in the protection of the islands' natural resources to secure wellbeing of Caymanian residents in the future.

The current MPAs and the proposed MPA enhancement are illustrated in Figure 17, Figure 18 and Figure 19. As shown in the figures, the MPA enhancement considers changes in the zone designation, the expansion of no-take zones and a more precise contouring.

In Grand Cayman, areas currently designated as Replenishment Zones would be refined and converted into Marine Reserves. Similarly, new Marine Reserve zones would be established in Old Man Bay, Gun Bay, and the southern coast of the island.

In Little Cayman, the MPA enhancement also entails the refinement of boundaries and change from Replenishment Zones and Marine Parks to Marine Reserve zones. Furthermore, the enhancement of the MPAs in Cayman Brac would involve the establishment of Marine Reserve zones in areas that currently lack protection, particularly in the northern coast.

The different zones in the current MPAs and those proposed for the MPA enhancement are further described in the subsections 4.1.2 and 0, respectively.

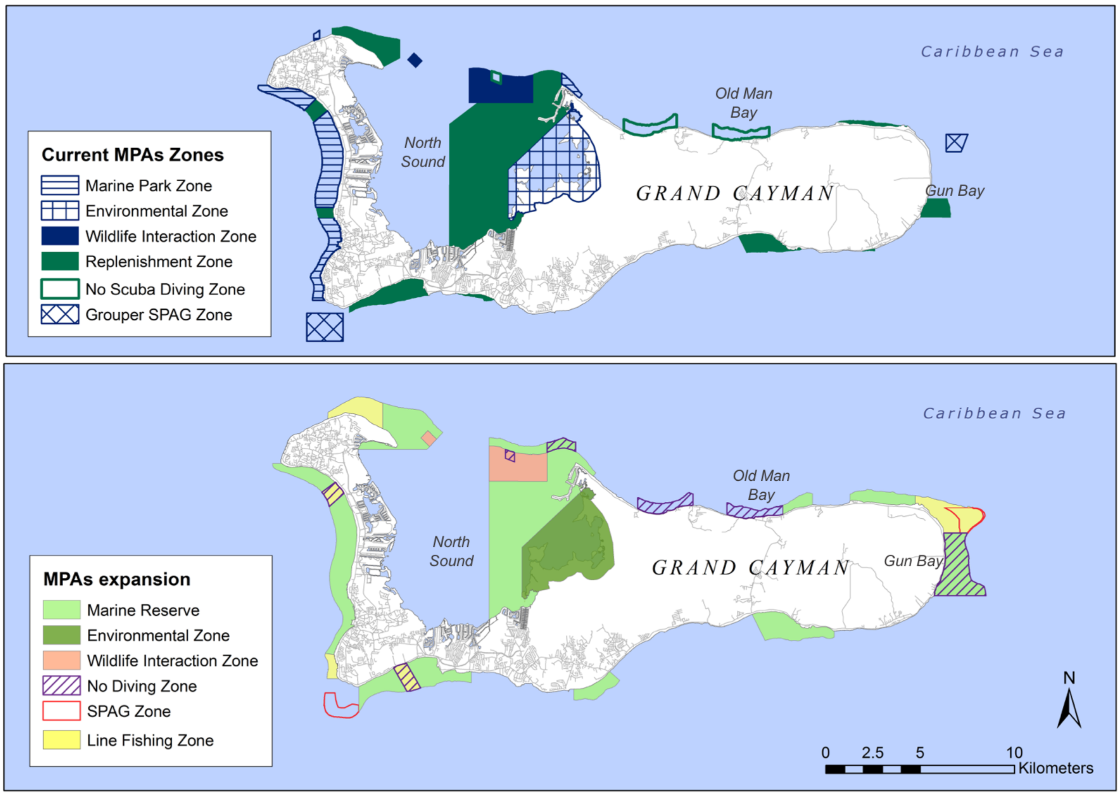


Figure 17 - Current MPAs (above) and proposed MPA enhancement (below) in Grand Cayman

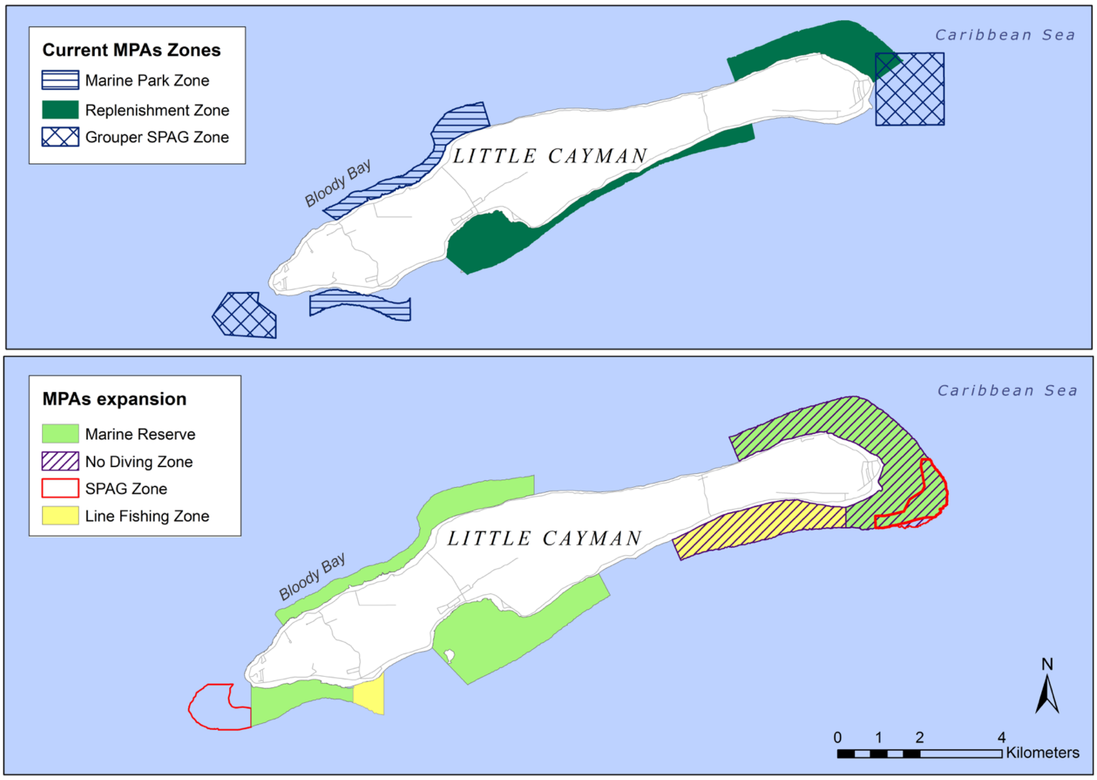


Figure 18 – Current MPAs (above) and proposed MPA enhancement (below) in Little Cayman

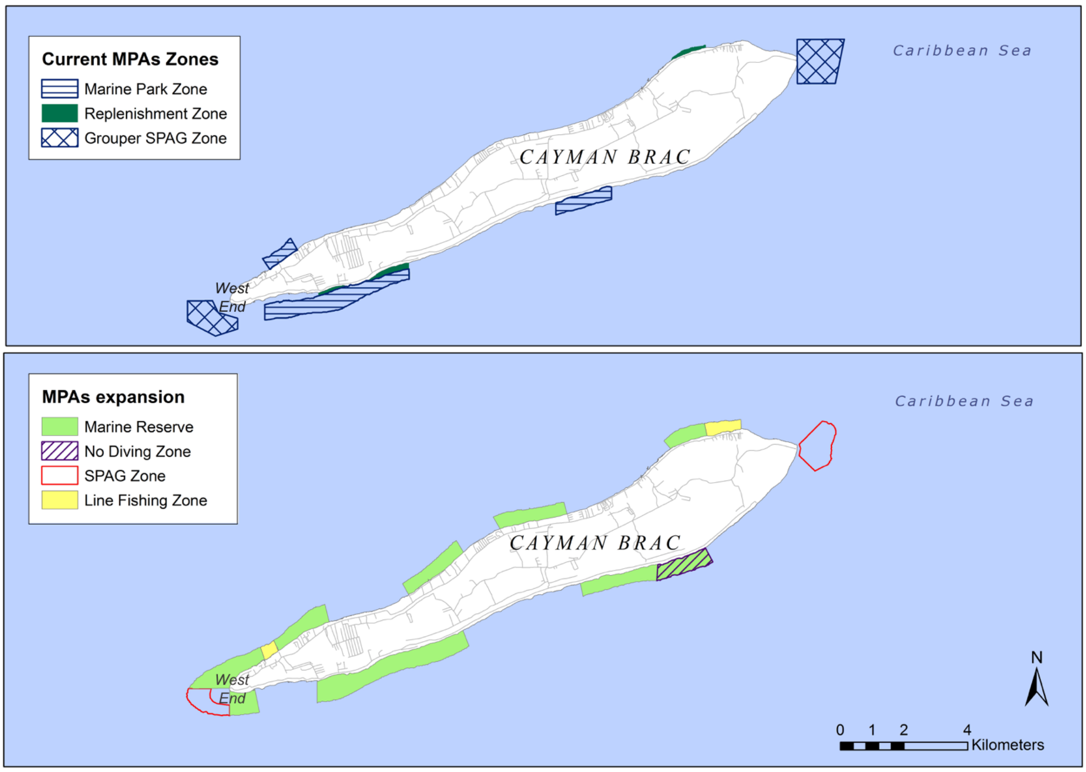


Figure 19 – Current MPAs (above) and proposed MPA enhancement (below) in Cayman Brac

4.1.2 Current MPAs

The different zones established in the current MPAs are summarized in Table 23. The detailed description of the regulations considered in the zonation of the existing MPAs can be consulted in Annex 7. As presented in Table 23, the Replenishment Zone covers the largest area of the existing MPAs, with more than 5,000 ha regulated under this zoning category. Replenishment zone place specific restrictions on fishing techniques and anchoring, and prohibit the extraction of conch and lobster. Other important zones in terms of extension include the Environmental Zone, Marine Park and Grouper Spawning Zone. These categories cover around 5,000 ha together (around 1,700 ha each). The strongest regulation of fishing activities, diving and anchoring is implemented in the Environmental Zone and Marine Parks. The Wildlife Interaction Zone and the No SCUBA Diving Zone are more limited in their extension, covering around 600 ha and 300 ha, respectively.

Table 23 – Zonation of current MPAs

Zone	Regulation	Area (ha)
Replenishment Zone	Area with specific restrictions to fishing techniques, as well as to anchoring. Conch and lobster taking forbidden.	5,020
Grouper Spawning Zone	Area where seasonal and fishing techniques restrictions apply.	1,720
Environmental Zone	Area with the strongest use restrictions. Fishing and diving are completely forbidden, as well as anchoring.	1,700
Marine Park Zone	Area with specific restrictions to fishing techniques and locations, as well as to anchoring.	1,640
Wildlife Interaction Zone	Area with strong restrictions to the interactions with wildlife, including the prohibition of fishing. Certain restrictions apply also to anchoring.	590
No SCUBA Diving Zone	Area where SCUBA diving is prohibited.	310

4.1.3 MPA enhancement

In this study, the MPA enhancement corresponds to a combination of changes in zone designation, increase in MPA coverage and more precise contouring of MPAs. With the MPA enhancement, changes are suggested to the zoning categories, as well as to the regulations described for each zone (Table 24). The MPA enhancement still includes the categories of Environmental Zone and Wildlife Interaction Zone. The Marine Parks defined in the current MPA framework, however, become Marine Reserves in the proposed MPA enhancement. Similarly, Line Fishing Only zones replace Replenishment Zones, and Spawning Aggregation (SPAG) Zones replace Grouper Spawning Zones. In terms of area, the enhancement would entail an expansion of 15% with respect to the area covered by current MPAs[11] and would double the size of no-take zones[12] in the Cayman Islands.

Marine Reserves would cover the major part of the MPAs (circa 8,260 ha, 66% of the total area of the MPA enhancement). No-Diving Zones would be the second largest in terms of total area, with more than 2,100 ha. The area of Environmental Zones would remain unchanged. The Line Fishing Only Zone would cover around 1,290 ha and the SPAG Zone would cover approximately 700 ha.

Table 24 – Proposed zonation for the MPA enhancement

Zone	Regulation	Area (ha)
Marine Reserve	No take zones from shoreline and to 150 ft. depth. (Marine Reserves will replace Marine Parks)	8,260
No Diving Zone	Areas where SCUBA diving can only be done with permission (No Diving Zones replace No SCUBA Diving/Restricted SCUBA Diving Zones)	2,120
Environmental Zone	Same regulation as in current MPAs	1,700
Line Fishing Only Zone	Areas where fishing is allowed, with certain restrictions on fishing techniques (Line Fishing Only Zones replace Replenishment Zones)	1,290
Wildlife Interactions Zone	Same as in current MPAs	520
Spawning Aggregation (SPAG) Zone	Former Grouper Spawning Zones are reviewed and overlaid with year-round No Diving Zones to give comprehensive protection of aggregations. (SPAG Zones replace Grouper Spawning Zones).	720

[11] To avoid double counting, the area covered by MPA is calculated in absolute terms. Overlapping polygons with 2 or more types of zones are considered only once for the calculation of total area.

[12] The estimated area of no-take zones considers additional restrictions to fishing. The no-take zones considered in this calculation include: Environmental Zone, Marine Park (or Marine Reserve, as in the MPA enhancement), Wildlife Interaction Zone and Grouper Spawning Zone (or Spawning Aggregation [SPAG] Zone, as in the MPA enhancement).

4.2 Methodology

4.2.1 Scenarios and parameters

Potential changes in costs and benefits are analyzed through a set of four scenarios (Table 25), which are defined by the following two parameters: the area under special protection and the degradation rates of different ecosystem types (Table 25). Scenario 1 and Scenario 2 are respectively defined in relation to the areas protected by current MPAs and the MPA enhancement. The analysis also considers different degradation rates through two hypothetical situations based on the effectiveness of MPA management. These hypothetical situations are respectively indicated by A (ineffective MPA management) and B (effective MPA management).

Table 25 – Overview of MPA scenarios used in the study

Scenarios	1. Current MPAs	2. MPA enhancement *
A. Ineffective MPA management	**Scenario 1A** Rates of ecosystem degradation are reduced by 10% within the boundaries of current MPAs	**Scenario 2A** Rates of ecosystem degradation s are reduced by 10% within the boundaries of the expanded MPA
B. Effective MPA management	**Scenario 1B** Rates of ecosystem degradation are reduced by 100% (no degradation in MPAs) within the boundaries of current MPAs	**Scenario 2B** Rates of ecosystem degradation are reduced by 100% (no degradation in MPAs) within the boundaries of the expanded MPAs

** The MPA enhancement encompasses changes in zone designation, increase in MPA coverage and more precise contouring of MPAs.*

The alternative management situations presented in Table 25 differ from each other in the effectiveness to minimize the baseline rates of ecosystem degradation within the boundaries of MPAs. The ineffective management situation entails a reduction of 10% of the degradation rates defined in the baseline situation. The effective management, on the other hand, represents the situation in which there is no ecosystem degradation within the MPA boundaries (Table 26).

It is important to note that minimizing ecosystem degradation to the rates defined in the two hypothetical management situations (i.e. scenarios A and B) will be determined by impacts and drivers beyond the control of managers, e.g. climate change and impacts of activities outside MPAs. With the available information at the time of writing, it is not possible to determine whether any of these hypothetical management situations

represents the effectiveness of the MPA management systems that are currently in place[13]. In the context of this study, the use of scenarios A and B is only intended to provide a realistic range of possible results of the MPA enhancement in the Cayman Islands, assuming that the management of these MPAs will minimize ecosystem degradation to a rate that falls between the extreme values proposed in scenarios A and B.

Although effective nature management within MPAs can also be expected to drive positive changes in ecosystems outside these areas, available data do not allow to quantify this effect[14] to a full extent in the Cayman Islands. The management scenarios proposed in this study therefore focus on the effect of management only within MPAs and do not reflect potential improvements in ecosystems situated beyond the MPA boundaries. Degradation rates outside the MPA boundaries are assumed as those defined for the baseline situation (Table 26), as described below.

Table 26 – Annual degradation rates estimated for the CBA (different scenarios; inside and outside MPA boundaries)

Average annual degradation rate	Outside MPAs*	In MPAs**			
	Baseline	1A	1B	2A	2B
Coral reef	-2.20%	-1.98%	0%	-1.98%	0%
Mangroves	-3.10%	-2.79%	0%	-2.79%	0%
Seagrass	-3.10%	-2.79%	0%	-2.79%	0%

** Degradation rates are estimated with available data for the Cayman Islands, except for seagrass degradation rates, which are assumed to be the same as those for mangroves.*

*** Degradation rates are estimated according to the assumptions specified for each scenario in Table 25.*

The degradation rates of coral reefs in the baseline situation (Table 26) are estimated with data compiled by Austin et al. (2014) from studies conducted in the Cayman Islands during the period between 1970 and 2010. The analysis of the data compiled for this 40-year period reveals an average decline in coral cover of more than 2% per year (i.e. from around 48% coral cover in 1970 to 20% in 2010). To be able to establish the link between the decline in coral reef cover and possible changes in ecosystem service provision, the decline in coral cover is used as a surrogate value to expected changes in coral reef area. Thereafter, the estimated area of coral reefs is directly linked to the relevant ecosystem services provided by this ecosystem type.

---

[13] The Darwin initiative project (Olynik et al., 2012) analysed optimal size and area of MPAs to cover different conservation targets according to given goals of protection in the Cayman Islands. However, the effectiveness to minimize ecosystem degradation rates within these areas has not yet been assessed in the Cayman Islands.

[14] Spill-over effect.

The degradation rates of mangroves in the baseline situation are estimated with data provided by the DoE on the mangrove area in the West Side of Grand Cayman over the period between 1976 and 2013. The degradation trends in this area are assumed to be comparable to those in other unprotected areas of mangroves in the Cayman Islands. Due to lack of data on seagrass degradation, the analysis of this ecosystem type is based on the same degradation rates as for mangroves (Table 26).

4.2.2 Changes in economic value

Comparisons between the above-mentioned scenarios are based on the analysis of changes in economic benefits and costs over a 25-year timeframe. These changes result from different rates of ecosystem degradation in areas situated inside and outside MPAs, either in the case of the existing MPAs framework or in the proposed MPA enhancement. Additionally, potential management costs arising from these two scenarios (i.e. current MPAs and MPA enhancement) are also considered in the analysis.

The benefits included in this study correspond to the economic value of the ecosystem services presented in Table 27. In all scenarios, the results of the ecosystem service valuation are used as the economic value in the first year of the timeframe. When no specific information is available, the analysis of benefits in subsequent years is based on informed estimates of changes in the value of ecosystem services over the period of the analysis.

The parameters and assumptions that support subsequent calculations are presented in Table 27. As described in this table, the estimation of changes in the value of fisheries considers the indirect effects that minimizing degradation rates of coral reef and expanding no-take zones may have on fish biomass. The average percent change in biomass due to no-take zones is obtained from information compiled by Lester et al. (2009) for tropical areas. This percent change is adjusted to the expected reduction in coral reef degradation rates and the area of no-take zones added to MPAs in each scenario. The total increase in biomass is assumed to be achieved in the 5th year of the analysis.

The pharmaceutical value associated to the extraction of coral is not expected to differ between scenarios, since the enhancement of MPAs will not entail management improvements in extraction sites or additional restrictions to this activity (Table 27).

The economic value associated to coastal protection, carbon sequestration and environmental amenities, on the other hand, is assumed to change in direct relation to changes in the area covered by specific ecosystem types (Table 27), which in turn change according to the conditions previously defined for each scenario in Table 25, above.

As described in the previous chapter (section 3.8), available figures for cultural and recreational ecosystem services provide an indication of the potential change in economic

value between the current MPA scenario and the MPA enhancement scenario[15]. The cultural and recreational value estimated in this study is therefore allocated only to the MPA enhancement scenario (i.e. 2a and 2b). This value is assumed to decline in relation to coral reef degradation (Table 27), as the results of the household survey used to analyse this service show that the quality of the coral reef is the main parameter respondents are willing to pay for (Schutter, 2014).

Table 27 – Overview of expected changes in the supply of ecosystem services over the timeframe of the analysis (25-year)

Ecosystem service	Main assumptions on changes in ecosystem services
Fisheries	Global average percent change in fish biomass due to no take zones in tropical areas is used as a surrogate value to biomass changes due to better enforcement and expansion of no-take zones in the Cayman Islands. The global average percent change in biomass (i.e. 230%) obtained from studies on 32 tropical no-take MPAs compiled by Lester et al. (2009) is adjusted in proportion to expected changes in coral reef cover and the area of no-take zones added to the MPAs in the Cayman Islands.
Pharmaceutical value	No difference can be predicted for this value in the different scenarios
Coastal protection	The coastal protection capacity, and hence, the value of this ecosystem service, changes at the same rates as coral reef cover
Amenity value	The amenity value of mangroves changes at the same rates as the area covered by this ecosystem
Carbon sequestration	The carbon sequestration capacity of mangroves and seagrasses changes at the same rates as the area covered by these ecosystems
Tourism value	The tourism value changes at the same rates as coral reef cover
Cultural and recreational value	The total WTP of local inhabitants for a well enforced and expanded MPA network is used as an estimation of the cultural and recreational value in Scenario 2. Since the majority of the activities considered in the household survey used to estimate the WTP depend on healthy coral reefs, this value is assumed to change in proportion to coral reef cover. The economic value associated to current MPAs (scenario 1) is not estimated in available surveys, and therefore, is set to '0' in the calculations.

For the estimation of MPA management costs, this analysis uses actual figures from the current MPA framework and informed estimates for the MPA enhancement provided by the DoE. The information provided indicates that additional budget for the MPA enhancement is mainly required for signage, equipment, infrastructure and extra staff.

[15] Through a household survey (Schutter, 2014), respondents were asked about their willingness to pay for better enforcement and expansion of the MPAs in the Cayman Islands. Further information is provided in section 3.8.

Monitoring, enforcement and other management activities are not expected to require a significant increase in budget, as major areas outside the existing MPAs are already monitored and managed.

Since the alternative management scenarios, A and B, are defined to deal with uncertainty about the effectiveness of current MPA management in the Cayman Islands, their budget requirements are not considered relevant for the overall goal of this study. Furthermore, the information available is insufficient to estimate such expenses and collecting new data on how external factors, such as the impacts of climate change and human development, might determine these costs is beyond the scope of this study. For these reasons, differences in costs required for scenarios of effective and ineffective management are not included in the CBA.

4.2.3 Net present value

The net present value (NPV) of each scenario corresponds to the accumulated net benefits, i.e. benefits minus costs, associated with marine and coastal ecosystems in the Cayman Islands over the pre-defined timeframe of 25 years. The results of the ecosystem service valuation and the management costs provided by the DoE serve as the starting point for this analysis, i.e. economic value in the first year of analysis. This economic value in the first year of analysis is therefore the same in all scenarios.

In subsequent years, the economic value is estimated according to the changes described in the previous section (Table 27). These changes are based on reference rates of ecosystem degradation for areas within and outside MPAs, the area covered by MPAs and average changes in biomass due to no-take zones.

To reflect the effects of time preference on the overall results, a discount rate is applied to calculate the annual net benefits of marine and coastal ecosystems. The application of a discount rate implies that a higher weight is assigned to the costs incurred and the benefits obtained in the present rather than those in the long term. The sum of the discounted net benefits for every year in the timeframe corresponds to the total NPV, which is used as one of the main indicators of monetary value to compare different scenarios.

The calculation of the total NPV is synthetized in the following formula:

$$Total\ NPV = \sum_{i=1}^{n} \frac{B_i - C_i}{(1-r)^i}$$

Where *Bi* corresponds to the economic benefits in year *i*, *Ci* to the costs in year *i*, *r* is the discount rate and *i* represents the year of analysis, assuming that the present year corresponds to 1.

To analyze the effects that changes in specific parameters might have on the overall results, a sensitivity analysis is conducted for different discount rates and different

degradation rates of coral reef, seagrass and mangroves. The sensitivity analysis is based on these parameters because of their importance for the calculations and the uncertainty created by the lack of data to provide robust estimates of their value within and outside MPAs in the Cayman Islands.

4.3 Results of the extended cost-benefit analysis

Through an extended CBA, this chapter compares costs and benefits arising from the four scenarios previously defined according to the proposed changes in the MPAs' boundaries and hypothetical levels of effectiveness in MPA management. Scenarios 1 and 2 refer to the current MPA framework and to the MPA enhancement, respectively. These two scenarios are divided in A and B to represent the extremes of a broad range of possibilities in terms of management effectiveness to mitigate ecosystem degradation rates. While Scenario A reflects an ineffective MPA management that minimizes degradation rates by 10%, Scenario B represents situation with effective management in which no degradation occurs within MPA boundaries. As noted in the methods section, the effectiveness of MPA management can be determined by management actions, but also by impacts and drivers beyond the control of managers, e.g. climate change and impacts of activities that take place outside MPAs.

Table 28 – Net present value in the four scenarios analyzed in the study (millions US$; 2.5% discount rate; 25-year timeframe; management costs included)

Scenarios*	1. Current MPAs	2. MPA enhancement **
A. Ineffective management*	$3,300	$3,320
B. Effective management*	$3,550	$3,780

** Please note that the effectiveness to minimize ecosystem degradation rates is determined by management actions, but also by external impacts and drivers beyond the control of MPA managers.*

*** The MPA enhancement encompasses changes in zone designation, increase in MPA coverage and more precise contouring of MPAs.*

The main indicator of economic value used in this analysis is the net present value (NPV) provided by each scenario over a 25-year timeframe. A general comparison of the four scenarios shows that the combination of MPA expansion with effective management (i.e. enhancement) offers the highest NPV (around US$3,780 million), and the scenario with current MPAs with ineffective management would offer the lowest value (approximately US$3,300 million) over the entire timeframe (Table 28). The differences between scenarios 2A (MPA enhancement with ineffective management) and 1B (current MPAs with effective management), however, suggest that an ineffective management would still have an important negative effect on the net value and this might not necessarily be outweighed by the positive effects of the MPA enhancement.

Table 29 – Net present value within and outside MPAs in scenarios 1 and 2 (average between ineffective and effective management; millions US$; 2.5% discount rate; 25-year timeframe; management costs included)

	In MPAs	Outside MPAs	Total NPV
Scenario 1 – Current MPAs	$1,060	$2,370	$3,430
Scenario 2 – MPA enhancement	$1,640	$1,910	$3,550

To analyze the economic value of the MPA enhancement alone, Table 29 compares the NPV created with current MPAs and with the MPA enhancement. The NPV in each scenario corresponds to the average value between the effective and ineffective management situations, estimated with a discount rate of 2.5%. As shown in Table 29, the NPV with the MPA enhancement would be approximately US$120 million higher than the NPV created with the current MPAs in a 25-year period (i.e. NPV of US$3,430, with current MPAs, and US$3,550, with the MPA enhancement). This means that the net benefits to be accumulated with the MPA enhancement over the next 25 years, could amount to US$120 million in total. Table 29 and Figure 20 also show that, while the MPA enhancement could safeguard 46% of the total NPV (US$1,640; Scenario 2), current MPAs help protect only 31% of the total NPV (US$1,060 million; Scenario 1).

Informed estimates conferred with the DoE suggest that the annual management costs will initially increase by approximately US$100,000 for signage, equipment, infrastructure and extra staff to support the MPA enhancement (Scenario 2). For the purpose of analysis, the management costs estimated in the first year are assumed to remain constant over the entire period of analysis. As previously described, management, monitoring and enforcement costs should not increase significantly due to the MPA enhancement, as major areas outside the existing MPAs are already patrolled and managed.

Although most comparisons presented in this chapter are based on NPV, annual values are additionally utilized to depict trends in the scenarios over the analysis timeframe. Figure 21 illustrates the differences in net annual benefits between the four scenarios, without using a discount rate. As observed in the figure, if MPA management is highly effective to minimize ecosystem degradation, the MPA enhancement (Scenario 2B) would yield substantially higher annual benefits than the current MPAs (Scenario 1B). With ineffective management, the benefits of MPAs are generally lower and although the differences between the MPA scenarios become less evident in the figure, the MPA enhancement (Scenario 2A) still provides higher benefits than the current MPA framework (Scenario 1A). The results presented in Figure 21 therefore suggest that even with a limited management capacity to tackle ecosystem degradation (scenarios 1A and 2A), the MPA enhancement should be more beneficial than the current MPA framework. However, these results also show that the effectiveness of the MPA management is essential to maximizing the annual benefits obtained from these areas.

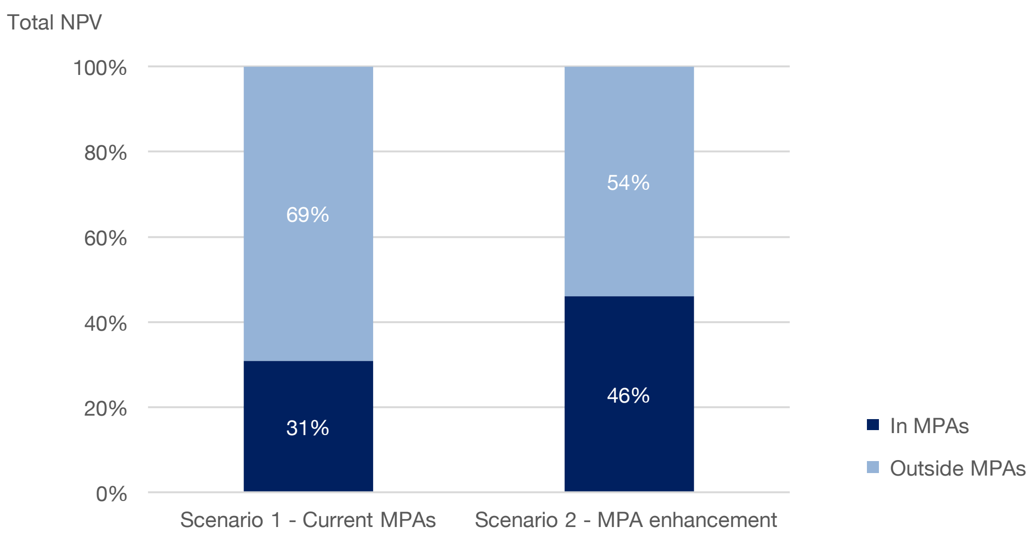


Figure 20 – Percentage of the total NPV that is safeguarded by MPAs in scenarios 1 and 2 (based on the average value between effective and ineffective management; 2.5% discount rate; 25-year timeframe; management costs included)

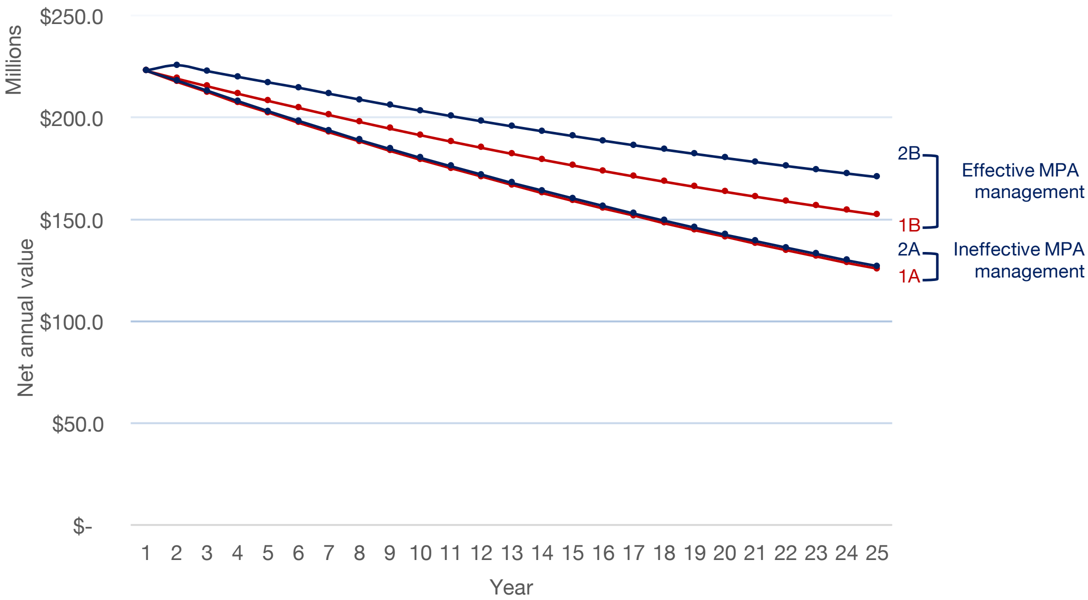


Figure 21 - Total annual net value in the four scenarios analyzed in the study (millions US$, no discount applied)

The last two sections of this chapter (4.3.2 and 4.3.3) describe and analyze the results presented in Figure 21 in detail. Additionally, the CBA results described below include the analysis of changes in value of ecosystem services due to the MPA enhancement, the main differences between current and enhanced MPAs in alternative management situations (scenarios A and B), and the sensitivity of the overall results to changes in key parameters and assumptions.

4.3.1 Overview of main changes in the value of ecosystem services

This section compares the accumulated benefits offered in the current-MPAs and the MPA-enhancement scenarios over the 25-year timeframe of analysis. The benefits considered in the analysis correspond to the ecosystem services valued in the previous chapter. In this section, all the values estimated in the current MPA and MPA enhancement scenarios, represent the average of the present value obtained from the effective and ineffective management with a 2.5% discount rate.

Figure 22 presents a breakdown of the accumulated benefits derived from ecosystem services over the entire timeframe of analysis. In both scenarios, current MPAs and MPA enhancement, the value that marine and coastal ecosystems have for tourism represents the largest portion (>70%) of the total economic benefits. The remaining economic benefits correspond mainly to the amenity value of mangroves, and the coastal protection, pharmaceutical and fisheries values attributed to coral reefs.

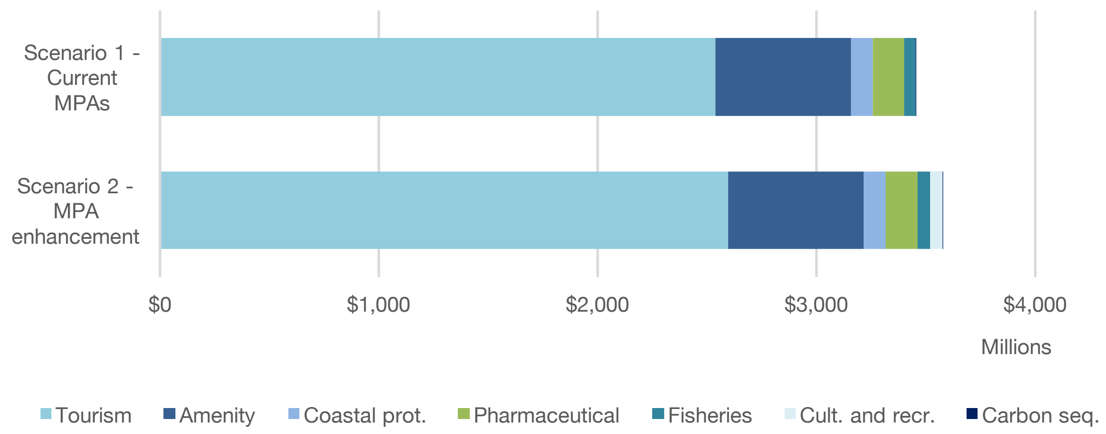


Figure 22 - Present value per ecosystem service in Scenario 1 – current MPAs (left) and Scenario 2 – MPA enhancement (average between ineffective and effective management; millions US$; 2.5% discount rate; 25-year timeframe; MPA management costs excluded)

The value of the carbon sequestration capacity of mangroves and seagrass is relatively minor in comparison with other benefits analyzed in the study and represents around 0.1% of the total benefits of both scenarios (Figure 22). The cultural and recreational value of marine and coastal ecosystems is only estimated for Scenario 2 (MPA enhancement), and represents the expected change in value due to the MPA enhancement with respect to the current MPA framework (Scenario 1). For Scenario 1, the cultural and recreational value is not estimated, as this was not part of the scope of the survey used as a reference for the study (Schutter, 2014). This value is consequently set as “0” in this scenario (Figure 22).

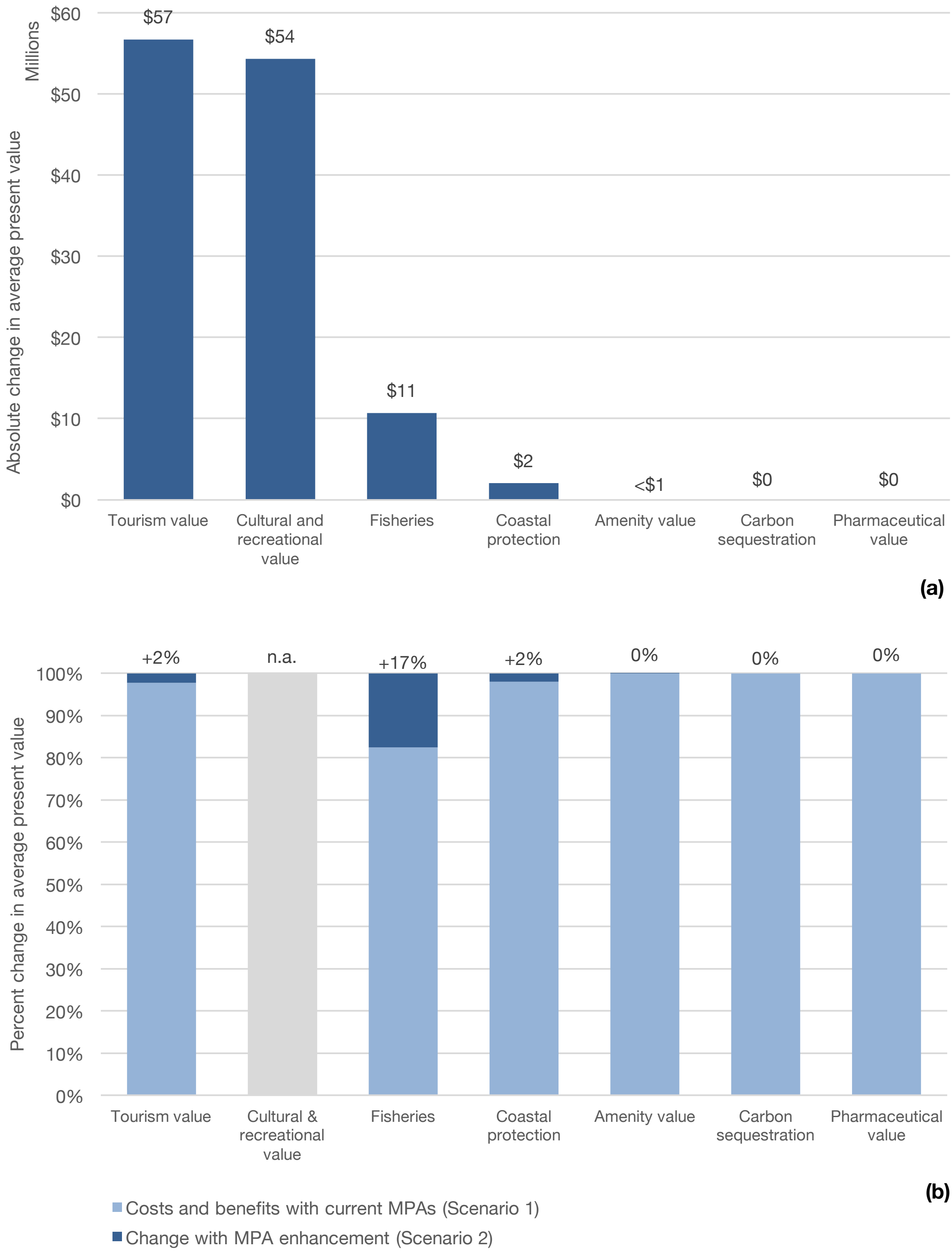


Figure 23 - Absolute (a) and relative percent (b) change in present value of benefits derived from the MPA enhancement (average present value of effective and ineffective management; 25-year timeframe; 2.5% discount rate; millions US$)

The sum of the present value of all the ecosystem services (i.e. benefits) described above represents around US$3,460 million in Scenario 1 (current MPAs) and US$3,580 in Scenario 2 (MPA enhancement)[16]. The consequent increase in benefits associated to the MPA enhancement, estimated with a 2.5% discount rate, results in approximately US$125 million over the entire analysis timeframe.

As depicted in Figure 23, the difference between scenarios 1 and 2 includes an absolute increase in the present value of tourism by approximately US$57 million (2% increase), in the cultural and recreational value by around US$54 million (unknown percent increase), in the value of fisheries by around US$11 million (17% increase) and in the coastal protection value by approximately US$2 million (2% increase) over the whole analysis timeframe. Changes in the present value of carbon sequestration and the amenities offered by mangroves to local properties are minor in comparison to the other changes in value. The pharmaceutical value, on the other hand, is not expected to change between scenarios (Figure 23).

Changes in the provision of ecosystem services that will occur as a result of the MPA enhancement are likely to affect several stakeholders in the Cayman Islands. Based on the changes presented in Figure 23, stakeholders from the tourism sector (e.g. tour operators, hotel and accommodation, food and catering, etc.) could be the largest beneficiaries of the MPA enhancement in absolute terms. This increase in benefits provided by nature, however, would represent only a 2% increase in present value compared with the current situation.

Local inhabitants are also important beneficiaries of the potential increase in the cultural and recreational value associated to the MPA enhancement (Figure 23). As described in the previous chapter (section 3.8), however, the study that is used as a basis to estimate this value (Schutter, 2014) only examines the willingness to pay for better enforcement and enhancement of MPAs. Therefore, it is uncertain whether the absolute increase in the cultural and recreational value associated to the MPA enhancement would represent a significant percentage of the present value provided by the existing MPAs (Figure 23).

Although the absolute change in present value of fisheries is lower than the increase in tourism and cultural and recreational values, this represents the highest relative increase in present value (17%) with respect to Scenario 1 (current MPAs). Despite the limitations that new no-take zones might represent for fishermen, the positive effect of the enhancement of these areas in terms of fish biomass can extend beyond the areas where

---

[16] MPA management costs are not included in these estimates. The MPA enhancement encompasses changes in zone designation, increase in MPA coverage and more precise contouring of MPAs.

fishing restrictions are implemented[17]. Therefore, fishermen that benefit from subsistence and small-scale commercial fishing, as well as local inhabitants that enjoy recreational fishing, can still be expected to perceive a significant relative gain with the MPA enhancement in the Cayman Islands (Figure 23).

In addition to the gains described above, all types of stakeholders in the Cayman Islands can potentially benefit from the MPA enhancement because of the increase in present value of the coastal protection services to properties and infrastructure due to the additional protection offered by a healthier coral reef.

Although the additional protection of carbon pools with the MPA enhancement can potentially benefit the Cayman Islands Government and other stakeholders, such as the international community, Figure 23 suggests that the difference between scenarios 1 and 2 would be very small in comparison with the changes expected in other benefits.

In addition to the benefits described above, the following two sections analyze the economic value that can be associated to the current MPAs and the MPA enhancement scenarios including management costs. The net benefits of these MPA scenarios are separately presented for the two hypothetical scenarios, A and B, defined in relation to the effectiveness of management.

4.3.2 Change in net benefits in the case of effective management (MPA management scenario B)

4.3.2.1 Net present value

Scenarios 1B and 2B describe the hypothetical situation in which MPA management is sufficiently effective to completely tackle ecosystem degradation inside MPAs. As previously presented in Table 28, under effective management, the current MPAs (Scenario 1B) would offer a NPV of approximately US$3,550 million. The MPA enhancement (Scenario 2B), on the other hand, would provide approximately US$3,780 million in NPV. If MPA management is effective to tackle ecosystem degradation, the MPA enhancement would therefore determine an increase in NPV of around US$230 million over the whole 25-year timeframe[18].

---

[17] Based on the results of 32 studies compiled and analyzed for tropical no-take zones (Lester et al., 2009), the estimated increase in biomass due to no take zones can reach values between 150% and 300%, which can benefit areas within and beyond the boundaries of these MPAs. For the calculations of the economic value of the MPA enhancement, this CBA uses a global average of 230% increase in biomass in no-take zones. Further information is provided in the methods section.

[18] Estimated with a discount rate of 2.5%.

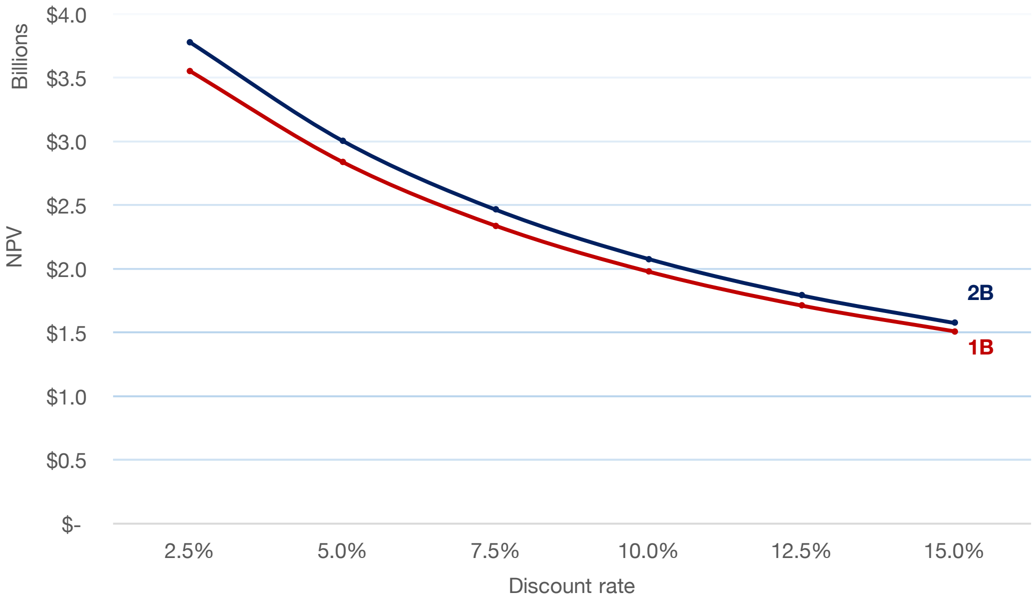


Figure 24 - Total NPV with effective MPA management in scenarios 1B and 2B (billions US$; different discount rates; 25-year timeframe)

When using different discount rates, the NPV estimated for the MPA enhancement is consistently higher than the one estimated for the current MPAs' scenario (Figure 24). This means that despite the lower importance given to future costs and benefits with higher discount rates, the MPA enhancement (Scenario 2B) yields a higher NPV than the current MPAs (Scenario 1B). The use of higher discount rates minimizes the difference in NPV between scenarios, but even in the most exaggerated and unrealistic case of using a discount rate of 15%, the MPA enhancement (Scenario 2B) offers US$66 million more than the current MPAs (Scenario 1B) over the 25-year analysis timeframe.

Since the baseline rates of ecosystem degradation are the basis to analyze the effectiveness of MPA management, potential uncertainties in the estimation of these rates can be expected to have influence on the results of the extended CBA. As previously described, the baseline degradation rates used in this analysis are estimated with local information, but the available datasets are not sufficiently comprehensive in terms of ecosystems, timeframes and spatial extension considered. To illustrate potential effects these data gaps could have on the total NPV and to give an indication of the robustness of the results, a sensitivity analysis is performed. This analysis considers the potential variation in the NPV derived from different baseline degradation rates of coral reefs, mangroves and seagrass (Figure 25).

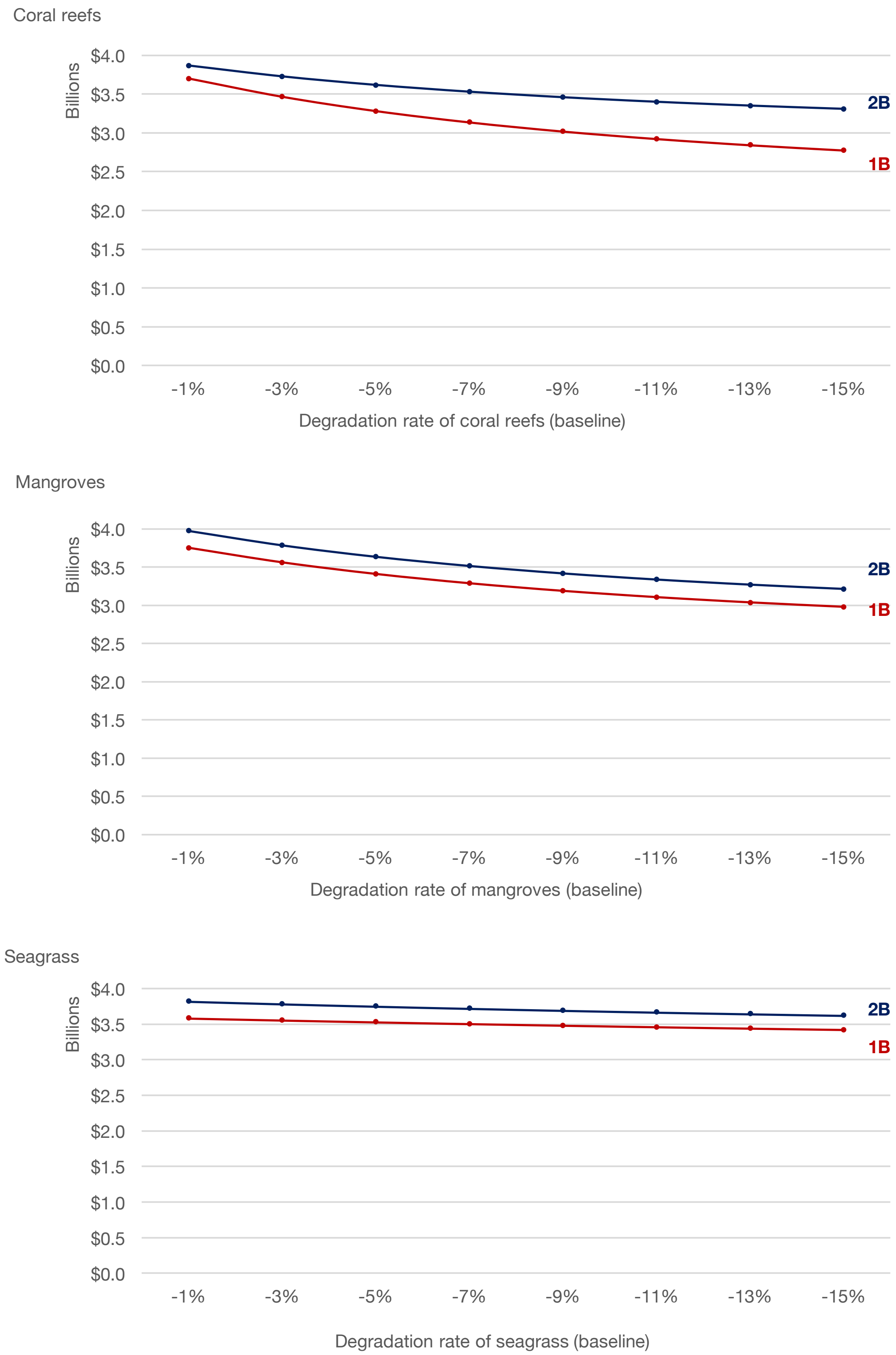


Figure 25 – Sensitivity of the results to different rates of ecosystem degradation (total NPV; billions US$; 2.5% discount rate; 25-year timeframe; Scenario B of effective MPA management)

As expected, the NPV decreases with higher degradation rates of all the ecosystems considered in the analysis. However, Figure 25 shows that the degradation of coral reefs has the highest impact on the NPV. If degradation rates of coral reef are assumed at -15% per year, the NPV is estimated to become 14% to 25% (in scenarios 2B and 1B, respectively) lower than that estimated with degradation rates of -1%. In the case of mangroves, the same difference in degradation rates, i.e. -15% and -1% per year, entails a difference in NPV of around 20% in both MPA scenarios (1B and 2B). For seagrass, however, the same difference in degradation rates represents a decrease in total NPV of only around 5%, also in both MPA scenarios (1B and 2B). The higher sensitivity of the results to the degradation of coral reefs and mangroves is explained by the several values associated to these ecosystem types, including the tourism, cultural and recreational, fisheries and coastal protection values associated to coral reefs and the amenity, carbon sequestration and tourism values derived from mangroves.

The sensitivity analysis of scenarios 1B (current MPAs) and 2B (MPA enhancement) with different rates of ecosystem degradation also show that the difference between these scenarios is more sensitive to the degradation rate of coral reef, rather than the degradation of mangroves or seagrass (Figure 25). Depending upon the degradation rate of coral reef, Scenario 1B (current MPAs) is estimated to yield an NPV that is between 5% (with -1% degradation rate of coral reef) to 16% (with -15% degradation rate) lower than the one obtained in Scenario 2B (MPA enhancement). The sensitivity of the results to coral reef degradation is explained by the substantial increase in area of this ecosystem type to be additionally protected in the MPA enhancement with respect to the current MPAs. This increase in protection exacerbates the positive effects estimated in the MPA enhancement scenario, particularly when high degradation rates are completely minimized in MPAs.

If alternative rates of degradation of mangroves and seagrass are used, on the other hand, the difference in NPV between scenarios 1B and 2B is relatively constant (ranging between 6% and 7% difference in NPV). This is because the areas of mangroves and seagrass protected in current MPAs and the MPA enhancement are relatively similar, hence the smaller differences between scenarios. These differences are illustrated in Figure 25, while the exact figures used to calculate the percent change in NPV are provided in Annex 8.

4.3.2.2 Annual net value

Under the effective management situation, the higher economic value of the MPA enhancement in comparison with the current MPAs is confirmed by the analysis of net annual values shown in Figure 26. With no discount applied, the net annual value obtained in Scenario 2B (MPA enhancement) is higher than the one in Scenario 1B (current MPAs) during the entire timeframe, except for the first year of analysis (i.e. baseline year).

In the second year of analysis, the increase in annual net value in Scenario 2B (MPA enhancement) reflects the additional WTP of local households for the MPA enhancement

and improved management. From year 2 onwards, both scenarios show a decreasing trend due to the continuous ecosystem degradation outside MPAs. With the MPA enhancement, however, this trend becomes less steep, as the new MPA boundaries secure a greater portion of the ecosystems providing the main services to the Cayman Islands. The difference between the annual net value in these scenarios increases from approximately US$6.4 million in the second year to US$18.5 million in year 25. This trend indicates that the MPA enhancement can provide increasingly higher annual benefits to local stakeholders than existing MPAs in the long term.

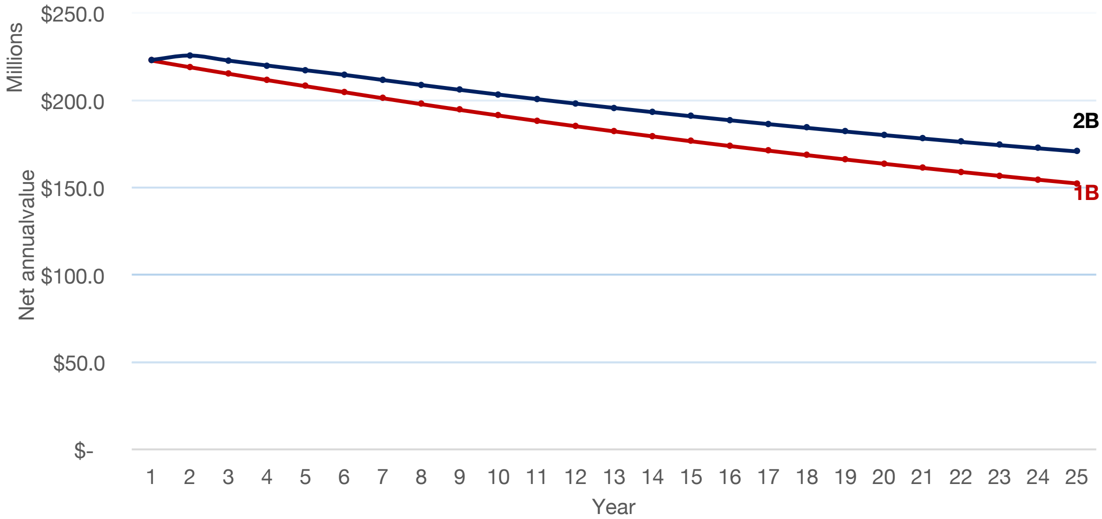


Figure 26 - Total annual net value with effective MPA management in scenarios 1B and 2B (millions US$)

It should be noted that the influence that effective MPA management can have on ecosystems outside the MPA boundaries, or spill-over effect, is not considered in this analysis. If this potentially positive effect was included, the decreasing trends in annual value in scenarios 1B and 2B could be expected to become less steep or even increasing. However, it remains uncertain whether this would significantly increase the difference in net present or net annual value between these two scenarios.

4.3.3 Change in net benefits in the case of ineffective management (MPA management scenario A)

4.3.3.1 Net present value

The scenarios 1A and 2A describe the situation in which management is only sufficiently effective to minimize the rates of ecosystem degradation by 10% within the boundaries of MPAs. As the rates of ecosystem degradation stay at relatively similar levels within and outside MPAs, the difference between current MPAs and the MPA enhancement can be expected to be much less evident than that observed in the scenarios with effective management.

When estimated with a discount rate of 2.5% (as in Table 28), the NPV of the ineffective management situation is estimated at around US$3,300 million with the current MPAs (Scenario 1A) and US$3,320 with the MPA enhancement (Scenario 2A). This indicates that if ecosystem degradation rates are reduced by 10%, then the MPA enhancement can offer an increase in total NPV (i.e. accumulated net benefits) of around US$20 million over the entire analysis timeframe.

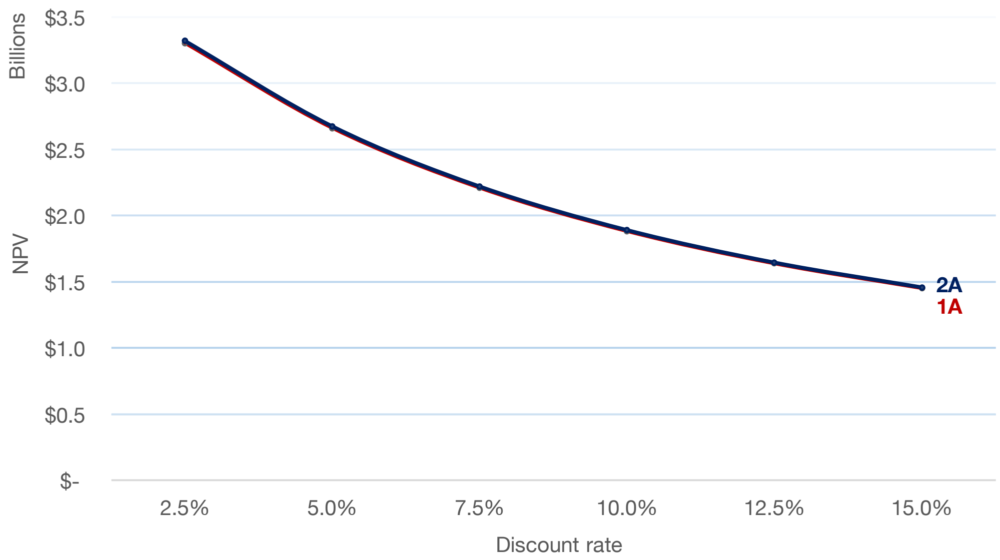


Figure 27 - Total NPV with ineffective MPA management in scenarios 1A and 2A (billions US$; different discount rates; 25-year timeframe)

If discount rates higher than 2.5% are used, the difference between NPVs obtained in the situations with the current MPAs and the MPA enhancement becomes smaller, and hardly visible in Figure 27, though the MPA enhancement still offers a higher economic value. With discount rates of 5% and 10%, the NPV associated to the MPA enhancement (Scenario 2A) would be, respectively, US$13 million and US$8 million higher than the NPV derived from current MPAs (Scenario 1A). And in the exaggerated case of using a discount rate of 15%, the additional NPV offered by the MPA enhancement (Scenario 2A) would be estimated at only US$5 million during the entire 25-year timeframe of analysis (Figure 27).

As described in the previous section, the potential effect of gaps of information about ecosystem degradation on the extended CBA is analyzed through a sensitivity analysis. Ecosystem degradation rates are used as the basis to analyze the effectiveness of MPA management and any uncertainties in the estimation of these rates are therefore expected to influence the results of the CBA. The sensitivity analysis specifically focuses on potential variations in NPV that can be derived from different baseline degradation rates of coral reefs, mangroves and seagrass (Figure 28).

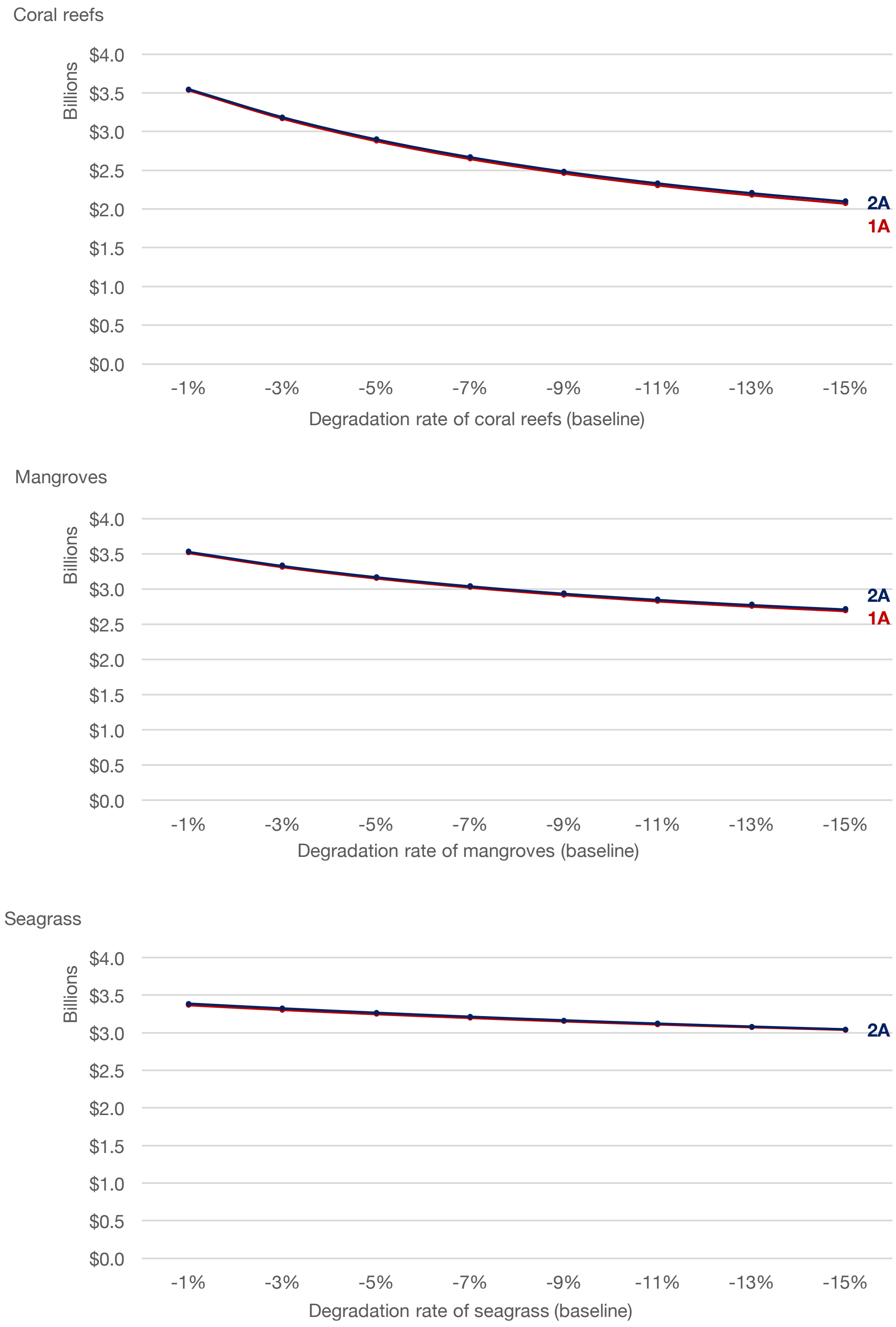


Figure 28 – Sensitivity of the results to different rates of ecosystem degradation (total NPV; billions US$; 2.5% discount rate; 25-year timeframe; Scenario A of ineffective MPA management)

As shown in Figure 28, in the ineffective MPA management situation (scenarios 1A and 1B), the NPV decreases with higher degradation rates of all the ecosystems considered in the analysis. The degradation of coral reefs, however, have the highest impact on the NPV. If degradation rates of coral reef are assumed at -15% per year, the NPV is estimated to be 41% lower than the NPV estimated with rates of -1% in both scenarios (1A and 2A). For mangroves, the same difference in degradation rates, i.e. from -1% to -15%, entails a decrease in NPV by 23% in both MPA scenarios. The same change in degradation rates, but for seagrass, would determine a decrease in the estimated NPV by around 10%, also in both scenarios.

The results of this sensitivity analysis also suggest that the difference in NPV between the current MPAs (Scenario 1A) and the MPA enhancement (Scenario 2A) is not substantially affected by different degradation rates (Figure 28). With the rates of ecosystem degradation considered in the analysis (i.e. between -1% and -15%), the difference in NPV estimated in scenarios 1A and 2A ranges from only 0.5% to 1.4%.

For scenarios 1A and 2A, a higher sensitivity of the NPV to the degradation of coral reefs is explained by the several values associated to this type of ecosystem, rather than other ecosystem types. The values used to calculate the percent change in NPV in scenarios 1A and 2A are provided in Annex 8.

4.3.3.2 Annual net value

If degradation rates are only tackled to a limited extent within MPAs (i.e. scenarios 1A and 2A), the MPA enhancement would provide higher benefits than the current MPAs on an annual basis, although the difference between scenarios in this case is substantially smaller than the one estimated under the effective management situation (i.e. scenarios 1B and 2B). With no discount applied, the additional net annual value obtained with the MPA enhancement varies from around US$0.5 million in year 2 to approximately US$1.3 million in year 25. In both scenarios, 1A (current MPAs) and 2A (MPA enhancement), the net annual value shows a decreasing trend (Figure 29).

As previously mentioned, this analysis does not consider spill-over effect, which refers to the impact management efforts in MPAs might have beyond their boundaries. Since the provision of ecosystem services outside MPAs can change due to spill-over effect, the decreasing trend in annual value presented in Figure 29 could be attenuated and become

less steep. This implies that the positive economic effects of the MPA enhancement will extend beyond the MPA boundaries and are likely higher and more diverse than expected

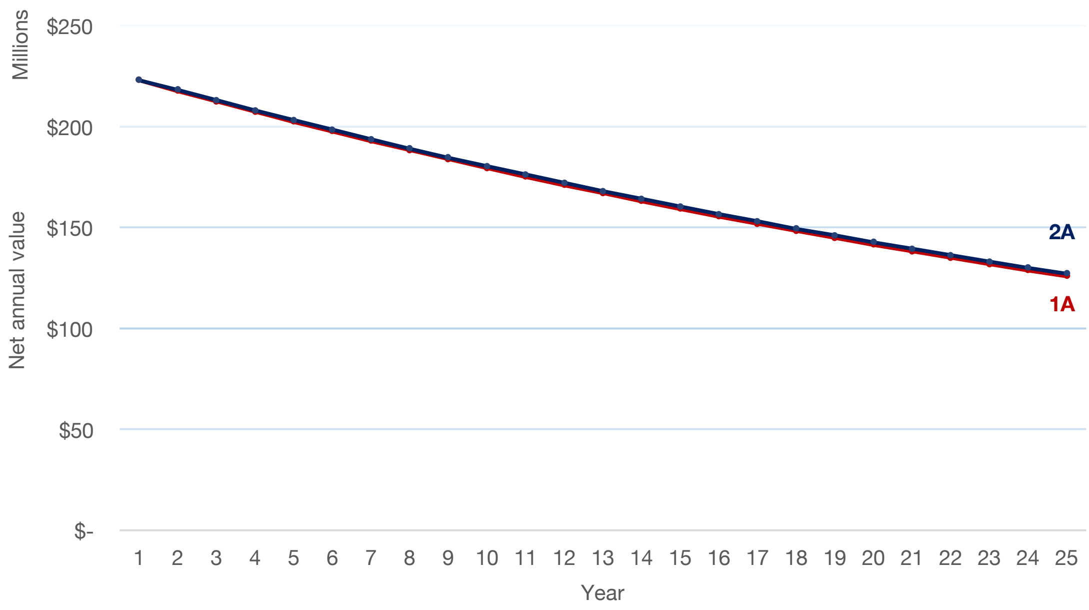


Figure 29 - Total annual net value with ineffective MPA management in scenarios 1A and 2A (millions US$)

Chapter 5: Conclusion and recommendations

The research set out to answer three research questions:

1. *What are the relevant ecosystem services in the Cayman Islands?*
2. *What is the current contribution of relevant ecosystem services to the economy of the Cayman Islands?*
3. *How would the socioeconomic benefits of local ecosystem services be affected by the enhancement of Marine Protected Areas (MPAs) in the Cayman Islands?*

In this last chapter, the answers to these questions are addressed and what can be learned. Based on the current value of the selected ecosystems and the expected changes in value in MPA enhancement scenario, it is concluded that enhancing the MPAs on the Cayman Islands will likely improve wellbeing of their residents.

5.1 Ecosystem services on the Cayman Islands

On the Cayman Islands, the marine environment provides important benefits, or ecosystem services, to a variety of stakeholders. To assess the importance of the marine ecosystems for wellbeing on the Cayman Islands, the economic value of seven ecosystem services is assessed: tourism, coastal protection, fisheries, local culture and recreation, carbon sequestration, pharmaceutical application of environmental products and the value of marine ecosystems as amenity to real estate. Together, these ecosystem services provide an annual total economic value (TEV) of **US$179 million.**

5.1.1 Tourism

The most important contribution to the TEV comes from the ecosystem services that support the tourism industry (i.e. approximately 91% of the TEV estimated in this study). In total, approximately 380,000 stay-over tourists and 1,600,000 cruise tourists visit the Cayman Islands each year. Many of these tourists choose the islands as their holiday destination because of the beautiful marine environment (i.e. beaches, coral reefs and mangroves). To determine the tourism value of local ecosystems a survey was conducted among 400 tourists visiting the Cayman Islands, recording the expenditures as well as the willingness-to-pay (WTP) for additional nature management. It is estimated that 39% of the added value that is created in the tourism industry (US$180 million per year) can be attributed to the marine environment; this amounts to an annual value of US$69 million per year. Additional to this, results indicate that tourists have an aggregate annual WTP for nature conservation of US$94 million. The high WTP of visitors for additional nature conservation measures suggests that a user fee system could be implemented without affecting the number of tourists visiting the islands. Together, the financial value and the WTP add up to a total economic tourism value of **US$163 million per year**.

5.1.2 Local culture and recreation

Many residents on the Cayman Islands engage in recreational activities, such as swimming, going to the beach and diving. Furthermore, a pristine natural environment is important for the cultural identity of the inhabitants. The importance of the natural environment to the residents of the three islands has been assessed through a residential survey. 384 households on the Grand Cayman, Little Cayman and Cayman Brac participated in this survey, which addressed a wide range of issues such as ecosystem threats, benefits, and preferred management of the marine environment. Although interaction with the ecosystems differs, residents on all islands expressed concerns regarding the state of their ecosystems. In fact, most of the population of each island is in favor of improving enforcement and expanding the Marine Protected Areas (MPAs) as proposed by the Department of Environment of the Cayman Islands Government in 2013. The results of household survey conducted in the light of this study in 2014 indicate that the enhancement plans are supported by 58% of the population on Grand Cayman, 63% of the population on Cayman Brac and 85% of the population on Little Cayman. To quantify the value of the marine environment to the residents of the Cayman Islands, the WTP for an enhancement of the MPAs is estimated. Per year, people would be willing to contribute a total of **US$5.6 million per year** for an increase in protected areas.

5.1.3 Amenity values

Marine ecosystems can also be an important amenity of houses on the Cayman Islands. A hedonic pricing analysis was conducted to assess this importance. Based on a large database with real estate transactions, which was provided by CIREBA, it is estimated that the vicinity to mangrove areas, beaches and waterfronts are all positively correlated to house prices (after controlling for other explanatory variables). This indicates that marine ecosystems contribute to higher property values in the Cayman Islands. However, these ecosystems are also under great pressure by coastal development on the islands.

5.1.4 Fisheries

The islands are home to a small artisanal fishery industry. People on the Cayman Islands fish for recreation, subsistence and commercial purposes, and a single fisherman can be motivated by a combination of these. Because this study focusses on the coastal marine ecosystems of the Cayman Islands only the catch of reef-related species is accounted for in the valuation of fisheries. It is estimated that the total reef-related catch is worth roughly **US$2.3 million per year**.

5.1.5 Pharmaceutical products

Coral reefs are studied all over the world for their application to pharmaceutical products. On the Cayman Islands, a cosmetic company discovered that the coral species Caribbean Sea Whip (*Plexaura homomalla*) could be used to produce black-sea red oil (BSRO), which

is subsequently used to produce a cosmetic eyelash maintaining serum. The company reached an understanding with the Department of Environment to harvest a sustainable amount of coral in exchange for royalties of between US$0.7 – 4.6 million per year. In addition, the value of this natural resource for production of the cosmetic products, is valued between US$0.9 – 9 million. Together, this amounts to a total economic value of between **US$1.6 - 13.6 million per year**.

5.1.6 Regulating services

The marine environment also provides important regulating ecosystem services. On a local scale, coral reefs protect the shorelines of the Cayman Islands against storms and hurricanes. This prevents erosion, flooding and thereby destruction of properties and infrastructure. If these reefs would severely degrade, this protective capacity would be lost. The damage that is avoided if the quality of coral reefs is maintained, amounts to **US$6 million per year.** On a global scale, the carbon sequestered by mangrove forests, sea grass beds and peat habitats contribute to climate regulation. Especially, the large mangrove and seagrass areas on Grand Cayman function as carbon sinks. In total, these ecosystems are expected to sequester around 15,000 mega grams (MG; equal to metric ton) per year. Based on the global market prices in carbon trading schemes, this ecosystem service can be valued at **US$290,000 per year.**

5.2 Cost-benefit analysis of MPA enhancement

The ecosystems on the Cayman Islands are under pressure by a variety of threats. Climate change, global development, pollution and disturbance all led to a continuous degradation of the marine ecosystems in the past decades. On average, coral cover is decreasing by 2.2% per year, and the area of mangroves and seagrass decreases by 3.1% percent per year. The degradation of ecosystems negatively affects the socioeconomic benefits of the ecosystem services e.g. a less healthy coral reef will attract less divers. To prevent further degradation of and conserve the benefits provided by the marine environment, the Department of Environment of the Cayman Islands Government (DoE) proposes to improve zone designation and expand the overall coverage of Marine Protected Areas (MPAs) Cayman Islands by 15% and to restructure the different user zones within these MPAs.

To analyze the socioeconomic effects of such an enhancement, the value of ecosystem services is compared in two policy scenarios: 1) maintaining the current network of MPAs; 2) expanding and restructuring the MPAs according to the plans proposed by the DoE. To reflect the uncertainty around the effectiveness of MPA management to reverse environmental degradation, two additional scenarios are analyzed per policy scenario in which MPA management is either: a) ineffective, resulting in a 10% reduction of the degradation rates in the MPAs; b) effective, resulting in 100% reduction of degradation rates in the MPAs. Together, this results in the comparison of four scenarios:

1a – Current MPA framework; ineffective MPA management
1b – Current MPA framework; effective MPA management
2a – MPA enhancement; ineffective MPA management
2b – MPA enhancement; effective MPA management

The analysis of the ecosystem service values over 25 years indicates that the overall TEV per year decreases in all four scenarios. The main reasons for this are that there are unprotected areas in all scenarios that face continuous degradation, amongst others caused by the fact that land-based pressures such as coastal development and pollution are unchanged. Despite that, the scenarios that reflect the MPA enhancement decrease less rapidly compared to the scenarios in which the current MPA framework is in place. This also leads to a higher Net Present Value (NPV) of the ecosystem service values over 25 years for the scenarios of the MPA enhancement:

NPV-scenario 2a ($3,320 million) > NPV-scenario 1a ($3,300 million)

NPV-scenario 2b ($3,780 million) > NPV-scenario 1b ($3,550 million)

The stakeholders that benefit most from better ecosystem services in the scenarios with an MPA enhancement are those involved in the tourism industry. The NPV of the economic value in the tourism industry is expected to be US$57 million higher if the MPA enhancement is implemented. The aggregate NPV for residents is expected to be 54 million US$ higher. Surprisingly, also the NPV for fishermen is expected to improve by 11 million US$ in the scenarios with an MPA enhancement. It has to be noted that this estimate reflects an overall improvement of the fish stocks over the course of 25 years. It is possible that fishermen will face slightly lower benefits on the short term due to increased restrictions. Due to the higher quality of the coral reefs, also the coastlines will be better protected as the expected damage will be reduced by 2% (2 million US$). The amenity value, carbon sequestration and the pharmaceutical value remain grossly unchanged between scenarios.

5.2.1 Limitations

Before discussing the policy implications of these results, it is necessary to address the limitations of the analysis. First, the study only incorporates a selection of ecosystem services on the Cayman Islands based on their perceived importance and the availability of data. Most notably the existence value that people abroad attach to the marine ecosystem services is not included. In a similar study in the Dutch Caribbean, researchers found that Dutch European residents attach a high WTP to nature conservation on the Dutch Caribbean Islands. British residents might have a similar perspective on the value of nature in their Overseas Territories. Secondly, the scenario analysis relies on a set of assumptions (presented in chapter 4). If these assumptions are proven to be invalid, the results would be affected. Furthermore, degradation of the marine environment is assumed to continue at a constant rate in the scenario analysis. In reality, this is not necessarily the

case, as degradation can be subject to specific events (e.g. a hurricane, specific development projects, or a bleaching event). This makes the future degradation rates unpredictable. To control for this level of uncertainty, a wide range of degradation rates was applied in the scenario analysis.

5.2.2 Recommendations

The results clearly highlight that enhancing the marine protected areas on the Cayman Islands results in higher socioeconomic benefits. The most important ecosystem services increase because of the MPA enhancement, some ecosystem services stay the same, but most importantly, none of the ecosystem services are expected to decrease in the scenario with the MPA enhancement. Even if MPA management proves to be ineffective in reversing the current rates of environmental degradation, the MPA enhancement is unlikely to lead to a loss in wellbeing on the Cayman Islands (based on the ecosystem services analysed in this study). In other words, society on the Cayman Islands only gains in overall economic benefits if the MPA enhancement is implemented. In addition, the enhancement plans require minimal financial investments; as the DoE already patrols most of the currently unprotected area already. The costs would be limited to updating the Marine Park signage and hiring one or two extra staff members. Given this information, it can be concluded that the MPA enhancement is a low-cost and low-risk investment with the opportunity to substantially improve wellbeing on the Cayman Islands.

References

Agardy, M. (1994). Advances in marine conservation: the role of marine protected areas. *Trends in Ecology & Evolution*, 9 (7): 267-270.

Angulo-Valdés, J.A. and Hatcher, B.G. (2010). A new typology of benefits derived from marine protected areas. *Marine Policy,* 34: 635-644.

Austin, T., Bush, P., Fenner, D., Manfrino, C., McCoy, C., Miller, J., Nagelkerken, I., Polunin, N., Weil, E. and Williams, I. (2014). *Cayman Islands: reports for individual countries and territories.* In: Jackson, J., Donovan, M., Cramer, K. and Lam, V. (eds.) Status and trends of Caribbean coral reefs: 1970-2012. IUCN, Gland, pp. 191-195.

Bettencourt, J. and Imminga-Berends, H. (2015). *Overseas Countries and Territories: Environmental Profiles*. Safège Consortium. 270 pp.

Bhakuni, D. and Rawat, D. (2005). *Bioactive Marine Natural Products*. New York: Springer. 382 pp.

Boonzaier, L. and Pauly, D. (2016). Marine protection targets: an updated assessment of global progress. *Onyx*, 50(1): 27-35.

Brander, L., Baulcomb, C., van der Lelij, J. A. C., Eppink, F., McVittie, A., Nijsten, L. and P. van Beukering. (2015). *The benefits to people of expanding Marine Protected Areas.* VU University, Amsterdam. 190 pp.

Burke, L., Greenhalgh, S., Prager, D., and Cooper, E. (2008). *Coastal Capital - Economic Valuation of coral reefs in Tobago and St. Lucia*. World Resources Institute, Washington D.C. 66 pp.

CIDOT [Cayman Islands Department of Tourism]. (2016). *Bi-Annual Statistics Report: Jan-June 2016.* CIDOT.

Cayman Islands Government. (2011). Economy. [Online] Available at: <http://www.gov.ky/portal/page/portal/cighome/cayman/theeconomy/economy>. Accessed on: November 17, 2016.

CBD [Convention on Biological Diversity] (2010). Aichi Biodiversity Targets. [Online] Available at: <https://www.cbd.int/sp/targets> Accessed on: January 17, 2017.

Cesar, H., and van Beukering, P. (2004). Economic valuation of the coral reefs of Hawaii. *Pacific Science,* 58(2): 231-242.

CIREBA. (2016). Cayman Islands Real Estate Brokers Association. Available at: <http://www.cireba.com/>. Accessed on: November 3, 2016.

Constanza, R., d'Arge, R., de Groot, R., Faber, S., Grasso, M., Hannon, B., and Sutton, P. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387: 253 - 260.

De Groot, R., Fisher, B., Cristie, M., Aronson, J., Braat, L., Haines-Young, R., Maltby, E., Neuville, A., Polasky, S., Portela, R. and Ring, I. (2010). *Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation.* In: Kumar, P. (ed.) The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations. Earthscan, London, pp. 9-40.

De Groot, R., Wilson, M., and Boumans, R. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41(3): 393-408 pp.

Dekkers, J., and Koomen, E. (2008). *Valuation of open space: hedonic house price analyses in the Dutch Randstad region.* Vrije Universiteit Amsterdam, Amsterdam. 19 pp.

Dunse, N., and Jones, C. (1998). A hedonic price model of office rents. *Journal of Property Valuation and Investment,* 16(3): 297-312.

Economics and Statistics Office - Cayman Islands Government. (2016). Indicators. Available at: <http://www.eso.ky/indicators_page.html#14>. Accessed on: October 2, 2016.

Ellison, J.C. (2008). Long-term retrospection on mangrove development using sediment cores and pollen analysis: A review. *Aquatic Botany,* 89: 93-104.

FEMA (2000). Coastal construction manual: principles and practices of planning, siting, designing, constructing and maintaining residential buildings in coastal areas. Volume I. Available at: <http://www.vcfloodinfo.com/pdf/coastalconstruction_vol1.pdf> Accessed on: June 20, 2017.

Government Administration Building (2015). *Exclusive License and Marine Resource Management Agreement.* George Town, Cayman Islands: Government Administration Building.

Haines-Young, R., and Potschin, M. (2013). *Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012*. EEA Framework Contract No EEA/IEA/09/003. Nottingham: Centre for Environmental Management, University of Nottingham. 19 pp.

Halpern, B. (2003). The impact of marine reserves: do reserves work and does reserve size matter? *Ecological Applications*, 13(1): S117-S137.

Halpern, B.S., Lester, S. and McLeod, K.L. (2010). Placing marine protected areas onto the ecosystem-based management seascape. *Proceedings of the National Academy of Sciences (PNAS)*, 107(43): 18312-18317.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R. and Watson, R. (2008). A global map of human impact on marine ecosystems. *Science*, 319: 948-952.

Henshall, B. (2009). Maintaining Reef Resilience: The Characteristics and Spatial Distribution of Fishing Pressure from the Recreational and Artisanal Fisheries of the Cayman Islands. School of Ocean Sciences, Bangor University, Wales. 107 pp.

Hoogeveen, R. (2016). A cost-benefit analysis of the MPA expansion in the Cayman Islands: A total economic valuation of the marine environment. IVM Institute for Environmental Studies, Amsterdam. 49 pp.

Howard, J., Hoyt, S., Isensee, K., Telszewski, M., and Pidgeon, E. (2014). Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrasses. Conservation International, Intergovernmental, Arlington. 180 pp.

IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). National Greenhouse Gas Inventories Programme, IGES, Kitakyushu.

IPCC. (2014). 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds.). IPCC, Geneva.

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

Kossoy, A., Peszko, G., Oppermann, K., Prytz, N., Klein, N., Blok, N., Lam, L., Wong, L and Borkent, B. (2015). *State and Trends of Carbon Pricing 2015 (September)*. World Bank, Washington D.C. 85 pp.

Laffoley, D., and Grimsditch, G. (2009). *The Management of Natural Coastal Carbon Sinks*. IUCN, Gland. 53 pp.

Lester, S.E., Halpern, B.S., Grorud-Colvert, K., Lubchenco, J., Ruttenberg, B.I., Gaines, S.D., Airamé, S. and Warner, R.R. (2009). Biological effects within no-take marine reserves: a global synthesis. *Marine Ecology Progress Series*, 384: 33-46.

MA [Millennium Ecosystem Assessment]. (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington D.C. 137 pp.

Maxey, K. (2016). Sales Maxey Cosmetics.

Meier, R., McCoy, C., Richardson, L., and Turner, J. (2011). *Quantifying the impact of recreational and artisanal fisheries in the Cayman Islands, through the use of socio-economic questionnaires*. Darwin Initiative Interim Report. 104 pp.

Olynik, J., Richardson, L. and Schill, S. (2012). *Marine ecological gap analysis methodology for the Darwin Initiative to enhance an established marine protected area system in the Cayman Islands.* The Cayman Islands Department of Environment, Bangor University and the Nature Conservancy. 41 pp.

Potts, T., Burdon, D., Jackson, E., Atkins, J., Saunders, J., Hastings, E., Langmead, O. (2014). Do marine protected areas deliver flows of ecosystem services to support human welfare? *Marine Policy*, 44: 139-148.

Reuchlin-Hugenholtz, E. and McKenzie, E. (2015). *Marine protected areas: smart investments in ocean health*. WWF, Gland. 19 pp.

Richardson, L., Bothwell, J., Ebanks-Petrie, G., Austin, T., McCoy, C., Olynik, J., Byrne, J., Schill, S. and Turner, J. (2013). *Darwin Initiative Marine Parks Review: Public Consultation Summary.* Darwin Initiative project 18-016. Bangor University, Cayman Islands Department of Environment, Grand Cayman. 100 pp.

Roberts, C.M. and Hawkins, J.P. (2000). *Fully protected marine reserves: a guide*. WWF Endangered Seas Campaign, Washington, D.C. 131 pp.

Rosen, A. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy*, 82(1): 34-55.

Sarkis, S., van Beukering, P., and McKenzie, E. (2010). *Total economic Value of Bermuda's Coral Reefs*. Bermuda: Department of Conservation Services, Government of Bermuda. 197 pp.

Schep, S., Guzmán, A., van Beukering, P., de Moel, H., Eiselin, M., Ayesu, S., Birikorang, G. Ansah, K. B. (2016). *The economics of the Atewa Forest Range, Ghana*. IUCN NL, A Rocha Ghana, IVM Institute for Environmental Studies, Wolfs Company, Amsterdam. 207 pp.

Schep, S., Johnson, A., van Beukering, P., and Wolfs, E. (2012). *The fishery value of coral reefs in Bonaire: applying various valuation techniques*. Institute for Environmental Studies. 39 pp.

Schutter, M. (2014). The economics of expanding the Marine Protected Areas of the Cayman Islands: The cultural and recreational value of the Marine Environment to the Cayman Islands' residents. IVM Institute for Environmental Studies, Amsterdam. 103 pp.

Selig, E.R. and Bruno, J.F. (2010). A global analysis of the effectiveness of Marine Protected Areas in preventing coral loss. PLoS ONE, 5(2): e9278.

Suzuki, A., and Kawahata, H. (2004). Reef Water CO2 System and Carbon Production of Coral Reefs: Topographic Control of System-Level Performance. In: Shiyomi, M., Kawahata, H., Koizumi, H., Tsuda, A. and Awaya, Y. (eds.) Global Environmental Change in the Ocean and on Land. Terrapub, Tokyo, pp. 229-248.

Taramelli, A., Valentini, E., and Serlacchini, S. (2014). A GIS-based approach for hurricane hazard and vulnerability assessment in the Cayman Islands. Ocean and Coastal Management, 108: 116-130.

Trading Economics (2016). [Online] Available at: <http://www.tradingeconomics.com/>. Accessed on: November 30, 2016.

UNEP [United Nations Environment Programme] (1992). *Convention on Biological Diversity*. UNEP, Nairobi.

Van Beukering, P., Brander, L., Tompkins, E. and McKenzie, E. (2007). *Valuing the Environment in Small Islands: an environmental economics toolkit*. JNCC. [Online] Available at: <http://jncc.defra.gov.uk/page-4065 > Accessed on November 30, 2016.

Van Beukering, P., Brouwer, R., Schep, S., Wolfs, E., Brander, L., Ebanks-Petrie, G., and Austin, T. (2014). *The impact of invasive species on tourism - The case of lionfish in the Cayman Islands*. Wolfs Company, IVM Institute for Environmental Studies, Amsterdam. 51 pp.

Van de Kerkhof, S., Schep, S., van Beukering, P., and Brander, L. (2014a). *The Tourism Value of Nature on Saba*. Wolfs Company, IVM Institute for Environmental Studies, Amsterdam. 79 pp.

Van de Kerkhof, S., Schep, S., van Beukering, P., Brander, L., and Wolfs, E. (2014b). *The Tourism Value of Nature on St Eustatius*. Wolfs Company, IVM Institute for Environmental Studies, Amsterdam. 63 pp.

Van Zanten, B., van Beukering, P., & Wagtendonk, A. (2014). Coastal protection by coral reefs: A framework for spatial assessment and economic valuation. *Ocean & Coastal Management*, 96: 94-103.

Waite, R., Burke, L. and Grau, E. (2014). *Coastal Capital: Ecosystem Valuation for Decision Making in the Caribbean*. Washington, DC: World Resources Institute. 78 pp.

Ware, J., Smith, S., and Reaka-Kudla, M. (1991). Coral reefs: sources or sinks of atmospheric COW? *Coral Reefs*, 11: 127-130 pp.

Watson, J.E.M., Dudle, N., Segan, N. B. and Hocking, M. (2014). The performance and potential of protected areas. *Nature*, 515(7525): 67-73.

Williams, I., and Ma, H. (2013). *Estimating Catch Weight of Reef Fish Species Using Estimation and Intercept Data from the Hawaii Marine Recreational Fishing Survey*.

Pacific Islands Fish. Sci. Cent. Admin. Rep. H-13-04. Pacific Islands Fish. Sci. Cent., Natl. Mar. Fish. Serv., HI 96822-2396. NOAA, Honolulu 53 pp.

World Bank and Ecofys (2016). *Carbon Pricing Watch 2016.* World Bank, Washington D.C. 15 pp.

WPC [World Parks Congress] (2014). The Promise of Sydney. IUCN World Parks Congress, Sydney, Australia. [Online] Available at: <http://worldparkscongress.org/downloads/approaches/ThemeM.pdf> Accessed on: January 17, 2016.

XE. (2016). XE Currency Converter: USD to KYD. Available at: <http://www.xe.com/currencyconverter/convert/?From=USDandTo=KYD>. Accessed on: October 14, 2016.

Zarate-Barrera T.G. and Maldonado J.H. (2015). Valuing Blue Carbon: Carbon Sequestration Benefits Provided by the Marine Protected Areas in Colombia*. PLoS ONE*. 10(5): 1-22.

Zeller, D., and Harper, S. (2009). *Fisheries catch reconstructions: Islands - Part I*. Fisheries Centre, University of British Columbia, Canada. Fisheries Centre Research Reports 17 (5). 104 pp.

Annexes

Annex 1 – Descriptive statistics of sold houses

Variable	Column1	Mean	Std.	Min	Max
House Price	CI$	721,158.90	761,479.90	2,456	7,749,000
Distance to reef	Feet	3,660.91	2,554.64	95.00	12,120.44
Distance to mangroves		1,007.34	1,190.10	0.40	6,667.15
Size house	FT^2	3,188.20	1,780.75	384.00	13,804.00
No of bedrooms	#	3.64	1.47	1.00	18.00
No of bathrooms	#	3.84	19.13	0.50	512.00
Days on the market	#	365.85	333.41	14.00	2,193.00
Population density	Population/km^2	532.43	343.88	26.80	890.50
Land use		0.98	0.14	0.00	1.00
view1	Beach front	0.13	0.34	0	1.00
view2	Canal front	0.16	0.36	0	1.00
view3	Garden view	0.56	0.50	0	1
view4	Pool view	0.08	0.28	0	1
view5	Water front	0.06	0.24	0	1
type1	Apartment	0.06	0.24	0	1
type2	Single Family Home	0.94	0.24	0	1
Boddentown	District	0.27	0.44	0	1
Cayman Brac	District	0.01	0.10	0	1
East end	District	0.02	0.15	0	1
Georgetown	District	0.36	0.48	0	1
Westbay	District	0.24	0.43	0	1
Northside	District	0.10	0.30	0	1
Little Cayman	District	0.01	0.07	0	1

Annex 2 – Baseline regression for coral reefs and mangroves

	Dependent variable: the logarithm of current selling price							
VARIABLES	Coral reef				Mangroves			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log distance to reef	-0.0534	-0.0517*	-0.0101	-0.01000				
	(0.0394)	(0.0273)	(0.0213)	(0.0214)				
Log distance to mangroves					-0.0685***	-0.0466***	-0.0414***	-0.0410***
					(0.0183)	(0.0104)	(0.00946)	(0.00949)
Log square feet		1.193***	0.995***	1.003***		1.184***	0.988***	0.995***
		(0.0435)	(0.0543)	(0.0532)		(0.0427)	(0.0526)	(0.0515)
Number of bedrooms			-0.0238	-0.0240			-0.0221	-0.0224
			(0.0171)	(0.0171)			(0.0169)	(0.0169)
Number of bathrooms			-0.000318	-0.000306			-0.000471*	-0.000458*
			(0.000264)	(0.000263)			(0.000252)	(0.000251)
Type 1 - Apartments			-0.190	-0.180			-0.184	-0.175
			(0.152)	(0.154)			(0.150)	(0.152)
View 1 – Beach front			0.835***	0.842***			0.849***	0.855***
			(0.0869)	(0.0879)			(0.0897)	(0.0908)
View 2 – Canal front			0.634***	0.631***			0.610***	0.607***
			(0.0477)	(0.0474)			(0.0453)	(0.0451)
View 4 – Pool front			0.266***	0.261***			0.265***	0.261***
			(0.0487)	(0.0478)			(0.0470)	(0.0463)
View 5 – Water front			0.411***	0.414***			0.414***	0.417***
			(0.0874)	(0.0886)			(0.0859)	(0.0872)
Days on the market				-5.73e-05				-5.84e-05
				(5.69e-05)				(5.57e-05)
Land use				-0.139**				-0.106*
				(0.0672)				(0.0643)
Constant	13.54***	4.068***	5.148***	5.245***	13.53***	4.015***	5.374***	5.438***
	(0.318)	(0.458)	(0.460)	(0.457)	(0.118)	(0.352)	(0.384)	(0.380)
Observations	711	711	711	711	711	711	711	711
R-squared	0.003	0.578	0.710	0.711	0.021	0.586	0.718	0.719

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 3 – Regression with distance to coral reefs and distance to mangroves

	Dependent variable: the logarithm of current selling price			
VARIABLES	(1)	(2)	(3)	(4)
Log distance to reef	-0.0692*	-0.0626**	-0.0174	-0.0173
	(0.0393)	(0.0273)	(0.0212)	(0.0212)
Log distance to mangroves	-0.0719***	-0.0497***	-0.0420***	-0.0415***
	(0.0185)	(0.0106)	(0.00947)	(0.00950)
Log square feet		1.183***	0.988***	0.995***
		(0.0423)	(0.0523)	(0.0512)
Number of bedrooms			-0.0222	-0.0225
			(0.0169)	(0.0169)
Number of bathrooms			-0.000467*	-0.000454*
			(0.000252)	(0.000251)
Type 1 - Apartments			-0.186	-0.177
			(0.150)	(0.152)
View 1 – Beach front			0.836***	0.842***
			(0.0863)	(0.0873)
View 2 – Canal front			0.618***	0.616***
			(0.0473)	(0.0471)
View 4 – Pool front			0.262***	0.258***
			(0.0468)	(0.0461)
View 5 – Water front			0.403***	0.407***
			(0.0862)	(0.0873)
Days on the market				-5.84e-05
				(5.55e-05)
Land use				-0.105
				(0.0664)
Constant	14.09***	4.535***	5.514***	5.575***
	(0.348)	(0.471)	(0.456)	(0.451)
Observations	711	711	711	711
R-squared	0.026	0.589	0.718	0.719

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 4 – Sensitivity test on separated districts

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	Boddentown			Westbay			Georgetown		
Log distance to reef	0.0103		0.0104	-0.0370		-0.0722	-0.0522		-0.0519
	(0.0334)		(0.0328)	(0.0506)		(0.0528)	(0.0325)		(0.0323)
Log distance to mangroves		-0.000514	0.000276		-0.107***	-0.111***		-0.0310***	-0.0309***
		(0.0144)	(0.0140)		(0.0204)	(0.0206)		(0.00977)	(0.00976)
Log square feet	0.645***	0.644***	0.644***	0.900***	0.854***	0.870***	1.083***	1.075***	1.070***
	(0.0671)	(0.0672)	(0.0675)	(0.115)	(0.0864)	(0.0855)	(0.132)	(0.131)	(0.131)
Number of bedrooms	-0.160***	-0.159***	-0.160***	-0.123***	-0.0676	-0.0763*	-0.0432*	-0.0409*	-0.0401
	(0.0425)	(0.0425)	(0.0428)	(0.0466)	(0.0412)	(0.0434)	(0.0243)	(0.0243)	(0.0245)
Number of bathrooms	0.148***	0.148***	0.148***	0.115**	0.0634	0.0719*	-0.000732***	-0.000846***	-0.000811***
	(0.0407)	(0.0407)	(0.0407)	(0.0462)	(0.0409)	(0.0423)	(0.000281)	(0.000267)	(0.000274)
Type 1 - Apartments	0.0517	0.0499	0.0517	-0.320**	-0.422***	-0.427***	-0.247	-0.220	-0.229
	(0.0657)	(0.0648)	(0.0661)	(0.157)	(0.134)	(0.136)	(0.224)	(0.222)	(0.222)
View 1 – Beach front	0.757***	0.749***	0.757***	1.421***	1.437***	1.350***	0.551	0.619	0.560
	(0.0865)	(0.0809)	(0.0866)	(0.228)	(0.184)	(0.190)	(0.408)	(0.424)	(0.409)
View 2 – Canal front	0.351***	0.361***	0.351***	0.732***	0.662***	0.674***	0.586***	0.560***	0.583***
	(0.0783)	(0.0683)	(0.0791)	(0.0886)	(0.0750)	(0.0783)	(0.0760)	(0.0685)	(0.0747)
View 4 – Pool front	0.237*	0.232*	0.237*	0.368***	0.379***	0.386***	0.155**	0.159***	0.154***
	(0.133)	(0.130)	(0.135)	(0.0874)	(0.0806)	(0.0797)	(0.0606)	(0.0609)	(0.0594)
View 5 – Water front	0.515***	0.506***	0.514***	0.601***	0.591***	0.527***	0.449***	0.451***	0.461***
	(0.135)	(0.131)	(0.137)	(0.157)	(0.143)	(0.147)	(0.151)	(0.144)	(0.143)
Days on the market	-1.93e-05	-2.14e-05	-1.90e-05	-0.000111	-7.16e-05	-6.76e-05	-2.14e-05	-2.13e-05	-1.59e-05
	(7.29e-05)	(7.30e-05)	(7.48e-05)	(7.02e-05)	(7.38e-05)	(7.22e-05)	(9.61e-05)	(9.50e-05)	(9.34e-05)
Land use	-0.0693	-0.0715	-0.0692	-0.281***	-0.146**	-0.166**	-0.0364	0.0144	0.0188
	(0.0634)	(0.0614)	(0.0638)	(0.0607)	(0.0625)	(0.0653)	(0.161)	(0.134)	(0.152)
Constant	7.766***	7.863***	7.766***	6.384***	7.008***	7.501***	5.045***	4.797***	5.238***
	(0.515)	(0.430)	(0.516)	(0.902)	(0.632)	(0.801)	(1.167)	(1.018)	(1.173)
Observations	191	191	191	169	169	169	254	254	254
R-squared	0.684	0.684	0.684	0.851	0.877	0.878	0.640	0.644	0.646

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Annex 5 – Sensitivity test on separated price ranges

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(13)	(14)	(15)
VARIABLES	House price < 200,000			House price 200,000-500,000			House price 500,000-1,000,000			House price > 1,000,000		
Log distance to reef	0.0185		0.0156	-0.00490		-0.00767	-0.00317		-0.00919	0.0102		0.00459
	(0.0485)		(0.0482)	(0.0182)		(0.0179)	(0.0165)		(0.0156)	(0.0314)		(0.0313)
Log distance to mangroves		-0.0145	-0.0140		-0.0141**	-0.0143**		-0.0221***	-0.0226***		-0.0331	-0.0329
		(0.0179)	(0.0178)		(0.00699)	(0.00693)		(0.00730)	(0.00741)		(0.0203)	(0.0205)
Log square feet	-0.00958	-0.00841	-0.00955	0.360***	0.364***	0.365***	0.217***	0.215***	0.214***	0.459***	0.460***	0.459***
	(0.129)	(0.127)	(0.129)	(0.0424)	(0.0424)	(0.0428)	(0.0513)	(0.0475)	(0.0472)	(0.125)	(0.120)	(0.121)
Number of bedrooms	-0.0197	-0.0187	-0.0184	-0.00924	-0.00871	-0.00834	-0.00263	-0.00148	-0.00171	0.114**	0.108**	0.109**
	(0.0278)	(0.0278)	(0.0282)	(0.0158)	(0.0153)	(0.0155)	(0.00868)	(0.00870)	(0.00850)	(0.0456)	(0.0448)	(0.0452)
Number of bathrooms	0.138*	0.143**	0.142**	-0.000554	-0.00132	-0.00148	0.0432***	0.0367***	0.0363***	-0.000315**	-0.000433**	-0.000434**
	(0.0708)	(0.0698)	(0.0706)	(0.0197)	(0.0194)	(0.0195)	(0.0133)	(0.0129)	(0.0126)	(0.000146)	(0.000172)	(0.000175)
Type 1 - Apartments	0.104	0.0693	0.0700	0.00128	0.00823	0.00610	-0.272***	-0.249***	-0.241***	0.446***	0.493***	0.495***
	(0.0785)	(0.0805)	(0.0807)	(0.0445)	(0.0446)	(0.0443)	(0.0704)	(0.0610)	(0.0599)	(0.110)	(0.100)	(0.103)
View 1 – Beach front	-4.163***	-4.152***	-4.130***	0.232**	0.243**	0.235**	0.165***	0.184***	0.176***	0.386***	0.418***	0.420***
	(0.0970)	(0.0705)	(0.114)	(0.102)	(0.0985)	(0.102)	(0.0418)	(0.0366)	(0.0392)	(0.0760)	(0.0832)	(0.0821)
View 2 – Canal front				0.237***	0.212***	0.218***	0.185***	0.190***	0.194***	0.0407	0.0748	0.0716
				(0.0397)	(0.0404)	(0.0423)	(0.0409)	(0.0399)	(0.0405)	(0.0720)	(0.0717)	(0.0772)
View 4 – Pool front	0.142	0.181	0.195	0.143***	0.150***	0.150***	0.0683*	0.0659*	0.0654*	-0.143*	-0.127	-0.128
	(0.104)	(0.114)	(0.137)	(0.0471)	(0.0470)	(0.0472)	(0.0389)	(0.0371)	(0.0373)	(0.0855)	(0.0874)	(0.0885)
View 5 – Water front	-0.0452	-0.0453	-0.0278	0.163**	0.156**	0.152*	0.0686	0.0890*	0.0849*	0.0562	0.0790	0.0794
	(0.236)	(0.234)	(0.244)	(0.0762)	(0.0777)	(0.0783)	(0.0450)	(0.0502)	(0.0512)	(0.123)	(0.121)	(0.121)
Days on the market	6.93e-06	1.34e-05	1.42e-05	-5.06e-05	-5.99e-05	-5.97e-05	-5.66e-05	-6.18e-05	-6.14e-05	-2.12e-05	-6.98e-06	-7.25e-06
	(0.000105)	(0.000108)	(0.000108)	(4.41e-05)	(4.53e-05)	(4.51e-05)	(4.19e-05)	(4.13e-05)	(4.16e-05)	(6.68e-05)	(6.77e-05)	(6.81e-05)
Land use	-0.269***	-0.299***	-0.282***	-0.0651	-0.0567	-0.0587	0.0880	0.108	0.113	-0.111*	-0.0556	-0.0555
	(0.0763)	(0.0632)	(0.0810)	(0.0652)	(0.0626)	(0.0633)	(0.0805)	(0.0865)	(0.0900)	(0.0621)	(0.0851)	(0.0854)
Constant	11.87***	12.11***	11.97***	10.01***	10.02***	10.08***	11.45***	11.56***	11.64***	9.795***	9.992***	9.961***
	(0.946)	(0.827)	(0.908)	(0.319)	(0.302)	(0.317)	(0.425)	(0.379)	(0.390)	(0.989)	(0.873)	(0.933)
Observations	89	89	89	310	310	310	159	159	159	159	159	159
R-squared	0.651	0.653	0.653	0.350	0.359	0.359	0.308	0.351	0.353	0.502	0.516	0.516

Robust standard errors in parentheses

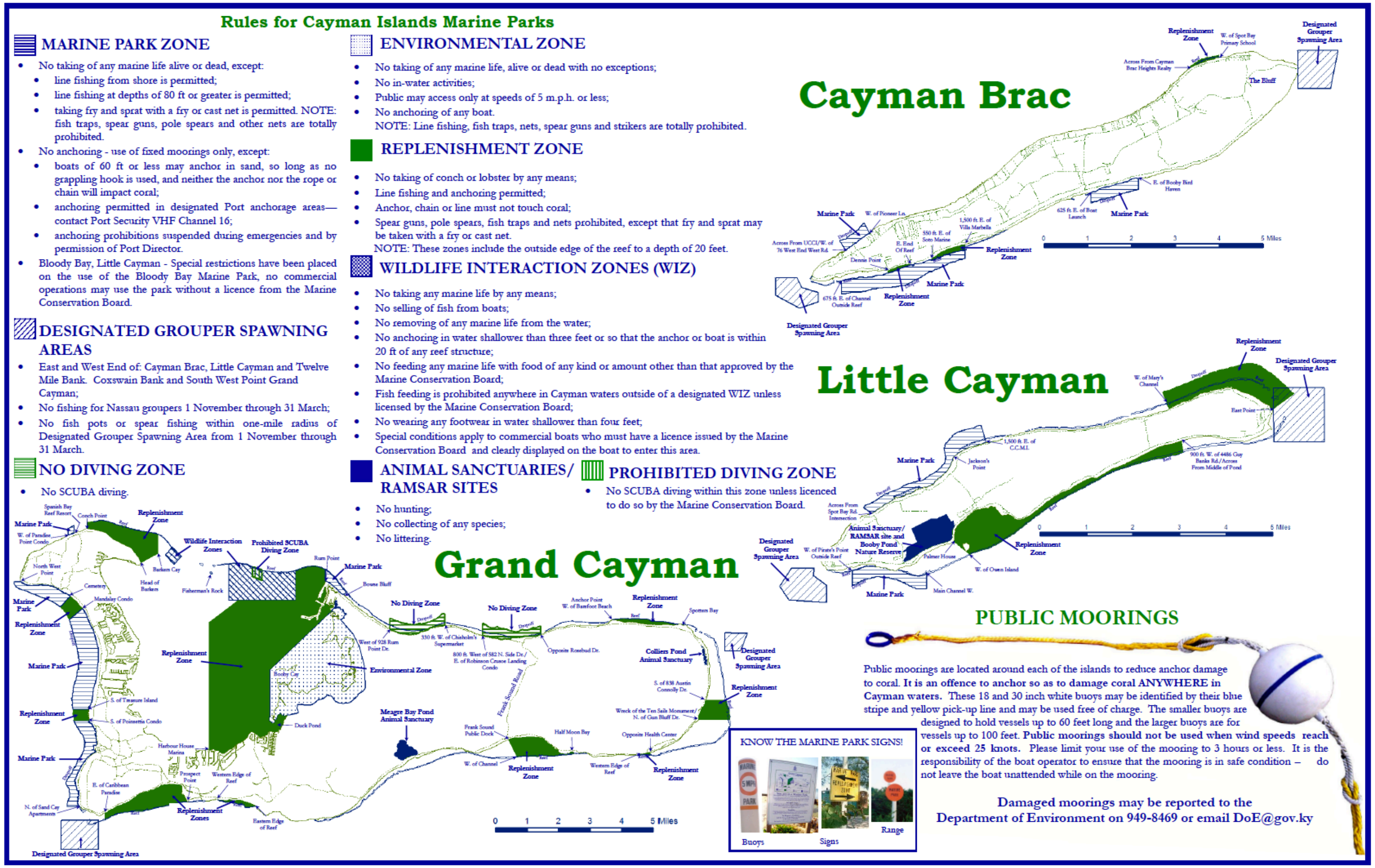
*** p<0.01, ** p<0.05, * p<0.1

Annex 6 – Characteristics of coast for Relative Reef Contribution

Factor	Level Of Coastal Protection				
	Very High 4	High 3	Medium 2	Low 1	None 0
Coastal Geomorphology	Rocky, Cliffed Coastline	Soft (Limestone) Cliffs or Low Bluffs	Mangroves	Beaches	N/A
Coastal Geology	Igneous and/or Volcanic	Metamorphic	Sedimentary	Unconsolidated Sediments	N/A
Coastal Protection Structures	Protected by 2 prominent headlands and breakwater	Protected by 2 prominent headlands	Seawalls, Riprap or Breakwaters	Protected by one or two small headlands	No protection by headlands
Wave Energy (~ Max. Wave Height [cm])	< 20	20 – 40	40 – 60	>60	N/A
Coral Reef Index *(sum of 3 factors / 10 *4)* **Reef Type** **Reef Distribution** **Reef Distance (m)**	Barrier Not applicable (N/A) < 250	Patch N/A 250 - 500	Fringe Continuous 500 - 1000	Apron Discontinuous > 1000	No reef present No reef present No reef present
Storm/Hurricane Events	Affected by 1-5 Tropical Storms every 10 years	Affected by at least 5 Trop. Storms every 10 years	Affected by at least a Category 1 every 25 years	Affected by at least a Category 3 every 25 years	N/A
Coastal Elevation (m)	> 12	5 – 12	1 – 5	0 – 1	< 0 (N/A) **
Coastal Slope (%)	6.2 – 9.7	2.6 – 6.2	1.1 – 2.6	0.4 – 1.1	N/A
Coastal Vegetation Index *(average of 2 factors)* **Type** **Distribution**	Mangroves > 75 % length of coastline	Coastal Woodlands 50% - 75 % of length	Thicket 25% - 50 % of length	Runners < 25% length of coastline	None No Vegetation
Coastal Anthropogenic Activities	No sand mining, coastal development, etc.	Misc. Other Activities	Either sand mining or coastal development	Sand mining and coastal development	N/A

Source: modified from Burke et al. (2008)

Annex 7 – Description of regulations considered in the existing MPA framework in the Cayman Islands



Annex 8 - Sensitivity of the results to different rates of ecosystem degradation

Total NPV with different rates of coral reef degradation (US$ millions; 2.5% degradation rates; 25-year timeframe)

NPV with different degradation rates of coral reefs	-1%	-3%	-5%	-7%	-9%	-11%	-13%	-15%
Scenario 1A – Current MPAs, ineffective MPA management	$3,532	$3,165	$2,877	$2,646	$2,459	$2,306	$2,179	$2,071
Scenario 2A – MPA enhancement, ineffective MPA management	$3,699	$3,465	$3,281	$3,135	$3,018	$2,922	$2,842	$2,775
Scenario 1B – Current MPAs, effective MPA management	$3,546	$3,184	$2,899	$2,670	$2,485	$2,333	$2,206	$2,100
Scenario 2B – MPA enhancement, effective MPA management	$3,866	$3,726	$3,616	$3,529	$3,458	$3,400	$3,350	$3,309

Total NPV with different rates of mangrove degradation (US$ millions; 2.5% degradation rates; 25-year timeframe)

NPV with different degradation rates of mangroves	-1%	-3%	-5%	-7%	-9%	-11%	-13%	-15%
Scenario 1A – Current MPAs, ineffective MPA management	$3,510	$3,310	$3,151	$3,021	$2,915	$2,826	$2,752	$2,688
Scenario 2A – MPA enhancement, ineffective MPA management	$3,750	$3,560	$3,408	$3,286	$3,187	$3,105	$3,036	$2,978
Scenario 1B – Current MPAs, effective MPA management	$3,527	$3,327	$3,169	$3,040	$2,935	$2,848	$2,774	$2,712
Scenario 2B – MPA enhancement, effective MPA management	$3,976	$3,786	$3,636	$3,515	$3,417	$3,336	$3,269	$3,212

Total NPV with different rates of seagrass degradation (US$ millions; 2.5% degradation rates; 25-year timeframe)

NPV with different degradation rates of seagrass	-1%	-3%	-5%	-7%	-9%	-11%	-13%	-15%
Scenario 1A – Current MPAs, ineffective MPA management	$3,367	$3,304	$3,248	$3,197	$3,151	$3,110	$3,073	$3,038
Scenario 2A – MPA enhancement, ineffective MPA management	$3,581	$3,553	$3,526	$3,501	$3,477	$3,455	$3,434	$3,415
Scenario 1B – Current MPAs, effective MPA management	$3,385	$3,322	$3,264	$3,212	$3,165	$3,122	$3,082	$3,046
Scenario 2B – MPA enhancement, effective MPA management	$3,815	$3,780	$3,747	$3,717	$3,689	$3,664	$3,641	$3,620