IVM Institute for Environmental Studies

# Reef Degradation and Tourism

## The macroeconomic costs of climate change on Bonaire

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# Summary

This paper studies the macroeconomic consequences of climate-induced reef degradation for Bonaire. Bonaire's coral reefs progressively face the unavoidable reality of climate change, with its effects increasing in severity. Degradation of the island's reef ecosystems may affect annual tourism arrivals as the reefs form one of the main attractions for visitors to Bonaire. Consequently, the industries that rely on tourist expenditures will suffer and thus the local economy. Coral reef-based tourism creates a unique opportunity to investigate the impacts of global warming on the macro-economic performance of Bonaire. This paper employs the emission scenarios SSP1-1.9, SSP2-4.5, SSP3-7.0, and SSP5-8.5 of the AR6 IPCC 2021 to study the effects of coral reef degradation on the social carrying capacity of the coral reefs. Subsequently, the potential effects of reduced dive tourism and the induced effects of a change in tourism demand are translated into changes in sectoral outputs by employing input-output analysis. Coral reef degradation is expected under all scenarios, except the SSP1-1.9 scenario where a slight recovery of coral reefs is possible.

This study finds a contraction in GDP between 25 USDm and 173 USDm by 2050 (between 2 to 18 percent of GDP in 2050), depending on the applied climate scenario. Moreover, a tourism income multiplier of 0.85x is found, which indicates a strong interlinkage between tourism income and the local economy, as from every dollar of tourism income 85% enters the local economy. This indicates that any losses in tourism demand will significantly result in macroeconomic damages for Bonaire. It can thus be expected that climate change will have a substantial impact on coral reefs as a vital tourism asset on Bonaire, with more extreme emission scenarios leading to stronger negative effects on the local economy.

# 1 Introduction

This report is part of a series of reports that were developed in 2022 as part of a study project to model the effects of climate change for the island of Bonaire in the Caribbean Netherlands. This project was commissioned by Greenpeace and was conducted by the Institute for Environmental Studies (IVM) at the Vrije Universiteit Amsterdam supported by Wolfs Company, Part of Grant Thornton. This sub report focuses the effects of climate change on the coral reefs surrounding the island and the way in which they are essential for the economy through their attractiveness to tourists. Climate change is projected to have negative impacts on coral reefs, which consequently is expected to have negative consequences for tourism arrivals and thus for the local economy on Bonaire. This report describes a combined ecological and input-output model that was developed to study the relationship between climate change, coral reefs and the local economy.

The economic importance of tourism to Caribbean Small Island Developing States (SIDS) cannot be overstated. Tourism is seen as a viable and, at times, only pathway to the economic development of small and isolated economies (Pratt, 2015). In particular, Bonaire has experienced exponential tourism growth over the last decades. The island is home to a unique marine environment that sustains high biodiversity and an abundance of coral reefs and fish (Bak *et al.*, 2005). These natural assets have been the driving force behind increasing tourism arrivals (Uyarra *et al.*, 2005).

In the past decades, various climate-related trends in combination with increased coastal development, have put increased pressure on the coral reefs of Bonaire, thereby jeopardizing the foundation of the island's tourism-based economy. The Caribbean region has been identified as among the most vulnerable areas to the devastating effects of climate change resulting from the strong effects of changes in ocean temperatures and circulation on local climates (Baban, 2003; Taylor *et al.*, 2012). An associated loss of nature will not only affect the attractiveness of Bonaire as a travel destination but may indirectly result in socio-economic impacts that affect the quality of life on the island, including health, natural resources, coastal protection, water and food security, and employment opportunities (Rhiney, 2015; Taylor *et al.*, 2018). These topics are further explored in the other sub reports that were developed in the context of this study.

In a post-colonial world where the traditional production of manufactured and agricultural goods is mainly of the past, tourism appears to be Bonaire's main avenue toward long-term economic and social development (Spencer, 2019). It is a far-reaching system that serves as the backbone of Bonaire's economy, maintaining and even encouraging growth in other vital industries (Schep *et al.*, 2013). Tourism provides private income and public tax revenues that support education, public services, employment, and infrastructure. However, the strong reliance on tourism assets makes the local population dependent on external rather than local resources. Since Bonaire is relatively limited in size and natural resources, the lack of a diversified local economy makes her inherently sensitive to exogenous shocks (Spies *et al.*, 2015). Given the economic importance of Bonaire's reefs for tourism, climate-induced risks could potentially have an impact on the livelihoods and human development of many Bonairians.

This study focuses on the associated direct and indirect economic consequences of tourism losses due to climate change. Specifically, “the macroeconomic impact of tourism losses” is defined as the changes in Gross Domestic Product (GDP) of Bonaire due to the induced effects of tourism demand. Currently, there is a limited understanding of the magnitude of economic exposure Bonaire faces if its marine environment degrades (Steneck *et al.*, 2019). This paper offers a preliminary investigation of a potential decline in tourism demand by employing four future climate scenarios addressed by the IPCC in its Sixth Assessment Report; SSP1-1.9, SSP2-4.5, SSP3-7.0, and SSP5-8.5 (IPCC, 2021). The ecological impacts of these climate scenarios are used to predict how changes in coral reef health along the leeward shore might influence diver arrivals on Bonaire. According to Wanhill (2006), “measuring the economic effects of tourism is best achieved through an input-output framework”, because of its ability to capture primary and secondary effects of tourism spending. Therefore, projected changes in reef quality are translated into macroeconomic and sectoral consequences by employing input-output modelling, based on multiplier effects.

Although this analysis presents by no means a complete understanding of all expected economic losses, it could serve as a relevant proxy to support informed decisions of policymakers or scholars on climate change in the Caribbean region. Following other macro-economic literature in the context of climate risks (e.g., Bueno *et al.*, 2008; Farid *et al.*, 2016), this paper creates projections for the middle of the century to ensure that the economic results are comparable. As such, this study’s research question aims to answer the prospective macroeconomic consequences of tourism losses due to climate-induced reef degradation for Bonaire by 2050.

The remainder of this thesis is as follows. Chapter 2 covers the background of the paper, discussing the current structure of Bonaire’s economy and its tourism sector. Chapter 3 describes the empirical design, including the data collection and experimental procedures to determine the changes in reef health and GDP. Next, chapter 4 summarizes the general results of the analysis. The discussion in chapter 5 puts the findings of this paper in perspective to other studies and reports possible limitations. Finally, chapter 6 answers the research question and concludes the study.

# 2 Backgrounds

Bonaire is a small island (288 km2) located in the Caribbean Sea, 80 km north off the coast of Venezuela, and is a special municipality within the Netherlands. Bonaire's terrain is predominantly low-lying and covered by low thorny vegetation (Uyarra *et al.*, 2005). The waters surrounding Bonaire and its satellite island, Klein Bonaire, are considered to be an exemplary model of self-financing marine protected areas (MPA's), as they have been well managed and fully protected to 60m depth since 1979 (Spalding *et al.*, 2001). However, as with other areas in the Caribbean, the reefs around the island have suffered from increased pressures of climate change, such as rising coral mortalities due to bleaching events and diseases (Spalding *et al.*, 2001), and local pressures, such as erosion and nutrient loading. In early 2022 the island was inhabited by 22.6 thousand residents, representing an increase of more than 6 thousand persons compared to early 2012 (CBS, 2022). Bonaire's GDP increased to 553 USDm in 2019, averaging a yearly volume growth of 2.7% since 2012 (CBS, 2020). In terms of economic size, Bonaire's GDP is similar to other SIDS such as Tonga (512 USDm) and Dominica (470 USDm) (World Bank, 2021).

*Table 1 Tourism Direct GDP of countries with a tourism-based economy*

| Caribbean | Year | % of total GDP | Europe | Year | % of total GDP |
|---|---|---|---|---|---|
| Aruba | 2013 | 20.0 | Montenegro | 2009 | 10.0 |
| Bahamas | 2004 | 21.6 | Iceland | 2017 | 9.0 |
| Bermuda | 2018 | 5.4 | Greece | 2017 | 7.0 |
| Bonaire | 2012 | 16.3 | | | |
| Dominican Republic | 1996 | 9.9 | | | |
| Jamaica | 2018 | 9.0 | | | |

Source: Central Bank of Bahamas (2005); Van de Steeg (2009); CBS (2012); TSA Bermuda (2012); World Bank (2021).

Bonaire's economy is firmly based on tourism, particularly the mainstay activity of scuba diving (KVK Bonaire, 2020; De Meyer, 1998). The "Centraal Bureau voor de Statistiek" (CBS) estimated in 2012 that the Direct GDP from tourism[1] amounted to 16.3% of total GDP. Table 2 reveals the relatively high exposure of Bonaire to tourism expenditures compared to other tourism countries. According to the World Bank (World Bank, p.23, 2020): "this high degree of dependence on external demand affects the magnitude and persistence in the case of an economic shock (..)". The "Hotels" and "Food services" sectors depend almost entirely on tourism revenues. At the same time, the industries "Trade", "Transport, information, and communication", and "Real estate activities" are also significantly exposed to tourism (CBS, 2012). There is limited recent

[1] Direct Gross Domestic Product from tourism only quantifies the immediate effects of tourism demand on economic output. These effects are also referred to as first-order effects. Indirect effects of tourism consumption on other industries are excluded(CBS, 2012).

data available on Bonaire's overall economic structure. Therefore, a baseline estimate of every industry's total output in 2017 was developed using the 2012 input-output table of Koks and Van Zanten (2015), in turn based on the work of Van De Steeg (2009) and Steenge (2010). The constructing process of the updated input-output table is described in Annex B. Table 2 provides the resulting approximation of Bonaire's economic structure in 2017.

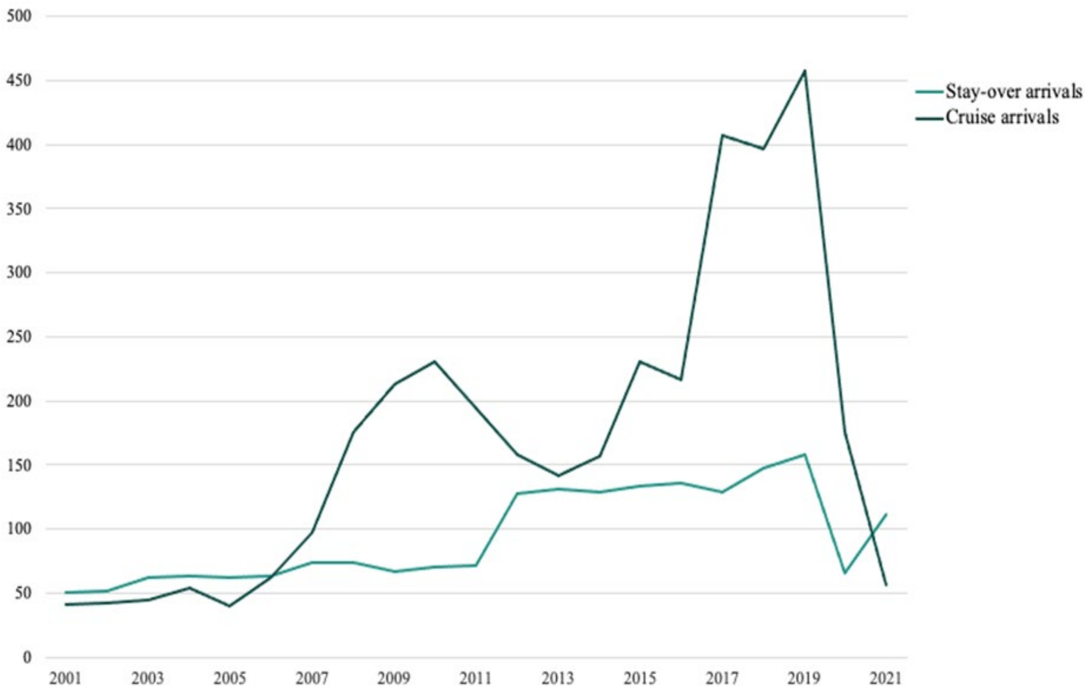
*Table 2 Economic structure of Bonaire (2017), in USDm*

| Sector | Gross Value Added |
|---|---|
| Agriculture, fishing, mining | 12 |
| Manufacturing | 9 |
| Electricity, gas, and water supply | 16 |
| Construction | 26 |
| Trade | 60 |
| Hotels | 24 |
| Food service | 20 |
| Transport, information, and communication | 50 |
| Financial Intermediation | 24 |
| Real estate activities | 48 |
| Public administration and defence | 57 |
| Education | 32 |
| Health | 53 |
| Other services | 29 |
| GDP, basic prices | 461 |
| Taxes – Subsidies | 19 |
| **Total GDP** | **480** |

Source: Author's estimates based on Van de Steeg (2009); Koks & Van Zanten (2015); CBS (2020).

The number of tourists arriving on Bonaire has been steadily increasing since 2001, although total tourist arrivals sharply declined between 2020 and 2021 due to COVID-19 restrictions. The annual number of stay-over tourists (i.e., tourists arriving by plane) reached its peak in 2019 when 158 thousand tourists visited the island. In addition, Tourism Corporation Bonaire (TCB) aims for 200 thousand stay-over tourists by 2027 to make the tourism industry 'the economic engine' of the island (Croes *et al.*, 2019). Similarly, the number of cruise tourists that disembarked on the island peaked in 2019 at 433 thousand (CBS, 2020). From March 2020 until August 2021, cruise tourism was entirely banned while the island's government also temporarily suspended several international flight routes (CBS, 2021), explaining the steep fall that can be observed in

Figure 1. Nevertheless, the TCB stated that it expects tourism arrivals to fully recover to pre-COVID levels at the end of 2022 (TCB, 2022).




Source: CBS (2014), CBS (2020), CBS (2020)

*Figure 1 Annual arrival of stay-over tourists and cruise tourists between 2001 and 2021 (in thousands)*

The added value of cruise tourism to the GDP of Bonaire when compared to stay-over tourism has been questioned in recent years (Wolfs *et al.*, 2015). Bonaire received nearly 450 thousand cruise tourists in 2019, the last pre-corona year (CBS, 2021). However, the average cruise tourist only spends 6 hours on the island, contributing significantly less to Bonaire's economy than the average stay-over tourist while still crowding the island (Wolfs *et al.*, 2015). Table 3 shows an estimate of the differences in the added value of the average stay-over tourist and the average cruise tourist for the baseline year of 2017. The table is constructed by updating the expenditure tables of Schep *et al.* (2013) with the "2017 Tourist Exit Survey" of STMP Bonaire (Croes *et al.*, 2019). In the case of missing data in the Tourist Exit Survey, the 'old' value obtained from Schep *et al.* (2013) is corrected for inflation for 2017. Similar to Schep *et al.* (2013), it is assumed that the added value of tourism accounts for 25% of total expenditures per category, excluding donations.

*Table 3 Overview of the differences in average tourism revenues between cruise tourism and stay-over tourism*

| **Activity** | **Added value (%)** | **Average cruise tourist expenditures** | **Added value of cruise tourist** | **Average stay-over tourist expenditures** | **Added value of stay-over tourist** |
|---|---|---|---|---|---|
| Average stay (in days) | | 1.0 | | 9.9 | |
| Diving | 25% | $6.21 | $1.55 | $16.30 | $4.07 |
| Snorkelling | 25% | $20.65 | $5.16 | $1.23 | $0.31 |
| Island Tours | 25% | $30.38 | $7.59 | $0.78 | $0.19 |
| Boats tours/rental | 25% | $7.05 | $1.76 | $1.43 | $0.36 |
| Groceries/Sundries | 25% | | - | $9.24 | $2.31 |
| Accommodation | 25% | - | - | $68.25 | $17.06 |
| Car rental | 25% | $0.21 | $0.05 | $16.98 | $4.24 |
| Local transport | 25% | $2.65 | $0.66 | $2.87 | $0.72 |
| Food & drinks | 25% | $17.10 | $4.27 | $42.95 | $10.74 |
| Shopping | 25% | $36.71 | $9.18 | $8.82 | $2.21 |
| Nightlife / Casino | 25% | $0.32 | $0.08 | $7.59 | $1.90 |
| Donations | 100% | $0.20 | $0.20 | $0.66 | $0.66 |
| Other | 25% | $0.65 | $0.67 | $13.41 | $3.35 |
| Total expenditure p.p per day | | $122.13 | $30.68 | $190.51 | $48.12 |
| **Total expenditure p.p per stay** | | **$122.13** | **$30.68** | **$1,886.27** | **$476.48** |

Source: Author's estimates based on Schep *et al.* (2013); Croes *et al.* (2019); CBS (2021).

Under the assumption that The added value of an average cruise tourist in 2017 amounted to 31 USD per day relative to 48 USD per day for an average stay-over tourist. This difference becomes significantly greater when considering the added value per stay. Since most cruise ships only dock in Kralendijk for one day, the added value of an average cruise tourist is the same per stay as per day. On the other hand, the average stay of a stay-over tourist is 9.9 days. Consequently, the added value of their total expenditure per stay amounts to 476 USD. As a consequence, it might be preferable to host stay-over tourist over cruise tourists, as they provide a higher added value per individual (Croes *et al.*, 2019; Rietveldt, 2022).

Many Bonairians and tourism sector stakeholders have advocated for low-density tourism by positioning Bonaire as an 'authentic high-end' destination based on nature (van der Werven *et al.*, 2010; Croes *et al.*, 2019). They argue that increasing Bonaire's competitive position compared to other luxurious destinations is the pathway to economic growth without sacrificing their valuable natural environment, as opposed to, for example, severe development. To increase profitability per tourist, Bonaire should aim for visitors that are willing to pay a premium for unique experiences, particularly in the diving segment. The United Nations Environment Programme (UNEP) estimated that the average diver in the Caribbean spends around 2,100 USD per trip, compared to 1,200 USD for general tourists (Heileman & Walling, 2005). However, if Bonaire is to enjoy these economic benefits in the long term, it heavily depends on the health of "its number one tourism attraction – the coral reefs" (Croes *et al.*, p.77, 2019). Schep *et al.*

(2013) state that tourists are less likely to visit Bonaire if the quality of the coral reefs declines. Similarly, Clegg *et al.* (2021) find that the likelihood of tourists returning to the holiday destination is highly related to their sensitivity to environmental degradation. Therefore, the potential tourism losses due to climate-induced reef degradation could be severe in the context of Bonaire.

There are a number of climate change related effects that are detrimental to coral reefs. The IPCC in its special report “The Ocean and Cryosphere in a Changing Climate” (IPCC, 2019) states with high confidence that coral reefs in warm water regions are expected to significantly decrease in area. Furthermore, this effect will occur even in a scenario where global warming is limited to 1.5 degrees Celsius, with higher temperatures leading to faster degradation of coral reefs. The primary drivers for this are an increase in thermal stress, ocean acidification and to a smaller extent increased storm damage (Hoegh-Guldberg *et al.*, 2017). These in turn lead to coral bleaching events and mass mortality events, as well as reduced coral recruitment and growth (Hoegh-Guldberg *et al.*, 2017). Combined, these effects are thus expected to lead to a decrease in the density and size of coral reefs, which in turn could lead to decreases in ecosystem services associated with coral reefs such as tourism and fisheries impacting local economies (IPCC, 2019). The Caribbean region is vulnerable to all of the effects of climate change on coral reefs, and these effects might be amplified by local stressors (de Bakker *et al.*, 2019). On Bonaire, there are a number of stressors that threaten coral reefs surrounding the islands. These include erosion due to grazing by wild goats, nutrient loading through wastewater and sewage leakage into the sea, invasive species and mechanical damage from human activity on the reefs through diving and sailing (de Bakker *et al.*, 2019). These stressors have direct negative consequences on the reefs and through as of yet unknown interactions with climate change effects might lead to further degradation of coral reefs in the future.

# 3 Materials and methods

This chapter presents the main methodology of this study. To recap, this report aims to assess the prospective economic consequences of tourism loss due to climate-induced reef degradation for Bonaire's economy by 2050. Figure 2 provides a framework for the methodology applied in this study. Since the magnitude of climate pressures on coral reefs is uncertain (Hoegh-Guldberg & Bruno, 2010), section one will describe the estimated global pressures of four IPCC AR6 climate scenarios for 2050. Next, section two states how this paper investigates the impact of climate change on coral reef health of Bonaire through four key health indicators (KHI's), namely: coral cover, macroalgae cover, the biomass of key herbivory fishes, and the biomass of key predatory fishes.

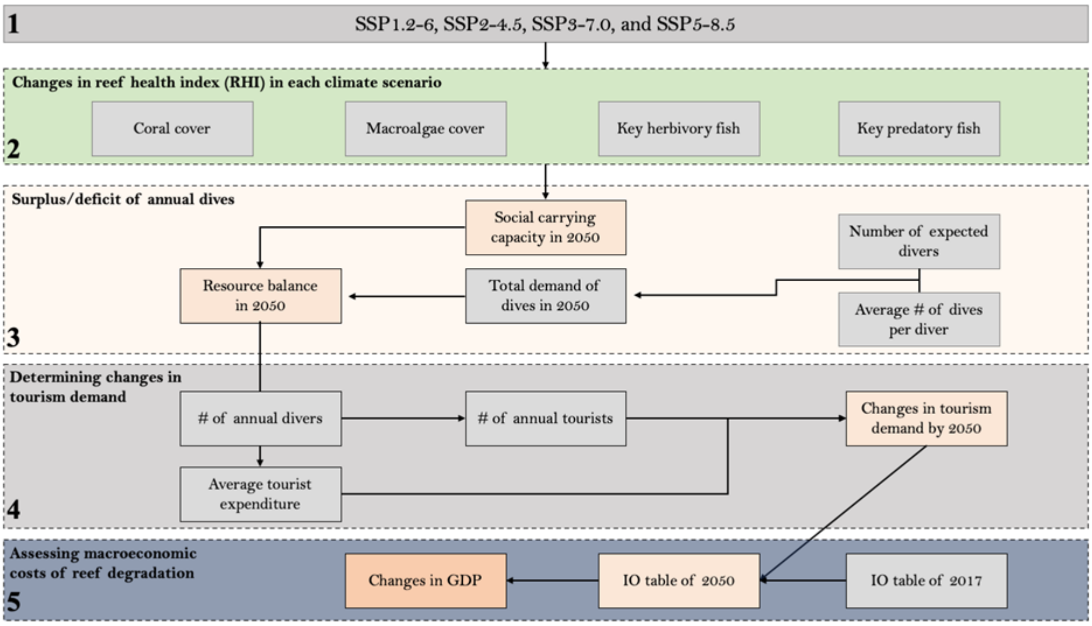



*Figure 2 Methodological framework*

In the third section, the social carrying capacity of the reef is described. This indicator captures the number of annual dives that can be supported to tourists and is based on the health of the reefs on the leeward side of Bonaire. To determine whether future tourism demand can be met in the case of reef degradation, section three also establishes the resource balance of the reef, which is calculated by subtracting the social carrying capacity from the total dive demand. Section four discusses how the environmental impacts are translated into economic consequences for tourism using an input-output methodology. Any potential deficits in the resource balance affect tourism demand through declining total tourist expenditures. Finally, section five describes how any losses in tourism expenditures are fed into the constructed IO table for 2050 to determine changes in the macroeconomic performance of Bonaire, proxied by changes in GDP relative to 2017 levels.

## 3.1 Scenario development

### 3.1.1 Climate change scenarios

Under conditions expected by 2050, direct and indirect anthropogenic pressures are expected to progressively result in rapid losses of coral-dominated reef systems in the Caribbean (Hoegh-Guldberg & Bruno, 2010). Various scholars have stated that thermal stress from rising sea surface temperature (SST) increases the probability of coral bleaching, causing more frequent mass coral mortality events (Cook *et al.*, 1990; Buddemeier *et al.*, 1993;). Furthermore, ocean acidification driven by increased concentrations of dissolved atmospheric carbon dioxide (CO2) is argued to compromise the recruitment of juvenile coral and carbonate accretion which is crucial for forming the three-dimensional structure of the reef (Hoegh-Guldberg *et al.*, 2017). The limited growth affects the resilience of coral reefs following disturbances. Finally, increases in mean annual air temperature (AT) have accelerated algae growth (Ye *et al.*, 2011). Researchers argue that increased algae cover introduces potentially harmful microbes throughout the reef ecosystem. These microbes threaten the reef ecosystem by depleting oxygen from the environment and attracting diseases (Hughes & Connel, 1999).

Though climate change effects were not modelled beyond 2050, due to the uncertainty of projecting multiple variables over a long period, we can make some observations on the effects of climate change on coral reefs beyond this horizon. The IPCC in its special report “The Ocean and Cryosphere in a Changing Climate” (IPCC, 2019) states with high confidence that coral reefs in warm water region are expected to significantly decrease in area by 2100. Furthermore, this effect will occur even in a scenario where global warming is limited to 1.5 degrees Celsius. The primary drivers for this are an increase in thermal stress, ocean acidification and to a smaller extent increased storm damage (Hoegh-Guldberg *et al.*, 2017). These in turn lead to coral bleaching events and mass mortality events, as well as reduced coral recruitment and growth (Hoegh-Guldberg *et al.*, 2017). The Caribbean region will not be spared these effects, as mass coral bleaching occurrence is predicted to be a near annual occurrence in the region under all but the RCP2.6 (global temperature rise below 2 degrees) climate scenario by 2100 (Figure 1). Furthermore, under the RCP8.5 scenario all coral reefs are projected to have died off by 2100. Combined, these effects are thus expected to lead to a decrease in coral area, which in turn could lead to decreases in ecosystem services associated to coral reefs such as tourism and fisheries impacting local economies (IPCC, 2019).

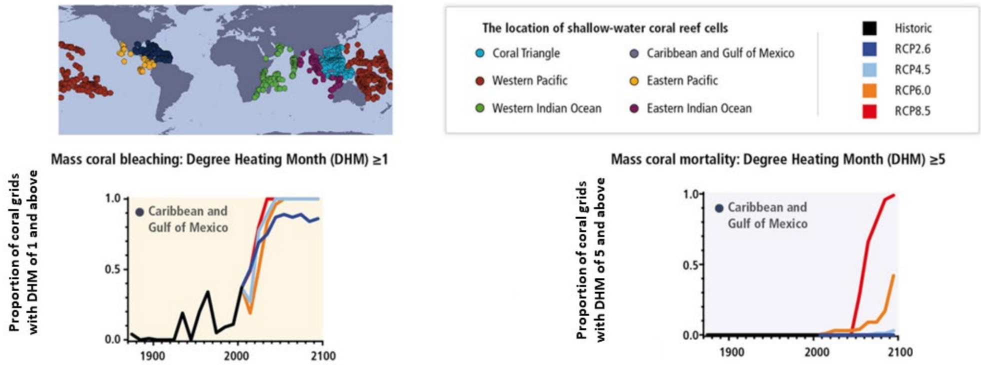



*Figure 3 Project occurrence of mass coral bleaching events and mass coral mortality events up to 2100 under IPCC climate change scenarios. Figure taken and adapted from Hoegh-Guldbergt et al. (2017)*

To proxy the magnitude of thermal stress and ocean acidification in the Caribbean by the middle of the century, this paper uses four climate scenarios of the Sixth Assessment Report of the IPCC (2021): SSP1.2-6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. The four climate scenarios start in the base year 2017 to match the last year for which ecological data on Bonaire's coral reefs is available. Furthermore, they provide climate estimates for 2030 (near term) and 2050 (midterm). Increases in air temperature (AT), sea surface temperature (SST), and the level of atmospheric carbon dioxide (CO2) concentrations differ between scenarios based on socio-economic assumptions and the level of climate change mitigation (IPCC, 2021). Table 4 summarizes the projections of AT, SST, and CO2 concentrations for each scenario based on the AR6 report (IPCC, 2021) and the GISS-E2.1 model of Miller *et al.* (2021). Current climate levels are assembled from several sources; SST data of the Caribbean is obtained from the Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program and the National Oceanographic Data Center (NODC). Air temperature is obtained from Taylor *et al.* (2018), and current CO2 concentrations are retrieved from the "ocean acidification product suite" of the NOAA Coastwatch (2022) for 2030 (near term) and 2050 (midterm).

*Table 4 Global mean AT, SST, and dissolved CO2 for the four considered climate scenarios*

| Climate scenario | Mean AT (Celsius) increase* | Mean SST (Celsius) | Mean atmospheric $CO_2$ concentration (parts per million) |
|---|---|---|---|
| Base year (2017) | +1.0 | 27.25 | 406.76 |
| IPCC 1-1.9 | | | |
| Near term (2030) | +1.33 | 27.64 | 422.99 |
| Midterm (2050) | +1.60 | 27.98 | 437.51 |
| IPCC 2-4.5 | | | |
| Near term (2030) | +1.33 | 27.69 | 439.09 |
| Midterm (2050) | +2.00 | 28.17 | 489.39 |
| IPCC 3-7.0 | | | |
| Near term (2030) | +1.33 | 27.69 | 454.81 |
| Midterm (2050) | +2.10 | 28.14 | 510.06 |
| IPCC 5-8.5 | | | |
| Near term (2030) | +1.38 | 27.81 | 466.29 |
| Midterm (2050) | +2.40 | 28.52 | 577.06 |

* Increase in mean air temperature is relative to the pre-industrial 1850-1880 base period.

Source: Lenssen *et al.* (2019); Chen *et al.* (2014); Miller *et al.* (2021); IPCC (2021); NOAA coast watch (2022).

## 3.2 Ecological module

### 3.2.1 Study area and data

The data of this paper utilizes 2017 as the baseline year to obtain the most complete dataset for coral cover. The study area covers the entire leeward side of Bonaire. The island's windward side is rarely used for tourism purposes and is, therefore, less economically relevant in the context of this study. The coral reefs on the leeward side of Bonaire cover 866 ha in total (Debrot *et al.*, 2018). The Reef Health Index (RHI) is employed to reflect the current health of the coral reefs (Kramer *et al.*, 2015). This index was developed to assess the state of the Mesoamerican Reef in the Caribbean (Diaz-Perez *et al.*, 2016). The coral reefs of Bonaire exhibit similar characteristics in coral species and depth as Mesoamerican reefs, making the RHI a valid indicator to proxy the state of Bonairian reefs (Meesters *et al.*, 2017). The RHI consists of four key health indicators:

- coral cover (in %),
- macroalgae cover (in %),
- biomass of key herbivorous fish (g/100m$^2$),
- biomass of key commercial fish (g/100m$^2$).

Each indicator is scored according to the range depicted in Figure 4. The final RHI score is the average sum of each indicator score. An RHI ranging between 1.0-1.8 indicates a reef in "Critical" state, 1.8-2.6 indicates a "Poor" state, 2.6-3.4 equals a "Fair" state, 3.4-4.2 "Good," and 4.2 – 5.0 is seen as "Very Good" (Kramer *et al.* 2015).

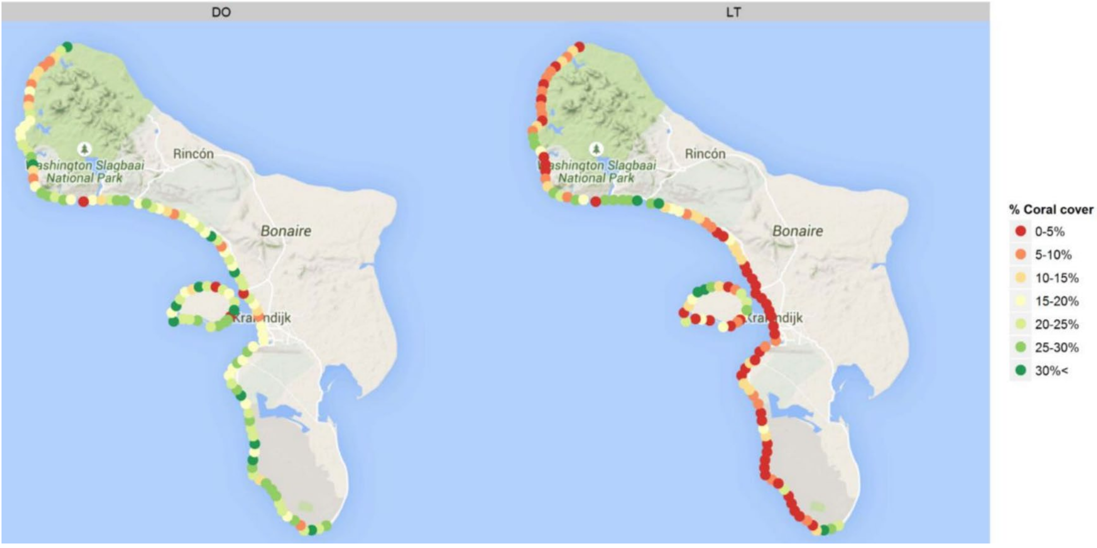
| Reef Health Index Indicators | Very Good (5) | Good (4) | Fair (3) | Poor (2) | Critical (1) |
|---|---|---|---|---|---|
| Coral Cover (%) | ≥40 | 20.0-39.9 | 10.0-19.9 | 5.0-9.9 | <5 |
| Fleshy Macroalgal Cover (%) | 0-0.9 | 1.0-5.0 | 5.1-12.0 | 12.1-25 | >25.0 |
| Key Herbivorous Fish (g/100m$^2$) *(only parrotfish and surgeonfish)* | ≥3480 | 2880-3479 | 1920-2879 | 960-1919 | <960 |
| Key Commercial Fish (g/100m$^2$) *(only snappers and groupers)* | ≥1680 | 1260-1679 | 840-1259 | 420-839 | <420 |

Source Kramer *et al.* (2015).

*Figure 4 The Reef Health Index (RHI) ranking criteria system*

Data on the status of the health indicators in 2017 was obtained by extrapolating the “Reef Health Index parameters of Bonaire reefs” of Meesters (2020) for the entire study area. Meesters captured point data of 115 transect zones at a 500-meter interval at two separate depths: 5 meters (shallow) and 10 meters (lower terrace). Figure 5 presents the location of these transect zones along the leeward coastline. Mean coral cover of all transect zones amounted to 11.2%, or 97 ha, in 2017 (Meesters, 2017). Next, mean macroalgae cover was estimated to be 44.5%, which aligns with the range estimates from 41.7% to 51.8% by Stokes *et al.* (2010). The average herbivory biomass was found to be 3179 g/100m2. Since commercial fish were not included in the dataset, average predatory biomass is used as a proxy for the weight of “snappers and groupers,” which equals 2121 g/100m2. Extrapolating these over the entire leeward side of Bonaire results in a herbivory population of 275.3 tonnes in biomass and a predatory population of 183.7 tonnes in biomass. The total estimated fish stock of 463 tonnes constitutes a slight decline relative to the total fish stock calculated by Koks & van Zanten (2015) for 2012 (514 tonnes).

Applying the RHI to the 115 individual transect zones of Meesters (2020) results in an average RHI of 2.9, which indicates that the average state of reefs on the Leeward side of Bonaire can be considered to be “Fair.” Specifically, 1 transect zone is in a “Critical” state, 24 zones are ranked as being in a “Poor” condition, 60 zones are in a “Fair” state, 30 are found to be in a “Good” state, and 0 zones are determined to be in a “Very Good” state.




Source: Zanke & De Froe (2017)

*Figure 5* *Maps of the mean coral cover per transect zone on the leeward side of Bonaire. On the left, the mean coral cover of the drop-off transect points (10 meters) is provided. The right map shows the mean coral cover of the lower terrace (5 meters)*

### 3.2.2 Conceptual Framework

To predict future changes in the RHI of the 115 transect points by 2050, an ecological module was constructed based on the GEM model of Koks & van Zanten (2015). Combining ecological and economical modelling has been applied several times in the context of coral reef systems (van der Lely *et al.*, 2013; Chang *et al.*, 2008) and combines social, economic, and ecological processes into socio-economic and ecological systems modules. The ecological module reflects the state of the coral reef ecosystems of Bonaire. The health of these marine systems is affected by local and global stressors and ecosystem properties, which ultimately affect dive tourism demand. Figure 6 shows the conceptual framework of the model. First, the key health indicators are impacted by global climate stressors (GS) through the external effects of “algal blooms, ocean acidification”, and “coral bleaching.” The magnitude of these global stressors depends on the CO2, SST, AT levels of the climate scenarios in Table 4. Furthermore, the coral reef ecosystem is impacted by local stressors (LS) through the external effects of “sedimentation run-off”, “overfishing”, and “tourism”. These stressors interact with the key health indicators and other ecosystem properties. A detailed description of all the different relationships and inputs of the model is provided in Annex A. Note that we did not incorporate any variables on coral reef restoration or other climate change adaptation measures, as there are no reliable projections on their effects.

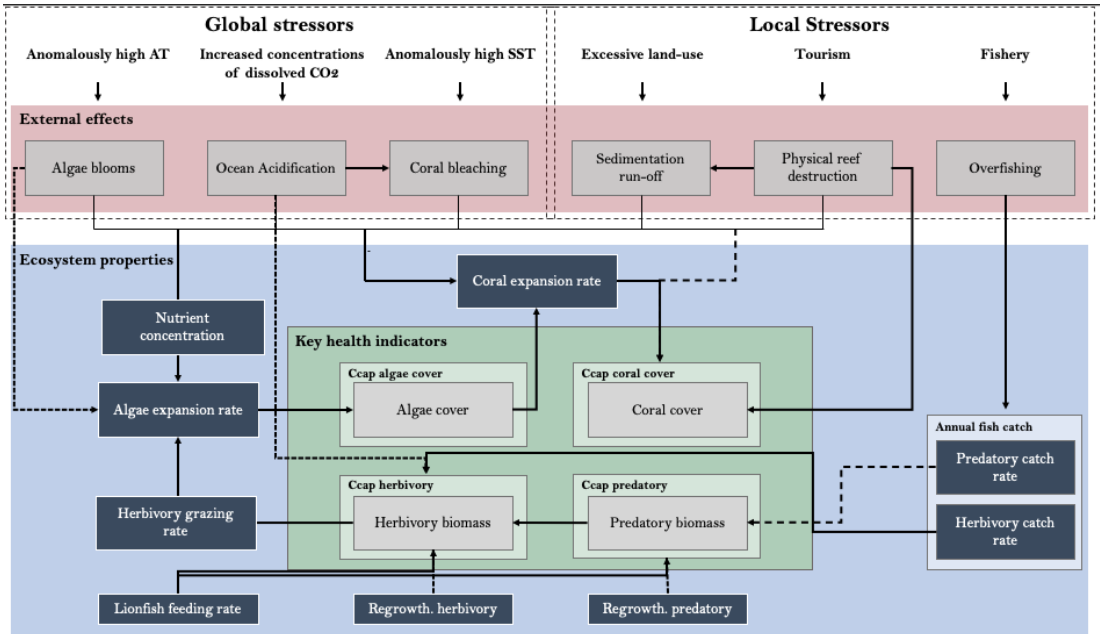



*Figure 6 Conceptual framework of the ecological module highlighting the interactive effects between external effects, ecosystem properties, and key health indicators*

## 3.3 Determining dive demand

In this study, the final demand of tourist-related industries depends on the total supply of dives that the coral reefs can facilitate. Bonaire is often labelled as “diver’s paradise”, and most tourists visit the island for diving purposes (TCB, 2008; Wolfs *et al.*, 2015). Sookram (2009) finds that reef degradation affects both the number of tourist arrivals as well as their expenditures, confirming the strong dependency of tourism revenues on quality dive sites. The concept of social carrying capacity is employed to predict changes in dive tourism demand. This variable captures the restricting factor of the available amount of healthy reef when visiting a diving site (Davis & Tisdell, 1995). The social carrying capacity of the coral reef on Bonaire is calculated using the approach of Koks and van Zanten (2015). This is done by multiplying the number of quality dive spots by the number of ‘divable’ hours and the maximum encounters of divers per dive slot at each dive site. According to the TCB (2021), Bonaire currently has 86 official diving sites on the leeward side: 60 of those are located off the coast of Bonaire and another 26 on Klein Bonaire. Following the threshold of Schuhmann *et al.* (2013), divers only derive positive utility if they run into seven or fewer other divers at a dive site. Additionally, it is assumed that divers spent an average time of 1.5 hours on a dive spot and that there are 10 ‘divable’ hours in a day (Wolfs *et al.*, 2015). Consequently, the total social carrying capacity in 2017 amounts to 1,464,867.

The ecological module directly links any changes in key health indicators in the reef ecosystem to the quality of the available dive spots on Bonaire using the previously mentioned 115 transect points. This paper assumes that each transect point represents a percentage of the 86 quality dive spots. In addition, when a transect zone reaches a final RHI below 1.8, its state is considered “Critical”, and it cannot supply any ecosystem services to divers anymore. Applying the scoring to the baseline year of 2017 reveals that 114 of the 115 transect points can be considered at least healthier than “Critical”. Consequently, changes in the number of quality dive sites are proxied by changes in the RHI of the 114 transect points. When a certain percentage of the 114 transect points degrade to ‘Critical’ in the following years due to climate impacts, the number of quality dive spots declines with the same percentage. As such, degrading coral reef declines the available amount of dive sites, thus, decreasing the supply of dives for tourists. Figure 7 presents a schematic overview of the previously described framework.

The total annual dive demand is estimated in Figure 8 by determining how many tourists on Bonaire are divers each year. Table B2 in Annex B provides an overview of the estimated diver arrivals between 2001 and 2017. The percentage of divers among stay-over tourists decreased between 2001 and 2012 (TCB, 2010; Schep *et al.*, 2013). To predict the number of stay-over divers for 2017, it is assumed that this historical trend stabilizes at 2012 levels. Consequently, 51.26% of the stay-over tourists in 2017 were divers. Simultaneously, Schep *et al.* (2012) found in their tourist survey that 4.35% of cruise tourists that arrived on Bonaire spent money on diving activities in 2012. Since there is no other historical data available on divers among cruise tourists on the island, this paper assumes that the 4.35% remains constant over the years. Finally, based on the expert opinion of Bart Snelder, head of the Council Underwater Resort Operators (CURO), it is expected that the average demand of a diver per stay is 10 dives. (Snelder, 2022). The final total dive demand for 2017 accounted for 835,867. Therefore, the resource balance in 2017, calculated by subtracting the total dive demand from the social carrying capacity, amounted to a surplus of 629.000 dives.

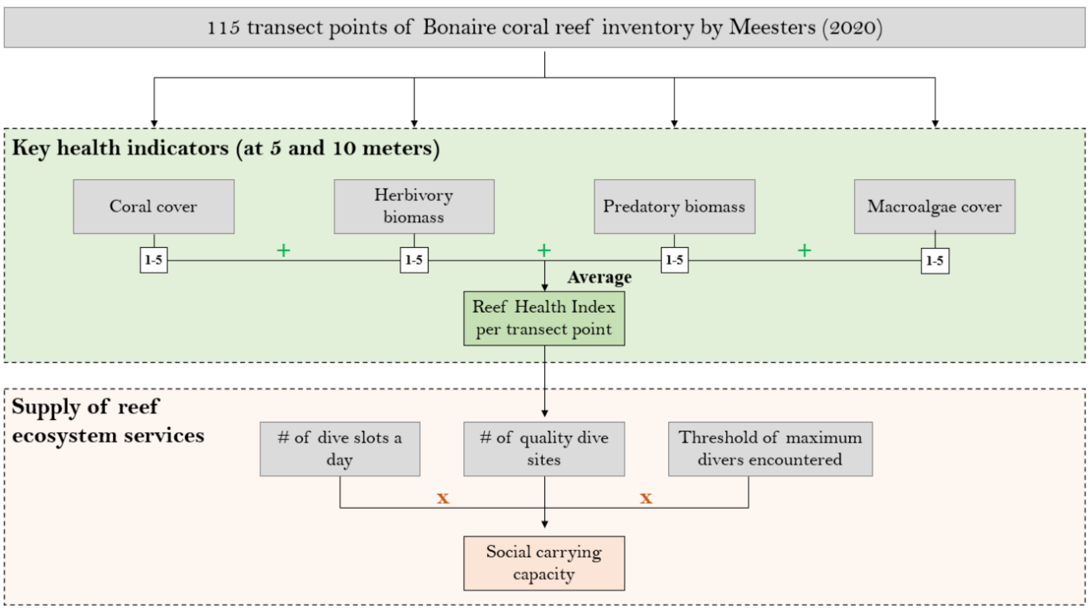



*Figure 7 Overview of established social carrying capacity using key health indicators obtained from Meesters (2020) extrapolated inventory of Zanke & DeFroe (2017)*

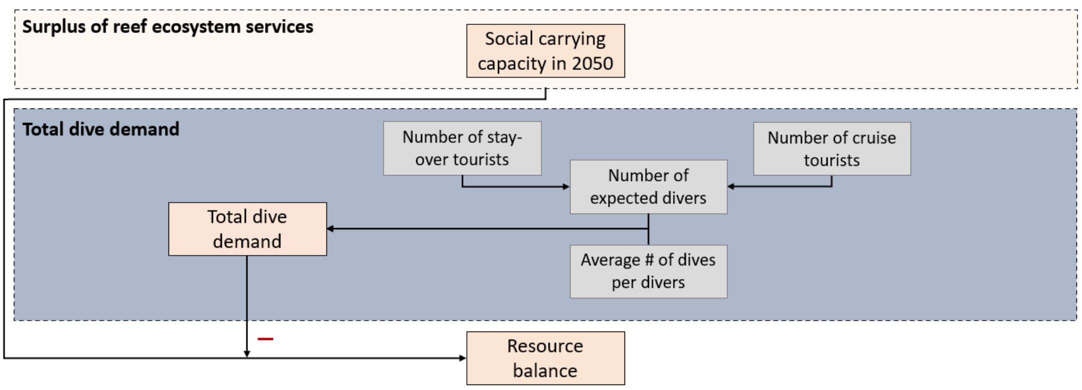



*Figure 8 Continued framework of establishing total yearly dive resource balance using the social carrying capacity of the coral reef and the total dive demand*

## 3.4 The Bonaire input-output table

### 3.4.1 Input-output modelling

Although Bonaire is a small island that primarily relies on economic developments outside its economy, the state of its coral reefs has proven to be the decisive factor in tourist destination choices (Uyarra *et al.*, 2005). Therefore, the tourism demand for Bonaire is assumed to be endogenous to the model, depending on the ecosystem's supply (e.g., the quality of the coral reefs). The majority of macro-economic literature that incorporates environmental information to make quantitative assessments employ either econometric, input-output (IO), or computable general equilibrium (CGE) models (Koks *et al.*, 2015). Econometric model building holds considerable promise in predicting cause-and-effect relationships. It benefits from statistical robustness in estimating both the magnitude and direction of change (Rose, 2004). However, econometric models have been sharply criticized due to their inability to deal with interrelationships (Koks *et al.*, 2016). Since an economy consists of a dynamic system of resource flows between industries, the econometric assumption of variable independence is unrealistic, thus, not functional for this study.

In contrast, IO and CGE models can integrate this potential ripple effect. Both methods employ a supply and use table (SUT), a matrix used to represent all transactions and transfers between economic agents within a structure, often during a specific accounting period (Reinert and Roland-Holst, 1997; Botzen *et al.*, 2020). A CGE model offers more flexibility as it can account for nonlinearity, substitution effects, and budget and technology constraints. However, it often depends on more restrictive assumptions than IO models (Rose, 2004; Koks *et al.*, 2016). Traditionally, scholars have preferred IO analysis to study the impacts of tourism on an economy due to its simplicity and well-documented assumptions and limitations (e.g., Fletcher 1989; Briassoulis 1991). An IO model can generally be regarded as a static demand-driven model that assumes a linear, time-invariant, fixed-proportions output function for all economic agents. A key strength of the analysis is the application of Leontief multipliers (Rose, 2004). These multipliers show the interrelation between the output of industries within an economy in case of a sudden shock. That is, IO methodology allows for identifying both direct and indirect effects of exogenous impulses to an economy, such as tourism losses.

Considering the simplicity and transparency of IO models, this paper will use IO analysis to link external ecological effects to economic impacts. This linkage allows us to determine the economy-wide impacts of environmental shocks from tourism losses to other industries in the economy of Bonaire. This concept is also known as the 'multiplier effect': the variances in output of other industries within an economy when the demand of a single industry changes. The magnitude of these interrelations is estimated by determining the multiplier coefficients. Annex A.2 offers further elaboration on how standard IO analysis is conducted and how IO multipliers are established.

### 3.4.2 Constructing input-output tables for Bonaire

As explained in the Background section, the IO table of 2017 for Bonaire is fully based on the updated IO table of Koks & van Zanten (2015) for 2012. This table is constructed using the SUT of 2004 for Bonaire and is structured as an industry-industry table. To estimate how the different industries have developed from 2012 to 2017, data on GDP growth and average salary growth per industry is retrieved from the CBS (2020). The resulting IO table for 2017 can be found in Annex B.1.

Due to the island's small size and remoteness, its industries require high levels of imports of agricultural and manufactured products to operate. Therefore, the total intermediate demand of each industry required for production was split into domestic products (locally produced) and external products (import). Next, to better align the tourist expenditure patterns (Table 3) with the industry categorization of the CBS, the "Horeca" sector is split up into the "Hotels" sector and the "Food services" sector. This subdivision is essential to capture the differences in expenditure profiles between stay-over tourists and cruise tourists. Since the tourism satellite account (TSA) of Bonaire (CBS, 2012) does not account for this subdivision, the relative share of the two industries is based on the TSA of Aruba (Steenge, 2010), which is assumed to have a similar structure as Bonaire. Data on tourism expenditures was retrieved from the exit survey of Schep *et al.* (2013) and the 2017 Tourist Exit Survey of STMP Bonaire (Croes *et al.*, 2019). Finally, the total tourism expenditures per category are matched with its related industry in the IO table. For instance, tourist expenditures on diving, snorkelling, and island tours are recreational activities, thus, allocated to the "Other services" sector, expenditures on groceries are allocated to the "Trade" sector, car rental expenditures to the "Transport" sector, and so on (Table 3). Expenditures on "Accommodation" are allocated for 47% to the "Hotels" sector and 53% to the "other real estate activities" sector, based on the 2017 Tourist Exit Survey (STMP Bonaire, 2017).

The economic structure of Bonaire in 2050 was predicted by updating the developed IO matrix of 2017 using a CRAS approach, as proposed by Lenzen *et al.* (2009). The CRAS-algorithm (cell-corrected RAS-algorithm) is an adoption of the original RAS-algorithm that was developed to update IO tables by Stone (1961). In his method, an old matrix A, with row sum $X_i$ and column sum $Z_i$ is transformed to a 'new' matrix Y that satisfies a 'new' set of given row sums and column sums with minimum loss of information (Stone, 1961). However, the original RAS method only works when the start matrix A solely has non-negative entries (Bacharach, 1970). Hence, Junius & Oosterhaven (2002) developed a general mathematic device that can be applied to original matrices with both negative and positive entries, which was later corrected by Lenzen *et al.* (2009) for additional issues, for example, when handling zeros as initial entries (Lenzen *et al.*, 2007). In addition, CRAS is also able to compromise between inconsistent matrix entries. This is especially helpful since the 'new' set of constraints for 2050 are obtained by making assumptions on sectoral and GDP growth for 2050. Three economic scenarios are developed for Bonaire: a (1) high growth scenario, a (2) business-as-usual (BAU) scenario, and a (3) low growth scenario. Again, the economic scenarios start in the base year 2017 and run until 2050. The GDP growth rates in every scenario were corrected for inflation to translate the economic impact of reef degradation on output to 2017 prices. The underlying assumptions of every scenario are provided in Annex C. The problem that needs to be resolved is to find a 'new' matrix Y that deviates least from the original matrix A, given the set of new row and column constraints, row vector $X_n$ and column vector $Z_n$. The matrix entries should be chosen in order to satisfy the following target function (Wiedmann *et al.*, 2007):

$$t'(A,Y) = arg\ arg \quad \sum_i \quad \sum_j \quad \left|z_{i,j}\right| ln\frac{z_{i,j}}{e} \qquad \text{With } z_{i,j} = \frac{x_{i,j}}{a_{i,j}} \qquad [1]$$

$$\text{s.t. } \forall i = \sum_j \quad x_{i,j} = X_n,\ \forall j = \sum_j \quad x_{i,j} = Z_n \qquad [2]$$

where target function *t'* is minimized, given the constraints that the sums of all sector outputs $x_{i,j}$ are equal to the column and row totals of the IO matrix. The three resulting IO tables for 2050 are provided in tables 16, 17 and 18 (Annex D).

## 3.5 Assessing the macroeconomic costs of reef degradation

The multiplier effects of tourism were estimated using the approach of Frechtling & Horvath (1999). The process of estimating total revenue losses was based on the number of stay-over and cruise tourist arrivals, the average numbers of nights spent on Bonaire, and the average tourist expenditures per tourist per day (Mayer & Vogt, 2016). First, the annual number of visitors to Bonaire was proxied using the resource balance. This paper assumes that divers will not visit the island if their dive demand cannot be met. In the case of a deficit in the resource balance, the demand for dives exceeds the supply. Consequently, not all divers that are willing to visit Bonaire can be facilitated. Assuming that every diver demands ten dives per stay (CURO, 2022), the number of divers that will not visit Bonaire could be calculated. For instance, when the resource balance equals -100 thousand dives in 2050, the demand of 10 thousand divers cannot be satisfied. Therefore, total tourism arrivals decline by 10 thousand on the island. However, the type of tourist arrivals should also be differentiated since stay-over tourists and cruise tourists have different expenditure patterns (Table 3).

According to Mercera (2022), CEO of TCB, Bonaire is planning to limit stay-over arrivals to a maximum of 250 thousand a year to prevent mass tourism on the island and to remain a unique destination. Assuming a similar growth rate of stay-over-arrivals as in the period of 2001 until 2019 (Table B1), it is expected that Bonaire will have reached the maximum amount of 250 thousand stay-over tourists by 2029. Simultaneously, cruise tourism is expected to be restricted to focus more on high-end tourism (Croes *et al.*, 2019). Cruise ships will most likely be limited to one ship a day, as suggested by Mercera (2022). Since cruise ships generally only visit Bonaire between October and April, and assuming an average capacity per ship of 1224 passengers (Wolfs *et al.*, 2015), this paper predicts a maximum of 259.5 thousand cruise tourist arrivals by 2050. As mentioned in section 3.3, it is assumed that 51.26% of total stay-over tourists and 4.35% of cruise tourists are divers. Employing these rates to the preceding example of a shortage of 10 thousand divers, we would find a decline of 9.2 thousand stay-over tourists arrivals and 0.8 thousand cruise tourist arrivals.

The decline in stay-over and cruise tourist arrivals affects the input-output table through the final tourism demand. In turn, final tourism demand is based on the average tourist spending, "the total consumption expenditure made by a visitor on behalf of a visitor for and during his/her trip and stay at destination" (UN, 1994, p. 21). A decline in X number of stay-over tourists on Bonaire would result in total tourist expenditures that are lowered by X multiplied by the average expenditures of a stay-over tourist (i.e., 1,886 USD per stay, Table 3). Similarly, a decline in Y amount of cruise tourists would result in a final demand that is lowered by Y multiplied by the average added value of a cruise tourist (i.e., 122.13 USD per stay, Table 3). The tourism revenue loss per category is matched to the impacted industry in the IO table based on Table 3. Due to the multiplier effect, explained in Annex A2.2, variances in the final demand of a specific industry will result in 'spill-over' effects to other industries. To calculate the change in the total output of each sector, a Leontief matrix needs to be constructed. This matrix provides the technical coefficients necessary to estimate changes in intermediate demand between industries when the final demand changes. Subsequently, the sum of all aggregated changes in intermediate demand reflects the level of changes in the total output of Bonaire. The last step to finding the total macroeconomic impact of reef degradation is to estimate changes in the GDP of Bonaire by 2050.

$$GDP = GVA + TP - SP \qquad [3]$$

Where GDP is the gross domestic product, GVA denotes the aggregated gross value added of all industries in Bonaire, TP describes the taxes on products, and SP defines the subsidies on products (Callen, 2012). Similar to the changes in intermediate demand, the changes in GVA, TP, and SP are estimated using the Leontief matrix. The coefficients of a sector's GVA ($CVA_i$) are obtained by dividing the value added per sector ($VA_i$) by the total output of the sector ($X_i$) (Furtuoso & Guilhoto, 2000). Subsequently, the $CVA_i$ are multiplied by the Leontief matrix $(I - A)^{-1}$ to obtain the technical coefficients $TVA_i$. Since total output $X_i$ decreases when the total intermediate demand decreases, changes in the GVA can be calculated by taking the sum of $TVA_i$ multiplied by the changes in total output $X_i$ of each sector. Hence, equation [4] can be developed.

$$\Delta GVA_{Bonaire} = \sum_i \quad (TVA_i * \Delta X_i) \qquad [4]$$

Likewise, changes in TP and SP are determined by calculating the corresponding technical coefficients $TTP_i$ and $TSP_i$ and multiplying them by the change in total output $X_i$ of each industry:

$$\Delta(TP - SP)_{Bonaire} = \sum_i (TTP_i * \Delta X_i) - \sum_i (TSP_i * \Delta X_i) \qquad [5]$$

Hence, if the coral reefs around Bonaire degrade, causing direct tourism demand in some sectors to decline, both direct and indirect economic consequences are expected to occur. Using the Leontief multipliers, the induced changes in intermediate demand between all sectors can be determined. The resulting decrease in total output per sector can subsequently be used to assess the changes in GDP, using equations [3], [4], and [5].

# 4 Results of the scenario analysis

This chapter follows from the previous methodology chapter and presents the main findings of this study. The scenario analysis describes the impact of four different climate scenarios on sectoral and macroeconomic output. The ecological module runs for 33 years, from 2017 until 2050, using climate data described in section 3.1.

## 4.1 The social carrying capacity of dive sites

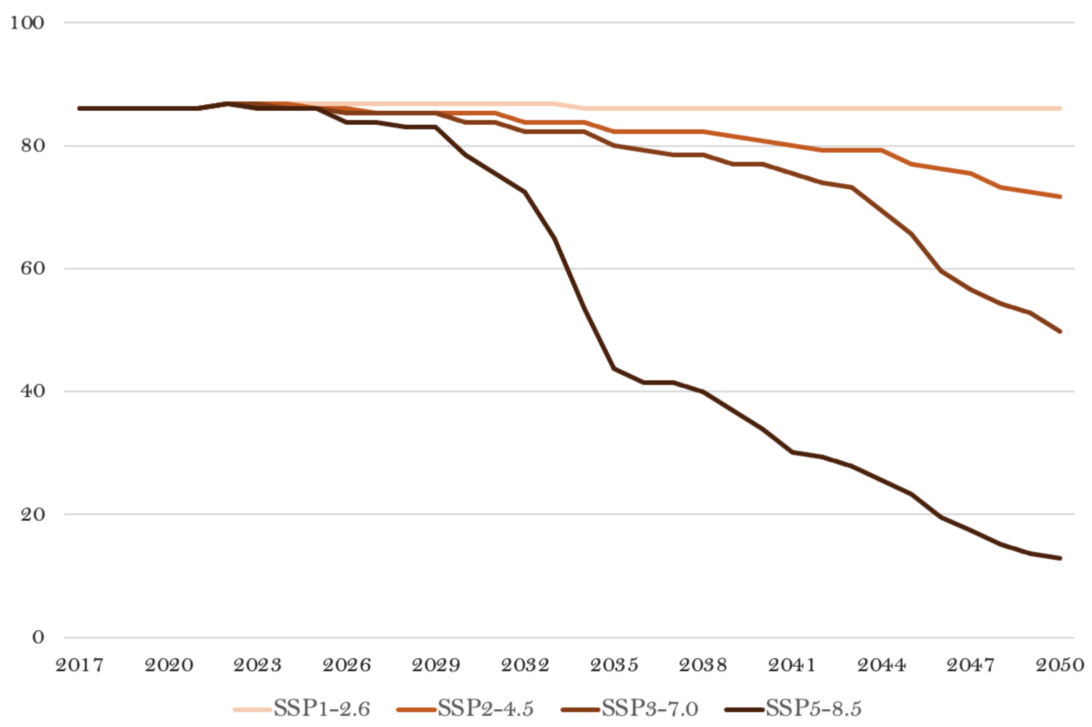



*Figure 9 The number of quality diving sites (86 at start in 2017) with a RHI > 1.8, between 2017-2050*

Figure 9 presents the impacts of the IPCC AR6 scenarios SSP1.2-6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 on the number of quality dive sites on the leeward side of Bonaire. Note that due to a recent coral bleaching event, coral reefs actually recover in the first years following 2017, leading to an initial slight increase the number of quality diving spots (Bakker *et al.*, 2019). All scenarios, except SSP1-1.9, exhibit a declining trend in quality dive sites after 2022, indicating that the health of the coral reefs is susceptible to climate pressures. SSP1-1.9 imagines a socioeconomic shift toward sustainability and a drastic cut in global emissions (Carbonbrief, 2018). As a consequence, the number of quality dive sites are expected to remain at 86 under this scenario. A rise in algae cover is offset by a moderate increase in herbivory fish populations and coral cover, which increases the average RHI score of the marine ecosystem to 3.18. Conversely, scenarios SSP2-4.5 and SSP3-7.0 result in significant reef degradation. In scenario SSP2-4.5, mean live coral cover falls to 7.4%, while total fish stock decreases from 463 to 262 tonnes.

Progress toward sustainability is expected to be too slow for Bonaire's coral reefs to resist the climate pressures. Ultimately, the number of quality dive spots drops from 86 to 72. Similarly, in SSP3-7.0 mean live coral falls to 3.9%, while the biomass of the total fish stock decreases from 463 tonnes to 156 tonnes by 2050. In addition, algae cover grew to its maximum of 82.2% due to steadily rising temperatures. As a result, the number of quality dive sites drops from 86 to 51. Finally, scenario SSP5-8.5 displays the most severe decline. The average RHI score of a transect point drops from 3.02 to 1.47, indicating that the coral reefs are in a "Critical" state. Mean live coral cover falls to 0% by 2050, and macroalgae cover grows exponentially. However, the leeward side still provides 12 quality dive sites out of the initial 86 as there are fish populations around, although small in size (94 tonnes).

Any changes in the quality of the dive sites are expected to decrease the supply of annual dives, thus affecting the resource balance. Recall that resource balance depends on the supply of annual dives and the total expected number of tourist arrivals. In section 3.5, it is assumed that by 2050, ceteris paribus, 250 thousand stay-over tourists and 259.5 thousand cruise tourists will arrive on the island. A certain share of these tourists are divers (Table B2). Subtracting the annual diving demand from the social carrying capacity of the coral reefs results in the resource balance of each scenario in Table 5. Subsequently, the surplus or deficit is calculated by dividing the resource balance by the average dive demand of an individual diver (10). The final step is calculating the split between the number of stay-over tourists and cruise tourists that cannot be facilitated.

## 4.2 Expected changes in tourism demand

Scenario SSP1-1.9 shows a positive resource balance, since the coral reefs are expected to have the capacity to carry all diver demand. The model predicts no decline in diver arrivals, hence, no changes in final tourism demand are expected. However, SSP2-4.5 displays a deficit of 174 thousand in the resource balance. The decline in quality dive spots decreases the social carrying capacity to a point where the dive demand exceeds the actual supply of dives. Consequently, 16.0 thousand stay-over tourists and 14.1 thousand cruise tourists are expected not to visit the island compared to the baseline scenario. This deficit progressively decreases with SSP3-7.0 and SSP5-8.5. In SSP3-7.0, 50.2 thousand stay-over tourists and 4.4 thousand cruise tourists are expected to not travel to Bonaire. In scenario SSP5-8.5 total losses in tourism arrivals decreases to 117.6 thousand tourists, resulting from a negative balance of 108.1 thousand stay-over tourists and 9.5 thousand cruise tourists.

Consequently, 16.0 thousand stay-over tourists and 14.1 thousand cruise tourists are projected not to visit the island. This deficit progressively decreases with SSP3-7.0 and SSP5-8.5. In SSP3-7.0, 50.2 thousand stay-over tourists and 4.4 thousand cruise tourists decide to not travel to Bonaire. In scenario SSP5-8.5 total losses in tourism arrivals decreases to 117.6 thousand tourists, resulting from a negative balance of 108.1 thousand stay-over tourists and 9.5 thousand cruise tourists. Changes in the final tourism demand, calculated by changes in the number of tourist arrivals multiplied by their average expenditures per stay, are summarized in Table 5. The loss in expenditure of an average cruise tourist equals to 122.13 USD, while the loss in expenditure of an average stay-over tourist amounts to 1886.27 USD, as seen in Table 3. Scenarios SSP2-

4.5, SSP3-7.0, and SSP5-8.5 results in losses in final tourism demand, ranging from 30.3 USDm to 205.0 USDm. The majority of the economic damage in final demand is caused by losses in stay-over tourists, since the greater expenditure patterns and higher percentage of divers among them, as compared to cruise tourists.

*Table 5 Overview of the expected diving demand and supply of quality dive sites in 2050 under each IPCC AR6 scenario. Percentages indicate change compared to baseline*

| **Climate scenario** | **Base line (2017)** | **SSP1-1.9** | **SSP2-4.5** | **SSP3-7.0** | **SSP5-8.5** |
|---|---|---|---|---|---|
| Quality dive sites (#) | 89 | 86 (-3%) | 72 (-19%) | 50 (-44%) | 13 (-85%) |
| Average RHI score | 2.9 | 3 (10%) | 2 (-22%) | 2 (-36%) | 1 (-49%) |
| Social carrying capacity | 1,515,967 | 1,464,867 (-3%) | 1,220,722 (-19%) | 848,081 (-44%) | 218,455 (-86%) |
| Annual number of dives | 868,014 | 1,394,365 (61%) | 1,394,365 (61%) | 1,394,365 (61%) | 1,394,365 (61%) |
| Resource balance | 647,953 | 70,501 (-89%) | - 173,643 (-127%) | - 546,284 (-184%) | - 1,117,592 (-272%) |
| Surplus/deficit of diver demand | 64,795 | 7,050 (-89%) | -17,364 (-127%) | -54,628 (-184%) | -117,592 (-272%) |
| Changes in # stay-over tourist arrivals | 0 | 0 | -15,959 | -50,207 | -108,074 |
| Changes in # cruise tourist arrivals | 0 | 0 | -1,406 | -4,422 | -9,518 |
| **Changes in final tourism demand (2017 prices)** | **0** | **0** | **-$30.27 mln** | **-$95.24 mln** | **-$205.02 mln** |

## 4.3 Input-output tables by 2050

Figure 10 presents the total output of each sector of the three economic scenarios by 2050, prior to the climate shocks of the IPCC scenarios. These structures were extracted from the underlying IO tables of 2050, assuming the “high growth,” “business-as-usual”, and “low growth” scenarios. In the “high growth” scenario, Bonaire’s nominal GDP grows from 480 USDm to 1065 USDm by 2050 (Annex D). Based on the expected population of 27.08 thousand by 2050 (CBS, 2022). this amounts to a GDP per capita of 39,364 USD, compared to 25,000 USD in the baseline. This relatively high increase in GDP per capita would confirm that Bonaire’s strategy to make the island a premium and exclusive destination is successfully implemented since high-value immigration and tourism are attracted. Next, the “business-as-usual” scenario returns a GDP of 951 USDm by 2050 (Annex D). Per capita, this equals 35.137 USD, indicating that Bonaire slowly grows to European Union averages (World Bank, 2021). Finally, GDP grows to 684 USDm in the ‘low growth’ scenario (Annex D). However, nominal GDP per capita stagnates at 25,288 USD due to population growth. Since the industries are assumed to grow with the same growth rates as the nominal GDP, the relative contribution of each industry to the total economic output of Bonaire remains the same in each scenario. Nevertheless, there were significant variances in economic output between the three scenarios. For instance, the added value of the "Trade" industry is 50 USDm higher in the "high growth" scenario than in the "low growth" scenario. Hence, the relative decline in GDP due to reef degradation will vary per scenario.

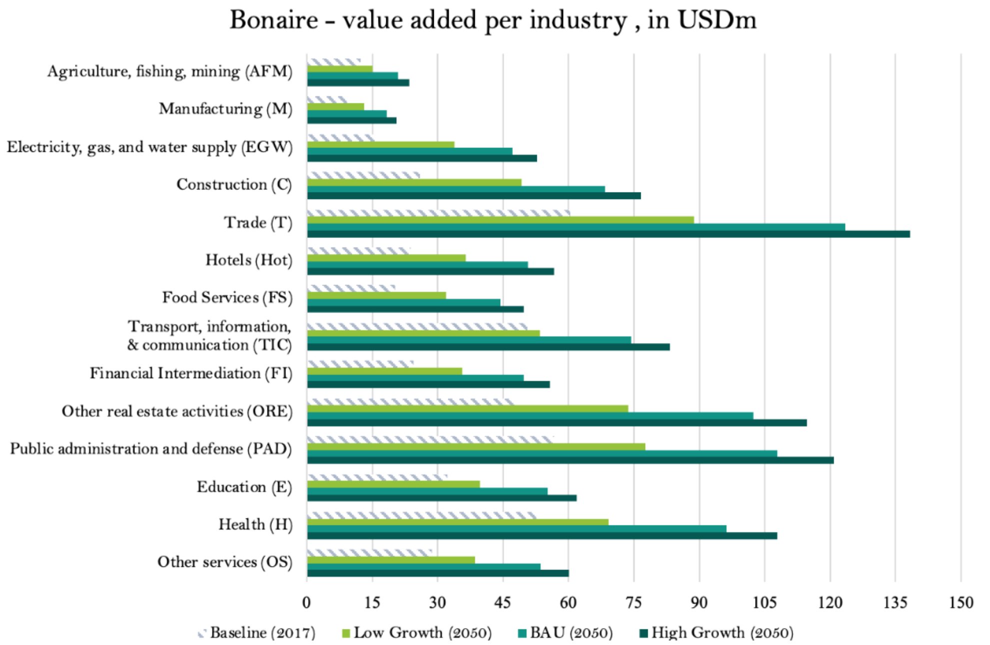



*Figure 10 Value added per industry in Bonaire per economic scenario, in USDm*

To estimate the indirect economic consequences of tourism losses, Leontief multipliers were estimated using the 'new' IO tables for 2050. A Leontief matrix is constructed by employing the methods described in Annex B. Since it was assumed that all industries have similar growth rates within an economic scenario, the interrelations between industries did not change relative to 2017. Annex B shows the Leontief matrix of all interrelationships within Bonaire's economy. The output multipliers range from 1.23x (Public administration and defence) to 1.82x (Hotels). The overall tourism output multiplier amounts to 1.57x, i.e., a decrease in tourism demand of 1 USDm results in a decrease in total output of 1.57 USDm. Consequently, total output in Bonaire under SSP2-4.5, SSP3-7.0, and SSP5-8.5 decreases, respectively, with 47.4 USDm, 49.2 USDm, and 321.1 USDm. These findings support the notion that tourism generates a large part of the economic activities in Bonaire. The change in nominal GDP is calculated by applying equations [3], [4], and [5] to the aggregated change in intermediate demand between every sector.

## 4.4 The economic consequences of tourism losses

Table 6 summarizes the total macroeconomic damages for Bonaire of tourism losses due to reef degradation. The indirect economic consequences are derived by feeding the declines in final tourism demand in each sector into the induced Leontief coefficients of the added value per sector. As determined above, scenario SSP1-1.9 does not result in any decline in tourism demand. Hence, no indirect economic consequences of reef degradation are found. In scenario SSP2-4.5, the decline of 30.3 USDm in final tourism expenditures is divided over the relevant industries according to the related expenditure categories (Table 3). Subsequently, this study finds that GDP is expected to shrink with 25.7 USDm. Considering the “high growth”, “business-as-usual”, and “low growth” scenarios, Bonaire is expected to potentially experience an economic contraction of respectively 2.4%, 2.7%, or 3.8%. Next, in scenario SSP3-7.0, the decline in the tourism expenditures of 95.2 USDm results in a GDP contraction of 80.8 USDm. In total, Bonaire’s GDP respectively shrinks by 7.6%, 8.5%, and 11.8% in the ”high growth”, “business-as-usual”, and “low growth” scenarios. SSP5-8.5 shows the most severe indirect economic losses. Total indirect economic losses amount to 173.9 USDm, amounting to a severe economic contraction of 25.4% in the “low growth scenario” case. Simultaneously, the economic damages are also significant in the “high growth” (-16.3%) and the “business-as-usual” (-18.3%) scenarios, especially when considering that the direct contribution of tourism to GDP is only 16.3% on Bonaire (CBS, 2012).

The tourism sectors such as “Hotels”, “Food services”, and “Other real estate activities” are seriously impacted in each scenario. For instance, in scenario SSP5-8.5, the added value of the “Hotels” sector shrinks by 28.7% of its initial value in 2017 (Table 2). The indirect consequences of tourism spending also become evident in other related industries such as the “Trade”, “Financial intermediation”, and “Other services” industries, where the latter is expected to experience a downfall in gross value added of 24.0 USDm in the worst-case scenario. All taken into account, the GDP multiplier of tourism spending amounts to 0.85x, indicating that a reduction in tourism demand of 1 USDm leads to a reduction of 0.85 USDm in Bonaire’s GDP.

*Table 6 GDP losses under climate scenarios considering low (LG) and high (HG) GDP growth scenarios. Losses are listed per sector as loss in value added. Values are in USDM*

| **Sector** | **Baseline** | | **SSP2-4.5** | | | **SSP3-7.0** | | | **SSP5-8.5** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Value added LG* | *Value added HG* | *Value added loss* | *% decrease under LG* | *% decrease under HG* | *Value added loss* | *% decrease under LG* | *% decrease under HG* | *Value added loss* | *% decrease under LG* | *% decrease under HG* |
| Agriculture, fishing, mining | **15.07** | **23.49** | 0.02 | *0.1%* | *0.1%* | 0.53 | *3.5%* | *2.3%* | 0.11 | *0.7%* | *0.5%* |
| Manufacturing | **13.16** | **20.50** | 0.43 | *3.3%* | *2.1%* | 1.36 | *10.4%* | *6.6%* | 2.94 | *22.3%* | *14.3%* |
| Electricity, gas, and water supply | **33.88** | **52.78** | 1.13 | *3.3%* | *2.1%* | 3.55 | *10.5%* | *6.7%* | 7.63 | *22.5%* | *14.5%* |
| Construction | **49.20** | **76.64** | 0.32 | *0.6%* | *0.4%* | 1.01 | *2.0%* | *1.3%* | 2.16 | *4.4%* | *2.8%* |
| Trade | **88.76** | **138.28** | 3.15 | *3.6%* | *2.3%* | 9.92 | *11.2%* | *7.2%* | 21.36 | *24.1%* | *15.4%* |
| Hotels | **36.41** | **56.72** | 1.56 | *4.3%* | *2.7%* | 4.90 | *13.5%* | *8.6%* | 10.55 | *29.0%* | *18.6%* |
| Food Services | **31.91** | **49.71** | 3.27 | *10.3%* | *6.6%* | 10.29 | *32.3%* | *20.7%* | 22.15 | *69.4%* | *44.6%* |
| Transport, information, and communication | **53.42** | **83.23** | 2.91 | *5.5%* | *3.5%* | 9.16 | *17.1%* | *11.0%* | 19.73 | *36.9%* | *23.7%* |
| Financial Intermediation | **35.72** | **55.65** | 1.52 | *4.3%* | *2.7%* | 4.78 | *13.4%* | *8.6%* | 10.29 | *28.8%* | *18.5%* |
| Other real estate activities | **73.63** | **114.71** | 5.98 | *8.1%* | *5.2%* | 18.80 | *25.5%* | *16.4%* | 40.47 | *55.0%* | *35.3%* |
| Public administration and defence | **77.55** | **120.82** | 0.66 | *0.8%* | *0.5%* | 2.07 | *2.7%* | *1.7%* | 4.46 | *5.8%* | *3.7%* |
| Education | **39.74** | **61.91** | 0.17 | *0.4%* | *0.3%* | 0.52 | *1.3%* | *0.8%* | 1.13 | *2.8%* | *1.8%* |
| Health | **69.22** | **107.83** | 1.02 | *1.5%* | *0.9%* | 3.20 | *4.6%* | *3.0%* | 6.89 | *10.0%* | *6.4%* |
| Other services | **38.57** | **60.10** | 3.54 | *9.2%* | *5.9%* | 11.20 | *29.0%* | *18.6%* | 23.98 | *62.2%* | *39.9%* |
| **Total** | **656.2** | **1,022.4** | **25.7** | ***3.9%*** | ***2.5%*** | **81.3** | ***12.4%*** | ***8.0%*** | **173.9** | ***26.5%*** | ***17.0%*** |

# 5 Discussion

## 5.1 Projections of reef degradation

The results show a significant negative relationship between increasing levels of climate pressures and reef health along the leeward shore. The ecological results in each scenario are supported by observed trends of other experts and scholars. In scenario SSP1-1.9, the RHI proxied coral reef health starts to moderately improve, in line with Steneck (2019) and Francisca (2022). Steneck (2019) states that the live coral cover on Bonaire has been recovering since 2015, following hurricane 'Omar' in 2008 and a severe bleaching event in 2010. In addition, Francisca (2022) argues in an interview that it seems like coral species and fish biodiversity have been improving since she joined STINAPA in 2018. Scenario SSP2-4.5 represents a worse future for the coral reef ecosystems. However, the severity of the ecological impact is still limited by 2050 relative to SSP3-7.0 and SSP5-8.5. Kalmus *et al.* (2022) state that 99% of global reefs are expected to experience severe bleaching events every five years by 2034, 2036, and 2040 under SSP5-8.5, SSP3-7.0, and SSP2-4.5, respectively. Hence, coral reef ecosystems under SSP2-4.5 have slightly more time to adapt to severe bleaching conditions, although too little to prevent drastic degradation around the middle of the century (UNEP, 2020). Under SSP5-8.5 and SSP3-7.0, CO2 atmospheric concentration levels reach 500 ppm in 2036 and 2047, respectively. According to Hoegh-Guldberg *et al.* (2007), 500 ppm is the 'tipping point' that drives coral reefs to functional collapse. The model of this paper shows similar results. In scenario SSP5-8.5, coral cover completely degrades, while coral cover decreases by almost 60% under SSP3-7.0.

Although the model only runs until 2050, it is vital to emphasize that coral degradation does not stop beyond at this threshold. It is hard to project the effects of climate change and local stessors on the coral reefs surrounding Bonaire specifically, but based on IPCC projections we can hypothesize about the future of the reefs. In the IPCC chapter " Changing Ocean, Marine Ecosystems, and Dependent Communities" (Bindoff *et al.*, 2019), projections for coral reef degradation up to 2100 are provided. These projections unambiguously indicate that warm water coral reefs are expected to experience very high risks of degradation even if global warming is limited to 1.5 degrees Celsius (Bindoff *et al.*, 2019). Of the potential shared socioeconomic pathways only under SSP1-1.9 will global warming be limited to approximately 1.6 degrees Celsius by 2050 and decline beyond this point. Consequently, unless society manages to reach net zero emission around 2050, it is very likely that Bonaire's coral reefs will degrade beyond 2050.

On a final note, it is important to note that these scenarios do not take into account either coral out planting operations nor local stressors, which might affect the quality of coral reefs positively and negatively respectively. This emphasizes the need to also take local action to maximize replanting operations and to minimize local stressors so as to not exacerbate the negative effects of climate change.

## 5.2 Multiplier benchmarking

Estimates in this study show that the macroeconomic losses of climate-induced reef degradation on Bonaire range from 25.6 USDm to 173.9 USDm by 2050. The GDP multiplier of tourism spending 0.85x indicates that Bonaire's GDP is sensitive to declines in tourism arrivals. The recent COVID-19 crisis highlighted a similar trend. The number of tourist arrivals on Bonaire decreased by 61% in 2020 due to travel restrictions, resulting in an estimated decrease in GDP of 19% despite substantial economic support from the national government that mitigate part of the tourism losses (World Bank, 2021; CBS, 2021). In the context of other Caribbean regions, there is limited research on the economic consequences of reef degradation in a macroeconomic setting. The majority of studies focus instead on the total economic value (TEV) of coral reefs, which does not include the induced effects of tourism spending. (i.e., Bonaire: Van der Lely *et al.*, 2013; Belize: Cooper *et al.*. 2009; Tobago & St. Lucia: Cannonier & Burke 2019; Jamaica: Edward, 2009). For instance, Van der Lely *et al.* (2013) reported a TEV of 105 USDm million for Bonaire's coral reefs in 2012. Tourism and recreational activities are estimated to contribute 39.9 USDm of total benefits (38%), based on the direct expenses of visitors on coral-related activities (Van der Lely *et al.*, 2013). Comparing the findings of Van der Lely *et al.* to the estimated induced effects of tourism by this paper (25.6 USDm - 173.9 USDm) highlights the multiplier effect of tourism spending within Bonaire's economy.

Several papers describe the link between tourism expenditure losses and GDP. According to Frechtling & Horvath (1999), smaller regions tend to have smaller tourism multipliers due to "import leakage", which is tourism revenue lost outside of the economy through the imports of goods and services to satisfy tourism demand. Similarly, Bonaire has a smaller GDP multiplier (0.85x) relative to other countries. For instance, Mariolis *et al.* (2021) investigated the multiplier effects of tourism in Germany and Spain during the COVID-19 recession in 2020. They find that a decrease of €1 million in travel receipts results in a decrease in GDP of €1.25 million in the German economy and a decrease in GDP of €1.33 in the Spanish economy. In the context of other SIDS, however, the tourism multiplier of Bonaire does not seem so small when considering the size of its economy. Several countries are summarized in Table 6 to give an impression of the range of tourism multipliers found by other studies. Bonaire has a higher tourism to GDP multiplier than larger economies such as Jamaica, Fiji, and St. Lucia, nearing the multipliers of the Bahamas and Antigua. This indicates that leakage in Bonaire remains moderately small, which further stresses the importance of tourism on the island.

Nevertheless, the differences between the sizes of regional tourism multipliers should be compared with care. Steenge (2010) points out that the economics of changes in tourism arrivals can be quite complex due to dynamic possibilities. For instance, the existence of a 'grey' or 'black' market in Bonaire could further complicate the implications of losses in tourism revenues. In addition, the interrelations between industries could change due to declines in tourism arrivals, for example, due to substitution effects. Consequently, Hughes (1994) states that it is faulty to apply the methodology of input-output analysis of one region to another area due to the structural context of tourism spending. In addition, the dynamic nature mentioned above can affect the linearity involved in IO analysis. The following section explores the potential issues that could arise when using an ecological extended IO analysis.

This study's environmental and economic modelling is prone to limitations due to assumptions, estimation methods, and data restrictions. The ecological module used to predict future changes in Bonaire's marine ecosystems rests on the assumption that the interactions between ecosystem properties and climate pressures can be quantified in linear relationships. However, coral reefs are dynamic and heterogeneous systems that will respond non-linear according to environmental changes (Wolfe & Roff, 2009). In addition, the heterogeneity of coral reefs makes it challenging to apply findings of academic literature in other regions to the context of Bonaire. Therefore, the explanatory power of the ecological module should be approached with caution. Next, the number of tourism arrivals in the model is dependent on the quality of the coral reefs along the leeward coast. This assumption makes it possible to translate climate change impacts to changes in tourism demand directly. However, the model ignores the vulnerability of tourism demand to other expected natural disasters under SSP3-7.0 and SSP5-8.5, such as more frequent hurricanes and storms (Taylor *et al.*, 2020). Likewise, climate change could negatively affect exogenous economic, social and political factors and increase the risk of global conflicts (IPCC, 2014), which would drive down tourism demand even further than predicted by the model. Finally, we assume that a lower carrying capacity of the reefs will lead to less visitors on Bonaire. This, however, also depends strongly on the quality of reefs elsewhere and the changing preferences of divers.

*Table 7 Tourism GDP multipliers of selected SIDS, ranked by multiplier*

| Rank | Country | GDP (2017) | Tourism GDP multiplier | Source |
|---|---|---|---|---|
| 1 | Bermuda | 7,142 | 1.22x | Archer and Fletcher (1990) |
| 2 | Dominca | 519 | 1.20x | Fletcher (1989) |
| 3 | Solomon | 1,484 | 0.99x | Archer and Fletcher (1990) |
| 4 | Aruba | 3,202 | 0.96x | Steenge (2010) |
| 5 | Antigua | 1,468 | 0.88x | Fletcher (1989) |
| 6 | Bahamas | 12,490 | 0.88x | Archer and Fletcher (1990) |
| 7 | Bonaire | 480 | 0.85x | Van der Knaap (2022) |
| 8 | Fiji | 5,353 | 0.82x | Britton (1983) |
| 9 | West Samoa | 832 | 0.66x | Archer (1989) |
| 10 | Jamaica | 14,810 | 0.60x | Fletcher (1989) |
| 11 | Cook Islanda | 486 | 0.55x | Milne (1987) |
| 12 | St. Lucia | 1,999 | 0.55x | Seward and Spinrad (1982) |
| 13 | Palau | 286 | 0.51x | Archer and Fletcher (1990) |
| 14 | Belize | 1,859 | 0.41x | Lindberg *et al.* (1996) |

Similarly, IO modelling implies several weaknesses. First, the IO framework rests on the assumption that a change in demand in a particular sector will result in a proportional change in output. As such, it ignores production constraints, substitution effects, and other dynamic factors that are relevant when economic conditions change. In addition, the ability of an economy to immediately respond to changes in the final demand has been questioned by several academics (Bryden, 1973; Briassoulis, 1991). IO analysis assumes that all rounds of tourism expenditures occur in a single calendar year. However, the secondary effects of tourism spending require some time to take place (Hughes, 1994). Consequently, multiplier analysis might overestimate the impact of tourism losses in the short-term but does not capture relevant dynamic variables over a more extended period. Second, IO modelling does not incorporate the consequences of coral reef degradation to the sectoral output, except from changes in the final tourism demand. For example, the output of fisheries in our model does not decrease when the total fish stock declines. In reality, however, the absence of fish will most likely result in lower earnings for fishermen and thus a lower economic output in that sector. Additionally, the potential shortage in fish does not result in higher prices in the IO Model as it cannot incorporate price mechanisms (Koks *et al.* 2016).

Finally, Bonaire fundamentally lacks available and recent data (Schep *et al.* 2013). The year 2017 is used as the base year in the model, as it was found to have the most complete dataset in terms of economic and ecological information of Bonaire. However, multiple variables had to be retrieved from earlier years and corrected or estimated for 2017 to fill in gaps in the data. For instance, the SUT table for 2017 was updated using the SUT table of 2012 by Koks & van Zanten (2015) due to a lack of publicly available data on sectoral output in Bonaire. Thus, diverse and up to date datasets will be vital to further strengthen the predictive power of the model that was developed in this study. This also holds true for data on non-diver tourists. There was simply not enough data to model the effect of coral reef degradation on tourists other than divers, though it can be assumed that degradation of coral reefs will also have effects on their arrivals.

# 6 Conclusion

In this study, we estimated the potential loss to Bonaire's GDP by 2050 resulting from climate-induced reef degradation using input-output modelling. Data on the state of coral reef along the leeward shore of Bonaire was drawn from 115 transect zones of Meesters (2020). In addition, the 2017 input-output table of Bonaire was constructed by updating the IO table of Koks & van Zanten (2015) using a CRAS approach. Reef degradation was treated as an exogenous shock to the IO model that affected the final sectoral output by 2050 through changes in the final dive tourism demand. This linkage was achieved by predicting the changes in the social carrying capacity of the coral reefs under the climate scenarios SSP1-1.9, SSP2-4.5, SSP3-7.0, and SSP5-8.5 to proxy how many divers could be facilitated annually.

The results of the ecological module showed that the average RHI declines in all climate scenarios by 2050, except under SSP1-1.9, indicating that the reef ecosystems are highly vulnerable to increases in SST, AT, and dissolved CO2. It is expected that under SSP2-4.5, SSP3-7.0, and SSP5-8.5, respectively, 17.3 thousand, 54.6 thousand, and 117.6 thousand tourists will decide not to visit the island by 2050 since there are too few quality dive sites left. Note that this is solely based on dive tourists, and thus might be underestimating the actual decrease in tourist numbers. After feeding the related sectoral output into the IO model, we predict a contraction in Bonaire's GDP ranging from 26.7 USDm under SSP2-4.5 to 173.8 USDm under SSP5-8.5 by 2050. In the most pessimistic scenario, Bonaire could experience an economic contraction of around 25.4%, which would have significant socio-economic implications for the island's inhabitants.

It is important to also note that a lot of households on Bonaire are already living on or below the bare minimum budget. A study commissioned by the Senate (Eerste Kamer) of the Dutch Parliament found that some 33% of households live on incomes that are lower than or equal to 75% of the average required budget to meet their basic needs, and 44% of households live on or below the average required budget (Regioplan Beleidsonderzoek, 2018). In addition, unemployment on Bonaire is higher than in continental Netherlands, particularly in the cohort of 15- to 25-year-olds where unemployment lies on 20,2 percent (Regioplan Beleidsonderzoek, 2018). The effects of climate change on coral reefs, tourism and GDP can be expected to further exacerbate the situation of the most vulnerable households, highlighting the potential human cost of climate change. GDP contraction could lead to a loss of jobs in the tourism sector as well as dependant sectors. To prevent this human cost, it is paramount to act against climate change. Scenario SSP1-1.9 proves that the coral reefs around Bonaire can recover from environmental shocks, and even improve, if the international community ratifies its climate agreements.

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# Annex A Detailed description of all inputs in the ecological module

## A.1 Ecological module – global pressures

### A.1.1 (GS) – Algae bloom

Changes in air temperature can provide favourable conditions for harmful algal blooms. Following Ye *et al.* (2011), the model assumes that an increase in mean annual AT of 1C increases mean algae cover by 0.145. Since algae compete with corals for benthic cover, a spike in algae growth decreases the coral expansion rate (Koks & van Zanten, 2015).

### A.1.2 (GS) – Ocean acidification

Ocean acidification is defined as a long-term decrease in the pH level of seawater, resulting from the uptake of atmospheric $CO_2$ (IPCC, 2019). Once dissolved in the ocean, C02 is a weak acid that reduces the calcification of coral. In turn, reduced calcification negatively affects the ability of coral to reproduce, thus, making the reef more prone to coral bleaching events and diseases. In the model, a 1% increase in CO2 decreases coral cover by 0.61%, based on regression estimates of Cheng *et al.* (2015).

### A.1.3 (GS) – Coral bleaching

Elevated sea surface temperatures increase the frequency of coral bleaching events, breaking down the critical symbiotic relationship between corals and zooxanthellae (Sully *et al.*, 2019). Bleached coral reefs have lower production rates, experience increased mortality, and are more susceptible to diseases (Ateweberhan *et al.*, 2013). When the mean annual SST is higher than 26.85C, it is assumed that a 1.59% increase in SST causes coral coverage to decline by 2.26% (Cheng *et al.*, 2015).

### A.1.4 (LS) – Sedimentation run-off

Sedimentation from run-off is considered one of the most significant sources of reef degradation in the Caribbean Sea (Rogers, 1985). Excessive sediment can damage or bury reefs, thereby blocking light available for photosynthesis (Rogers, 1990). As such, sedimentation limits the maximum potential level of coral cover on Bonaire. Similar to Koks & van Zanten (2015), the sedimentation rate is subtracted from the maximum percentage of coral cover, which is estimated to be 60% by the IUCN (2011). The sedimentation rate is ex-ante predicted by breaking down the different land uses around the coast. This rate is obtained by extrapolating the estimates of the GEM model (Koks & van Zanten, 2015) for the years following 2017.

### A.1.5 (LS) – Physical reef destruction

"Physical reef destruction" is an external effect that is caused by divers and snorkelers during their diving activities. Multiple studies indicate that divers damage coral reefs by touching them or by raising sediment onto the reef (Talge, 1991; Zakai & Furman, 2002; Hawkings *et al.*, 2002). Even relatively low levels of coral use for diving are found to significantly affect patterns of coral cover loss (Hawkins *et al.*, 2002). Physical reef destruction is included in the ecological module using an equation constructed by Hasler and Ott (2008), which depends on the number of dives per dive site and the coral mortality when damaged. In the baseline, 2017, assuming a total number of around 9 thousand dives per dive spot, a damage rate of 3.3%, and coral mortality when damaged of 50%, the annual mortality corresponds to 1.5% of total coral cover.

### A.1.6 (LS) – Overfishing

Lastly, overfishing is another threat that affects the health of Bonaire's reef ecosystem. Algae abundance can successfully be controlled by a healthy population of grazing herbivore fish (Hixon & Brostoff, 1996). In 2010, fishing on parrotfishes was banned on Bonaire to stop the alarming decline of the herbivory fish stock (STINAPA, 2022). However, catching parrotfishes still occurs in other areas close to the reefs. In addition, catching other important grazing herbivory fish, such as the surgeonfish, is still allowed, and there are reports of illegal fishing on the island (WWF, 2022). Consequently, the fishing rate of herbivore fish is assumed to be 1.5% in the base year of 2017. In addition, the fishing rate for predatory fish is assumed to be 5% in the model (Koks & van Zanten, 2015). Since de Graaf *et al.* (2016) argues that the status of reef fishing on Bonaire is fully exploited, it is assumed that the fishing rates will remain constant over the following years.

## A.2 Ecological module – Key Health Indicators (KHI's)

### A.2.1 (KHI) – Macroalgae cover

The mean macroalgae cover at year t is directly influenced by the algae expansion rate, the maximum capacity of algae cover, and the mean air temperature. Algae expansion rate depends on the concentration of nutrients and herbivory fish in the water. Algae require nutrients like nitrates and phosphates to grow (Hughes *et al.*, 2010). Higher concentrations of these nutrients due to sedimentation and waste management increase the growth rate of algae. Similar to Van der Lely *et al.* (2013), nutrient concentrations are proxied by the level of phosphates (mol/g) in the water, which is obtained from Koks & van Zanten (2015). However, algae growth is controlled by the maximum algae cover of 82.2% (IUCN, 2011) and the herbivory grazing rate (Jackson *et al.*, 2014). Next, as mentioned above, rising temperatures create favourable conditions for algae to grow and, thus, positively correlate with algae cover (Ye *et al.*, 2011). Taken all into account, the following relationship is developed for macroalgae cover at time t in equation [1].

| Ecosystem property | Equation |
|---|---|
| **1. *Macroalgae cover$_t$ (%)*** | $= \text{Macroalgae cover}_{t-1} * (1 + \text{algae expansion rate}_t) * (1 - \frac{\text{Macroalgae cover}_{t-1}}{\text{Ccap algae cover}_{t-1}}) + \text{ATincrease}_t * 0.145$ |
| Algae expansion rate$_t$ | $= 10 * \text{Phosphate concentration}_t - 0.22 - \text{herbivore grazing rate}_t$ |
| Herbivore grazing rate$_t$ | $= 0.003 * \text{herbivory biomass}_t - 0.0164$ |

Source: Koks & van Zanten (2015); Ye *et al.* (2011); Van der Lely (2013).

*Figure 11 Structure of equation [1] to estimate changes in macroalgae cover at year t*

## A.2.2 (KHI) – Herbivory biomass

The total herbivory biomass of the fish population depends on several ecosystem properties. First, changes in the herbivory stock are influenced by the herbivory reproduction rate. The maximum reproduction rate amounts to 25% but is also affected by the maximum carrying capacity of the total fish stock (Koks & van Zanten, 2015). Next, the herbivory fish population is controlled by the predatory fish and lionfish population. This paper assumes a 15% reduction rate of herbivory fish resulting from predators (Koks & van Zanten, 2015). However, elevated dissolved CO2 levels have been found to disrupt the ability of herbivory fish to detect predatory fish (Dixson *et al.*, 2009; Munday *et al.*, 2010). Based on Munday *et al.* (2010), larval fish spend 30-45% more time in water containing prey cues with elevated C02 levels. Therefore, the feeding activity rate of Koks & van Zanten (2015) for 2012 is increased by 30%. The feeding rate of lionfish is based on data from STINAPA (2018) and Koks & van Zanten (2015) and depends on the total biomass of lionfish. In turn, the lionfish biomass is positively related to increases in SST (Mostowy *et al.*, 2020). Finally, the herbivory fish population is also threatened by factors like overfishing and coral cover loss. This paper assumes a catching rate of 5% for predatory fishes by fisheries. In addition, the findings of 12 independent papers show a linear relationship between coral cover decline and herbivory fish abundance of 0.61 (Wilson *et al.*, 2006). Equation [2] summarizes all interactions.

| Ecosystem property | Equation |
|---|---|
| **2. Herbivory biomass$_t$(tonnes)** | $= \text{Herbivory biomass}_{t-1} + \text{regrowth herbivory}_{t-1} - (0.15 * 1.3 * \text{predatory biomass}_{t-1}) - \text{annual herbivory catch} - (\text{lionfish feeding rate}_{t-1} * \text{herbivory biomass}_{t-1}) + \Delta\text{coralcover}_t * -0.61$ |
| Regrowth herbivory$_t$ | $= 0.25 * \text{herbivory biomass}_t * (1 - \frac{\text{herbivory biomass}_t}{\text{Ccap herbivory biomass}_t})$ |
| Annual herbivory catch$_t$ | $= 0.02 * \text{herbivory biomass}_t$ |
| Lionfish feeding rate$_t$ | $= 0.0063 * \text{lionfish stock}_t - 0.0025$ |

Source: Wilson *et al.* (2006); Dixson *et al.* (2010); Munday *et al.* (2010); Mostowy *et al.* (2020); STINAPA (2019); Koks & van Zanten (2015).

*Figure 12 Structure of equation [2] to estimate changes in herbivory biomass*

### A.2.3 (KHI) – Predatory biomass

The predatory biomass at year t is established using a similar approach to the herbivory biomass. The reproduction of the population is assumed to be 10%, based on Koks & van Zanten (2015). As mentioned in the overfishing section, the annual predatory catch is estimated to be 5% of the standing stock. Finally, it is assumed that the lionfish feeding rate affects the predatory stock similarly to the herbivory stock. Equation [3] provides an overview of how the predatory biomass is determined.

| *Ecosystem property* | *Equation* |
|---|---|
| **2. Herbivory biomass$_t$(tonnes)** | $= \text{Herbivory biomass}_{t-1} + \text{regrowth herbivory}_{t-1} - (0.15 * 1.3 * \text{predatory biomass}_{t-1}) - \text{annual herbivory catch} - (\text{lionfish feeding rate}_{t-1} * \text{herbivory biomass}_{t-1}) + \Delta\text{coralcover}_t * -0.61$ |
| Regrowth herbivory$_t$ | $= 0.25 * \text{herbivory biomass}_t * (1 - \frac{\text{herbivory biomass}_t}{\text{Ccap herbivory biomass}_t})$ |
| Annual herbivory catch$_t$ | $= 0.02 * \text{herbivory biomass}_t$ |
| Lionfish feeding rate$_t$ | $= 0.0063 * \text{lionfish stock}_t - 0.0025$ |

Source: Wilson *et al.* (2006); STINAPA (2019); Koks & van Zanten (2015); Munday *et al.* (2010).

*Figure 13 Structure of equation [3] to estimate changes in predatory biomass at year t*

### A.2.4 (KHI) – Live coral cover

Live coral cover at year t depends on the coral expansion rate, the maximum coral cover, and the physical reef destruction by divers. It is also affected by global climate stresses as increases in SST and dissolved CO2. The maximum coral cover is assumed to be 60%, based on the IUCN (2011). Since coral cover competes with algae cover for benthic cover, the coral expansion rate is negatively impacted by the macroalgae cover (Tanner, 1995). The assessed relationships between coral cover, physical reef destruction, SST, and CO2 are described above.

| *Ecosystem property* | *Equation* |
|---|---|
| **3. Predatory biomass$_t$ (tonnes)** | $= \text{Predatory biomass}_{t-1} + \text{regrowth predatory}_{t-1} - \text{annual predatory catch} - \text{lionfish feeding rate}_{t-1} * \text{herbivory biomass}_{t-1}$ |
| Regrowth predatory$_t$ | $= 0.1 * \text{predatory biomass}_t * (1 - \frac{\text{predatory biomass}_t}{\text{Ccap predatory biomass}_t})$ |
| Annual predatory catch$_t$ | $= 0.05 * \text{predatory biomass}_t$ |
| Lionfish feeding rate$_t$ | $= 0.0063 * \text{lionfish stock}_t - 0.0025$ |

Source: IUCN (2011); Koks & van Zanten (2015); Tanner (1995).

*Figure 14 Structure of equation [4] to estimate changes in coral cover at year t*

# Annex B Conducting IO analysis for Bonaire

## B.1 Standard input-output modelling

In its most basic form, IO analysis can be seen as a set of linear equations, with each equation reflecting the distribution of an industry's output within an economy (Leontief, 1986). The fundamental data required in an IO model is captured by a supply and use table (SUT). The table rows represent the output flows from each sector, regarded as the producers, to itself and other sectors within the economy, regarded as consumers. The columns in the table represent the inputs an industry needs from other industries to produce its output (Miller & Blair, 2009). Leontief establishes several assumptions to maintain simplicity in the IO model: First, the IO model is linear, meaning there is no possibility of economies of scale. Second, industries cannot substitute inputs. Third, the basic IO model does not incorporate the production restrictions of companies. Finally, firms in an industry setting are assumed to be identical (van Leeuwen *et al.*, 2001).

To conduct basic IO analysis, every industry's technical coefficient needs to be calculated. These are the proportion of inputs required from industry *i* to produce one output of $X_j$ (Koks & van Zanten, 2015). The technical coefficient can be calculated using the following expression:

$$a_{i,j} = \frac{z_{i,j}}{Z_j} \qquad [6]$$

In other words, the technical coefficient $a_{ij}$ can be calculated by dividing the intermediate demand of industry *i* to industry *j* divided by the entire intermediate demand for the goods of industry *i*. A matrix of these technical coefficients present the technical structure of an entire economic environment. An overview of a standard IO table is presented in Table 7.

*Table 8 Example of a basic input-output table (retrieved from Koks & van Zanten, 2015)*

| | | Purchasing sector | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Final Demand | Total |
| Selling sector | 1 | $z_{11}$ | $z_{12}$ | $z_{13}$ | $f_1$ | $X_1$ |
| | 2 | $z_{21}$ | $z_{22}$ | $z_{23}$ | $f_2$ | $X_2$ |
| | 3 | $z_{31}$ | $z_{32}$ | $z_{33}$ | $f_3$ | $X_3$ |
| | Value Added | $VA_1$ | $VA_2$ | $VA_3$ | | $VA$ |
| | Import | $I_1$ | $I_2$ | $I_3$ | | $I$ |
| | **Total** | $Z_1$ | $Z_2$ | $Z_3$ | $F$ | $\sum Total$ |

The upper left square presents an overview of all the intermediate transactions between the industries within an economy. The supplemental row classified as *Value Added* shows all other required inputs not produced within industries, such as employment costs (labour), fixed capital, or income. The input *Import* should be accounted for in separate rows since they are exogenous economic inputs. In the upper right corner, the column *Final Demand* describes how industry sales are distributed over the final market (Miller & Blair, 2009). For example, transportation in Bonaire is a required input for the production of other sectors (intermediate demand) but is also a service that is sold to stay-over tourism (final-demand transaction). Next, the column in the lower right corner represents the primary expenses that result from the *Final Demand*. Koks & van Zanten (2015) assume these to be equal to zero.

Row vectors $Z_n$ and column vectors $X_n$ should always be equal (Bockarjova, 2007). This double-entry bookkeeping approach ensures that no errors are made in constructing the intermediate and final demands. The row vectors reflect the value of products sold by industry *i* to all other sectors. Similarly, the column vectors present the intermediate sales of all industries to industry *i*. Taken all into account, the total output for industry 1 can be expressed as:

$$X_1 = \sum_{j=n} z_{1,j} + f_i \qquad [7]$$

Where $X_1$ represents total output of industry 1, and $\sum_{j=n} z_{1,j} + f_i$ represents the sum of all products sold to other sectors ($z_{1,j}$) added with the final demand ($f_i$) of all final goods and services. Combining equation [6] and [7] results in the following equation:

$$X_1 = a_{i,j} X_i + f_i \quad \forall i \qquad [8]$$

Combining all technical coefficients will lead to the following matrix A:

$$A = [a_{11} \cdots a_{1j} \vdots \ddots \vdots a_{i1} \cdots a_{ij}]$$

[9]

Formula [8] can subsequently be rewritten in the following equation, using matrix A:

$$X = AX + F \qquad [10]$$

$$X\,(1 - A) = F \qquad [11]$$

$$X = (I - A)^{-1} * F \qquad [12]$$

Where X represents the vector of total output, I reflects the identity matrix, A represents the matrix with technical coefficients, and F provides the vector of final demand (van Leeuwen *et al.*, 2001). The inverse of $(I - A)$ of equation [11] is the Leontief Inverse, defined as the required increase in economic activity of every industry to satisfy an increase of in final demand of one unit in another industry (Leontief, 1986). This is also known as the multiplier effect, which will be described in the next section.

## B.2 Multiplier effects

A key advantage of IO models is that direct and indirect effects can be determined through multipliers. When the demand of an industry changes due to an unexpected shock, the multiplier enables us not only to estimate how the production of that industry changes, but it also allows us to determine changes in production of other industries that are supplying to that specific sector (Wolfs *et al.*, 2015). To calculate this multiplier, the Leontief inverse $(I - A)^{-1}$ of equation [11] is used. First, the A-matrix of the technical coefficients needs to be constructed using formula [9], based on the estimated technical coefficients calculated in equation [6]. Next, in equation [10], the technical coefficients of each cell are multiplied with the corresponding vector of total output X obtained from the input-output table. Then, equation [10] is rewritten to formula [11] to eliminate the X on both sides of the equation. However, this equation cannot be used yet to determine changes in final output (X). To solve this, both sides are multiplied by $(I - A)^{-1}$. This results in a Leontief inverse matrix that shows the interrelations between sectors within an economy.

For instance, let us assume a small economy consisting of three sectors. The agriculture sector (AS), which produces 20 units of output annually; the food service (FS) sector, which sells a total of 18; and the transport sector (TS), which supplies 10 units in total. Table 8 provides the SUT table of the fictive economy.

*Table 9 Example of fictive small economy*

| | | AS | FS | TS | F | Total ($X_j$) |
|---|---|---|---|---|---|---|
| **Sector** | AS | 7 | 0 | 3 | 10 | 20 |
| | FS | 1 | 5 | 2 | 10 | 18 |
| | TS | 2 | 2 | 1 | 5 | 10 |
| | Labour | 10 | 6 | 4 | | |
| | **Total ($X_j$)** | 20 | 18 | 10 | | |

In the first column, it can be observed that the agriculture sector needs seven units of its own production, zero units of the food service sector, two units of the transport sector, and ten units of labour to produce its total output of 20. Similarly, the intermediate demand of the other two sectors can be seen in columns two and three. The next step is to calculate the matrix of technical coefficients. For cell z_(1,j) in the upper left corner, the technical coefficient is determined by dividing the total output of 20 by the corresponding value of 7. This results in a coefficient of 0.35. By repeating this step for every cell in the grey area, the matrix of Table 9 is obtained.

*Table 10 Matrix of technical coefficients.*

| | | | |
|---|---|---|---|
| **A** | 0.35 | 0.00 | 0.15 |
| | 0.05 | 0.28 | 0.20 |
| | 0.10 | 0.11 | 0.10 |

To obtain the Leontief inverse presented in Table 10. Now, the multipliers of each sector can be retrieved from the matrix. For instance, the multiplier effect of the agriculture sector is the sum of the coefficients in the first column: 1.58 + 0.16 + 0.20 =

1.94. The magnitude of this multiplier shows that when the final demand of the agriculture sector increases by one unit, it increases agriculture production by 1.58, the food service sector by 0.16, and the transport sector by 0.20. Thus, the sum of 1.94 indicates the ‘spill-over’ effect of an increase in the final demand of one sector to all other sectors in an economy.

*Table 11 Leontief inverse of technical coefficients*

| | | | |
|---|---|---|---|
| $(I-A)^{-1}$ | 1.58 | 0.04 | 0.27 |
| | 0.16 | 1.44 | 0.35 |
| | 0.20 | 0.18 | 1.18 |

# Annex C Economic scenario development

*Table 12 Overview of nominal GDP growth and tourist arrivals in each economic scenario*

| Economic scenario | 2017 | 2050 |
|---|---|---|
| High Growth - GDP | 480 | 1065 |
| BAU - GDP | 480 | 951 |
| Low Growth - GDP | 480 | 684 |
| Stay-over tourists | 128500 | 158200 |
| Cruise tourists | 407300 | 259460 |

Source: Estimates based on van der Werven *et al.* (2010), Cruise *et al.* (2017), CBS (2020), CBS (2021), and World Bank Outlook (2022).

The economic scenario development starts in 2020, as economic information for the years 2018 and 2019 can be obtained from the CBS (2020). All GDP growth rates can be found in Annex B2. The underlying socio-economic assumptions of the “high growth scenario” are derived from the strategic development plans of the World Bank (2022), van der Werven *et al.* (2010), and Cruise *et al.* (2017). The economy is diversified through a broader tourism product portfolio, an improved hotels sector, increasing activities in the financial and the IT sector, and knowledge development in the field of (bio-)pharmaceutical and health industries. In addition, the production of bio-pharmaceutics and agricultural products increases, which improves Bonaire’s trade balance within the Caribbean region. After the COVID crisis, where Bonaire has experienced an estimated economic contraction of -19.0% in 2020, nominal GDP is expected to grow by 2.9% in 2021, following the trends of other Caribbean countries (excluding Guyana) (World Bank, 2022). Next, nominal GDP growth in Bonaire is expected to accelerate in 2022 and 2023 due to recovering international tourist arrivals and sharp declines in COVID-19 cases. As a result, GDP grows respectively by 5.4% and 4.0%. Finally, from 2023 on, GDP is expected to grow with a constant rate of 2.8% based on the average growth rate of Bonaire since 2012 (CBS, 2021), reaching 1065 USDm by 2050.

The BAU scenario is based on historical trends and estimates of the World Bank Outlook (2022) for the Caribbean region. Bonaire continues to depend on incoming tourism and imports heavily. As such, it follows the economic growth of surrounding countries in the area. After an increase in nominal GDP in 2021 of 2.93%, the World Bank expects an average year-on-year economic growth of 2.7% between 2022 and 2030. Next, from 2030 to 2040, this growth slightly decreases to an annual increase of 2.5%. Finally, from 2040 on, GDP is expected to grow by 2.4% annually (World Bank, 2022). Ultimately, GDP reaches 951 USDm by 2050.

The “low growth” scenario assumes that the size of Bonaire’s economy stabilizes due to “brain drain” issues. Historically, the Caribbean has experienced one of the highest levels of skilled migration flows. Similarly, slightly less than half of the young adults between 17 and 25 in Bonaire move to the Netherlands to pursue an education (CBS, 2018). In addition, Bonaire is not compensated by retrieving higher-skilled people since return rates are meagre (Romeijnders, 2022). Consequently, a shortage of supply in the workforce is expected after 2021, limiting the island's economic growth. From 2021 on, Bonaire's GDP is expected to grow with the average inflation rate between 2010 and 2021, amounting to 684 USDm by 2050

# Annex D Additional tables and figures

*Table13 Historic distribution of type of tourist arrivals on Bonaire between 2001-2017*

| Year | Stay-over Tourists (SOT) | % divers / SOT | Cruise Tourists (CT) | % divers/total CT | Total diver arrivals | Total demand of dives |
|---|---|---|---|---|---|---|
| 2001 | 50,395 | 64.78% | 40,535 | 4.35% | 34,408 | 344,080 |
| 2002 | 52,085 | 63.42% | 42,181 | 4.35% | 34,869 | 348,690 |
| 2003 | 62,179 | 55.59% | 44,601 | 4.35% | 36,504 | 365,040 |
| 2004 | 63,156 | 56.65% | 53,343 | 4.35% | 38,098 | 380,980 |
| 2005 | 62,550 | 61.97% | 40,077 | 4.35% | 40,506 | 405,060 |
| 2006 | 63,552 | 63.83% | 61,844 | 4.35% | 43,253 | 432,530 |
| 2007 | 74,309 | 57.09% | 97,635 | 4.35% | 46,671 | 466,710 |
| 2008 | 74,342 | 57.07% | 175,702 | 4.35% | 50,067 | 500,670 |
| 2009 | 66,998 | 52.06% | 213,191 | 4.35% | 44,152 | 441,520 |
| 2010 | 70,539 | 54.99% | 230,933 | 4.35% | 48,837 | 488,370 |
| 2011 | 72,000 | 54.14% | 193,775 | 4.35% | 47,413 | 474,130 |
| 2012 | 127,600 | 51.26% | 157,600 | 4.35% | 72,263 | 722,630 |
| 2013 | 131,000 | 51.26% | 142,100 | 4.35% | 73,332 | 733,320 |
| 2014 | 128,600 | 51.26% | 156,400 | 4.35% | 72,724 | 727,240 |
| 2015 | 133,400 | 51.26% | 230,200 | 4.35% | 78,395 | 783,950 |
| 2016 | 135,800 | 51.26% | 216,500 | 4.35% | 79,029 | 790,290 |
| **2017** | **128,500** | **51.26%** | **407,300** | **4.35%** | **83,587** | **835,870** |

Based on CBS (2022); TCB (2017); TCB (2008)

*Table 14 Estimated GDP inflation rate and growth rates**

| Year | Inflation Rate | High growth rate | BAU rate | Low growth rate |
|---|---|---|---|---|
| 2020 | -2.5 | -19.00% | -19.00% | -19.00% |
| 2021 | 1.7 | 2.93% | 2.93% | 1.70% |
| 2022 | 12.4 | 5.39% | 2.70% | 1.41% |
| 2023 | 7.8 | 4.01% | 2.70% | 1.41% |
| 2024 -2030 | 1.41 | 2.80% | 2.70% | 1.41% |
| 2031-2040 | 1.41 | 2.80% | 2.50% | 1.41% |
| 2041-2050 | 1.41 | 2.80% | 2.40% | 1.41% |

* Growth rates include inflation rates Source: World Bank Outlook (2022); Attradius (2022); CBS (2020)

*Table 15 Estimated IO table of Bonaire for 2017*

| | 2017 in USDm | Intermediate demand | | | | | | | | | | | | | | Dom. Produc | Final Demand | | | | | | Total Product |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AFM | M | EGW | C | T | Hot | FS | TC | F | ORE | PAD | ED | H | OS | | Regular Export | Stay-over tourism | Cruise tourism | Final C | Invest. | Invent. | |
| Intermediate demand | Agriculture, fishing, mining | 0.00 | 0.72 | 0.00 | 1.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.65 | 7.02 | 0.00 | 0.00 | 0.00 | 0.00 | 26.82 | 36.5 |
| | Manufacturing | 0.17 | 0.25 | 0.10 | 0.00 | 0.86 | 1.66 | 2.14 | 0.46 | 0.97 | 0.54 | 1.29 | 2.62 | 1.76 | 0.92 | 13.73 | 4.52 | 4.11 | 3.94 | 16.05 | 18.77 | -43.94 | 17.2 |
| | Electricity, gas, and water supply | 4.04 | 0.13 | 0.05 | 0.13 | 3.20 | 4.63 | 0.78 | 0.80 | 0.43 | 1.08 | 0.55 | 0.46 | 1.12 | 3.96 | 21.36 | 0.20 | 0.00 | 0.00 | 6.65 | 0.00 | 0.00 | 28.2 |
| | Construction | 0.22 | 0.00 | 0.00 | 2.16 | 0.56 | 1.61 | 0.21 | 0.00 | 0.21 | 0.88 | 0.00 | 0.00 | 0.00 | 0.15 | 6.00 | 0.68 | 0.00 | 0.00 | 1.36 | 30.31 | 0.00 | 38.3 |
| | Trade | 2.34 | 0.34 | 4.85 | 0.98 | 2.38 | 8.10 | 7.97 | 6.59 | 0.67 | 1.12 | 1.43 | 1.21 | 8.31 | 1.43 | 47.72 | 2.01 | 8.28 | 7.93 | 36.41 | 6.20 | 10.25 | 118.8 |
| | Hotels | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.95 | 0.00 | 0.23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.17 | 0.00 | 76.63 | 0.00 | 0.68 | 0.00 | 0.00 | 83.5 |
| | Food Services | 0.00 | 0.31 | 0.00 | 0.00 | 3.80 | 0.69 | 0.32 | 0.94 | 0.82 | 0.34 | 0.65 | 0.00 | 0.89 | 1.74 | 10.49 | 0.00 | 23.57 | 3.28 | 11.42 | 0.00 | 0.00 | 48.8 |
| | Transport, information, and communicati | 7.02 | 1.05 | 1.84 | 0.89 | 11.57 | 3.35 | 0.61 | 14.68 | 1.53 | 1.53 | 3.17 | 0.41 | 3.00 | 3.90 | 54.55 | 4.28 | 13.86 | 8.83 | 12.42 | 0.00 | 0.00 | 93.9 |
| | Financial Intermediation | 0.71 | 0.83 | 1.47 | 3.18 | 7.94 | 8.42 | 3.83 | 2.92 | 2.17 | 2.83 | 0.22 | 0.00 | 1.18 | 2.12 | 37.82 | 0.00 | 0.00 | 0.00 | 4.38 | 0.00 | 0.00 | 42.2 |
| | Other real estate activities | 0.90 | 0.58 | 0.26 | 0.63 | 7.34 | 1.50 | 0.91 | 4.97 | 2.27 | 0.45 | 2.25 | 3.80 | 2.60 | 4.99 | 33.45 | 0.00 | 4.22 | 0.00 | 24.58 | 0.00 | 0.00 | 62.2 |
| | Public administration and defense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.44 | 0.00 | 0.00 | 66.31 | 0.00 | 0.00 | 71.7 |
| | Education | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.36 | 0.63 | 0.00 | 0.93 | 0.00 | 4.00 | 0.45 | 7.38 | 0.00 | 0.00 | 0.00 | 35.15 | 0.00 | 0.00 | 42.5 |
| | Health | 0.84 | 2.04 | 0.81 | 0.39 | 4.27 | 7.70 | 1.55 | 2.11 | 4.82 | 1.79 | 1.28 | 0.00 | 0.58 | 0.57 | 28.75 | 0.00 | 0.00 | 0.00 | 56.62 | 0.00 | 0.00 | 85.4 |
| | Other services | 0.11 | 0.00 | 0.00 | 0.00 | 0.14 | 0.26 | 0.01 | 0.31 | 0.00 | 0.18 | 0.00 | 0.00 | 0.24 | 0.08 | 1.33 | 0.00 | 7.05 | 2.98 | 41.56 | 0.00 | 0.00 | 52.9 |
| | Total | 16.35 | 6.25 | 9.38 | 10.29 | 42.06 | 43.86 | 18.32 | 35.37 | 14.53 | 10.73 | 11.76 | 8.51 | 23.69 | 20.28 | **271.39** | 24.14 | 137.72 | 26.95 | 313.58 | 55.29 | -6.87 | **822.2** |
| | Import | 7.26 | 1.27 | 3.18 | 1.63 | 15.53 | 15.12 | 9.29 | 7.58 | 2.78 | 3.48 | 3.11 | 1.50 | 8.50 | 3.75 | 83.99 | 0.00 | 23.02 | 15.74 | 79.67 | 54.79 | 6.50 | 263.7 |
| | Taxes - Subsidies | 0.55 | 0.34 | 0.13 | 0.44 | 0.79 | 0.67 | 0.81 | 0.48 | 0.45 | 0.31 | 0.24 | 0.20 | 0.49 | 0.21 | 6.12 | 0.00 | 3.47 | 1.79 | 5.59 | 1.96 | 0.36 | 19.3 |
| | ValueAdded | 12.33 | 9.31 | 15.51 | 25.99 | 60.42 | 23.84 | 20.33 | 50.49 | 24.44 | 47.72 | 56.64 | 32.32 | 52.70 | 28.68 | **460.71** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 460.7 |
| | Compensation of Employees | 5.75 | 7.41 | 8.59 | 33.30 | 33.91 | 16.79 | 14.32 | 22.45 | 12.74 | 12.33 | 44.53 | 32.32 | 35.59 | 16.50 | 296.53 | | | | | | | |
| | Consumption of Fixed Capital | 2.10 | 1.59 | 3.98 | 0.43 | 3.15 | 3.36 | 2.86 | 13.39 | 1.97 | 12.86 | 3.68 | 0.00 | 0.00 | 1.21 | 50.57 | | | | | | | |
| | Operating surplus/mixed income gross | 4.48 | 0.32 | 2.94 | -7.73 | 23.35 | 3.69 | 3.15 | 14.65 | 9.72 | 22.53 | 8.43 | 0.00 | 17.11 | 10.97 | 113.61 | | | | | | | |
| | TotalOutput | 36.5 | 17.2 | 28.2 | 38.3 | 118.8 | 83.5 | 48.8 | 93.9 | 42.2 | 62.2 | 71.7 | 42.5 | 85.4 | 52.9 | **822.2** | 24.1 | 164.2 | 44.5 | 398.8 | 112.0 | 0.0 | **1565.9** |
| | GDP | **480.0** | | | | | | | | | | | | | | | | | | | | | |

*Table 16 An overview of the Leontief matrix based on the sectoral output of 2050*

| | | AFM | M | EGW | C | T | Hot | FS | TIC | F | ORE | PAD | ED | H | OS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sector** | **AFM** | 1.00 | 0.04 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **M** | 0.01 | 1.02 | 0.01 | 0.00 | 0.01 | 0.03 | 0.05 | 0.01 | 0.03 | 0.01 | 0.02 | 0.06 | 0.03 | 0.02 |
| | **EGW** | 0.18 | 0.03 | 1.02 | 0.02 | 0.05 | 0.10 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 | 0.12 |
| | **C** | 0.01 | 0.00 | 0.00 | 1.09 | 0.01 | 0.03 | 0.01 | 0.00 | 0.01 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 |
| | **T** | 0.12 | 0.06 | 0.20 | 0.04 | 1.05 | 0.15 | 0.19 | 0.10 | 0.05 | 0.03 | 0.03 | 0.04 | 0.12 | 0.07 |
| | **Hot** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **FS** | 0.01 | 0.03 | 0.01 | 0.00 | 0.04 | 0.02 | 1.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.00 | 0.02 | 0.04 |
| | **TIC** | 0.19 | 0.07 | 0.08 | 0.04 | 0.10 | 0.07 | 0.04 | 1.15 | 0.05 | 0.03 | 0.05 | 0.02 | 0.05 | 0.08 |
| | **F** | 0.05 | 0.07 | 0.07 | 0.10 | 0.09 | 0.14 | 0.10 | 0.05 | 1.07 | 0.06 | 0.01 | 0.01 | 0.03 | 0.06 |
| | **ORE** | 0.06 | 0.06 | 0.04 | 0.03 | 0.09 | 0.05 | 0.05 | 0.09 | 0.08 | 1.02 | 0.04 | 0.11 | 0.05 | 0.12 |
| | **PAD** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 |
| | **ED** | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.02 | 0.00 | 0.01 | 1.00 | 0.05 | 0.01 |
| | **H** | 0.04 | 0.13 | 0.04 | 0.03 | 0.05 | 0.12 | 0.05 | 0.04 | 0.12 | 0.04 | 0.02 | 0.01 | 1.02 | 0.03 |
| | **OS** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 |
| | **Total** | **1.67** | **1.51** | **1.48** | **1.41** | **1.51** | **1.82** | **1.56** | **1.52** | **1.48** | **1.26** | **1.23** | **1.29** | **1.40** | **1.58** |
| | **Taxes** | 0.01 | 0.02 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| | CVA | 0.33 | 0.56 | 0.56 | 0.67 | 0.51 | 0.28 | 0.41 | 0.55 | 0.58 | 0.76 | 0.79 | 0.75 | 0.62 | 0.52 |

[See Figure 10 for the abbreviations of every industry]

*Table 17 The estimated IO table of Bonaire for 2050 in "high growth" scenario*

| 2050 in USDm | Intermediate demand | | | | | | | | | | | | | | Dom. Produc | Final Demand | | | | | | Total Product |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AFM | M | EGW | C | T | Hot | FS | TC | F | ORE | PAD | ED | H | OS | | Regular Export | Stay-over tourism | Cruise tourism | Final C | Invest. | Invent. | |
| **Intermediate demand** | | | | | | | | | | | | | | | | | | | | | | |
| Agriculture, fishing, mining | 0.00 | 1.38 | 0.00 | 4.96 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.34 | 14.99 | 0.00 | 0.00 | 0.00 | 0.00 | 49.30 | 70.6 |
| Manufacturing | 0.30 | 0.50 | 0.31 | 0.00 | 1.83 | 3.67 | 4.85 | 0.71 | 2.05 | 1.20 | 2.55 | 4.66 | 3.35 | 1.78 | 27.77 | 10.28 | 7.71 | 8.43 | 33.99 | 34.84 | -86.08 | 36.9 |
| Electricity, gas, and water supply | 11.74 | 0.44 | 0.27 | 0.57 | 11.18 | 16.81 | 2.93 | 2.02 | 1.49 | 3.95 | 1.79 | 1.36 | 3.51 | 12.67 | 70.72 | 0.74 | 0.00 | 0.00 | 23.16 | 0.00 | 0.00 | 94.6 |
| Construction | 0.59 | 0.00 | 0.00 | 9.02 | 1.82 | 5.44 | 0.73 | 0.00 | 0.68 | 3.00 | 0.00 | 0.00 | 0.00 | 0.44 | 21.72 | 2.36 | 0.00 | 0.00 | 4.40 | 85.95 | 0.00 | 114.4 |
| Trade | 4.55 | 0.77 | 16.86 | 2.96 | 5.56 | 19.67 | 19.88 | 11.08 | 1.56 | 2.75 | 3.11 | 2.37 | 17.35 | 3.06 | 111.52 | 5.02 | 17.06 | 18.66 | 84.74 | 12.66 | 22.08 | 271.7 |
| Hotels | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 17.04 | 0.00 | 0.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 17.49 | 0.00 | 186.29 | 0.00 | 1.87 | 0.00 | 0.00 | 205.7 |
| Food Services | 0.00 | 0.79 | 0.00 | 0.00 | 10.04 | 1.89 | 0.90 | 1.79 | 2.15 | 0.95 | 1.60 | 0.00 | 2.10 | 4.20 | 26.40 | 0.00 | 54.91 | 8.72 | 30.06 | 0.00 | 0.00 | 120.1 |
| Transport, information, and communicati | 10.00 | 1.73 | 4.68 | 1.97 | 19.81 | 5.97 | 1.11 | 18.09 | 2.60 | 2.75 | 5.05 | 0.59 | 4.59 | 6.11 | 85.04 | 7.84 | 20.91 | 15.22 | 21.17 | 0.00 | 0.00 | 150.2 |
| Financial Intermediation | 1.30 | 1.76 | 4.82 | 9.02 | 17.50 | 19.28 | 9.01 | 4.64 | 4.76 | 6.55 | 0.44 | 0.00 | 2.33 | 4.27 | 85.68 | 0.00 | 0.00 | 0.00 | 9.61 | 0.00 | 0.00 | 95.3 |
| Other real estate activities | 1.92 | 1.42 | 0.99 | 2.08 | 18.71 | 3.98 | 2.47 | 9.12 | 5.77 | 1.21 | 5.34 | 8.11 | 5.92 | 11.64 | 78.67 | 0.00 | 9.49 | 0.00 | 62.43 | 0.00 | 0.00 | 150.6 |
| Public administration and defense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 12.34 | 0.00 | 0.00 | 139.88 | 0.00 | 0.00 | 152.2 |
| Education | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.93 | 1.24 | 0.00 | 1.80 | 0.00 | 7.74 | 0.81 | 13.52 | 0.00 | 0.00 | 0.00 | 68.80 | 0.00 | 0.00 | 82.3 |
| Health | 1.43 | 4.04 | 2.46 | 1.04 | 8.77 | 16.46 | 3.40 | 3.12 | 9.85 | 3.86 | 2.45 | 0.00 | 1.07 | 1.07 | 59.03 | 0.00 | 0.00 | 0.00 | 115.92 | 0.00 | 0.00 | 174.9 |
| Other services | 0.21 | 0.00 | 0.00 | 0.00 | 0.32 | 0.59 | 0.02 | 0.49 | 0.00 | 0.42 | 0.00 | 0.00 | 0.47 | 0.16 | 2.68 | 0.00 | 13.75 | 6.65 | 91.63 | 0.00 | 0.00 | 114.7 |
| Total | 32.04 | 12.83 | 30.38 | 31.60 | 95.52 | 110.79 | 45.30 | 53.45 | 32.17 | 26.63 | 24.15 | 17.09 | 48.44 | 46.19 | **606.59** | 53.57 | 310.13 | 57.68 | 687.66 | 133.45 | -14.71 | **1834.4** |
| Import | 14.05 | 2.85 | 11.00 | 4.87 | 36.11 | 36.54 | 23.08 | 12.70 | 6.44 | 8.50 | 6.73 | 2.93 | 17.66 | 7.97 | 191.43 | 0.00 | 47.20 | 36.87 | 184.55 | 111.24 | 13.93 | 585.2 |
| Taxes - Subsidies | 1.05 | 0.76 | 0.46 | 1.30 | 1.84 | 1.60 | 2.01 | 0.80 | 1.03 | 0.76 | 0.51 | 0.39 | 1.01 | 0.45 | 13.98 | 0.00 | 7.07 | 4.17 | 12.88 | 3.95 | 0.78 | 42.8 |
| ValueAdded | 23.49 | 20.50 | 52.78 | 76.64 | 138.28 | 56.72 | 49.71 | 83.23 | 55.65 | 114.71 | 120.82 | 61.91 | 107.83 | 60.10 | **1022.37** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1022.4 |
| Compensation of Employees | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | |
| Consumption of Fixed Capital | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | |
| Operating surplus/mixed income gross | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | |
| TotalOutput | 70.6 | 36.9 | 94.6 | 114.4 | 271.7 | 205.7 | 120.1 | 150.2 | 95.3 | 150.6 | 152.2 | 82.3 | 174.9 | 114.7 | **1834.4** | 53.6 | 364.4 | 98.7 | 885.1 | 248.6 | 0.0 | **1650.4** |
| GDP | **1065.2** | | | | | | | | | | | | | | | | | 1650.4 | | | | |

*Table 18 Estimated IO table of Bonaire for 2050 in "low growth" scenario*

| | 2050 in USDm | Intermediate demand | | | | | | | | | | | | | | Dom. Produc | Final Demand | | | | | | Total Product |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AFM | M | EGW | C | T | Hot | Res | TC | F | ORE | PAD | ED | H | OS | | Regular Export | Stay-over tourism | Cruise tourism | Final C | Invest. | Invent. | |
| Intermediate demand | Agriculture, fishing, mining | 0.00 | 0.89 | 0.00 | 3.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.07 | 9.62 | 0.00 | 0.00 | 0.00 | 0.00 | 31.64 | 45.3 |
| | Manufacturing | 0.19 | 0.32 | 0.20 | 0.00 | 1.17 | 2.36 | 3.11 | 0.46 | 1.32 | 0.77 | 1.64 | 2.99 | 2.15 | 1.14 | 17.83 | 6.60 | 4.95 | 5.41 | 21.82 | 22.36 | -55.25 | 23.7 |
| | Electricity, gas, and water supply | 7.54 | 0.28 | 0.17 | 0.36 | 7.17 | 10.79 | 1.88 | 1.29 | 0.96 | 2.53 | 1.15 | 0.87 | 2.26 | 8.13 | 45.39 | 0.47 | 0.00 | 0.00 | 14.87 | 0.00 | 0.00 | 60.7 |
| | Construction | 0.38 | 0.00 | 0.00 | 5.79 | 1.17 | 3.49 | 0.47 | 0.00 | 0.44 | 1.92 | 0.00 | 0.00 | 0.00 | 0.28 | 13.94 | 1.51 | 0.00 | 0.00 | 2.82 | 55.17 | 0.00 | 73.4 |
| | Trade | 2.92 | 0.49 | 10.82 | 1.90 | 3.57 | 12.62 | 12.76 | 7.11 | 1.00 | 1.77 | 2.00 | 1.52 | 11.14 | 1.96 | 71.58 | 3.22 | 10.95 | 11.98 | 54.39 | 8.12 | 14.17 | 174.4 |
| | Hotels | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.94 | 0.00 | 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 11.23 | 0.00 | 119.58 | 0.00 | 1.20 | 0.00 | 0.00 | 132.0 |
| | Restaurants | 0.00 | 0.51 | 0.00 | 0.00 | 6.44 | 1.21 | 0.58 | 1.15 | 1.38 | 0.61 | 1.03 | 0.00 | 1.35 | 2.69 | 16.95 | 0.00 | 35.24 | 5.60 | 19.30 | 0.00 | 0.00 | 77.1 |
| | Transport, information, and communicati | 6.42 | 1.11 | 3.00 | 1.26 | 12.71 | 3.83 | 0.71 | 11.61 | 1.67 | 1.76 | 3.24 | 0.38 | 2.95 | 3.92 | 54.58 | 5.03 | 13.42 | 9.77 | 13.59 | 0.00 | 0.00 | 96.4 |
| | Financial Intermediation | 0.83 | 1.13 | 3.09 | 5.79 | 11.23 | 12.38 | 5.78 | 2.98 | 3.06 | 4.21 | 0.29 | 0.00 | 1.50 | 2.74 | 54.99 | 0.00 | 0.00 | 0.00 | 6.17 | 0.00 | 0.00 | 61.2 |
| | Other real estate activities | 1.23 | 0.91 | 0.63 | 1.33 | 12.01 | 2.55 | 1.59 | 5.86 | 3.70 | 0.78 | 3.43 | 5.21 | 3.80 | 7.47 | 50.50 | 0.00 | 6.09 | 0.00 | 40.07 | 0.00 | 0.00 | 96.7 |
| | Public administration and defense | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 7.92 | 0.00 | 0.00 | 89.79 | 0.00 | 0.00 | 97.7 |
| | Education | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.24 | 0.80 | 0.00 | 1.16 | 0.00 | 4.97 | 0.52 | 8.68 | 0.00 | 0.00 | 0.00 | 44.16 | 0.00 | 0.00 | 52.8 |
| | Health | 0.92 | 2.59 | 1.58 | 0.66 | 5.63 | 10.57 | 2.18 | 2.01 | 6.33 | 2.47 | 1.58 | 0.00 | 0.69 | 0.69 | 37.89 | 0.00 | 0.00 | 0.00 | 74.41 | 0.00 | 0.00 | 112.3 |
| | Other services | 0.13 | 0.00 | 0.00 | 0.00 | 0.20 | 0.38 | 0.02 | 0.32 | 0.00 | 0.27 | 0.00 | 0.00 | 0.30 | 0.10 | 1.72 | 0.00 | 8.83 | 4.27 | 58.82 | 0.00 | 0.00 | 73.6 |
| | Total | 20.57 | 8.23 | 19.50 | 20.29 | 61.31 | 71.11 | 29.08 | 34.31 | 20.65 | 17.09 | 15.50 | 10.97 | 31.09 | 29.65 | **389.35** | 34.38 | 199.06 | 37.03 | 441.40 | 85.66 | -9.44 | **1177.4** |
| | Import | 9.02 | 1.83 | 7.06 | 3.13 | 23.18 | 23.45 | 14.82 | 8.15 | 4.13 | 5.46 | 4.32 | 1.88 | 11.34 | 5.12 | 122.88 | 0.00 | 30.30 | 23.67 | 118.46 | 71.40 | 8.94 | 375.6 |
| | Taxes - Subsidies | 0.67 | 0.49 | 0.30 | 0.84 | 1.18 | 1.03 | 1.29 | 0.52 | 0.66 | 0.49 | 0.33 | 0.25 | 0.65 | 0.29 | 8.97 | 0.00 | 4.54 | 2.68 | 8.26 | 2.53 | 0.50 | 27.5 |
| | ValueAdded | 15.07 | 13.16 | 33.88 | 49.20 | 88.76 | 36.41 | 31.91 | 53.42 | 35.72 | 73.63 | 77.55 | 39.74 | 69.22 | 38.57 | **656.23** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 656.2 |
| | Compensation of Employees | 0.28 | 0.63 | 1.73 | 3.88 | 5.71 | 3.41 | 2.39 | 1.65 | 1.79 | 3.20 | 0.23 | 0.00 | 0.92 | 1.44 | 27.25 | | | | | | | |
| | Consumption of Fixed Capital | 0.41 | 0.51 | 0.35 | 0.89 | 6.11 | 0.70 | 0.66 | 3.25 | 2.16 | 0.59 | 2.72 | 3.92 | 2.34 | 3.91 | 28.53 | | | | | | | |
| | Operating surplus/mixed income gross | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | | | |
| | TotalOutput | 45.3 | 23.7 | 60.7 | 73.4 | 174.4 | 132.0 | 77.1 | 96.4 | 61.2 | 96.7 | 97.7 | 52.8 | 112.3 | 73.6 | **1177.4** | 34.4 | 233.9 | 63.4 | 568.1 | 159.6 | 0.0 | **1059.4** |
| | GDP | **683.7** | | | | | | | | | | | | | | | | | | | | | |

*Table 19 An overview the ecological module under scenario SSP1-1.9*

| | 2017 | 2018 | 2019 | 2020 | 2021 [F] | 2022 [F] | 2023 [F] | 2024 [F] | 2025 [F] | 2026 [F] | 2027 [F] | 2028 [F] | 2029 [F] | 2030 [F] | 2031 [F] | 2032 [F] | 2033 [F] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Global Effects** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Thermal stress** | | | | | | | | | | | | | | | | | |
| Sea surface temperature (Celcius) | 27.25 | 27.27 | 27.28 | 27.30 | 27.33 | 27.37 | 27.40 | 27.44 | 27.47 | 27.50 | 27.54 | 27.57 | 27.61 | 27.64 | 27.67 | 27.71 | 27.74 |
| *Change in SST (%)* | 0.00 | 0.06 | 0.06 | 0.06 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| Air temperature (Celcius) | 1.00 | 1.02 | 1.04 | 1.07 | 1.09 | 1.11 | 1.13 | 1.15 | 1.17 | 1.20 | 1.22 | 1.24 | 1.26 | 1.28 | 1.30 | 1.33 | 1.35 |
| *Absolute change (%)* | 0.00 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| **Ocean acidification** | | | | | | | | | | | | | | | | | |
| CO2 concentration (parts per million) | 406.76 | 408.72 | 411.66 | 414.24 | 416.45 | 417.18 | 417.90 | 418.63 | 419.35 | 420.08 | 420.81 | 421.53 | 422.26 | 422.99 | 423.71 | 424.44 | 425.16 |
| *Change in CO2 (%)* | 0.00 | 0.48 | 0.72 | 0.63 | 0.53 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| **Local Effects** | 2017 | 2018 | 2019 | 2020 | 2021 [F] | 2022 [F] | 2023 [F] | 2024 [F] | 2025 [F] | 2026 [F] | 2027 [F] | 2028 [F] | 2029 [F] | 2030 [F] | 2031 [F] | 2032 [F] | 2033 [F] |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Fish stock** | | | | | | | | | | | | | | | | | |
| Annual catch herbivory (%) | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Annual catch herbivory (tonnes) | 4.13 | 4.27 | 4.36 | 4.43 | 4.49 | 4.57 | 4.60 | 4.62 | 4.64 | 4.66 | 4.66 | 4.66 | 4.66 | 4.65 | 4.64 | 4.63 | 4.62 |
| Annual catch predatory (%) | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Annual catch predatory (tonnes) | 9.19 | 9.19 | 9.20 | 9.20 | 9.20 | 9.19 | 9.18 | 9.17 | 9.15 | 9.13 | 9.10 | 9.07 | 9.03 | 8.99 | 8.95 | 8.90 | 8.84 |
| **Run-off** | | | | | | | | | | | | | | | | | |
| Nutrient concentration (µmol/g) | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.08 |
| Sedimentation rate | 16.10 | 16.21 | 16.33 | 16.44 | 16.56 | 16.67 | 16.78 | 16.90 | 17.01 | 17.12 | 17.24 | 17.35 | 17.47 | 17.58 | 17.69 | 17.80 | 17.91 |
| Sediment influence Ccap | 18.77 | 18.90 | 19.03 | 19.17 | 19.30 | 19.43 | 19.57 | 19.70 | 19.83 | 19.96 | 20.10 | 20.23 | 20.36 | 20.49 | 20.62 | 20.76 | 20.89 |
| Max Ccap coral (%) | 60.00 | | | | | | | | | | | | | | | | |
| Arable land (ha) | 110.00 | 110.15 | 110.30 | 110.46 | 110.61 | 110.76 | 110.91 | 111.06 | 111.21 | 111.37 | 111.52 | 111.67 | 111.82 | 111.97 | 112.12 | 112.28 | 112.43 |
| Built up | 4900.92 | 4998.26 | 5095.61 | 5192.95 | 5290.30 | 5387.64 | 5484.98 | 5582.33 | 5679.67 | 5777.02 | 5874.36 | 5971.71 | 6069.05 | 6166.39 | 6263.74 | 6361.08 | 6458.43 |
| Overgrazed (ha) | 3198.00 | 3202.41 | 3206.82 | 3211.23 | 3215.64 | 3220.05 | 3224.46 | 3228.87 | 3233.28 | 3237.69 | 3242.10 | 3246.51 | 3250.92 | 3250.92 | 3253.86 | 3256.07 | 3258.27 |
| Shrubs/woodland (ha) | 12920.00 | 12818.09 | 12716.19 | 12614.28 | 12512.38 | 12410.47 | 12308.56 | 12206.66 | 12104.75 | 12002.84 | 11900.94 | 11799.03 | 11697.13 | 11697.13 | 11629.19 | 11578.24 | 11527.28 |
| Total area (ha) | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 |
| **Tourism** | | | | | | | | | | | | | | | | | |
| Total number of dives | 835866.50 | 930361.30 | 1010032.70 | 413894.30 | 595144.80 | 1010032.70 | 1062173.85 | 601096.25 | 607107.21 | 613178.28 | 619310.07 | 625503.17 | 631758.20 | 638075.78 | 644456.54 | 650901.10 | 657410.11 |
| Dive sites | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 | 86.75 |
| Dives per site | 9719.38 | 10818.15 | 11744.57 | 4812.72 | 6920.29 | 11642.44 | 12243.46 | 6928.71 | 6998.00 | 7067.98 | 7138.66 | 7210.05 | 7282.15 | 7354.97 | 7428.52 | 7502.80 | 7577.83 |
| Physical destruction diving | 0.0160 | 0.0178 | 0.0194 | 0.0079 | 0.0114 | 0.0192 | 0.0202 | 0.0114 | 0.0115 | 0.0117 | 0.0118 | 0.0119 | 0.0120 | 0.0121 | 0.0123 | 0.0124 | 0.0125 |
| Physical destruction diving (ha) | 1.56 | 1.84 | 2.07 | 0.87 | 1.29 | 2.24 | 2.39 | 1.37 | 1.40 | 1.43 | 1.45 | 1.47 | 1.49 | 1.51 | 1.53 | 1.55 | 1.57 |
| **Ecological indicators** | 2017 | 2018 | 2019 | 2020 | 2021 [F] | 2022 [F] | 2023 [F] | 2024 [F] | 2025 [F] | 2026 [F] | 2027 [F] | 2028 [F] | 2029 [F] | 2030 [F] | 2031 [F] | 2032 [F] | 2033 [F] |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Coral cover** | | | | | | | | | | | | | | | | | |
| Coral reef (ha) | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 |
| *Ccap coral cover (%)* | 41.33 | 41.20 | 41.07 | 40.93 | 40.80 | 40.67 | 40.53 | 40.40 | 40.27 | 40.14 | 40.00 | 39.87 | 39.74 | 39.61 | 39.48 | 39.34 | 39.21 |
| Coral cover (%) | 11.20 | 11.89 | 12.33 | 12.72 | 13.05 | 13.45 | 13.67 | 13.79 | 13.98 | 14.11 | 14.22 | 14.29 | 14.35 | 14.40 | 14.44 | 14.47 | 14.50 |
| *Relative change in cover cover (%)* | 0.00 | 0.06 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ccap coral cover (ha)* | 357.94 | 356.79 | 355.64 | 354.49 | 353.33 | 352.18 | 351.03 | 349.88 | 348.73 | 347.57 | 346.42 | 345.27 | 344.12 | 343.00 | 341.85 | 340.72 | 339.58 |
| Coral cover (ha) | 96.99 | 102.96 | 106.81 | 110.12 | 112.97 | 116.49 | 118.36 | 119.44 | 121.04 | 122.23 | 123.12 | 123.79 | 124.31 | 124.72 | 125.05 | 125.34 | 125.58 |
| **Fish stock** | | | | | | | | | | | | | | | | | |
| *Ccap herbivory* | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 |
| Stock herbivory | 275.33 | 284.70 | 290.49 | 295.37 | 299.47 | 304.54 | 306.89 | 307.88 | 309.57 | 310.55 | 310.97 | 310.98 | 310.69 | 310.19 | 309.54 | 308.79 | 307.95 |
| Relative herbivory change | | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.01 | 0.00314 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ccap Predatory* | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 |
| Stock Predatory | 183.72 | 183.85 | 183.93 | 183.96 | 183.95 | 183.85 | 183.65 | 183.37 | 182.99 | 182.53 | 181.97 | 181.33 | 180.61 | 179.80 | 178.91 | 177.94 | 176.89 |
| Relative Predatory change | | 0.001 | 0.000 | 0.000 | 0.000 | -0.001 | -0.001 | -0.002 | -0.002 | -0.003 | -0.003 | -0.004 | -0.004 | -0.004 | -0.005 | -0.005 | -0.006 |
| *Ccap total* | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 |
| Stock total | 462.74 | 472.27 | 478.17 | 483.13 | 487.30 | 492.35 | 494.58 | 495.37 | 496.78 | 497.38 | 497.34 | 496.80 | 495.88 | 494.67 | 493.23 | 491.60 | 489.82 |
| *Absolute change in stock* | - | 9.53 | 5.90 | 4.96 | 4.17 | 5.05 | 2.23 | 0.79 | 1.40 | 0.60 | -0.04 | -0.54 | -0.92 | -1.21 | -1.44 | -1.63 | -1.78 |
| **Other Benthic cover** | | | | | | | | | | | | | | | | | |
| *Ccap algae cover (%)* | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 |
| Algae cover (%) | 44.47 | 49.85 | 55.24 | 60.58 | 65.42 | 69.59 | 73.09 | 75.82 | 77.87 | 79.37 | 80.41 | 81.11 | 81.56 | 81.85 | 82.02 | 82.12 | 82.18 |
| *Relative change in algae (%)* | - | 0.12 | 0.11 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sand/rubble/sponge cover (%) | 44.33 | 38.26 | 32.43 | 26.70 | 21.54 | 16.96 | 13.25 | 10.39 | 8.15 | 6.52 | 5.37 | 4.59 | 4.08 | 3.75 | 3.54 | 3.40 | 3.32 |
| **Intrinsic ecological drivers** | 2017 (H) | 2018 (E) | 2019 (E) | 2020 (E) | 2021 [F] | 2022 [F] | 2023 [F] | 2024 [F] | 2025 [F] | 2026 [F] | 2027 [F] | 2028 [F] | 2029 [F] | 2030 [F] | 2031 [F] | 2032 [F] | 2033 [F] |
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **Fish growth** | | | | | | | | | | | | | | | | | |
| Regrowth herbivory | 44.70 | 45.38 | 45.76 | 46.07 | 46.32 | 46.61 | 46.74 | 46.80 | 46.89 | 46.94 | 46.96 | 46.96 | 46.95 | 46.92 | 46.89 | 46.85 | 46.80 |
| Regrowth predatory | 13.12 | 13.12 | 13.13 | 13.13 | 13.13 | 13.12 | 13.12 | 13.10 | 13.09 | 13.07 | 13.04 | 13.02 | 12.98 | 12.95 | 12.91 | 12.87 | 12.82 |
| Lionfish stock | 3.69 | 3.72 | 3.76 | 3.80 | 3.88 | 3.96 | 4.04 | 4.13 | 4.22 | 4.31 | 4.40 | 4.49 | 4.58 | 4.68 | 4.78 | 4.88 | 4.98 |
| % change fish stock by Lionfish | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |

| | 2034 [F] | 2035 [F] | 2036 [F] | 2037 [F] | 2038 [F] | 2039 [F] | 2040 [F] | 2041 [F] | 2042 [F] | 2043 [F] | 2044 [F] | 2045 [F] | 2046 [F] | 2047 [F] | 2048 [F] | 2049 [F] | 2050 [F] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Global Effects** | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
| **Thermal stress** | | | | | | | | | | | | | | | | | |
| Sea surface temperature (Celcius) | 27.78 | 27.81 | 27.82 | 27.83 | 27.84 | 27.86 | 27.87 | 27.88 | 27.89 | 27.90 | 27.91 | 27.92 | 27.93 | 27.95 | 27.96 | 27.97 | 27.98 |
| *Change in SST (%)* | 0.12 | 0.12 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Air temperature (Celcius) | 1.37 | 1.39 | 1.41 | 1.43 | 1.46 | 1.48 | 1.50 | 1.52 | 1.54 | 1.56 | 1.58 | 1.60 | 1.63 | 1.65 | 1.67 | 1.69 | 1.70 |
| *Absolute change (%)* | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| **Ocean acidification** | | | | | | | | | | | | | | | | | |
| CO2 concentration (parts per million) | 425.89 | 426.62 | 427.34 | 428.07 | 428.80 | 429.52 | 430.25 | 430.97 | 431.70 | 432.43 | 433.15 | 433.88 | 434.61 | 435.33 | 436.06 | 436.78 | 437.5 |
| *Change in CO2 (%)* | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 |
| **Local Effects** | 2034 [F] | 2035 [F] | 2036 [F] | 2037 [F] | 2038 [F] | 2039 [F] | 2040 [F] | 2041 [F] | 2042 [F] | 2043 [F] | 2044 [F] | 2045 [F] | 2046 [F] | 2047 [F] | 2048 [F] | 2049 [F] | 2050 [F] |
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
| **Fish stock** | | | | | | | | | | | | | | | | | |
| Annual catch herbivory (%) | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Annual catch herbivory (tonnes) | 4.61 | 4.59 | 4.61 | 4.64 | 4.66 | 4.69 | 4.72 | 4.75 | 4.78 | 4.82 | 4.85 | 4.89 | 4.93 | 4.97 | 5.01 | 5.06 | 5.10 |
| Annual catch predatory (%) | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Annual catch predatory (tonnes) | 8.79 | 8.73 | 8.66 | 8.60 | 8.54 | 8.47 | 8.41 | 8.35 | 8.28 | 8.22 | 8.16 | 8.10 | 8.03 | 7.97 | 7.91 | 7.85 | 7.79 |
| **Run-off** | | | | | | | | | | | | | | | | | |
| Nutrient concentration (µmol/g) | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 |
| Sedimentation rate | 18.03 | 18.14 | 18.26 | 18.37 | 18.48 | 18.60 | 18.71 | 18.82 | 18.94 | 19.05 | 19.16 | 19.28 | 19.39 | 19.50 | 19.62 | 19.73 | 19.84 |
| Sediment influence Ccap | 21.02 | 21.15 | 21.29 | 21.42 | 21.55 | 21.68 | 21.82 | 21.95 | 22.08 | 22.21 | 22.35 | 22.48 | 22.61 | 22.74 | 22.88 | 23.01 | 23.14 |
| Max Ccap coral (%) | | | | | | | | | | | | | | | | | |
| Arable land (ha) | 112.58 | 112.73 | 112.88 | 113.03 | 113.19 | 113.34 | 113.49 | 113.64 | 113.79 | 113.94 | 114.10 | 114.25 | 114.40 | 114.55 | 114.70 | 114.85 | 115.0 |
| Built up | 6555.77 | 6653.11 | 6750.46 | 6847.80 | 6945.15 | 7042.49 | 7139.84 | 7237.18 | 7334.52 | 7431.87 | 7529.21 | 7626.56 | 7723.90 | 7821.24 | 7918.59 | 8015.93 | 8113.2 |
| Overgrazed (ha) | 3260.48 | 3262.68 | 3271.84 | 3275.55 | 3279.26 | 3282.97 | 3286.68 | 3290.38 | 3294.09 | 3297.80 | 3301.51 | 3305.22 | 3308.93 | 3312.64 | 3316.35 | 3320.06 | 3323.7 |
| Shrubs/woodland (ha) | 11476.33 | 11425.38 | 11213.82 | 11128.12 | 11042.42 | 10956.73 | 10871.03 | 10785.33 | 10699.64 | 10613.94 | 10528.24 | 10442.55 | 10356.85 | 10271.16 | 10185.46 | 10099.76 | 10014.0 |
| Total area (ha) | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.92 | 21128.9 |
| **Tourism** | | | | | | | | | | | | | | | | | |
| Total number of dives | 663984.22 | 670624.06 | 677330.30 | 684103.60 | 690944.64 | 697854.08 | 704832.62 | 711880.95 | 718999.76 | 726189.76 | 733451.65 | 740786.17 | 748194.03 | 755675.97 | 763232.73 | 770865.06 | 778573 |
| Dive sites | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 | 86.00 |
| Dives per site | 7720.75 | 7797.95 | 7875.93 | 7954.69 | 8034.24 | 8114.58 | 8195.73 | 8277.69 | 8360.46 | 8444.07 | 8528.51 | 8613.79 | 8699.93 | 8786.93 | 8874.80 | 8963.55 | 9053.1 |
| Physical destruction diving | 0.0127 | 0.0129 | 0.0130 | 0.0131 | 0.0133 | 0.0134 | 0.0135 | 0.0137 | 0.0138 | 0.0139 | 0.0141 | 0.0142 | 0.0144 | 0.0145 | 0.0146 | 0.0148 | 0.0149 |
| Physical destruction diving (ha) | 1.60 | 1.62 | 1.66 | 1.70 | 1.74 | 1.78 | 1.82 | 1.86 | 1.90 | 1.94 | 1.98 | 2.02 | 2.06 | 2.10 | 2.14 | 2.18 | 2.23 |
| **Ecological indicators** | 2034 [F] | 2035 [F] | 2036 [F] | 2037 [F] | 2038 [F] | 2039 [F] | 2040 [F] | 2041 [F] | 2042 [F] | 2043 [F] | 2044 [F] | 2045 [F] | 2046 [F] | 2047 [F] | 2048 [F] | 2049 [F] | 2050 [F] |
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
| **Coral cover** | | | | | | | | | | | | | | | | | |
| Coral reef (ha) | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 | 866.00 |
| *Ccap coral cover (%)* | 39.08 | 38.95 | 38.81 | 38.68 | 38.55 | 38.42 | 38.28 | 38.15 | 38.02 | 37.89 | 37.75 | 37.62 | 37.49 | 37.36 | 37.22 | 37.09 | 36.96 |
| Coral cover (%) | 14.53 | 14.55 | 14.75 | 14.95 | 15.14 | 15.34 | 15.53 | 15.71 | 15.90 | 16.07 | 16.25 | 16.42 | 16.59 | 16.75 | 16.90 | 17.06 | 17.20 |
| *Relative change in cover cover (%)* | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *Ccap coral cover (ha)* | 338.44 | 337.31 | 336.12 | 334.98 | 333.83 | 332.68 | 331.53 | 330.39 | 329.24 | 328.09 | 326.94 | 325.80 | 324.65 | 323.50 | 322.36 | 321.21 | 320.06 |
| Coral cover (ha) | 125.79 | 125.96 | 127.71 | 129.43 | 131.13 | 132.80 | 134.45 | 136.07 | 137.65 | 139.21 | 140.72 | 142.20 | 143.64 | 145.04 | 146.39 | 147.70 | 148.96 |
| **Fish stock** | | | | | | | | | | | | | | | | | |
| *Ccap herbivory* | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 | 785.40 |
| Stock herbivory | 307.07 | 306.14 | 307.56 | 309.12 | 310.81 | 312.64 | 314.60 | 316.69 | 318.89 | 321.21 | 323.64 | 326.17 | 328.79 | 331.50 | 334.28 | 337.13 | 340.04 |
| Relative herbivory change | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| *Ccap Predatory* | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 | 642.60 |
| Stock Predatory | 175.76 | 174.56 | 173.27 | 172.00 | 170.73 | 169.46 | 168.19 | 166.93 | 165.68 | 164.42 | 163.17 | 161.92 | 160.67 | 159.43 | 158.18 | 156.94 | 155.70 |
| Relative Predatory change | -0.006 | -0.007 | -0.007 | -0.007 | -0.007 | -0.007 | -0.007 | -0.007 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 |
| *Ccap total* | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.00 | 1428.0 |
| Stock total | 487.92 | 485.88 | 486.06 | 486.38 | 486.84 | 487.43 | 488.17 | 489.03 | 490.01 | 491.11 | 492.33 | 493.64 | 495.06 | 496.56 | 498.13 | 499.78 | 501.49 |
| *Absolute change in stock* | -1.91 | -2.03 | 0.18 | 0.32 | 0.46 | 0.60 | 0.73 | 0.86 | 0.98 | 1.10 | 1.21 | 1.32 | 1.41 | 1.50 | 1.58 | 1.65 | 1.71 |
| **Other Benthic cover** | | | | | | | | | | | | | | | | | |
| *Ccap algae cover (%)* | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 | 82.20 |
| Algae cover (%) | 82.22 | 82.23 | 82.24 | 82.25 | 82.25 | 82.25 | 82.25 | 82.24 | 82.24 | 82.24 | 82.24 | 82.24 | 82.24 | 82.24 | 82.24 | 82.24 | 82.24 |
| *Relative change in algae (%)* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sand/rubble/sponge cover (%) | 3.26 | 3.22 | 3.01 | 2.81 | 2.61 | 2.42 | 2.23 | 2.04 | 1.86 | 1.68 | 1.51 | 1.34 | 1.17 | 1.01 | 0.86 | 0.71 | 0.56 |
| **Intrinsic ecological drivers** | 2034 [F] | 2035 [F] | 2036 [F] | 2037 [F] | 2038 [F] | 2039 [F] | 2040 [F] | 2041 [F] | 2042 [F] | 2043 [F] | 2044 [F] | 2045 [F] | 2046 [F] | 2047 [F] | 2048 [F] | 2049 [F] | 2050 [F] |
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
| **Fish growth** | | | | | | | | | | | | | | | | | |
| Regrowth herbivory | 46.75 | 46.70 | 46.78 | 46.86 | 46.95 | 47.05 | 47.15 | 47.25 | 47.35 | 47.46 | 47.57 | 47.68 | 47.79 | 47.90 | 48.00 | 48.10 | 48.20 |
| Regrowth predatory | 12.77 | 12.71 | 12.66 | 12.60 | 12.54 | 12.48 | 12.42 | 12.36 | 12.30 | 12.24 | 12.17 | 12.11 | 12.05 | 11.99 | 11.92 | 11.86 | 11.80 |
| Lionfish stock | 5.08 | 5.19 | 5.22 | 5.26 | 5.29 | 5.33 | 5.37 | 5.41 | 5.44 | 5.48 | 5.52 | 5.56 | 5.59 | 5.63 | 5.67 | 5.71 | 5.75 |
| % change fish stock by Lionfish | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |

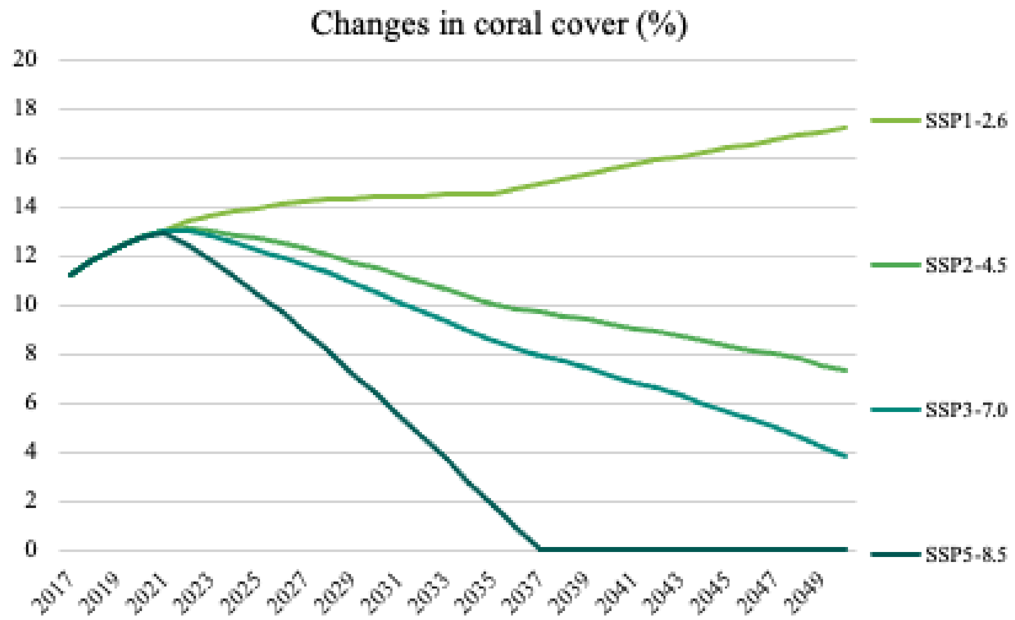


*Figure 15 The development of coral cover between 2017 and 2050 under all climate scenarios*

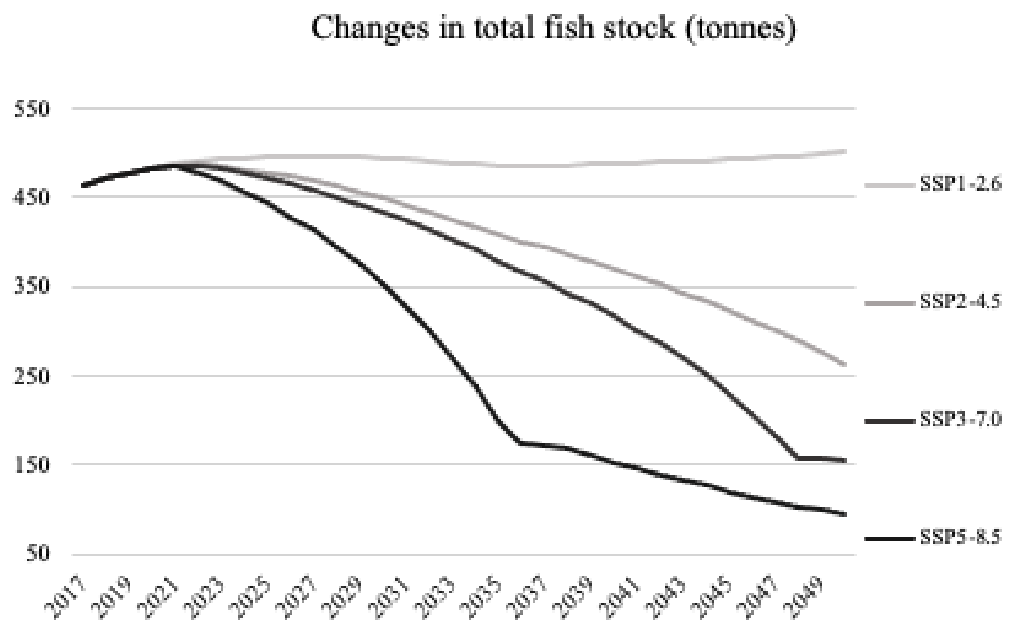


*Figure 16 The development of the total fish stock between 2017 and 2050 under all climate scenarios*

# Annex E List of experts interviewed

| Organisation | Function | Expert | Referred to in |
|---|---|---|---|
| Delphins Beach Resort | General Manager | David Rietveld | 2. Background |
| WWF | Sr. Advisor Oceans<br>Sr. Aquarist | Monique van de Water<br>Sander van Lopink | Annex A.3 |
| CURO/ Wannadive | Representative/Owner | Bart Snelder | 3. Methods |
| BBE | Policy Advisor | Anja Romeijnders | 2. Background |
| STINAPA | Marine-biologist | Roxanne-Liana Francisca | 5. Discussion |
| CBS | Manager of Statistics Office Bonaire | Henk van de Velden | 3. Methods |