What is Bonaire’s Cruise Tourism Worth?

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Summary

The ecosystems of the island of Bonaire support a range of activities that depend on the quality of the natural environment. Tourism is one of these activities and it represents an important source of income for the local economy. Tourism in Bonaire can be divided in stay-over tourism and cruise tourism. Whether further development of cruise tourism is desirable for Bonaire is constantly under discussion. It is thought that more cruise tourists will contribute to economic growth. But, at the same time, there is a fear that an increase in the number of cruise tourists and the investments in infrastructure and other facilities to facilitate this growth will put extra pressure on the ecosystems. And these are the same ecosystems that are vital in attracting not only cruise tourists, but also stay-over tourists.

This study aims at providing quantitative and qualitative information on the potential benefits and negative effects of an expansion of the cruise tourism industry on Bonaire. For this purpose, a socio-economic valuation was first conducted to understand the cruise tourism industry in Bonaire. This resulted in insights that include tourist's expenditures, the different actors on the island that benefit from these expenditures, the dependency of certain sectors on tourism related revenues and the attitude of tourists towards certain social and environmental changes in the island. This information is derived from tourist surveys, a business survey and literature review.

Second, with the information gathered, and making use of an economic Input-Output model for Bonaire that is linked to an ecologic model, three different cruise tourism growth scenarios were analysed: a baseline scenario, a moderate growth scenario and a rapid growth scenario. This analysis resulted in the calculation of economic benefits that would result from an increase in the number of cruise tourists in each scenario. At the same time, using the ecologic module that is linked to the economic Input-Output model, the socio-environmental impact on a number of natural indicators was also assessed. Certain environmental effects of cruise tourism, like waste production, water consumption and the ecologic footprint of cruise ships, could not be included in the ecologic module and were, therefore, assessed separately from the model.

The surveys conducted amongst tourists have shown the importance of maintaining a healthy reef and the tranquillity on the island. Especially stay-over tourists indicated that they are not willing to return to a more crowded island or an island with a degraded coral reef. Both the survey and the scenario analysis indicate that sectors that benefit the most from the growth of the cruise industry are the transport, restaurant, ‘other services’ (which include tour operators) and trade sectors.

The scenario analysis further indicates that an increase in cruise tourism will generate a growth in GDP within the period of the analysis (until 2024). While the economy grows as a whole, more jobs will be generated. However, given the seasonal character of cruise tourism and the sectors that benefit the most from it, most of the jobs created appear to be in lower income categories. As a result of potential population growth to fill in these new jobs, household consumption and GDP per capita do not increase as much as the GDP growth might suggest. Household consumption at the end of the analysis period (2024) is only $234 higher in the rapid growth scenario compared to the baseline scenario.

The economic growth caused by cruise tourism expansion also results in socio-environmental impacts, as higher number of visitors will increase direct pressures on the ecosystems that are visited. The main impacts that have been analysed are change in land use, decrease in coral cover, water consumption and waste generation and the potential decrease of stay-over tourists as a result of coral reef degradation and more built-up land.
However, not all potential socio-environmental impacts could be included in the scenario analysis. If cruise tourism industry is to expand even further, Bonaire must expand its infrastructure. This means that investments need to be made to accommodate larger amounts of tourists. The scenario analysis does not take into account the impact of these potential infrastructure projects like additional port infrastructure, proper waste management system, water management, more roads and more ground transportation. It was also not possible to assess the effects on the environment and the return rate of stay-over tourists caused by crowding in specific areas and on peak moments.

The results of the study demonstrate that there are external effects related to the expansion of cruise tourism. For example, a decrease in stay-over tourists as a result of rapid growth of the cruise tourism industry may have significant implications for the hotel industry. To make decisions regarding cruise tourism expansion, such external effects should be taken into account. Furthermore, investing on an environmental friendly expansion and the enforcement of environmental regulations will also be of high importance to avoid endangering the ecosystems and, thereby, the tourism industry as a whole. More research on the local impacts of cruise tourism and the effects on the stay-over sector are necessary to draw conclusions on the desirability of the expansion of cruise tourism for the island.
Acknowledgements

This study would not have been possible without the enormous support of numerous people and organisations in the period between 2012 and 2014. First of all, on Bonaire we want to thank Ruth Schipper-Tops from the Ministry of Economic Affairs, Caribbean Netherlands for commissioning this assignment and from the same ministry a special thanks to Hayo Haanstra, Astrid Hilgers, Huib de Bliek, and Pieter van Baren for making this research possible in the first place and special thanks to Paul Hoetjes, for facilitating the study and for helping us overcome hurdles that we encountered during the course of the study. Additionally, we would like to thank the Directorate of Spatial Planning and Development, Unit Nature and Environment, especially Frank van Slobbe and Peter Montanus for their valuable input, and special thanks to Boudewijn ‘Bous’ Scholts Carbo TTC Inc and Eric Witten for validating our report. Other people that helped us were Kris Kats from Proes consultancy, Jan Jaap van Almenkerk from KibraHacha foundation, and Jozef van Brussel from ministry of Infrastructure & Environment the Netherlands. For the information from the tourism industry a special thanks to all businesses that have participated in the business survey and a special thanks to Joanny Trinidad and Marjolijn van Kooten and Lara Chirino from Tourism Cooperation Bonaire. Furthermore a special thanks to Irene Dingjan from BONHATA, Martien van der Valk from Bonaire Hospitality Group, and The Chamber of Commerce & Industry Bonaire. A warm thank you for the time invested to Tante Vita and Papi Cecilia, Bas Noij from Bonaire Explorer Association, and Bart Snelders from CURO. And a very special thanks to Corine Gerharts and Jan Baten from Bonaire Tours & Vacations and their team for their incredible support. A very special thanks as well to Yvonne and Chris Schultheiss from Bonaire Destination Services and their team for helping out to collect many cruise passengers data. Also a special thanks to all the guides of Sue Felix Archie tours Bonaire. And a thank you to Augusto Montbrun and Paul Coolen from Buddy Dive resort, who showed us the coral nursery.

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1 Introduction

The island of Bonaire is internationally known for its unique coral reef and the easy access to it. The reef is an important asset to the tourism industry in Bonaire, which is considered to be the biggest economic driver on the island. In 2014 the island was home to 18,413 residents and had a tourism industry divided in stay-over tourists and cruise tourists. Growing from 50,000 to a maximum of 230,000 cruise tourists in 10 years’ time, this small island has seen a vast expansion of the cruise tourism industry. Although there is no information available about how much the cruise tourism industry contributes to the bulk of Bonaire’s economy, this increase indicates that the cruise tourism industry is of substantial size for the island.

There are currently discussions about whether further development of cruise ship tourism for Bonaire is desirable. On the one hand, more cruise tourists have the potential to contribute to economic growth. On the other hand, further development of the cruise tourism industry implies that necessary investments will have to be made in order to create an appropriate infrastructure and sufficient facilities for the visitors. An increase in the number of tourists and investments in infrastructure and other facilities will put extra pressure on the ecosystems. These are the very ecosystems that play a major role in attracting tourists to the island in the first place. In other words, increasing the number of tourists might have positive effects for the economic development on the island, but the question remains whether those effects are sustainable in the long run. If excessive development causes the health of Bonaire’s ecosystem to decline, the effects will also be visible in the tourism industry. Heavily degraded coral reefs (and other ecosystems) are not nearly as attractive to tourists as relatively healthy ones, hereby impacting the attractiveness of a tourist destination (Asafu-Adjaye et al., 2008). This has an especially strong impact considering that most of the tourists visiting Bonaire are divers and repeating visitors.

To provide quantitative and qualitative information on the potential benefits and negative effects of an expansion of the cruise tourism industry in Bonaire, a socio-economic valuation study is conducted to understand the cruise tourism industry in Bonaire. Certain environmental effects of cruise tourism, like waste production and water consumption, are also investigated. This information is derived from tourist surveys, a business survey and literature review.

Based on the analysis of the cruise tourism industry in Bonaire, including tourist expenditures and some socio-economic results, a scenario analysis is carried out. In this analysis, three different scenarios are compared using an input-output model with an ecologic module, to determine the potential economic benefits and some environmental impacts of a further expansion of cruise tourism.

Chapter 2 describes the cruise tourism industry in Bonaire. Chapter 3 presents the methodology of the tools that were used for the scenario analysis, namely an input-output model with an ecologic module. The results of the scenario analysis are set out in Chapter 4. Chapter 5 finally discussed these results and provides the main conclusions of the study. The Annexes at the end of the report provide some additional or in depth background and technical information of topics mentioned throughout the report, for further reference.
2 The cruise tourism industry in Bonaire

2.1 Bonaire

The Caribbean Archipelago includes the Netherlands Antilles (800 km2), which are divided in two groups of islands: the leeward group which incorporates the islands of Aruba, Bonaire and Curaçao, also known as the ABC islands, and the windward group which consist of the islands of Saba, Sint Eustatius and Sint Maarten (Figure 1).

Figure 1 - Location of Bonaire in the Caribbean Sea.

Bonaire is located 46 km east from Curaçao, 80 km north from Venezuela and 129 km east from Aruba. The surface of Bonaire is 288 km² plus another 6 km² for the adjacent island of Klein Bonaire. It measures 38 km from North to South and a maximum of 11 km wide from East to West (Wolfs, 2010; CBS, 2001). The capital is Kralendijk, the biggest city on the island. Population count varies from source to source but according to the Centraal Bureau voor de Statistiek (CBS, 2014c), there are 18,413 people living on the island.

The different ecosystems of Bonaire provide several ecosystem services¹ to its residents, visiting tourists and international researchers (Lacle et al., 2012; Schep et al., 2012a; Schep et al., 2012b). Cruise tourism also depends on the ecosystem services provided by Bonaire’s beaches and coral reefs.

¹ For a detailed explanation of the ‘Ecosystem Services’ approach see Annex A – Ecosystem services.
2.2 Methodology

Figure 2 presents the development of tourist arrivals to Bonaire between 1999 and 2013. In order to investigate the cruise tourism industry on Bonaire, two tourist surveys (Schep et al., 2012a), a field trip to investigate a mature cruise tourism industry on St. Maarten, multiple interviews with experts and a desk research were carried out. Wolfs Company furthermore conducted a business survey among 146 businesses in different sectors on Bonaire (Wolfs Company, in preparation). The two tourist surveys focused on the tourists’ perception and behaviour on Bonaire. The first survey was conducted on a face-to-face basis with departing tourists on Bonaire at the airport for stay-over tourists and at downtown Kralendijk for cruise tourists. Tourists responded a more extensive follow-up survey via Internet. Some additional demographics, like income and education were also asked in this online survey. To determine the tourists’ attitudes towards the environment and acquire more information on the support of environmental management measures, a few questions on environmental awareness were also included. But most importantly for the calculations of consumer and producer surpluses, the expenditures and WTP were inquired.

2.3 Number of visitors

On Bonaire the number of cruise tourist visitors has been increasing exponentially since 2005 reaching a top in 2010-2011, although the number of cruise-ships that dock has been decreasing. The number of stay-over tourists arriving per plane has been fairly steady over the last years, with an increase in 2012 (82,000 tourists) compared to the number in 2010 (70,000 tourists) (CBS, 2014a).

The insular Caribbean is one of the most tourism dependent regions in the world with a contribution of the broader travel and tourism economy estimated at 14.8% of the region’s GDP and contributing to a possible 2.4 million jobs (ECLAC, 2005). According to Waite et al. (2013), tourism in the Caribbean depends largely on coastal resources. Consequently most development takes place in the coastal zone and most of the impacts occur in the coastal zone as well.

Even though it has not been recorded how many visitors actually disembarked in Bonaire in 2012, the TCB (2014b) estimated a total of over 150,000 passengers in the ships arriving to Bonaire in 2012 and a little less than 150,000 in 2013. The estimate of the amount of cruise passengers for the 2014-2015 season is around 183,000 (TCB, 2014a) which represents a decrease from the 211,000 in 2010-2011, but an increase from the past two years. This indicates that the cruise tourism industry is of substantial size for the island in terms of numbers of tourists. However, information on the exact number of cruise visitors disembarking and the contribution of the cruise tourism industry to the bulk of the Bonairean economy has not been widely studied. The cruise season runs from October until May. Because of the hurricane season no cruise ships visit Bonaire in the months June till September.

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2 For more information about the actual surveys and methodology of the surveys, please refer to Schep et al. (2012a).
2.4 Facts and fables in the cruise tourism industry

Stay-over tourism is more developed on Bonaire than cruise tourism. Bonaire has seen a steady amount of stay-over tourists arriving to the island in the last decade, while cruise tourism has expanded rapidly. The novelty has led to many speculations about the added value of cruise tourism. Both opponents and supporters of cruise tourism claim facts about the industry that this chapter aims to discuss.

2.4.1 Do cruise tourists disembark while on Bonaire?

A point of debate has been the number of cruise tourists that disembark while on Bonaire. Wolfs Company conducted an exercise in the light of this study, where the number of tourists that disembarked from 14 cruise ships was counted for a period of three hours. Compared with the capacity of these ships, it was calculated that, on average, 92.9% of the tourists disembarked on Bonaire. However, the counting exercise did not extend through the whole period that the cruise ships were docked. Taking this into consideration and given that the crew of the cruise ships is not incorporated in the total amount of reported cruise tourist arrivals, it is plausible that an equivalent of 100% of the cruise ships' passenger capacity disembarks. We have used this assumption for the calculations in the remaining part of this report, while in theory the actual percentage of people disembarking from the ships can even be higher than 100% of the passenger capacity.

2.4.2 Do cruise tourists return?

It might be the case that a tropical island is much more interchangeable for a cruise tourist than for a stay-over tourist. Stay-over tourists choose specifically to go to
Bonaire instead of another island in the Caribbean, while cruise tourists visit many different islands during their cruise and might not have such a strong preference for a specific island on the itinerary. The results shown in Figure 3 support this hypothesis: compared to stay-over tourists, cruise tourists are less certain of a return trip to Bonaire. 85% of the stay-over tourists want to return to Bonaire, compared to roughly 80% of the cruise tourists. However, over 60% of the stay-over tourists are certain of this, while a less than 40% of the cruise tourists are certain of their answer.

Figure 3 - Answer of tourists to question: “Will you return to Bonaire in the future?” (Schep et al., 2012a)

Figure 3 indicates that the answers to the question on the willingness to return are very similar to the number of repeating visitors; the number of visitors that actually have visited Bonaire in the past. Although the percentages are somewhat lower, there is still a large difference between stay-over and cruise tourists. While around 20% of the cruise visitors have visited Bonaire before, around 55% of the stay-over visitors did so. This may also indicate that cruise tourists have a less particular preference for Bonaire as a destination. Another interesting finding is that the conversion from cruise tourism to stay-over tourism is negligible (Figure 4). Almost none of the returning stay-over tourists visited Bonaire as a cruise tourist and vice versa.

Figure 4 - The amount of returning visitors in the tourist exit survey (Schep et al., 2012a)

Tourists were asked whether they would return to Bonaire if certain social and environmental characteristics of the island would change. A large fraction of the tourists answered that they will refrain from revisiting Bonaire if 1) crowdedness increases with 50%, and 2) if the quality of the reefs significantly deteriorates. The results of this question are shown in Figure 5. These results indicate the importance for
tourists of a well-preserved reef. However, the quality of the reefs appears to be significantly more important for the stay-over tourists than for the cruise tourists. Only 10% of the stay-over tourists seem to be willing to return if the quality of the reef deteriorates, while more than 30% of the cruise tourist would be willing to return in these circumstances. The results also show the dangers of over-developing the tourism industry. If the cruise tourism industry is to expand further, it could have serious repercussions for the number of returning tourists, given that the stay-over tourists appear to be more sensitive to crowdedness than the cruise tourists.

![Figure 5 - Answer of tourists. Left: Would you return to a more crowded Bonaire (50% more buildings and people)? Right: Would you return to a Bonaire with coral reefs in a significantly worse state? (Schep et al., 2012a)](image)

2.4.3 Activities on Bonaire

Figure 6 depicts the participation of tourists in certain marine based activities. It appears that cruise tourists value the beach, swimming, snorkelling and boat tours as the most appreciated activities to do in, on and around the water and the Bonaire National Marine Park. A large part of the cruise tourists thus participate and enjoy the water based activities Bonaire has to offer: almost 55% of all cruise tourists indicated that they have been out to snorkel. These results also indicate that a healthy environment is an important factor in determining the importance of Bonaire as a port of call.

![Figure 6 - The participation rate of tourists in specific water-based activities (Schep et al., 2012a)](image)
When looking at the cruise tourists and their participation in terrestrial activities (Figure 7), shopping, touring and Klein Bonaire come out on top. Klein Bonaire, a small island just off the coast, and most of the other tour activities that depend heavily on the natural environment of Bonaire are the most important. Again, this indicates that the natural aspects of Bonaire are very important to distinguish itself as a port of call from other ports. Shopping, however, also seems very important for most of the cruise tourists, which could indicate that retailers on the island depend on the amount of cruise tourists visiting Bonaire.

![Figure 7 - The participation rate in land-based activities (Schep et al., 2012a)](image)

### 2.4.4 Expenditures

Table 1 shows the average expenditures of cruise tourists in different categories. Again, the importance of shopping becomes clear. Many tourists state to engage in shopping and the average expenditures are relatively high compared to the overall expenditures, with an average expenditure of $42 per shopping tourist. Although the expenditure by cruise tourists on shopping is not the highest of the categories in Table 1, it is the activity in which the most cruise tourists participate. Less people appear to spend money on tours, but the expenditures on tours, snorkelling and boats, are much higher than they are for shopping, which makes these sectors very relevant as well.

*Table 1* Average expenditures per person per day for tourists that spent money on each of the expenditure categories. The percentages reflect the part of the tourists that spent money on a particular category. For a more detailed data set, see Schep et al., (2012a).

<table>
<thead>
<tr>
<th>Activities</th>
<th>Mean expenditures</th>
<th>% of cruise tourists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local transport</td>
<td>$19</td>
<td>9%</td>
</tr>
<tr>
<td>Tours</td>
<td>$68</td>
<td>42%</td>
</tr>
<tr>
<td>Diving</td>
<td>$61</td>
<td>4%</td>
</tr>
<tr>
<td>Snorkeling</td>
<td>$58</td>
<td>30%</td>
</tr>
<tr>
<td>Boats</td>
<td>$82</td>
<td>10%</td>
</tr>
<tr>
<td>Food &amp; drinks</td>
<td>$19</td>
<td>46%</td>
</tr>
<tr>
<td>Shopping</td>
<td>$42</td>
<td>68%</td>
</tr>
<tr>
<td>Casino</td>
<td>$3</td>
<td>1%</td>
</tr>
<tr>
<td>Donation</td>
<td>$4</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>$23</td>
<td>3%</td>
</tr>
</tbody>
</table>
2.5 Structure of the industry

The Bonairean cruise tourism industry is defined as that part of the local economy that depends on the revenues earned from cruise tourism. To perform an analysis of the economic benefits and environmental impacts of cruise tourism it is important to determine the size of the revenues and to identify the parties that depend on these. The aim of this section is to provide an overview of the industry, the involved parties and financial flows in the industry. Figure 8 provides this overview schematically, which will be further explained in the rest of this section. The financial flows can be broadly divided in two main categories:

1) Tourist expenditures that flow through the cruise-line companies before they reach Bonairean parties. These parties are the government, shipping agencies and tour operators.

2) Expenditures that are done directly by tourists while on the island. Independent tour suppliers, taxis, retailers and cafeteria are mainly dependent on the latter type of expenditures.

Figure 8 - A schematic overview of the cruise tourism industry on Bonaire (in the period 2012-2014). The boxes represent different actors in the industry, while the arrows represent the financial flows.
2.5.1 Cruise companies

Table 2 shows the ships that visited Bonaire in the season 2012-2013 and their capacity (TCB, n.d.). For more information on the cruise companies, see Annex C – Cruise companies.

Table 2  Cruise ships that visited Bonaire in the 2012-2013 season.³

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Cruise line</th>
<th>Capacity</th>
<th># Visits</th>
<th>Total visitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aida Luna</td>
<td>AIDA Cruises</td>
<td>2,194</td>
<td>8</td>
<td>17,552</td>
</tr>
<tr>
<td>Alexander von Humboldt</td>
<td>--</td>
<td>510</td>
<td>1</td>
<td>510</td>
</tr>
<tr>
<td>Amadea</td>
<td>--</td>
<td>600</td>
<td>1</td>
<td>600</td>
</tr>
<tr>
<td>Club Med 2</td>
<td>Club Med Cruises</td>
<td>372</td>
<td>1</td>
<td>372</td>
</tr>
<tr>
<td>Delphin</td>
<td>Kreuzfahrten</td>
<td>470</td>
<td>1</td>
<td>470</td>
</tr>
<tr>
<td>Eclipse</td>
<td>Celebrity/RCL</td>
<td>2,582</td>
<td>6</td>
<td>15,492</td>
</tr>
<tr>
<td>Emerald Princess</td>
<td>Princess Cruises</td>
<td>3,100</td>
<td>6</td>
<td>18,600</td>
</tr>
<tr>
<td>Freewinds</td>
<td>Majestic CL</td>
<td>150</td>
<td>63</td>
<td>9,450</td>
</tr>
<tr>
<td>Grandeur of the Seas</td>
<td>Celebrity/RCCL</td>
<td>2,446</td>
<td>20</td>
<td>48,920</td>
</tr>
<tr>
<td>Island Sky</td>
<td>Noble Caledonia</td>
<td>114</td>
<td>2</td>
<td>228</td>
</tr>
<tr>
<td>Kristina Katarina</td>
<td>Katarina Cruises</td>
<td>450</td>
<td>2</td>
<td>900</td>
</tr>
<tr>
<td>Maasdam</td>
<td>HAL</td>
<td>1,258</td>
<td>3</td>
<td>3,774</td>
</tr>
<tr>
<td>Noordam</td>
<td>HAL</td>
<td>1,920</td>
<td>5</td>
<td>9,600</td>
</tr>
<tr>
<td>Prinses Daphne</td>
<td>World Cruises</td>
<td>500</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>Prinsendam</td>
<td>HAL</td>
<td>835</td>
<td>1</td>
<td>835</td>
</tr>
<tr>
<td>Queen Elizabeth</td>
<td>Cunard</td>
<td>2,175</td>
<td>1</td>
<td>2,175</td>
</tr>
<tr>
<td>Rotterdam</td>
<td>HAL</td>
<td>1,920</td>
<td>1</td>
<td>1,920</td>
</tr>
<tr>
<td>Seaborn Quest</td>
<td>HAL</td>
<td>450</td>
<td>2</td>
<td>900</td>
</tr>
<tr>
<td>Silver Whisper</td>
<td>Silver Cruises</td>
<td>382</td>
<td>2</td>
<td>764</td>
</tr>
<tr>
<td>Statendam</td>
<td>HAL</td>
<td>1,258</td>
<td>1</td>
<td>1,258</td>
</tr>
<tr>
<td>The World</td>
<td>--</td>
<td>200</td>
<td>2</td>
<td>400</td>
</tr>
<tr>
<td>Vision of the Seas</td>
<td>Celebrity/RCCL</td>
<td>2,345</td>
<td>5</td>
<td>11,725</td>
</tr>
<tr>
<td>Westerdam</td>
<td>HAL</td>
<td>1,918</td>
<td>1</td>
<td>1,918</td>
</tr>
</tbody>
</table>

Total season 2012-2013 136 148,863

As can be seen in table 3, the companies face several expenses on Bonaire: payments to the government, the tour operators and port services. As Bonaire is part of the itinerary of a cruise in which multiple islands are visited, it is difficult to determine the profits for cruise companies with regard to the cruise industry on Bonaire specifically. However, since none of the cruise companies have operations on Bonaire, it is more important for this research to determine the income streams from the cruise companies to the dependent parties on Bonaire.

Table 3  Overview of the required port services

<table>
<thead>
<tr>
<th>Port services</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour dues</td>
<td>Extra launch</td>
</tr>
<tr>
<td>Wharfage</td>
<td>Extra line boat</td>
</tr>
<tr>
<td>Pilotage (in+out)</td>
<td>Line handling</td>
</tr>
<tr>
<td>Pilot launch (in+out)</td>
<td>Agency fee</td>
</tr>
</tbody>
</table>

³ The total number of cruise tourists on this table does not correspond to the number of cruise tourists used in this report for the year 2012, because the table shows the estimated cruise tourist arrivals on a season basis (i.e. two broken years: from November 2012 to April 2013).
2.5.2 Government

Governmental income is the first financial flow that we identify entering Bonaire through the cruise line companies. The cruise companies pay a head tax to the Bonairean government of $2 per tourist measured by the capacity of the vessel. For the crew, no taxes are paid.

2.5.3 Shipping agencies

The second cost for the cruise companies are expenses for port services that are provided by two shipping agencies. Mooring the ship at a Bonairean pier requires more than simply throwing the lines out. The services that are necessary are displayed in Table 3. These are provided by two companies that operate on Bonaire: BAS shipping and Maduro & sons. For some services the port of Bonaire receives a share through the shipping agencies. Total costs range between $3,500 to $5,500 per vessel for different sizes and companies.

2.5.4 Tour operators and suppliers

A large share of tourists explores Bonaire by booking an organised tour with a tour operator before they arrive. Bonaire Destination Services (BDS) and Bonaire Tours and Vacations (BT&V) are the islands operators that offer an assortment of tours. The tours are sold to the cruise companies, which sell them to the tourists. Tour operators charge between $20 and $40 for their tours. BDS and BT&V (personal communications, June 2012) estimate that the prices paid by tourists on-board of the cruise ships are roughly 180% to 200% of the prices the tour agencies charge to the cruise companies. BT&V sold around 24,000 tours in the 2011-2012 season but estimated a decline in 2012-2013 because of the expected decline in cruise tourists.

The tour operators then buy the tours from tour suppliers that run their own enterprise, but are connected to the tour agencies (so called sub-contractors). Table 4 presents the list of tour suppliers that are connected to BT&V. The mark-up the operators charge is estimated to be around 25% of the price that a supplier asks for a tour (based on interview with local expert, 2013). We estimate that at least 45 people are involved in the tour industry on a full-time basis and roughly 30 on a part-time basis.

Table 4 Tour suppliers connected to BT&V (as of 2012)

<table>
<thead>
<tr>
<th>Operators that are connected to BT&amp;V:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The Seacow</td>
</tr>
<tr>
<td>• Dive Friends</td>
</tr>
<tr>
<td>• The Mangrove Center</td>
</tr>
<tr>
<td>• Butterfly Farm Bonaire</td>
</tr>
<tr>
<td>• The Bike Shop</td>
</tr>
<tr>
<td>• Mushi-Mushi Sailing</td>
</tr>
<tr>
<td>• Achie Tours</td>
</tr>
<tr>
<td>• Tropical Travel</td>
</tr>
<tr>
<td>• Bowalie Yachts</td>
</tr>
<tr>
<td>• Windows at the Sea</td>
</tr>
<tr>
<td>• Bigfoot Tours</td>
</tr>
<tr>
<td>• Piskatur Fishing Charters</td>
</tr>
<tr>
<td>• Mangazina di Rei</td>
</tr>
</tbody>
</table>
2.5.5 Independent tour suppliers

Not all tours and activities are booked on board of the ships. In the period of 2012-2014, there was a substantial part of cruise tourists that booked their tours independently. Near the pier, there is a little market where independent tour suppliers (that are not connected to a tour operator) can sell their tours. However, many tours are booked online in advance.

There are some tour operators that use both tour agencies and sell tours independently. Most of the independent tour operators are connected to the Bonaire Explorer Association (BEA), which aims to organise the independent operators and smoothen operations at the pier. The organization does not sell tours.

2.5.6 Taxis

Not all tourists decide to take an organised tour. Taxi drivers can be hired to visit specific locations, but they can also offer tours around the island. Based on an interview with an expert of the Tourism Corporation Bonaire (TCB), in 2012 there were around 36 licensed taxis active on Bonaire, which could transport around 285 tourists at once. When there are two cruise ships on Bonaire the capacity is not sufficient and an additional 9 drivers are allowed to drive cruise tourists around the island. See Table 5 for an overview of the capacity per taxi and an estimate of their earnings.

Normally all taxi drivers make at least one trip on a day that a cruise boat arrives. It is usually not possible for the drivers to make more than 2 trips on one day and a transport drive to the Sorobon area. The average tour costs around $25 per person and the trip to Sorobon $10 dollars for a return. This means that taxi drivers in aggregate earn at least $7,125 per day and a maximum of $17,100 per day if every driver does two tours and a transport on a day with one cruise ship. Including all auxiliary drivers, these potential revenues rise to $8,175 and $19,620.

Table 5 The capacity and earnings of taxis and auxiliary drivers

<table>
<thead>
<tr>
<th>Taxis</th>
<th>Capacity per taxi</th>
<th>Amount of taxi</th>
<th>1 tour (25 USD$ per seat)</th>
<th>2 tours + transport (60 USD$ pp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6</td>
<td>$600</td>
<td>$1,440</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>$600</td>
<td>$1,440</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>20</td>
<td>$4,000</td>
<td>$9,600</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>$275</td>
<td>$660</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>$600</td>
<td>$1,440</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>$1,050</td>
<td>$2,520</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>36</td>
<td>$7,125</td>
<td>$17,100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Auxiliary drivers</th>
<th>Capacity</th>
<th>Amount</th>
<th>1 tour (25 USD$ per seat)</th>
<th>2 tours + transport (60 USD$ per seat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7</td>
<td>$700</td>
<td>$1,680</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>$150</td>
<td>$360</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>$200</td>
<td>$480</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>9</td>
<td>$1,050</td>
<td>$2,520</td>
</tr>
</tbody>
</table>
2.5.7 Other business owners

A range of additional expenditures is made by cruise tourists. Tourists do spend some money on food and beverages during their stay. But also buy local goods from retailers or market stall vendors. Schep et al. (2012a) estimated these expenditures to be on average $28.50 on shopping at retailers and $9 on food and beverages, both per cruise tourist. For 158,000 cruise tourists during a year, this would amount to $4.5 million for retailers and $1.4 million for the cafeteria.

Retailers and cafeteria that are likely to benefit most from cruise tourism are the ones that are located on the promenade near the cruise pier and on and around the Kaya Grandi. We estimate that between 25 and 35 cafeteria, 20 to 25 retailers and around 8 market vendors in Kralendijk benefit from the cruise tourists. The establishments at Sorobon (the Beach Hut in particular), Plaza and the Spice Beach Club are also likely to benefit. 7 percent of our cruise respondents visited Sorobon and 13 percent visited Eden Beach (the Spice Beach Bar beach). The amount of visitors to Plaza is unknown. Based on the data collected in the business survey by Wolfs Company in 2014 (Wolfs Company, in preparation), we estimate that 40% of the customers in the retail sector are cruise tourists. In the food and beverages sector, this is estimated to be 17.5%.
3 Methodology: Economic input-output and environmental indicators

3.1 Introduction

In the previous chapter, the cruise tourism industry in Bonaire was presented. We will use an input-output model (IO Model) to analyse the economic and environmental impact of different scenarios of cruise tourism in Bonaire. This model will help us calculate the effects for the economy from an increase in the number of cruise tourists. In addition, the model will also allow us to explore how an increase in the number of cruise tourists will impact the environment and how this will affect the natural stocks required for the economic development in the island. In the first section of this chapter, we will present the number of tourists that is used as the starting point for the scenario analysis. Next, we will briefly introduce the GDP figures of Bonaire and the method for calculating the economic value of cruise tourism. In section 3.4, we will refer to some of the external environmental effects of cruise tourism. In the last section, the IO Model will be explained, including its ecologic module.

3.2 Number of tourists

Bonaire receives around 80,000 stay-over tourists and around 150,000 cruise tourists per year. For the IO Model, the number of tourists that arrived in Bonaire in 2012 is used as the starting point. In 2012, 80,000 stay-over tourists arrived in Bonaire by plane. The stay-over tourists stay on average 7 days on Bonaire (CBS, 2014c).

In 2012, cruise ships with an average capacity of 1,500 cruise passengers per ship, visited Bonaire (CBS, 2014c), for a total of approximate 158,000 cruise tourists. This total estimate is based on the actual total passenger of the ship that arrived. While there is no official account of how many passengers actually disembark on Bonaire, we have assumed that 100% of the passengers disembark (see 2.4.1 for the calculations that support this assumption). The cruise ship tourists that disembark spend on average 6 hours on the island (Schep et al., 2012a).

3.3 The economic value of cruise tourism

3.3.1 GDP and economic industries

Bonaire’s GDP in 2012 was $372 million (CBS, 2014b). As presented in Figure 9, the hotels and restaurants industries, which are the most evidently affected by the number of tourists visiting Bonaire, represent an important economic pillar of Bonaire’s economy. However, most of the other industries also benefit from tourists visiting the island, such as manufacturing; trade; transport and communication, and other services.

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*The IO Model was developed by Van Zanten and Koks (2015) commissioned by Wolfs Company as part of its Green Economy project in Bonaire. It provides a tool to test the economic and environmental impacts of potential policy decisions. Given that tourism is such an important pillar in Bonaire’s economy, it was designed to also allow testing scenarios of tourism development.

*Based on the figures of the CBS for the years 2012 and 2013.
Visitors are attracted by the unique combination of terrestrial and marine ecosystems and the variety of activities they can enjoy on the island, such as diving, snorkelling, kayaking, windsurfing, sailing and bird watching (Info Bonaire, 2012).

The division in economic industries shown in Figure 9 is based on the industry classification used in the IO Model (as further explained in section 3.5 below), which follows the international standards for industrial classification of economic activities developed by the United Nations. Since tourism is not one of these industries, it is difficult to measure the total percentage of the GDP that represents the value added of the expenditures made by tourists that visit Bonaire. In the next section, we will present an economic valuation of the tourism in Bonaire. In addition, and as further explained in section 3.5 below, the IO Model will be used to calculate how a change in the number and composition of tourists will modify the production in the different industries and ultimately the added value to the economy by these industries.

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*The portion of Bonaire’s GDP that is attributed to taxes and subsidies ($15 million) is not depicted in Figure 9.*
3.3.2 An economic valuation of tourism

According to the definitions of Hein (2010) and van Beukering et al. (2007b) tourism is identified as a direct-use value. It is different from a direct-use provisioning ecosystem service like fisheries in the sense that there are no physical goods that represent the benefits. The benefits are intangible experiences. A market valuation technique is therefore not always applicable, since the services are not necessarily traded on a market; i.e. tourists can easily benefit from the ecosystems on their own. There are a few possibilities to value touristic ecosystem services, of which the willingness to pay net factor income and the production function approach are the most similar to the market valuation technique described by Hein (2010). By investigating what tourists pay to consume a particular ecosystem service, the net income value of that amount can be calculated to determine the producer surplus of the service. Using the composite value of the Producer Surplus (PS) and the Consumer Surplus (CS), the total ecosystem service value of tourism on Bonaire has already been calculated by Schep et al., (2012a). The valuation and aggregation procedure is also explained in that study. For a detailed description of the results of the tourist survey, see Schep et al. (2012a).

Below, we will update the results of the CS obtained in the TEEB study, based on the baseline number of tourists (see section 3.2). Afterwards, we will explain how the expenditures made by tourists will be used in the IO Model in order to determine tourists’ contribution to Bonaire’s economic industries.

Consumer surplus

As mentioned in the TEEB study, the CS is calculated using the WTP estimates determined in the Choice Experiment. This CS is also valid for the ecosystem services that are not paid for. For example, hiking around Bonaire is only valued by means of the CS, since it is not a service that is bought from a provider.

Based on the results of the Choice Experiment, which were corrected for confidence and to prevent biases caused by an overrepresentation of stay-over tourists in the sample, the TEEB study arrived at a total WTP for cruise tourists for ecosystem protection (terrestrial and marine environment), environmental management, maintaining safety and tempering the crowdedness on the island of $7,900,000. Table 6 shows an update of the CS values obtained in the TEEB study according to the number of tourists in 2012. There is no significant difference in the WTP for stay-over and cruise tourists. However, because stay-over tourists stay roughly 10 days longer compared to cruise tourists (who only visit for a day), Average WTP per trip is a factor 10 times higher for stay-over tourists.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Average WTP stay-over</th>
<th>Total WTP stay-over (82,000)</th>
<th>Average WTP cruise</th>
<th>Total WTP cruise (158,000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine environment</td>
<td>$219</td>
<td>$17,958,000</td>
<td>$21</td>
<td>$3,318,000</td>
</tr>
<tr>
<td>Terrestrial environment</td>
<td>$21</td>
<td>$1,722,000</td>
<td>$2</td>
<td>$316,000</td>
</tr>
<tr>
<td>Environmental management</td>
<td>$41</td>
<td>$3,362,000</td>
<td>$4</td>
<td>$632,000</td>
</tr>
<tr>
<td>Safety</td>
<td>$186</td>
<td>$15,252,000</td>
<td>$18</td>
<td>$2,844,000</td>
</tr>
<tr>
<td>Crowdedness</td>
<td>$54</td>
<td>$4,428,000</td>
<td>$5</td>
<td>$790,000</td>
</tr>
</tbody>
</table>

Table 6 Total WTP for maintenance of the marine and terrestrial environment, for extra environmental management, and for maintaining the safety and tranquility of the island (in US$ per year)
Since there is no tourism satellite account (TSA) available for Bonaire, data from several sources is used to acquire an estimation of the tourism expenditures of both the stay-over and cruise tourists. Trade data has been obtained from the Statistical Office of the Netherlands (CBS) for the year 2012 and the results of the tourist exit survey, conducted by Schep et al. (2012a). With this data, several steps are taken to come to the specific tourism expenditures. To start with, the expenditure pattern of a stay-over and a cruise tourist is identified. More specifically, the products and services that are identified in the tourist exit survey, including the amount of money spent on these goods and services, are allocated to the different sectors. For instance, the amounts spent on accommodation by a stay-over tourist are allocated to the hotel sector. The next step is to determine the total tourist expenditures, based on the amount of stay-over and cruise tourists that come to the island yearly. In 2012, there were 82,000 stay-over tourists and 158,000 cruise tourists (CBS, 2014a). Finally, these tourist expenditures have been slightly rescaled to match with the total export minus the export trade data in the IO Model. In the model, it is assumed that all cruise tourists disembark from the cruise ships.

3.4 The environmental impact of cruise tourism

3.4.1 Tourist-related impacts

Coral reefs and consequently beach ecosystems are threatened through various global and local forces. The global level lies outside Bonaire’s mitigation capabilities, the local threats posed to coral reefs, however, lie within the control of Bonaire and can be avoided through sustainable management. One of the threats posed to coral reefs at the local level is through the increase in tourism (Burke and Maidens, 2004). Cruise tourism results in large groups of people visiting natural and cultural sites in a short period of time. Increase in cruise ship tourism can lead to overcrowding and congestion in a short time frame. The overcrowding issue in this case has two aspects. The first is an environmental threshold, such as for solid waste disposal and sewage treatment. The second is the perception of overcrowding because of cruise visitors using recreational areas (Sorobon survey, 2010). The Caribbean reefs are at serious risk, caused by many stressors such as sediment run-off, untreated waste and pollution from cruise ships and an increase in the amount of tourists on the island.

Tourism is an important driver behind the economy of Bonaire. However, this economic contribution comes with a price. The economic benefits derived from tourist expenditures and income for local residents has also a costs side. Costs not only include operational costs, but also economic leakage, social and environmental costs.

Cruise tourism environmental impact

Tourists are attracted to conservation areas whereas these areas encounter the worst environmental damage (Davenport and Davenport, 2006). As a result of high numbers of visitors in a short period, the carrying capacity of fragile areas can be exceeded and in some cases impacts are irreversible (Debrot et al., 2012). Johnson (2002) uses a life-cycle analysis to define the different types of cruise tourism impacts. This resulted in:

- Infrastructure impacts, such as the construction of cruise passenger terminal facilities and its modifications necessary to the natural environment;

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7 Adapted from Van Zanten and Koks (2015).
• Operational impact involving energy, water usage and impact of the cruise ship on the marine environment;
• Distribution impacts by supplying a cruise liner with provisions (not a major contributor on Bonaire, because the provision of food and water to the ships is limited, (pers. comm. cruise ship agency on Bonaire));
• Use impacts of tourism visiting the island, such as water use, driving around etc.;
• Waste impacts of the cruise ship (Bonaire does not have the proper equipment to process waste from ships and is therefore able to refuse the acceptance of waste by cruise ships).

Furthermore, the environmental impact can be direct and indirect. With direct impact we mean impact by activities tourists undertake causing physical damage and ecological disturbance on Bonaire. Indirect impact is defined as impact to coastal habitats caused by development of marine recreational activities and related pollution, such as sewage and waste on Bonaire. For an overview of activities with direct and indirect impact, see Annex E.

**External effects in the model**

The IO Model focuses on certain impacts, denominated *External Effects*, which are caused by the economic activity in general but which are also influenced by the number and composition of tourists. These external effects are: physical reef destruction, nutrient concentration and sedimentation. These external effects are taken into account in the IO Model to calculate how the changes in numbers of tourists may impact the environment. These external effects, as well as how they are accounted for in the model, are further described in section 3.5.

**Other impacts**

There are other environmental impacts of cruise tourism, which were investigated but which could not be taken into account in the model. These include nutrient enrichment and toxic effects by sunscreen contribute to the possibility of going over the threshold of beach carrying capacity. For information on each of these other impacts see Annex F – Other socio-environmental impacts of cruise tourism

### 3.4.2 Ecological footprint of cruise ships: Acquatrail

Cruise ships also have an ecologic footprint on the coastal waters of Bonaire. Marine Positive developed a model in cooperation with the Polytechnic University of Marche, Italy, called Acquatrail (www.marinepositive.com). The Acquatrail is the aquatic equivalent of the carbon footprint in the sense that it takes water pollutants into consideration, i.e. gaseous, liquids and solids that damage aquatic environments. By contributing alongside carbon and water footprints it provides a holistic picture of anthropogenic impacts on marine environments. The Acquatrail accounts for multiple stressors on the affected ecosystems. The data required for the input of the Acquatrail calculations was provided by IMARES, a research institute that is part of Wageningen University. Given that it is difficult to calculate in a reliable manner the impacts of this ecological footprint in the Bonaire economy, this footprint was not incorporated in the IO Model. For the results of the calculation of the ecological footprint of cruises in Bonaire, see Annex G – The ecological footprint of cruise ships.
3.5 The IO Model with an ecological module

3.5.1 Bonaire’s IO Model

Standard input-output (IO) models are, in their most basic form, a simple system of equations, each one of which describes the distribution of an industry’s product throughout the economy. More specifically, IO models describe the economy through sets of interrelationships between sectors themselves (the producers) and others (the consumers). These interrelationships between sectors are driven by intermediate demand and come as a result of fixed production coefficients in each sector. In an IO model, the ‘world’ is assumed to be demand driven, which means that the production in industries is driven by the final demand. The final demand in itself consists of the demand from consumption of goods from households, governments, exports and investments. IO models are the basis of IO tables, which can be described as a numerical representation of the economy, showing all the economic relations previously described. In this section, we will briefly explain how the IO table for Bonaire, including specific tourism exports, has been constructed. This table forms the basis of Bonaire’s IO Model, which will also be explained in this section. Finally, we will explain how this model will be used to compare cruise tourism scenarios by looking at the multiplier effects and the environmental impacts.

Bonaire’s IO table and IO Model

An input-output (IO) table can be defined as a table that shows, in monetary units, an overview of all the transactions within and between sectors and other economic actors in a given region (such as households and governmental agencies), for a specific region and for a specific time period (Miller and Blair, 2009). One of the key inputs for an IO table is a supply and use table (SUT). A supply table describes the supply of goods and services, which are either produced in the domestic industry or imported. The use table shows where and how goods and services are used in the economy. Furthermore the use table shows the income generated in the production process (Eurostat, 2008).

The IO table for Bonaire is based on the SUT of Bonaire, developed for the year 2004 by the Statistical Bureau of the Dutch Antilles. The compilation of the resulting IO table is almost fully based on the work of Van De Steeg (2009) and Steenge (2010). Bonaire’s IO table is further an industry-industry table with a fixed product sales structure, known as ‘model D’ (Eurostat, 2008). This means that that the table describes the economy in terms of industries interacting with each other and that each product is assumed to have its own specific sales structure, irrespective of the product mix. Given the particular characteristics of Bonaire’s economy, the SUT table was slightly adjusted to be able to apply model D.

Due to the differences in the economy (changes of government structure, etc.) and currency (from Antillean Guilders to US dollars) since 2004, Bonaire’s IO table is updated to 2012, using the latest GDP numbers published by the Dutch statistical bureau (CBS). It is important to note that this update is based on rough estimates of the GDP and no changes have been made to the economic structure of the island. Since 2010, however, the island has undergone some strong institutional changes in the government sector. As such, it is (even more) important that outcomes of the model should be interpreted only as rough estimates.

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8 Sections 3.5 to 3.7 have been taken and adapted from Van Zanten and Koks (2015).
9 For an explanation on IO tables in general, see Annex H – Input-Output Tables.
10 For an overview of the adjustments applied, see Van Zanten and Koks (2015).
In the standard IO model, Wassily Leontief makes a number of assumptions to keep his model simple (Leeuwen et al., 2001):

- It is a linear model. In other words, no economies of scale are possible.
- Substitution between inputs in the basic IO model is not possible.
- The basic IO model does not take into account that there are limits to the production capacities of firms.
- The model considers that all firms are homogenous in each sector.

To be able to perform a standard IO analysis, technical coefficients must be defined. For an overview of the technical coefficients, see Annex I – IO Coefficients.

### 3.5.2 The ecological module

To show the consequences of economic activity as well as the economic importance of ecosystem services, an ecological module was created and linked to the IO Model. The ecological module is based on the marine module of the dynamic ecological-economic simulation models developed by Cado van der Lelij et al. (2013; 2014) for Bonaire, Saba and St. Eustatius. It is linked to the IO Model through externalities and the ecological inputs (i.e. ecosystem services) of sectors in the economy of Bonaire. To improve the performance and to ensure compatibility with the IO Model, a number of modifications were made to the original model developed by Cado van der Lelij et al. (2013). In the following sub-sections, we will briefly outline the concept of system-dynamic stock and flow models. We also describe the module development by describing each external effect and ecologic input. The geographical coverage of the ecological module is the leeward side of Bonaire. This choice is justified as the windward-side of the island is hardly used for recreational purposes and is affected by anthropogenic stressors to a lesser extent. The ecological module was further calibrated using historical data (see Annex J – Calibration of the ecological module using historic data).

#### System-dynamic stock and flow models

To model and improve understanding of non-linear dynamic systems, such as coral reefs, system-dynamic models are a powerful tool to describe the main components of a system and their interactions over time (Chang et al., 2008). The components of a system are described as set of key state indicators (e.g. stocks), such as coral cover or a capital stock in the economy (Costanza and Ruth, 1998). The state indicators are affected by periodical flows such as annual fish catch or an annual investment in the capital stock. The ecological module linked to the IO Model only describes the ecological system. It is connected to the macro-economic IO Model through external effects and ecological inputs that are a consequence or a prerequisite for economic activity.

#### Conceptual Framework

Figure 10 shows the conceptual framework of this ecological module. The grey box represents the IO Model. Connected to the IO Model are the external effects of, and ecological inputs (i.e. ecosystem services) for, economic activity on the island. The marine ecosystem is affected by the external effects as well as by fishing and indirectly by land use, both of which are defined as ecological inputs. The ecological input ‘coral reef use’ describes what percentage of the social carrying capacity of the coral reef is used. This input is determined by both the production in the dive sector and available coral cover. The conceptual framework identifies three types of benthic cover: coral cover, algae cover and a rest category that consists of sand, rubble (e.g. dead corals) and sponges. In the reef ecosystem, corals and algae are competing. Higher levels of algae cover decrease the coral expansion rate and higher nutrient concentrations
cause a higher algae expansion rate. The stock of grazing herbivory fish ('Herbivory biomass'), however, controls growth of algae cover by constraining its carrying capacity. The stock of herbivory fish is controlled by the stock of predatory fish, which is affected by fishing. In addition, the carrying capacity of coral cover (i.e. the maximum potential) is constrained by the rate of sedimentation on the reef caused by terrestrial runoff, which depends on the type of land use and the level of (over)grazing. Finally, coral cover is affected by physical destruction as a result of diving activities.

Figure 10 - Conceptual framework of the ecological module and the connection to the IO model.

3.6 External effects

3.6.1 Physical reef destruction

Several studies from the Caribbean and the Red Sea have reported that diving activities damage coral reefs by touching corals (Dixon et al., 1993; Hasler and Ott, 2008; Hawkins et al., 2005; Tratalos and Austin, 2001; Zakai and Chadwick-Furman, 2002)\(^\text{11}\). In the ecological module, it is assumed that 50% of the damaged coral dies-off. We stress that this assumption is a gross approximation. Many studies attempted to quantify the relation between diving activity and damage to coral colonies (e.g. Jameson et al., 1999; Zakai and Chadwick-Furman, 2002), but the effect on live coral cover is rarely examined (Hawkins et al., 1999).

In the module, the total number of dives per year is linked to the production of the dive sector in the IO Model. In the baseline year, 2012, we assumed a total number of approximately 870,000 dives, based on an estimate provided by STINAPA 750,000-

\(^{11}\) See full references in Van Zanten and Koks (2015).
1,000,000 (pers. com. Frank van Slobbe). This corresponds to 22 dives per diving stay-over tourist (36,000, 44% of total stay-over tourists), 30 dives per diving resident (2,000) and 2 dives per diving cruise tourist (16,000, 4% of total cruise-tourists). In the baseline, 2012, this means that there are 11,500 dives per site on 75 good quality dive sites, resulting in an annual die-off of 1.9% of the total coral cover.\(^\text{12}\)

3.6.2 Nutrient concentration

Nutrient enrichment or eutrophication of coastal waters can lead to algal overgrowth of coral reefs (Hughes et al., 2010; Rogers, 1990).\(^\text{13}\) Higher concentrations of nitrates and phosphates are often a result of sewage (e.g. from septic tanks, open sewage systems, yachts) and sediments that contain nutrients (Cado van der Lelij et al., 2013; Slijkerman et al., 2014). As proposed by Cado van der Lelij et al. (2014), we use phosphate (PO\(_4\)) concentration as a proxy-variable for the total nutrient concentration. Although Chorophyll A is considered to be a more appropriate indicator for eutrophication of the, there is no long term monitoring data available. This information is available for phosphate.

According to observations by Slijkerman et al. (2014), the current average PO\(_4\) concentration in the sensitive zone of the Bonaire’s leeward-side is 0.049μmol/g. Nutrient concentration is linked to the IO Model using the findings of Bonaire’s waste management action plan; 68% of nutrient leaching along the leeward shore is attributable to the hotel sector, 14% to cruise tourism (which is part of the transport sector) and 18% to the real estate sector.

3.6.3 Sedimentation

Sediments on the reef caused by terrestrial runoff can bury the corals or damage them. As a result of sedimentation corals smother because there is less light available for photosynthesis (Fabricius, 2005; Hughes et al., 2010; Rogers, 1990).\(^\text{14}\) Often, there is a direct relationship between the land-use in the coastal watershed and sedimentation rates on adjacent coral reefs (Brodie et al., 2012; Hunter and Evans, 1995)\(^\text{15}\) because barren or agricultural land is characterized by higher erosion and runoff levels than vegetated land. Following Cado Van Der Lelij et al. (2014), we have defined the sedimentation rate as a constraint to the carrying capacity of coral cover (i.e. the highest level to which coral cover can grow) (see Figure 10). The sedimentation rate is deducted from the maximum potential level of coral cover on Bonaire, which is set at 57%. With a low sedimentation rate of about 3 (which means that most of Bonaire is covered by shrubs or woodland), this number corresponds to the earliest observed data from 1970s of around 54% coral cover (Bak et al., 2005). In the module, the sedimentation rate is determined by the composition of land use classes on Bonaire. Barren or overgrazed agricultural land strongly contributes to runoff and sedimentation as well as unpaved roads in urban areas. Healthy shrub and woodland have low levels of runoff. To link sedimentation rate to the IO Model, land use and the type of land use per sector was estimated using the Bonaire spatial development plan (Eilandgebied Bonaire, 2010).

\(^{12}\) For a detailed overview of available historic data on this topic, see Van Zanten and Koks (2015), Annex 1.

\(^{13}\) See full references in Van Zanten and Koks (2015).


\(^{15}\) See full references in Van Zanten and Koks (2015).
3.7 Ecological inputs

3.7.1 Land use

Every sector in the economy uses a certain area of land. As sectors grow or decline, the amount of land they use will increase or decrease and direct and indirect effects of changing land use will affect the ecological system. Using Bonaire’s spatial development plan, land was allocated to sectors. Table 7 shows the allocation of land use over the different sectors for the baseline year. The amount of arable land was estimated at 110 hectares (pers. comm. Jan Jaap van Almenkerk), the area of overgrazed land was estimated following Cado Van Der Lelij et al. (2014).

Table 7: Land use by sectors in the economy of Bonaire in the baseline year

<table>
<thead>
<tr>
<th>Sector</th>
<th>Land use class</th>
<th>Land use (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, fishing, mining</td>
<td>Arable</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>Overgrazed</td>
<td>3198</td>
</tr>
<tr>
<td></td>
<td>Shrubs/woodland</td>
<td>2720</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Built-up</td>
<td>94</td>
</tr>
<tr>
<td>Electricity, gas, and water supply</td>
<td>Built-up</td>
<td>140</td>
</tr>
<tr>
<td>Construction</td>
<td>Built-up</td>
<td>30</td>
</tr>
<tr>
<td>Trade</td>
<td>Built-up</td>
<td>114</td>
</tr>
<tr>
<td>Hotels</td>
<td>Built-up</td>
<td>405</td>
</tr>
<tr>
<td>Restaurants</td>
<td>Built-up</td>
<td>4</td>
</tr>
<tr>
<td>transport and communication</td>
<td>Built-up</td>
<td>610</td>
</tr>
<tr>
<td>Financial Intermediation</td>
<td>Built-up</td>
<td>2</td>
</tr>
<tr>
<td>Other real estate activities</td>
<td>Built-up</td>
<td>1780</td>
</tr>
<tr>
<td>Public administration and defense</td>
<td>Built-up</td>
<td>113</td>
</tr>
<tr>
<td>Education</td>
<td>Built-up</td>
<td>19</td>
</tr>
<tr>
<td>Health</td>
<td>Built-up</td>
<td>17</td>
</tr>
<tr>
<td>Other services</td>
<td>Built-up</td>
<td>73</td>
</tr>
</tbody>
</table>

3.7.2 Coral cover use

This variable describes the share of the reef’s social carrying capacity that is used for diving. Social carrying capacity is a concept that incorporates crowding on dive sites as a limiting factor (Davis and Tisdell, 1995). The level for the social carrying capacity is established using a threshold proposed by Schuhmann et al. (2013). Schuhmann et al. (2013) state that divers only derive a positive utility from a dive if they encounter seven or less than seven other divers on the site. Assuming 10 ‘divable’ hours per day, an average time spent on the dive site of 1.5 hours, and 75 good quality dive sites, a diver on Bonaire in the baseline year encounters on average 4.7 other divers on the dive site. This equals a current coral cover use of 68% of the social carrying capacity.
3.7.3 Other environmental impacts studied in the scenario analysis

The following two impacts of tourism activity are also used in the scenario analysis in the next chapter. These two impacts have not been included in the ecological module described above. Therefore, the calculation of the effects of the number of tourists in the different scenarios is calculated separately from the IO Model.

Water usage

Desalination through seawater reverse osmosis (SWRO) is the main source of drinking water on Bonaire (Reijtenbagh, 2010). The desalination plant produces 3.2 million litres of drinking water per day (transpack.nl) and has the capacity of producing 4.3 million litres of drinking water per day (Bonaire Investment Guide, 2003). General Electric produces this drinking water for Bonaire and WEB (governmental organisation) distributes the water to the households, hotels and establishments. Several hotels and resorts produce their own drinking water.

A second source of fresh water is the sewage water treatment plant, which produces up to 478,000 litres per day. The purified water is used for irrigation in agriculture and hotel gardens and is not suitable for consumption. The recently constructed second sewage water treatment plant will increase the production of fresh water for irrigation.

The last source of fresh water in Bonaire is rain. However, since the average rain fall in Bonaire is around 550 mm per year, which is a small amount compared to the production of the desalination and sewage water treatment plants and considering that it is unknown how much of the rain actually is collected, rainfall will not be taken into account in further calculations.

The local population of Bonaire in 2012 consisted of 16,541 people with a water consumption of 175 litres per capita per day (Chase, 2009).

The assumption is that cruise tourists use 40 litres of drinking water per capita per day, based on one water or land-based activity, toilet usage and consumption. We further assume that cruise ships are not supplied by Bonaire with fresh water. The average water use of the cruise tourists in 2012 can be calculated multiplying the water use of a cruise tourist per day (40 litres) with the cruise tourist arrivals for that year (158,000 cruise tourists in 2012) with the average length of stay of 1 day, which results in is 6,320,000 litres.

Table 8 Assumed water usage by tourist per day (Gossling et al., 2012)

<table>
<thead>
<tr>
<th>Water use category - direct</th>
<th>Litres per tourist per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodation</td>
<td>84 - 2000</td>
</tr>
<tr>
<td>Activities</td>
<td>10 - 30</td>
</tr>
</tbody>
</table>

According to Gössling et al. (2012) stay-over tourists use 140 more litres of water on holidays than at home, see Table 8. The biggest water users are hotels (irrigation of their gardens, daily cleaning of hotel rooms, offering of swimming pools, the cooking and laundry for their guests) and a more recreational approach of tourists towards water use compared to their water usage approach at home (Eurostat, 2009). Water-saving technologies could save 30% of the in- and outdoor water consumption in hotels (Cooley et al., 2007 and O’Neill et al., 2002).

A rough estimation of the average water use on the island based on the 2012 visitation adds up to 3.4 million litres per day, see Table 9.
Table 9 Overview of water usage per day per group of persons in 2012

<table>
<thead>
<tr>
<th>Water usage</th>
<th>Litres per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residents</td>
<td>2,894,675</td>
</tr>
<tr>
<td>Stay-over tourist</td>
<td>495,370(^{16})</td>
</tr>
<tr>
<td>Cruise tourists</td>
<td>23,087(^{17})</td>
</tr>
<tr>
<td>Daily average</td>
<td>3,413,132</td>
</tr>
</tbody>
</table>

Note: No data considering the water use of agriculture and industry could be found.

There is a threat regarding the use of SWRO techniques in desalination plants. Not all aquatic microorganisms can be removed by SWRO, leading to production of water which is not suitable as drinking water, and the aquatic microorganisms can pollute the filters used in SWRO, which in the long term also can lead to less well purified water (Henthorn, 2010). An unsustainable increase in tourism can lead to more nutrient rich water due to an increase in sewage and wastewater. This, in combination with increasing seawater temperatures will increase algal blooms (large concentrations of aquatic microorganisms). In the past few years several SWRO plants around the world temporarily had to stop desalination of seawater because of high concentrations of aquatic microorganisms (Henthorn, 2010). Other disadvantages of increasing dependence on desalination are an increase in energy consumption; desalination techniques are energy-intensive compared to other methods of water production and the need to import more fuels to run the desalination plant leading to additional emissions of greenhouse gases (UNEP, 1997).

**Litter (solid waste)**

On the island of Bonaire many different kinds of solid waste are generated. The types of waste range from food waste, plastics, paper, and garden waste to chemical waste including batteries for instance (Nam Trung and Kumar, 2015). All these types of waste are collected on Bonaire and brought to a landfill or stored, except for small batteries. In 2011, the department of infrastructure and environment initiated a first project to separate waste and introduce a recycling program. So far all waste has been brought to the landfill or stored despite any ecological dangers, except for small batteries. This has deep impacts on the environment and humans living in proximity. Chemical and toxic substances may reach the soil, groundwater, and air. The amount of solid waste generated in the Latin American and Caribbean Region by the local inhabitants per capita per day is according to the World Bank 1.1kg (Hoornweg and Bhada-Tata, 2012). However the waste production of 1 person on Bonaire is assumed to be 0.67 kilogram per person per day (Witteveen and Bos, 2011). This adds to a total amount of waste production by local inhabitants of around 4 million kilograms per year. Other research concludes that waste generated per cruise ship tourist is 3.5 kg per day for which it is assumed that half of it is generated on land during their excursion (Bonaire Investment Guide, 2003). This results in a total generation of approximately 277,000

\(^{16}\) This is calculated by multiplying the number of stay-over tourists in 2012 (82,000) by their average stay on the island (7 days) and dividing this between 365 days, which results in an average of 1.573 stay-over tourists per day. This average is then multiplied by an average use of 315 litres per stay-over tourist per day (140 litres more than the residents). However, it should be noted that the number

\(^{17}\) This daily average is calculated based on the length of the cruise season (274 days).
kilogram of solid waste by cruise tourists in 2012\(^{18}\). To pick-up, transport and process household waste costs $11.20 per 80 kilogram of waste\(^{19}\). Therefore the estimated cost of waste produced by cruise tourists in 2012 is $38,710, with a total of $747,261 for the total overall waste of local inhabitants, stay-over tourists and cruise tourists.

According to Witteveen and Bos (2011) between the 1,050 ton and 1,500 ton of waste is produced by business such as hotels and resorts of which a fragment is produced by cruise tourists through the usage of eat and drinking establishments. These establishments produce a total of 2,000 ton of waste per year\(^{20}\). Within the composition of the waste the percentage organic material and packaging, such as glass, plastics and paper is higher than in waste from households (Witteveen and Bos, 2011).

### 3.8 The use of the IO Model and environmental effects to compare cruise tourism scenarios

#### 3.8.1 Multiplier effects and cruise tourism scenarios

One of the key strengths of the IO methodology is the use of multipliers. By using the multiplier, we can determine how an exogenous impulse to the economy in a specific sector will affect not only the production of that sector, but also the production of other sectors that are supplying to that sector. In other words, the multiplier captures both the direct and indirect effects of an exogenous change to the economy. The Leontief inverse (Equation [8]), as explained in Annex I – IO Coefficients, can be used to determine this multiplier. For a better understanding of the multiplier, see Annex K – Example of the multiplier effects, which provides a small example.

As a result of tourism, the multiplier effect occurs as well. The additional number of tourists increases the demand in certain sectors directly. The sectors that benefit directly from cruise tourism are the manufacturing, trade, restaurant, transport, and other services sector. Because of the increased demand in these sectors, production grows. To facilitate this production, the demand in secondary sectors (financial mediation, construction etc.) increases as well. The increase in final production of the entire economy is therefore larger than the direct expenditures by the cruise tourists.

#### 3.8.2 Environmental impacts and cruise tourism scenarios

The cruise tourism scenarios that will be assessed in the next chapter will contain ecological effects as well. These ecological effects in the model are dependent on changes in the various economic sectors. Based on the changes in the economic sectors indicators for coral cover, land-use, sedimentation and nutrient loading change as well. Furthermore, the different economic sectors depend on the quality of the coral reef. The model calculates the percentage of the coral stock that is used as input to the production in economic sectors. If this percentage surpasses the 100%, this indicates that the economy of Bonaire needs more than the available coral stock to produce. In other words, that would be an unrealistic scenario.

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\(^{18}\) However the estimation of Witteveen and Bos (2011) is much lower, they estimate that 100,000 cruise tourists produce waste equal to ca. 275 residents of Bonaire.

\(^{19}\) Personal communication with Selibon in 2012.

\(^{20}\) Estimations are derived from a combination of estimates of Witteveen and Bos (2011) and actual figures of Selibon 2011.
4 Scenario analysis

4.1 Scenarios

In this scenario analysis, we assess certain socioeconomic and environmental effects of the development of the cruise tourism industry on Bonaire. Three different scenarios are analyzed: a baseline scenario, a moderate growth scenario and a rapid growth scenario. The scenario analysis starts in 2012, the last year for which the data required for the IO Model is available. The economic model runs for 12 years until 2024 and assumes no inflation and no growth of the domestic production through other factors than tourism. For the ecological effects, an additional 12-year prognosis is given to provide insight in the long-term effects through 2036. The tourism growth scenarios are depicted in Figure 11.

Using 2012 as a starting point, a baseline scenario is assumed for the number of cruise and stay-over tourists. In 2012, the amount of stay-over tourists that came to Bonaire was 82,000. The average growth in stay-over arrivals between 1999 (61,495 stay-over tourists) and 2012 was 2.2% per year. For the further analysis, we assume that this growth continues (although slightly slower) so that it reaches a total number of 100,000 stay-over tourists in 2024. Since the scope of this report is to assess the effects of changes in the cruise tourism sector, the amount of stay-over tourists will stay the same in each scenario we analyse. We do acknowledge, however, that the amount of stay-over tourists can be indirectly affected by an increase in the amount of cruise tourists. Stay-over tourists on Bonaire visit the island for its unspoiled beauty and tranquillity (Schep et al., 2012a) and there are indications that crowding might have a negative effect on their willingness to return (see Figure 5).

The cruise tourist arrivals, on the other hand, change in each scenario. Between 2001 and 2013, the cruise tourism industry has been subject to a volatile development, reaching its peak in 2010 with over 230,000 visitors and decreasing between 2010 and 2013. In the baseline scenario we assume that the amount of cruise tourist arrivals steadily recovers to a total of 200,000 tourists in 2024. In the other two scenarios we assume a growth in the number of cruise tourists. In the moderate growth scenario, we assume that the number of cruise tourists reaches a number of 400,000 tourists in 2024. For a regional reference: this is comparable to the amount of cruise visitors in Curacao in 2012 (431,555). For the rapid growth scenario, we assume that the number of cruise visitors reaches 650,000, which is comparable to the number of cruise tourists in Aruba in 2013 (688,568).
4.2 Effects on production and added value

In 2012, the combined total production for all economic sectors amounted to $633.9 million. For all scenarios the demand increases due to the increase in cruise and stay-over tourists. In respectively the baseline, moderate and rapid growth scenarios, total production amounts to $681.6 million, $724.9 million and $779.1 million.

The increased number of visitors has direct implications for the demand within certain sectors on Bonaire. Cruise tourists spend their money directly in the manufacturing, trade, restaurant, transportation and communication, and the other services sectors. Figure 12 presents the total production in each sector for the various scenarios in 2024. The figure also includes total production in the initial situation in 2012, which is the same for each scenario. It is clear that the sectors that depend directly on cruise tourism grow stronger as more cruise tourists arrive to the island. However, also other sectors grow indirectly as a result of the growing cruise tourism industry.

Hotels, on the other hand, do not seem to benefit from an increase in the cruise tourism industry. Although the sector’s production increases compared to the 2012 situation due to the growth in the stay-over arrivals, the production within the sector in 2024 is similar for the baseline, moderate and rapid growth scenarios. Construction; agriculture,
fishing and mining; and public administration do not seem to benefit from the growing tourism industry (both cruise and stay-over) at all.

The Bonairean Government aims to facilitate economic growth through the diversification of the island’s economy (OLB, 2014). In general, the sectors that benefit most from the increase in cruise tourism seem to be the largest economic sectors. This is not surprising, since tourism is the most important economic pillar on Bonaire. However, development in the cruise tourism industry does not contribute to the diversification of the economy that the island government aims to achieve.

Figure 12 – Total production in each economic sector.

4.3 GDP and household expenditures

To investigate whether the increase in production results in an increase in wealth on Bonaire, it is not relevant to look at the total production, which includes imports and the intermediate demand between economic sectors. Traditionally, the Gross Domestic Production (GDP) is considered to be an important indicator for wealth. Also household consumption provides an insight in the livelihoods of residents on Bonaire.
Table 10 presents household consumption and GDP in totals for Bonaire and per capita. All scenarios demonstrate an increase in total household expenditures and GDP. In the baseline scenario household consumption and GDP increase with respectively 6.5% and 6.7%. These percentages are logically higher in the growth scenarios. For the rapid growth scenario, both indicators increase with 20.3% and 22.4% compared to the initial situation in 2012. This does not necessarily mean an increase in wealth per capita for the people of Bonaire. The work force necessary to supply the increased demand for labour will require a growth of the population. This increase in work force cannot probably be realised by natural growth alone, but would probably result in more immigration.

Therefore, GDP and household consumption per capita give a better insight in the potential change of income for residents. Due to the large population increase, the increase in GDP per capita is much lower compared to the absolute increase in total GDP: 0.8% and 4.2% in respectively the baseline and rapid growth scenarios within a 12-year timeframe. The growth of the household consumption per capita is even slower; in the rapid growth scenario the annual consumption per capita is $234 higher than in the baseline scenario.

Table 10 – Household consumption and Gross Domestic Product (GDP) in total and per capita for each cruise tourism growth scenario. Note: for population growth it is assumed that the population grows with the same speed as the available amount of jobs, i.e. that the unemployment rate and employment-population ratio remain stable.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Household consumption</td>
<td>Absolute</td>
<td>206.0</td>
<td>219.3</td>
<td>231.9</td>
</tr>
<tr>
<td>(in millions USD$)</td>
<td>Δ %</td>
<td>6.5%</td>
<td>12.6%</td>
<td>20.3%</td>
</tr>
<tr>
<td>Gross Domestic Product</td>
<td>Absolute</td>
<td>373.1</td>
<td>398.2</td>
<td>424.2</td>
</tr>
<tr>
<td>(in millions USD$)</td>
<td>Δ %</td>
<td>6.7%</td>
<td>13.7%</td>
<td>22.4%</td>
</tr>
<tr>
<td>Household consumption</td>
<td>Absolute</td>
<td>$12,453</td>
<td>$12,518</td>
<td>$12,630</td>
</tr>
<tr>
<td>per capita</td>
<td>Δ %</td>
<td>0.5%</td>
<td>1.4%</td>
<td>2.4%</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>$22,555</td>
<td>$22,731</td>
<td>$23,101</td>
<td>$23,507</td>
</tr>
<tr>
<td>Population</td>
<td>16,541</td>
<td>17,518</td>
<td>18,362</td>
<td>19,427</td>
</tr>
<tr>
<td></td>
<td>Δ %</td>
<td>5.9%</td>
<td>11.0%</td>
<td>17.4%</td>
</tr>
</tbody>
</table>

4.4 Effect on jobs

Figure 13 provides an overview of the amount of jobs in each economic sector and for each of the three scenarios. The sectors that benefit the most are naturally the ones catering directly to the cruise tourists’ needs. The trade, restaurants, transport and other services (which include tour operators) sectors all see an increase in the amount of jobs as the number of cruise tourists increases. The construction sector, hotels, public administration and education seem to benefit the least from the increase in cruise tourism.
Figure 13 - Number of jobs in each economic sector in each scenario

If we look at the total amount of jobs in each scenario, we see that all scenarios demonstrate an increase compared to the initial situation in 2012. The number of jobs in the baseline scenario increases with 6%, with 9% in the moderate growth scenario and 17% in the rapid growth scenario. Note that in each scenario, part of this growth is caused by the increased amount of stay-over visitors.

Table 11 presents the number of jobs per income category and the change in the number of jobs compared to the initial situation expressed in percentages. Results indicate that most of the jobs that are created fall in the lower income category. Although the difference in jobs between the baseline and rapid growth scenarios is 819 jobs, 522 of these will pay wages below $20,000 per year. In the middle-income category, there will be 207 more jobs in the rapid growth scenario compared to the baseline scenario. For the high-income category the difference is 90 jobs.
Table 11 - Number of jobs in each income category.

<table>
<thead>
<tr>
<th>Income category</th>
<th>Initial situation (2012)</th>
<th>Baseline (2024)</th>
<th>Δ %</th>
<th>Moderate growth (2024)</th>
<th>Δ %</th>
<th>Rapid growth (2024)</th>
<th>Δ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low income</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&lt;$20,000 per year)</td>
<td>4,136</td>
<td>4,411</td>
<td>7%</td>
<td>4,642</td>
<td>12%</td>
<td>4,933</td>
<td>19%</td>
</tr>
<tr>
<td>Middle income</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($20,000 - $40,000 per year)</td>
<td>2,060</td>
<td>2,167</td>
<td>5%</td>
<td>2,259</td>
<td>10%</td>
<td>2,374</td>
<td>15%</td>
</tr>
<tr>
<td>High income</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&gt; $40,000 per year)</td>
<td>900</td>
<td>938</td>
<td>4%</td>
<td>978</td>
<td>9%</td>
<td>1,028</td>
<td>14%</td>
</tr>
<tr>
<td>Total</td>
<td>7,096</td>
<td>7,516</td>
<td>6%</td>
<td>7,878</td>
<td>11%</td>
<td>8,335</td>
<td>17%</td>
</tr>
</tbody>
</table>

Although a relatively large part of the Bonairean population is estimated to live in poverty (OLB estimates between 40-60% of the population; personal communication, 2015) this does not seem to be caused by unemployment: in 2012, Bonaire faced an unemployment rate of 5.8%. The Directie Samenleving & Zorg indicates that a lack of structurally available jobs and the fact that minimum wages are not sufficient are the main causes for poverty. This leads to insufficient income, even for people who are employed. With an 8-month season and relatively low-income employment, an increase in cruise tourism is not likely to create the type of employment that will improve the livelihoods of the segment of the Bonairean population with the lowest income.

4.5 Ecological effects

4.5.1 Coral cover and land-use

The increased number of tourists has an impact on the natural environment of Bonaire. This is the same natural environment that is an important selling point to attract tourists to the island in the first place. Around 70% of the stay-over tourists dives, 80% snorkels and 60% of the cruise tourists snorkel while on Bonaire (Schep et al., 2012a). Ironically, their presence puts pressure on the coral reef they come to enjoy.

The impacts on the coral reef ecosystem that are modelled in this scenario analysis are: the physical destruction of corals by divers and snorkelers and the increase in nutrient levels in the coastal waters due to coastal development, an increase in visitors and population growth. Due to the population growth, land-use intensifies as well. As an indication: in the rapid growth scenario the area of built-up land increases with 21.8% between 2012 and 2024. See Figure 14 for an overview of the increase in built up land in each scenario. As a result of changes in land-use sedimentation increases, thereby impacting coastal water quality and affecting the health of the coral reef ecosystem. In the rapid growth scenario, sedimentation has increased with 6% in 2024 and nutrient levels will be 24% higher.
A good indicator for the health of the coral reef is provided by its coral cover, which is defined as the percentage of the reef that is covered with live coral colonies. The status quo (green dotted line) in Figure 15 indicates that the coral cover on Bonaire is recovering from the last hurricane in 2010, during which many corals died. Until the horizon of the analysis the status quo indicates a growth of coral cover up till 36.2% in 2036, a very unique value for Caribbean coral reefs. In the three growth scenarios, this recovery is also visible in the first few years of the analysis. However, due to the increased pressures by cruise and stay-over tourists, coral cover starts to decrease in each growth scenario after a few years. For the baseline scenario, this results in a coral cover of 35.4% in 2036, for the moderate growth scenario in 34.6% in 2036 and for the rapid growth scenario in 33.5% in 2036.

The decrease in coral cover combined with the increased number of divers and snorkelers results in a more extensive use of the coral reef as a production input for the tourism sector. To investigate how extensive the coral reef is used, the model makes use of the social carrying capacity. The concept of social carrying capacity in the context of coral reef use has been explained in section 3.7.2 of this report.
According to Figure 16, in all scenarios the intensity of coral reef usage increases with the number of cruise visitors. The only scenario that reaches the limit of available coral reef resources is the rapid growth scenario: which reaches the limits of its natural capital in 2036. However, the increased intensity of coral reef usage in the other scenarios does limit the possibilities for development of the stay-over industry. In other words, the baseline scenario offers more potential for the development of the stay-over tourism industry compared to the rapid and moderate growth scenarios.

![Graph](image)

*Figure 16 – Percentage of coral reef used for recreational activities. 100% usage represents the physical limit and the carrying capacity of the coral reef on Bonaire.*

### 4.5.2 Solid waste

In section 3.5.2, we described the calculations for the waste production in Bonaire. An increase in visitors and residents will lead to an increase in the production of solid waste. Figure 17 presents the total production of solid waste in all three scenarios for residents, cruise and stay-over tourists. Compared to the situation in 2012, the production of waste increases for all three groups. For stay-over tourists, the amount of solid waste produced is the same in each scenario. Due to the increase in the number of residents in the various growth scenarios, waste production increases accordingly. As the group of cruise tourists grows faster, so does the amount of waste it produces.
The increased amount of waste leads to an increase in the waste collection costs. Figure 18 demonstrates the costs in each growth scenario. Compared to the baseline scenario, the increase in waste production by cruise tourists and the associated population growth lead to an additional amount of $200,000 for collection. The fact that waste is collected does not necessarily lead to processing of the waste. Currently, most of the solid waste on Bonaire is transported to the landfill.
4.5.3 Water use

The background and calculations of the water use by residents, stay-over tourists and cruise tourists are set out in section 3.5.2. An increase in visitors and residents will result in a larger water use in all three groups. Figure 19 presents the total water use per day for all three groups in the three scenarios. The red dotted line shows the capacity of the desalination plant to produce fresh water. Due to the increase in the number of residents in the various growth scenarios, water use increases accordingly. As the group of cruise tourists grows fastest, so does the amount of water this group consumes.

![Figure 19 – Total water use per day. The red dotted line shows the capacity of the desalination plant](chart)

Currently, the desalination plant produces 3.2 million litres of water per day. Without even taking into account the fresh water demand of agriculture and industry, the water use on Bonaire according to Figure 19 appears to exceed the current production in all three scenarios. The calculation demonstrates only the average water consumption per day, suggesting that it might be difficult for Bonaire to provide enough drinking water in the summer when the majority of stay-over tourists are on the island or when more than one cruise ship arrives on the same day. As mentioned before, several hotels and resorts produce their own drinking water, but this has not been taken into consideration to calculate the production capacity.

4.6 Decrease in stay-over tourism as a result of an increase in cruise tourism

Schep et al. (2012a) indicate that there is a high probability that an increase in visitors to the island leads to a lower return rate of stay-over visitors, which are averse to crowding. For an island like Bonaire, where almost 60% of the tourists are returning visitors, a lower willingness to return can have severe economic effects. Figure 5 in section 2.4.2 shows the willingness to return of stay-over visitors if the island or its marine environment would change. In the 2012 state of the island, 60% of the stay-over tourists were willing to return, while only 15% was certain not to return. These percentages change dramatically if the island develops. In the case of a more crowded island (i.e. 50% more people and buildings), only 12% wants to return. In the rapid growth scenario of the analysis in this chapter, the area of built-up land increases with 21.8% in 2024 and 44% in 2036 compared to the situation in 2012. This indicates that
the rapid growth scenario is likely to decrease the return rate of many of the current stay-over visitors.

Let’s assume that no additional visitors will visit Bonaire if the island does not engage in additional marketing activities to attract new tourists. Then, if we link the willingness to return of stay-over tourists to the number of cruise visitors and residents, we will encounter a decrease in stay-over arrivals. Figure 20 presents the development of stay-over visitors in each scenario. In the rapid growth scenario, the number of stay-over tourists will decrease to roughly 67,500 visitors. If the decrease in stay-over visitors is indeed the result of an increase in cruise tourists, economic benefits in the rapid growth scenario will grow substantially slower: a GDP of $421.2 million instead of $456.7 million. Although most economic sectors will still experience economic growth, the hotel and real estate industries will experience negative growth. The real estate industry will have decreased with 2% and the hotel industry with almost 18% in 2024.

![Figure 20 – Prognosis of stay-over arrivals as a result of an increase in cruise tourism arrivals.](image)

### 4.7 Limitations

Environmental and economic modelling requires making assumptions. This is not different for the IO Model. The limitations of the model are fourfold: there is a lack of data, input-output modelling does not allow for dynamic ecological modelling, seasonal and spatial distributions of tourism are not taken into account, and not all possible impacts of cruise tourism were taken into account in the analysis.

First of all, there is a fundamental lack of data on Bonaire. De data required for the model was most complete for the year 2012, which was therefore chosen as the starting point of the scenario analysis. However, there is still a lack of data regarding the dependence of companies on Bonaire on the natural environment. The impacts are often estimated based on literature studies regarding environmental impacts elsewhere. Data on the intermediate demand that formed the basis for the input-output table dates back to 2004. Although we assume that demand between economic sectors is not subject to much variability we cannot support this assumption empirically.
Secondly, the IO Model does not incorporate the natural resources dynamically. The changes in the economy do not take into consideration the potential losses of income as a result of the environmental changes in each scenario. For example, in the IO Model degradation of the coral reef does not lead to a decrease in income for the dive industry. In reality, however, this is likely to be the case.

Furthermore, the IO Model does not take into account any spatial variety in impacts, nor does it take seasonality of the cruise season into account. Cruise tourists only visit Bonaire during an 8 month season. In the Caribbean hurricane season there are no calls to the Bonairean port by any cruise ships. The IO Model, however, uses and produces annual values. The implication of this simplification of reality is that the increase in jobs and income is not structural. Rather, most of the job opportunities are likely to be filled by seasonal employees from outside of Bonaire. The spatial limitations result in an underestimate of environmental and crowding effects on certain locations. Some areas are visited more by cruise tourists than others, but the model only takes impacts on an island wide scale into account. This means that the impacts of the cruise tourism growth can be larger in more popular areas, whereas impacts are likely to be less significant on the sites that are not visited as much by cruise tourists.

No research has been done in relation to assess the social carrying capacity of the island and the effects that this may have on the different types of tourists. For example, an increase in cruise tourism may surpass the social carrying capacity of the beaches (see Annex F – Other socio-environmental impacts of cruise tourism). This may have a negative effect, although to a different extent, on return rates for stay-over and cruise tourists. Furthermore, the IO Model does not contemplate the effects that a more crowded or built up island may have in the return rate of stay-over tourists, since it is not possible to model this.
5 Discussion & Conclusions

Bonaire has been experiencing a vast increase in cruise tourists over the last decade. Like the development of the tourism industry in general, the expansion of cruise tourism can be seen as a double-edged sword: on the one hand, it increases economic benefits, while on the other hand, it puts extra pressure on the social and environmental carrying capacity of the island. In this report, both positive and negative effects of development of the cruise tourism industry were evaluated. To do so, Chapter 2 provides a description of the various actors and activities in the tourism industry. The main beneficiaries that were identified on the island were tour operators, tour suppliers, retailers, restaurants and cafes, taxis, shipping agencies and the island government. It is hard to determine the part of the tourist expenditures that remain on Bonaire, since many of the tours offered on Bonaire are sold on the ships through the cruise companies.

An important thing to note is that if cruise tourism industry is to expand even further, Bonaire must expand its infrastructure, in terms of roads, sewage, water management and waste management. This means that investments need to be made to accommodate larger amounts of tourists. The higher number of visitors will also increase direct pressures on the ecosystems that are visited: more snorkelers lead to more damage to the coral reef. Regulation, but more importantly, the enforcement of environmental legislation is therefore paramount. On the other hand, growth of the cruise tourism sector also increases economic activity in various economic sectors on Bonaire.

The increase in pressures on the natural environment and the islands infrastructure is likely to impact the tourism sector in general. The surveys conducted amongst the tourists have shown the importance of maintaining a healthy reef and the tranquillity on the island. Many stay-over tourists indicated that they are not willing to return to a more crowded island or an island with a degraded coral reef. If the state of the reef on Bonaire is to deteriorate to such an extent, the consequences could be that less tourists, be they cruise or stay-over, will return to the island. Therefore the dilemma for decision makers will be that a negative decision to invest on an environmentally friendly expansion will endanger the very industry they are trying to expand.

The expansion of the cruise tourism should have its limits, the main reason being the effects of crowdedness on the stay over tourists. The stay-over tourists contribute by far the most to the revenue produced by the tourism industry. 82,000 thousand stay-over tourists visit Bonaire annually and they provide over 80% of the revenue produced in the tourism industry. Compared to the approximately 158,000 cruise tourists that visit Bonaire, it shows that the value of a stay-over tourist is definitely something to consider when planning an expansion of cruise tourism.

To illustrate the effects of cruise tourism expansion, an input-output model that incorporates environmental effects was used in this report. Three different growth scenarios for the cruise tourism industry were analysed: a baseline scenario, in which the annual number of cruise tourists increases to 200,000 in 2024; a moderate growth scenario, in which 400,000 tourists visit Bonaire in 2024; and a rapid growth scenario with 650,000 cruise tourists in 2024. In all scenarios, the stay-over industry grows slightly till 100,000 visitors per year.

The model indicates that the economic activity increases as a result of the growth in the cruise tourism industry. Sectors that benefit most from the growth are the transport, restaurant, other services and trade sectors. While the economy grows as a whole, most jobs are created in lower income categories. As a result, household consumption and
GDP per capita do not increase as much. Household consumption is only $234 higher in the rapid growth scenario compared to the baseline scenario.

The small economic growth caused by cruise tourism expansion also result in environmental impacts. Based on the model, it can be concluded that built-up land increases from 3,400 hectares till almost 4,900 hectares in 12 years in the rapid growth scenario. Furthermore, water usage and solid waste production increase as the number of visitors increases. As a result of the increased sedimentation and nutrient loading in the coastal waters, coral cover will decrease.

Despite the fact that the model demonstrates various environmental impacts on Bonaire, many other impacts are not incorporated. Especially crowding in specific areas and on peak moments and environmental impacts are not taken into account. This means that the model is likely to underestimate these effects for some areas that are of particular interest to cruise tourists (e.g. Klein Bonaire, Sorobon, etc.). The fact that the model only provides annual values is a simplification. Furthermore, the cruise industry is subject to great seasonal variety, which means that created jobs are mainly seasonal jobs.

In general the identified economic and environmental effects calculated with the IO Model are relatively small. Large infrastructural investments to accommodate more cruise tourists are therefore not necessarily beneficial to the island. Especially the risk of losing the Bonaire's most valuable economic driver as a result of an increase in cruise tourism might be an important reason to carefully consider where and how to invest. A decrease in stay-over tourists as a result of the rapid growth scenario has significant implications for the hotel industry.

Finally, the scenario analysis does not take into account site-specific impacts due to increases in cruise tourism. Pressures on specific areas might increase disproportionally to other areas due to the increases. Also effects on the stay-over tourism sector are not evaluated. Increase in cruise tourism might have an effect on the return rates of stay-over tourists. More research on the local impacts of cruise tourism and the effects on the stay-over sector are therefore necessary to draw conclusions on the desirability of cruise tourism for the island.
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Annex A – Ecosystem services

Every good or service provided by the ecosystems of Bonaire has an attached economic value. By summing up their values, the total economic value of coral reef ecosystems is obtained. The TEV represents the value of an ecosystem which brings benefits to people. To put an economic value on the goods and services provided by marine or terrestrial ecosystems it was necessary to conduct an extended study of the literature and projects done in past years to analyse Bonaire’s benefits, along with a close communication with relevant stakeholders.

The value placed on an ecosystem service represents the level of preference of individuals on that good or service. The most common unit that expresses this value is “money” (van Beukering et al., 2007b). Even goods without a market price can be expressed in monetary terms by using monetary values such as willingness to pay (WTP), willingness to accept (WTA), market and non-market value, financial and economic value, costs and benefits, producer and consumer surplus, etc. (van Beukering et al., 2007b)\(^2\).

The TEV is calculated by summing the use and non-use value of coral reefs, which are defined by the type of their use (Figure A 1).

\[\text{Total Economic Value (TEV)} = \text{Use Values} + \text{Non-use Values}\]

\[\begin{align*}
\text{Use Values} & \rightarrow \text{Direct Use Values} & \text{Example:} & \text{Timber, fisheries, aquarium trade, ornaments} \\
\text{Use Values} & \rightarrow \text{Indirect Use Values} & \text{Example:} & \text{coastal protection, aesthetic beauty for real estate} \\
\text{Use Values} & \rightarrow \text{Option Values} & \text{Example:} & \text{Genetic materials for pharmaceutical purposes} \\
\text{Use Values} & \rightarrow \text{Bequest Values} & \text{Example:} & \text{Avoided damage climate change for future generations} \\
\text{Use Values} & \rightarrow \text{Use Values} & \text{Example:} & \text{Existence of endangered and nearly extinct species}
\end{align*}\]

Figure A 1- The TEV of an ecosystem

First, direct use values represent those goods and services that can be directly used by humans and have a market price. They can be consumptive (extractive) and non-consumptive (non-extractive). Extractive uses are represented by the goods which once consumed are not returned to the ecosystem, such as timber, fish for food and aquarium trade. Non-extractive uses are services provided by the ecosystem that are not extracted, for example recreation and education. Second, indirect use values are more difficult to value and are represented by diverse benefits provided by the ecosystem in an indirect way. Some examples are biological support to fisheries and turtles, physical protection of coast, carbon storage, etc. Third, non-use values illustrate the value place by people on different goods and services by taking into account any present or future use of them. Fourth, bequest values express the benefits that a good and service have for future generations, such as avoided damage due to climate change.

\(^2\) For a detailed and complete explanation for each of the different evaluation methods see the works of van Beukering et al. (2007b)
change, while existence values represents the benefits of knowing that a good or service exists, for example, simply the existence of certain species gives happiness to some people. Fifth, a combination between use and non-use value result in a new sub-category, the option value. This value shows the significance a good or service have in the present for a potential future use. An example is the potential to derive a remedy for cancer from the substances found on reefs (van Beukering et al., 2007b).

*Non-use values* illustrate the value place by people on different goods and services by taking into account any present or future use of them.

*Bequest values* express the benefits that a good and service have for future generations, such as avoided damage due to climate change, while existence values represents the benefits of knowing that a good or service exists, for example, simply the existence of certain species gives happiness to some people.

A combination between use and non-use value result in a new sub-category, the option value. This value shows the significance a good or service have in the present for a potential future use. An example is the potential to derive a remedy for cancer from the substances found on reefs (van Beukering et al., 2007b).
Annex B – Additional findings, tables and figures

Figure A 2 shows the appreciation by tourists of some activities on the island. The overall trend in these figures is that the cruise tourists enjoy Bonaire as a tropical island. There seems to be little difference how stay-over tourists and cruise tourists appreciate certain aspects of the island. The most pronounced difference can be seen in how the two types of tourists enjoyed the presence of other visitors on the island and the view of the ships. Although there is no causal reason to assume this difference, it is valid to presume that these differences are in part related to the fact that cruise tourists only visit the island for one day. Their enjoyment of other visitors is part of the experience of visiting an island. The stay-over tourists, on the other hand, associate the viewing of ships with more tourists and thus, with crowdedness.

Figure A 2 - How much did the tourists enjoy the following aspects on a scale of 1 to 5? (Schep et al., 2012a)
Figure A 3 - The appreciation of the land-based activities (Schep et al., 2012a).
Annex C – Cruise companies

According to ECLAC (2005) three major cruise companies, Carnival, Royal Caribbean and Star Cruises control over 90% of the Caribbean cruise market. These companies have established several interest associations, such as the Cruise Lines International Association (CLIA), the International Council of Cruise Lines (ICCL) and the Florida-Caribbean Cruise Association (F-CCA), to promote the interests of the cruise industry. So, the cruise ship industry is highly concentrated and dominated by three companies. Carnival, the largest cruise ship company, includes Carnival Cruise Lines, Princess, Holland America Line, Costa Cruise, P&O Cruises, AIDA, Cunard, Ocean Village, P&O Australia, Swan Hellenic, Seabourn and Windstar. The other two major companies are Royal Caribbean, which includes Royal Caribbean Cruises and Celebrity, and Star Cruises which includes Star Cruises, Norwegian Cruise Line, Orient Lines and the recently established NCL North America for two United States flagged cruise ships.
Annex D – Cruise tourism on St Maarten

A survey was conducted on the island of St. Maarten. The aim was to provide a more in depth understanding of what are the consequences of cruise tourism for a small tropical island. Interviews conducted with a series of experts and professionals provided detailed information on some of the challenges that the cruise tourism industry on St. Maarten face. See the end of this Annex for an overview of the individuals that were interviewed.

Estimations by experts indicate that 80% of the revenue on St. Maarten is generated by the 400,000 stay-over visitors. The reason why cruise tourists contribute such a small share to the revenue is in part because cruise tourism is an all-inclusive package deal. Demographics show that the crews of cruise ships spend more in a port of call than the cruise tourists do. In 2011, the spending of cruise tourists was $147 per person per visit and this is decreasing, the spending of a crewmember is supposedly $240 per visit and this is increasing.

The St. Maarten Group of Harbour Companies owns and manages the port of St. Maarten (portofstmaarten.com). In 2001, St. Maarten Group of Harbour Companies had 1 jetty with 4 places for ships to dock. In 2006 – 2007 they developed a second jetty with financial aid of a big cruise company and now St. Maarten harbour can handle 26,000 passengers in one day. The harbour of St. Maarten is a private entity and it is difficult to receive statistics. St. Maarten Harbour Group of Companies generates revenue from several sources such as concession fees, turnover tax and income tax. They handle on average 20,000 cruise visitors per day when cruise ships are in their harbour.

One of the issues St. Maarten Harbour Group of Companies mentioned regarding cruise tourism was the infrastructure of the Dutch part of the island St. Maarten, which does not have the capacity to handle over 26,000 cruise passengers in one day. Therefore a lot of cruise passengers visit the French part of St. Maarten, resulting in economic leakage, while the Dutch part of the island pays for the costs.

A water sports activity operator who depends on the tourism industry explained that cruise tourism business is high volume with small margins. The high costs tour operators incur, require them to realize certain economies of scale. When interviewed, the business of the expert interviewed depended for 70% on cruise ship visitors. He mentioned that the costs of cruise tourism are not restricted to operating costs. In his view, also costs of environmental impact, cost of coastal development and social costs of unconstrained population growth to service this market should be taken into account.

Regarding environmental damage by cruise ships the maritime experts on St. Maarten did not experience any serious damage caused by cruise ships. The ships have to comply with MARPOL rules and regulations. Cruise ships do deposit their solid waste in separated packages of carton, plastics and metal waste on St. Maarten. The ships are not allowed to dispose ballast water and their grey water is processed somewhere else. The ships are not allowed to show any emission (plumes) when docking in the harbour. However, during a 4 day visit on the island by one of the authors of this report several ships were seen not complying with the no-emissions regulation. Some ships have been equipped with a new type of propeller, one which causes less upwelling of sand and other solid particles. However, from the plane when arriving or leaving St. Maarten one can see the enormous spots of suspended sand in the water.
One of the biggest issues according to the St. Maarten harbour authority is the absence of a disaster contingency plan. They do not know how to respond if 7 ships would cause a calamity. Another impact mentioned is the possibility of cruise tourists as disease vectors, thereby transmitting any sickness one of the passengers has onto the island. Furthermore, the experts indicated that St. Maarten had to dredge the bay in order for the big ships to enter their harbour. This could have caused the collapse of natural cliffs on the other side of the bay, but research is necessary to make a connection. These experts emphasized that proper policy, legislation and enforcement should be in place before expanding cruise tourism.

Table A 1 provides an overview of the individuals that were interviewed in St. Maarten.

Table A 1 Cruise Tourism Experts and Professionals on St. Maarten.

<table>
<thead>
<tr>
<th>Name &amp; title</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucy Gibbes, Department head</td>
<td>Directorate of Economy, Transportation &amp; Telecommunication, Government of Sint Maarten</td>
</tr>
<tr>
<td>Valya Pantophlet, Executive Director</td>
<td>St. Maarten Hospitality &amp; Trade Association</td>
</tr>
<tr>
<td>Mike Stamm, Policy advisor</td>
<td>Shipping and Maritime Affairs, Department of Civil Aviation, Shipping and Maritime Affairs, Ministry of Tourism, Economic Affairs, Transportation &amp; Telecommunication, Sint Maarten</td>
</tr>
<tr>
<td>Colin Percy, Owner</td>
<td>Colin Percy, Sint Maarten 12 metre challenge</td>
</tr>
<tr>
<td>Mark Mingo, Chief Executive Officer</td>
<td>Mark Mingo, Chief Executive Officer, St. Maarten Harbour Group of Companies</td>
</tr>
<tr>
<td>Richard van der Mark</td>
<td>Richard van der Mark, Chief Executive Officer, St. Maarten Harbour Group of Companies</td>
</tr>
<tr>
<td>Edmond Johnson, Manager Maritime</td>
<td>St. Maarten Harbour Group of Companies</td>
</tr>
<tr>
<td>Marcel Gumbs, Managing Director</td>
<td>Public Affairs Consultant &amp; Representation, MGC &amp; Associates</td>
</tr>
</tbody>
</table>
Annex E – Overview of touristic activities and their environmental impact

Table A 2 Overview of direct environmental impact of tourism

<table>
<thead>
<tr>
<th>Activities with direct environmental impact</th>
<th>Actual and/or potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swimming and wading</td>
<td>Physical damage and ecological disturbance (Hawkins et al., 1999 and Manning, 2006)</td>
</tr>
<tr>
<td>Sunbathing</td>
<td>Physical damage, such as:</td>
</tr>
<tr>
<td></td>
<td>- breaking corals;</td>
</tr>
<tr>
<td></td>
<td>- damage from anchoring and boat groundings.</td>
</tr>
<tr>
<td>Surfing</td>
<td>Ecological disturbance, such as:</td>
</tr>
<tr>
<td></td>
<td>- trampling sea grass beds;</td>
</tr>
<tr>
<td></td>
<td>- kicking up sediment;</td>
</tr>
<tr>
<td></td>
<td>- contributing to over-exploitation of fish stocks.</td>
</tr>
</tbody>
</table>

Table A 3 Overview of direct environmental impact of tourism

<table>
<thead>
<tr>
<th>Activities with indirect impacts</th>
<th>Actual and/or potential impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resort development, construction and operation</td>
<td>Nutrient enrichment by sewage disposal</td>
</tr>
<tr>
<td>Construction of artificial beaches</td>
<td>Litter (solid waste)</td>
</tr>
<tr>
<td>Construction of piers</td>
<td>Increased sedimentation</td>
</tr>
<tr>
<td></td>
<td>Damage to corals by leakage of cleaning materials and waste ending up in the marine environment</td>
</tr>
</tbody>
</table>

22 Davenport and Davenport (2006) refer to a study by Hawkins et al. (1999) on the Caribbean coral communities at Bonaire in which Hawkins et al. suggested abrasion and tissue loss in corals due to diver damage facilitates disease transmission, particularly in large, massive corals.

23 Manning (2006) mentions that taking small boats directly to an adjacent reef or beach may be seen as very positive by visitors and tour managers, but places fragile environments at risk.
Annex F – Other socio-environmental impacts of cruise tourism

Nutrient enrichment by sunscreen

Personal care products have an impact on aquatic organisms similar to that of other contaminants (Danovaro et al., 2008). Such as stimulants, fragrances, sunscreens, antimicrobials, and insect repellents directly introduced to surface waters via release from the skin during swimming or bathing (Matamoros et al., 2009). Danovaro et al. (2008) state that sunscreens, by promoting viral infection, potentially play an important role in coral bleaching in areas prone to high levels of recreational use by humans. Danovaro et al. (2008) calculated that an average dose application of 2 mg/cm² of sunscreen (dose suggested by the U.S. FDA) for a full body surface of 1.0 m² results in an average usage of 20 g per application. We consider a conservative measure of two daily applications per cruise tourist visiting 6 hours. Based on these assumptions the annual sunscreen used on Bonaire by cruise tourists in 2012 would have been around 6,200 kilo. According to their experiment, Danovaro et al. (2008) estimated that at least 25% of the amount applied is washed off during swimming and bathing. That would be approximately 1,550 kilo per year, based on the number of cruise tourists that visited Bonaire in 2012.

According to Danovaro et al. (2008) sunscreen addition even in very low quantities (i.e., 10 µL/L) resulted in the release of large amounts of coral mucous (composed of zooxanthellae and coral tissue) within 18–48 hr, and complete bleaching of hard corals within 96 hr. Bleaching was faster in systems subjected to higher temperature, suggesting synergistic effects with this variable. Be aware that his experiments took place in a confined space with no open access to the ocean. And 1,550 kilo per year in the coastal waters of Bonaire should be a negligible amount. However sunscreen usage of local residents and stay-over tourists is not taken into account.

Labille et al. (2012) investigated the environmental impact of nanomaterials and the UV blocker nanoparticles used in sunscreens appear as the nanomaterial category with the highest priority for future exposure studies. When they are washed from the skin, their dumping into the aquatic environment most probably induces their aging and generation of new residues with new surface properties, for which the fate and impact are yet unknown.

Beach capacity

Just like an ecosystem, a beach has a social carrying capacity. Simply put it means the maximum amount of tourists that can be contained within a specific site. In the context of beaches it is the maximum amount of tourists a location can endure before the tourists themselves start perceiving the crowdedness as unpleasant, hereby halting the influx of tourists. Therefore, the beaches and the amount of space each beach has can be seen as a threshold for the amount of tourists Bonaire can handle. The international standard maximum social carrying capacity is 10m² (Savariades, 2000). A beach the size of 40,000m² can hold 4,000 individuals that are, in theory, not bothered by the other individuals on the beach. Beyond this point, the beach goers start incurring a negative perception of their experience on the beach. Also, the amount of individuals that are going to the beach also diminishes.

Considering the maximum carrying capacity of 10m² per person as international standard to benefit from a beach visit (Savarides, 2000), on a 37,500m² beach area, 3,750 people at any given time could enjoy from their stay on that beach. With the
limitation of not knowing how many stay over tourists will target the same beach, we can assume that so far the average social carrying capacity for the considered area is generally not reached during the high season.

However, based on surveys conducted on Sorobon Beach, in the Lac Bay, (Debrot, 2012), responses demonstrated that at 400 people occupancy, the maximum social carrying capacity was already reached, as more than 50% of the interviewed people wished to share the place with less people. Crowding was experienced at different levels of visitor densities. The number of people stating that they didn’t mind or wanted more beach visitors was consistently low (below 10%).
Annex G – The ecological footprint of cruise ships

Total emissions in Bonaire waters

IMARES estimated the emissions and environmental concentrations, based on general calculations, and modelling. These values are in turn submitted to Marine Positive Ltd. Marine Positive used this data to calculate the monetary equivalent of the emissions on Bonaire. No additional field measurements were done for this study.

Some basic assumptions are made:

- Selection of cruise ships: ships visiting Bonaire in the season 2011-2012 are taken into account (table A 4)
- The “Freewinds” is not taken into account due to lack of information on actual port calls.
- Based on international regulations, no bilge water, black water and grey water are discharged in Bonaire’s waters. This is thus not taken into account in the assessment by IMARES. However this is taken into account by the Acquatrail model, because of its holistic view on marine pollution.
- No information on oil and grease could be found during execution of this study, and these components could not be taken into account in the assessment.
- Region: The emissions are estimated for the “Bonaire region”. This region is defined by:
  - Shipping lane: based on the fact that the ships enter Bonaire from the territorial Water line (12 nm). The emissions in the shipping lane are estimated on a 2* 12 nm length, and estimated duration based on their individual speed.
  - Harbour: it is assumed that the ship moors around 10 AM, and departs around 17 PM. Total duration in the port per visit is 7 hours.
- Tug boats assisting cruise ships are not included.

### Table A 4

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Cruise line</th>
<th>passengers</th>
<th>Visit Bonaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>AidaLuna</td>
<td>AIDA Cruises</td>
<td>2,050</td>
<td>7</td>
</tr>
<tr>
<td>Azura</td>
<td>P&amp;O Cruises</td>
<td>3,080</td>
<td>3</td>
</tr>
<tr>
<td>Breamar</td>
<td>Fred Olsen</td>
<td>927</td>
<td>2</td>
</tr>
<tr>
<td>Caribbean Princess</td>
<td>Princess Cruises</td>
<td>3,100</td>
<td>12</td>
</tr>
<tr>
<td>Emerald Princess</td>
<td>Princess Cruises</td>
<td>3,100</td>
<td>10</td>
</tr>
<tr>
<td>Grandeur of the Seas</td>
<td>Celebrity/RCCL</td>
<td>2,446</td>
<td>18</td>
</tr>
</tbody>
</table>

24 This Annex was prepared by Allard Marx (Marine Positive), Diana Slijkerman, Pepijn de Vries, Narangarel Davasuuren (all IMARES) and Jorge Amrit Cado van der Lely.
Below follows a set of summaries that provide antifouling emissions and the related concentrations in the environment (see Table A 5, Table A 6 and Table A 7). Specifications per ship and visit, and division to compartment (harbour versus shipping lane) are provided in this chapter.

A thorough search of the EPA toxicity database was conducted in order to find No Effect Concentrations (NOEC) of antifouling compounds on corals. The lowest values found are presented by IMARES. These NOEC values are much higher (up to factor 100,000) than the calculated environmental concentrations. It is assumed that these calculated concentrations of antifouling impose no acute risk for corals. The Acquatrail used values of the EPA database although the figures used are from a different year and the model did take liquid gas emissions into account.

Table A 5  Antifouling emissions in season 2011-2012

<table>
<thead>
<tr>
<th></th>
<th>Copper</th>
<th>TBT</th>
<th>Diuron</th>
<th>Irgarol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Emission (grams)</td>
<td>11512</td>
<td>1713</td>
<td>464</td>
<td>464</td>
</tr>
</tbody>
</table>

Table A 6  Antifouling concentrations in the environment after 10 years, based on emissions in season 2011-2012

<table>
<thead>
<tr>
<th>Concentration (µg/L)</th>
<th>Copper</th>
<th>TBT</th>
<th>Diuron</th>
<th>Irgarol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>0.00032</td>
<td>0.00005</td>
<td>0.00001</td>
<td>0.00001</td>
</tr>
<tr>
<td>Average</td>
<td>0.00024</td>
<td>0.00004</td>
<td>0.00001</td>
<td>0.00001</td>
</tr>
<tr>
<td>Median</td>
<td>0.00004</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
</tbody>
</table>

Table A 7  Gross Gaseous emissions

<table>
<thead>
<tr>
<th>Total emissions 2011-2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$ (tonnes)</td>
</tr>
<tr>
<td>CO$_2$ (tonnes)</td>
</tr>
<tr>
<td>SO$_2$ (tonnes)</td>
</tr>
</tbody>
</table>

Emissions and re-suspension of sediment of cruise ships

In upcoming sections, the emissions from antifouling paints and gaseous emissions are further described and specified for the Bonaire region. Emissions from black water, grey water, bilge water, ballast water and oil and grease were not further specified in this study. Cruise ship emissions are categorised in:

- Black water
• Grey water
• Ballast water
• Bilge water
• Antifouling
• Oil and grease
• Gaseous emissions

Black water & Grey water

“Black water,” is the sewage from vessels consists of human body waste and the waste from toilets and other receptacles intended to receive or retain body waste (including medical waste). Grey water is wastewater generated from domestic activities such as laundry, dishwashing, and bathing.

On Bonaire, black water and grey water are not disposed on land (personal comment Van Slobbe). Black and grey water from the cruise lines visiting Bonaire are processed through a Marine Sanitation Device (MSD), certified in accordance with US or international regulations, prior to discharge. Discharge takes place only when the ship is at minimum distance of 12 nautical miles from land.

We assume that the visiting vessels act according to this international agreement, and that no black and grey water is disposed in the coastal waters of Bonaire. IMARES considers wastewater is no aspect of the cruise ship footprint for Bonaire. However Marine Positive, who develops and calculates the Acquatrail, is of the opinion that the total environmental impact of cruise ships should be considered. Therefore, the Acquatrail did take the environmental impact outside of the 12 nautical miles from land into the total calculations.

Bilge water

Large vessels such as cruise ships have several additional waste streams that contain sludge, waste oil, and oily water mixtures, including fuel oil sludge, lubricating waste oil, and cylinder oil, that find their way to the bilge. The bilge water can be managed in one of two ways (Sweeting et al., 2003):

1. Retained on board in a holding tank and discharged later to a reception facility on shore; or
2. Treated on board with an Oily Water Separator (OWS).

The treated bilge water can be discharged overboard in accordance with applicable standards and regulations while the petroleum products extracted by the OWS (i.e., oily waste) are retained in a dedicated holding tank on board (and later are incinerated and/or off-loaded in port).

The international standard established by MARPOL (Annex I), and implemented into United States law by APPS, states that machinery space waste including bilge water may be discharged overboard if it contains a concentration of 15 ppm oil or less. This only applies to ships beyond the 12 nm limit, provided that the ship is underway. IMARES assumes that the vessels act according to the international agreements, and that no bilge water is discharged in the coastal waters of Bonaire. Thus, according to IMARES bilge water is not an aspect of the cruise ship footprint for Bonaire.

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25 This statement holds for all cruiselines, but remains uncertain for Fred Olsen and Hansa kreuzfahrten lines.
Ballast water

Cruise ships use ballast water to stabilize the vessel during transport. Ballast water is often taken on in the coastal waters in one region after ships discharge wastewater or unload cargo, and discharged at the next port of call. Ballast water discharge typically contains a variety of biological materials, including plants, animals, viruses, and bacteria. These materials often include non-native, nuisance, exotic species that can cause extensive ecological and economic damage to aquatic ecosystems. Ballast water discharges are believed to be one of the leading sources of invasive species. Emissions ballast water and invasive species are not included in the assessment of IMARES as ballast water is assumed not to be discharged in the coastal zone.

Oil and grease

Oil and grease are used on e.g. propeller shaft, and can leak into the water during normal use. In extreme cases when propeller shafts break, these compounds will spill into the environment. No specifications on type of oil and grease, and the spillage, and uses could be retrieved during this quick scan study.

Antifouling

Anti-fouling paint is a type of coating applied to the hull of a ship in order to slow the growth of organisms that attach to the hull and can affect a vessel's performance and durability. Antifouling paints contain toxic substances that hamper growth of barnacles, algae, and other marine organisms. Usual substances are copper, organotin compounds, or other biocides. For each ship, the emissions from antifouling paints are estimated. Only the active ingredient is taken into account. No emissions from auxiliary substances were calculated, as information on these substances could not be retrieved during this study.

Sedimentation

Large cruise ships can re-suspend amounts of sediment that drift onto nearby reefs. The research from Jones (2011) states that based on existing literature, the intensity, duration and frequency of sediment exposure were considered unlikely to result in discernible physiological impacts on adult corals in the short term. However, it could not discount long-term effects on juvenile coral survival and settlement success. Corals beside the shipping channel are likely to be exposed for several hours to suspensions of very fine sediments. Most studied corals have been found to move sediment influxes of up to 50 mg DW sediment in cm² with comparative ease and up to 200 mg DW sediment cm² within a few days. However, this could result in a diminished ability to generate new recruitment. Over many years there could be a gradual loss of the existing coral community and replacement by more sediment tolerant species or communities. Further and more applied research should be done on Bonaire on this topic. One of the possibilities given by Jones is that lower speed of the cruise ship generates lower sediment suspension (Jones, 2011).

Results

As shown in Table A 8, the total costs that cruise ships entering the Bonaire harbour impose on the environment in 2011 is estimated above $100,000. For these calculations of costs as represented in gaseous emissions, antifouling emissions, liquid and solid waste emissions are included using various sources to estimate the monetary value of the environmental impact.
### Overview of elements, quantities and costs of the environmental impact of cruise ships entering Bonaire harbour

<table>
<thead>
<tr>
<th>Environmental impact</th>
<th>Quantity</th>
<th>Value</th>
<th>Total in euro</th>
<th>Total in US$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gaseous Emissions (tonnes)</strong></td>
<td>Euro/tonne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>5496</td>
<td>8</td>
<td>43,968</td>
<td>57,376</td>
</tr>
<tr>
<td>NOX</td>
<td>44.6</td>
<td>32</td>
<td>1,427</td>
<td>1,862</td>
</tr>
<tr>
<td>SO2</td>
<td>109</td>
<td>64</td>
<td>6,982</td>
<td>9,112</td>
</tr>
<tr>
<td><strong>Antifouling Emissions (kg)</strong></td>
<td>Euro/kg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBT</td>
<td>1.71</td>
<td>7,417</td>
<td>12,683</td>
<td>16,551</td>
</tr>
<tr>
<td>Copper</td>
<td>11.51</td>
<td>552</td>
<td>6,354</td>
<td>8,291</td>
</tr>
<tr>
<td>Diuron</td>
<td>0.46</td>
<td>4,108</td>
<td>1,890</td>
<td>2,466</td>
</tr>
<tr>
<td>Irgarol</td>
<td>0.46</td>
<td>1,369</td>
<td>630</td>
<td>822</td>
</tr>
<tr>
<td><strong>Liquid (wastewater) Emissions (m3)</strong></td>
<td>Euro/m3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black water</td>
<td>13,467</td>
<td>0.05</td>
<td>673</td>
<td>879</td>
</tr>
<tr>
<td>Grey water</td>
<td>67,292</td>
<td>0.1</td>
<td>6,729</td>
<td>8,781</td>
</tr>
<tr>
<td><strong>Solid Waste</strong></td>
<td>Euro/tonne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid waste</td>
<td>337</td>
<td>4</td>
<td>1,348</td>
<td>1,759</td>
</tr>
<tr>
<td><strong>Total environmental costs</strong></td>
<td></td>
<td></td>
<td>82,684</td>
<td>107,899</td>
</tr>
</tbody>
</table>

*Note: Conversion rate from euro to USD is 1.288 on 13 September 2012*

The gaseous emissions CO2, NOx and SO2 were converted using US-EPA (2008) as a source. Direct Emissions from stationary combustion sources were based on EPA430-K-08-00326 used by Marine Positive and estimated using an inventory of data from GaBi 4.3 software. The monetary conversion factors take into consideration the vulnerability of tropical aquatic ecosystems and are as follows: 8 Euro/ton CO2, 32 Euro/ton NOx and 64 Euro/ton SO2. These monetary values are based on EU trading costs (minimal estimate). NOx and SO2 are based on vulnerability due to eutrophication potential.

The antifouling emissions are based on potential ecotoxicological effect and ecosystem values. For antifouling (TBT, Copper, Diuron, Irgarol) Marine Positive used values of each category on the NOEC basis, estimating the overall surface in contact with water and the depreciation of one hectare of ecosystem at ca. 4,500 Euro/ha (Costanza et al., 1997).

Liquid wastewater emissions and solid waste projections of on board waste are calculated as a negative ecosystem externality (external costs) due to human sewage on the ship. Estimates for black and grey waters taking into account are a per-person average of black water equal to 0.02 m3/d and of grey water equal to a 0.1 m3/d. The quantity of water was multiplied by an empirical cost equal to 20-40% of the taxes.

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payable to have water treatment based on Italian costs. For solid waste Marine Positive used an average per-person of 0.5 kg/d. The total was multiplied by 5% of the taxes payable for refuse disposal based on Italy (personal comment Marine Positive).
Annex H – Input-Output Tables

Input-Output Tables

Not only the absolute values on an IO table are interesting, we also need to calculate the technical coefficients. A matrix with these technical input-output coefficients can be defined as the technical structure of the whole economic system. As can be seen in Table A 9, an IO table can be split up into four parts (Leeuwen et al., 2001):

- In the upper left corner, the table shows all the intermediate transactions of the different sectors.
- In the lower left corner, the table shows the primary costs. These are the value added and imports per sector. The value added represents payments to labour, capital, natural resources and the government.
- In the upper right corner, the table shows the final demand. The final demand can be defined as a delivery which is bought without any means of further processing. The final demand represents, in general, household demands, business investments, government demands and export to other regions.
- In the lower right corner, the table shows the primary costs that flow directly to the final demand. These are usually considered as zero.

Table A 9 - Example of an Input-Output table

<table>
<thead>
<tr>
<th>Selling sector</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Final Demand</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchasing sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$z_{11}$</td>
<td>$z_{12}$</td>
<td>$z_{13}$</td>
<td>$f_1$</td>
<td>$X_1$</td>
</tr>
<tr>
<td>2</td>
<td>$z_{21}$</td>
<td>$z_{22}$</td>
<td>$z_{23}$</td>
<td>$f_2$</td>
<td>$X_2$</td>
</tr>
<tr>
<td>3</td>
<td>$z_{31}$</td>
<td>$z_{32}$</td>
<td>$z_{33}$</td>
<td>$f_3$</td>
<td>$X_3$</td>
</tr>
<tr>
<td>Value Added</td>
<td>$VA_1$</td>
<td>$VA_2$</td>
<td>$VA_3$</td>
<td>$VA$</td>
<td></td>
</tr>
<tr>
<td>Import</td>
<td>$I_1$</td>
<td>$I_2$</td>
<td>$I_3$</td>
<td>$I$</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$Z_1$</td>
<td>$Z_2$</td>
<td>$Z_3$</td>
<td>$F$</td>
<td></td>
</tr>
</tbody>
</table>

Furthermore, we can separate the table into column and row vectors. Column vectors represent the intermediate purchases of each sector $j$ (i.e. the sales of all sectors to sector $j$). The row vectors represent the amount of goods that are sold by sector $i$ to all other sectors and that are sold as final goods and services. In that respect, the total output for sector 1 can be written as follows:

$$X_1 = \sum_{j=1}^{n} z_{1j} + f_1$$  \hspace{1cm} [1]

The fundamental law of input-output ‘accounting’ equilibrium says that corresponding row and column totals of an IO table must be equal (Bockarjova, 2007). In other words, the following equality must hold:

$$\sum_{i=1}^{n} z_{i1} = \sum_{j=1}^{n} z_{1j}$$  \hspace{1cm} [2]
Annex I – IO Coefficients

These coefficients show the ratio of inputs needed from sector $i$, to produce one output of $X_j$. Equation [3] shows the equation to calculate each technical coefficient.

$$a_{ij} = \frac{z_{ij}}{Z_j}$$  \[3\]

This allows us to rewrite equation [1] into:

$$X_i = \sum_{j=1,n} a_{ij}X_j + f_i \quad \forall i$$  \[4\]

All technical coefficients put together will result in the following matrix $A$:

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1j} \\ \vdots & \ddots & \vdots \\ a_{i1} & \cdots & a_{ij} \end{bmatrix}$$  \[5\]

Equation [4] can then be rewritten, in matrix form, resulting in the following equation:

$$X = AX + F$$  \[6\]

To solve for the gross output of each sector, given a set of final demand requirements, we can rewrite this equation as follows:

$$X(I - A) = F$$  \[7\]

$$X = (I - A)^{-1}F$$  \[8\]

where:

- $X = \text{vector of total output}$
- $F = \text{vector of final demand}$
- $I = \text{Identity matrix}$
- $A = \text{matrix with technical coefficients}$

In Equation [8], $(I - A)^{-1}$ is known as the Leontief Inverse, which indicates how much each sector must increase its output as a result of demands to deliver an additional unit of final goods and services. Solving this equation, however, is only possible when the IO table is in correct balance, which means that the column totals equal the row totals. In other words, the total supply is equal to the total demand for each industry in the region (Equation [2]).
Annex J – Calibration of the ecological module using historic data

System dynamic simulation models are often characterized by high levels of uncertainty. This uncertainty is related to a lack of data to describe causal links in the system, or to uncertainty about the architecture and simplifications made in the conceptual model. To test and calibrate the model, we use historic time series data for the period 1994-2012 (for another example of this type of model calibration, see Chang et al., 2008).

Figure A 4 - Observed and predicted development of the percentage coral and algae cover

As a result of numerous coral reef monitoring programs (e.g. Bak et al., 2005; Jackson et al., 2014; Steneck et al., 2013), times series data is available on key state indicators such as coral cover, algae cover and herbivory and predatory fish stocks. However, since there are no historical IO models available for this time period, we used a number of development proxy-variables that drive changes in the coral reef ecosystem, such as the number of tourists (cruise and stay-over), population, fishing rate, and historic land use, to estimate historic external effects and ecological inputs. Annex 1 includes an overview of the available historic data. With the historical data on external effects and ecological inputs, we have predicted the ecosystem change over the period 1994-2012.

Figure A 4 shows the observed and predicted variation of coral and algae cover since 1994. The observed data shows that coral cover gradually declined from 49% to 45% over de period 1994-2010. As a result of a coral bleaching event in 2010, coral cover decreased with 10% and algae cover increased with about 7.5%. After the bleaching event, coral cover is showing signs of recovery and algae cover is declining. As a result of this recovery, coral cover is growing and algae cover is declining in the first years after the baseline year. Due to the stochastic nature of coral bleaching and coral diseases (i.e. the module cannot predict these types of events), the effects of these types of events are exogenous inputs to the ecological module.

Figure A 5 shows the observed and predicted variation of the predatory and herbivory fish stock. The predatory fish stock witnessed a significant decline until 2006, most likely as a result of overfishing. From 2004 onwards there are fish protected areas, which might have contributed to an increase of predatory biomass since 2006 (Steneck et al., 2013). The herbivory fish stock increased over the period 1994-2003 to levels which were unique in the Caribbean (Jackson et al., 2014). After a steep decline between 2003 and 2008, the herbivory fish stock is showing early signs of recovery in the most recent monitoring report (Steneck et al., 2013).
Figure A 5 - Observed and predicted development of the predatory and herbivory fish stock biomass (tons).
Annex K – Example of the multiplier effects

Let’s assume we have a small island economy, as shown in Table A 10.

Table A 10 - Fictive small island economy

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Agri</th>
<th>Mining</th>
<th>Manu</th>
<th>Final Demand (F)</th>
<th>Total (X_j)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agri</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Mining</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Manu</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>Labor</td>
<td>11</td>
<td>5</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>12</td>
<td>24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All units in the table are in millions of dollar. On this island, we have an agricultural, a mining and a manufacturing sector. If we look at the second row of the table, we see how much of each sector uses of the products produced by the mining sector. In the first column, we see that the agricultural sector does not use anything produced by the mining sector (cell $z_{21}$). In the second column, we see that the mining sector itself uses two million dollar worth of its own production (cell $z_{22}$). In the third column, we find that the manufacturing sector uses 10 million dollar worth of production by the mining sector (cell $z_{23}$). In addition, nothing is consumed by the final demand ($f_2$), which we assume are the households on this island. These summed up, results in a total production of 12 million dollar ($X_2$ in Table A 10, and the summation as in Equation [1]). To produce this, the mining sectors uses three million dollar worth of production by the agricultural sector (first row, second column), two million dollar worth of production of its own (second row, second column) and two million worth of production from the manufacturing sector (third row, second column). Finally, the mining sector requires 5 million dollar worth of labor to produce this total of 12 million dollar. In this case, Equation [2] holds and the total supply and demand is ‘balanced’.

The next step is to determine the matrix of technical coefficients, the A-matrix (Equation [5], which can be done by calculating the technical coefficient for each cell in the light green box of Table A 10, by applying Equation [3]). This results in the following matrix:

Table A 11 - Matrix of technical coefficients

<table>
<thead>
<tr>
<th></th>
<th>Agri</th>
<th>Mining</th>
<th>Manu</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.083</td>
<td>0.250</td>
<td>0.208</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.167</td>
<td>0.417</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
<td>0.167</td>
<td>0.250</td>
</tr>
</tbody>
</table>

If we look at the upper left cell in the matrix (first row, first column), we see a value of 0.083. This is calculated by simply filling in Equation [3]: 1/12. The same holds for the value of 0.417 (second row, third column: 10/24. Now, with the calculation of the A-matrix, we can rewrite Equation [1] into Equation [4]. If we again go to the second row of Table 2, Equation [1] would result in 0+2+10+0 = 12. For Equation [4], this would be: 0.000*12+0.167*12+0.417*24 + 0 = 12. In matrix form, Equation [4] can simply be rewritten into Equation [6]. Now, for simple calculations we seemed to have a problem: we have X on both sides of the equation. As such we want to rewrite the equation to make sure we have only one X in the equation. A first step is to rewrite Equation [5] into Equation [6], which results in only one remaining X in the equation. This equation, unfortunately, does not allow us yet to simply assess changes in gross output (X). As such, a final step is to multiply both sides of the equation with $(I-A)^{-1}$. This results in
Equation [8], where \((I-A)^{-1}\) is defined as the Leontief inverse. Table A 12 shows the Leontief inverse for our small island economy.

**Table A 12 - Leontief Inverse**

<table>
<thead>
<tr>
<th>((I-A)^{-1})</th>
<th>1.09</th>
<th>0.44</th>
<th>0.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.35</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td>0.30</td>
<td>1.50</td>
<td></td>
</tr>
</tbody>
</table>

Now, we can extract the multipliers from Table A 12. The multiplier for the agricultural sector will be the sum of the first column: 1.09+0.00+0.00 = 1.09. In other words, a one million increase in final demand to the agricultural sector will result in 1.09 million extra production from the agricultural sector itself and not additional benefits to other sectors. For the mining sector (second column), we do see ‘spillover’ effects. The sum of the second column: 0.44+1.35+0.30 = 2.09. In other words, a one million increase in final demand will result in a 0.44 million dollar increase of production in the agricultural sector, a 1.35 million dollar increase in the mining sector and a 0.30 million dollar increase in the manufacturing sector.