IVM Institute for Environmental Studies

The fishery value of coral reefs in Bonaire

Applying various valuation techniques

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Summary

Fishing provides an important source of income and livelihood on the Caribbean Island of Bonaire, also many people fish for recreational purposes. A large part of the catch is composed of reef-dependent species, which rely on the health and productivity of local coral reefs. To assist decision-makers in understanding and managing these fragile ecosystems contributing to Bonairean well being the economic value of reef-dependent fisheries is determined. Furthermore, the spatial distribution of the economic value of the reef fisheries is revealed to help decision makers understand which areas of reef are most economically important from a fisheries perspectives.

By estimating the economic value of the reef fisheries, which consists of both recreational and commercial fishing, the total socio-economic value of reef fishing on Bonaire is estimated. Commercial fishing is valued using the ‘net factor income approach’. The recreational value of the reef fisheries is calculated using both the ‘choice modelling’ and the ‘market valuation’ method. The commercial and recreational values are combined to arrive at a total, annual reef-fisheries value for the Island of Bonaire. This aggregate value is then combined with spatial fisheries production data using ArcGIS to create a fisheries value map of Bonaire.

The reef-related total commercial fisheries are valued at almost $400,000 annually. The recreational fishery value is estimated at an economic value of almost $700,000 per annum. These calculations have been used to create an allocation function, which estimates the spatial distribution of the fisheries value along the coral reefs of Bonaire. This in turn can be used to support long-term decision-making for example regarding specific locations for coastal zone development and its impact on commercial and recreational fisheries.

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1 Introduction

The project “What’s Bonaire Nature Worth?” aims to perform a socio-economic valuation of Bonairean nature. The framework that is used to do so in the entire project is based on the valuation of ecosystem services. Ecosystem services are defined as goods services that human beings derive from ecosystems. The marine ecosystems provide a “provisioning service” where fish are a food source. The purpose of this report is to determine the fisheries value of the marine ecosystems on Bonaire; in other words, the welfare that is created in the fishing industry by local marine ecosystems.

Fishing is an important activity on Bonaire. Although it is in potential conflict with other ecosystem services, such as snorkelling and diving, it is also an important source for income and livelihood for some locals and many people fish for recreational purposes. While the fishing industry is locally focused and export of fish is non-existent, both locals and many tourists eat the locally caught fish. Research from Laclé (2012) indicates that the recreational and subsistence values of fishing are significant. Of the entire local population, 15-20% percent practices either recreational or subsistence fishing. Only 5% of these recreational fishers indicate that there is a financial incentive to fish. Part of the catch contains pelagic species, such as the wahoo (*Acanthocybium solandri),* common dolphin fish (*Coryphaena hippurus)* and several species of tuna. The other part of the catch is composed of reef-related species, which we define as species that are reef dependent for at least one stage in their life-cycle. The value of reef-related catch is related to the health and productivity local coral reefs. This study focuses on the value of local ecosystems, so only the reef-related part of the catch is used for valuations.

The purpose of this chapter is to investigate the socio-economic value of fishing on Bonaire. We estimate the magnitude of the fishery, making a distinction between recreational and commercial fishing. This chapter continues with a brief discussion of methods used to calculate the ecosystem service value of fishing. A few studies from other locations are evaluated and compared with the situation in Bonaire. Then, the chosen methodology is explained after which the results are discussed. The final part of this chapter will be about the spatial allocation of the fishing value.

2 Background and methodology

2.1 Valuing Fisheries as an Ecosystem Service

To use the terminology of the Millennium Ecosystem Assessment (MEA, 2005) fisheries can fall into two different categories of ecosystem services: direct-use and non-use value. When fishing happens in order to provide food, that direct-use is termed a "provisioning" service. Both commercial and subsistence fishing fall into this category. The value of such a service is determined by the quantity of fish and the type of species that are caught, and a market valuation is the most common approach for quantifying it (Hein, 2010, ch. 2).[1]

Recreational fishing is also a direct-use value. However, this value is more difficult to quantify than the commercial fishing value, because it is not directly related to catch quantity or any tradable good. Rather, valuation differs between individuals and dependents on the perceived quality of the experience. Appropriate approaches include cost method and contingent valuation method (CVM). It is not possible for us to use a cost method, in which incurred costs (both opportunity costs and expenses) are used as a measure to determine what people are willing to pay in order to perform the activity, because there is no available data on these costs. Therefore we use CVM to explore fishers' willingness to pay (WTP) for recreational fishing. CVM is appropriate because fishing costs are likely different from the value that people would attribute to the experience of fishing, whereas WTP measures what someone is willing to offer in order to practice the activity.

Van Beukering *et al*. (2011) use contingent valuation to determine the WTP of recreational fishers to avoid a 20% loss in fish catch. From this 20% loss they calculate the total WTP for the entire recreational catch. WRI (2008) uses an opportunity cost approach to calculate the value of recreational fishing. Based on the time invested in recreational fishing and the wages the fishers would earn while working, the authors estimated the value of recreational fishing. However, such information is not available for the recreational fishers on Bonaire. Therefore, we use a choice experiment comparable to the one used by Van Beukering et al. (2011) to determine WTP.

This study also evaluates the non-use value of fishing. According to Dilrosun (2004) and the Beleidsnota Cultuur Bonaire (2010), fishing has a prominent place in Bonairean culture; it contributes to cultural identity. WTP is also the best approach for calculating the cultural value of fishing, since there is no other way to quantify a cultural non-use value (Hein, 2010).

Previous studies valuing fishing on Caribbean islands have divided commercial and recreational fishing. For example, World Resource Institute (WRI), uses such a division when investigating the socio-economic values of coastal ecosystems for several Caribbean islands: Jamaica (Waite *et al.* 2011), Tobago and St. Lucia (Burke *et al.* 2008), Belize (Cooper *et al.* 2009) and the Dominican Republic (Wielgus *et al.* 2010). Van Beukering *et al*. (2011) also use this division for their work on the US Virgin Islands (USVI). They use a net revenue approach, calculating commercial fishing value

[1] Hein (2010) and van Beukering *et al.* (2007) define the value of an ecosystem service as the sum of the consumer surplus (CS) and the producer surplus (PS). This is the standard economic method to calculate the welfare created by a specific market. Producer surplus is defined as the difference between the market price and the price at which suppliers are willing to sell their product. The consumer surplus is defined as the difference between the consumers' willingness to pay for the good and the price the consumers are actually paying.

as the revenue minus the costs that are required to catch the fish, and estimating the costs at around 25% of the fishers' gross income. WRI uses a net revenue approach in St. Lucia and Tobago, also with a cost estimate of 25% (Burke *et al.* 2008), but used gross revenues when calculating fishing value for the other islands (Waite *et al.* 2011; Wielgus *et al.* 2010; Cooper *et al.* 2009)

Because our study focuses on the ecosystem services provided by the local ecosystems on Bonaire, we focus on reef-dependent species. We omit migratory pelagic fish, which are caught on open sea, feed on pelagic prey, and only visit Bonaire during specific seasons. Van Beukering *et al.* (2011), based on previous studies, estimate that 80 percent of the catch in the USVI is reef-dependent species. However, personal observations suggest that this percentage is lower on Bonaire where there is greater dependence on pelagic, migratory fish. WRI used either the type of fishing gear (Burke *et al.* 2008) or data on landings to distinguish between pelagic and reef-related catch (Waite *et al.* 2011; Cooper *et al.* 2009). Fishing on Bonaire is done mostly with hand lines or by trolling, fishers alternate between techniques, and the gear data does not specify frequencies per fisher, so a distinction based available gear data is not possible. Also, while trolling targets pelagic species and hand lines target reef-dependent species, both types of fish can be caught using either technique. Therefore another distinction is necessary for this study. We use a distinction based on the target species in each season, which is explained in more detail in Section 2.3.

2.2 Data

This study uses data from Laclé (2012) to calculate values for subsistence and recreational fishing. These values are combined because the distinction between subsistence and recreational fishing is vague. A more detailed composition of the fishing value would enable us to determine the effects on welfare distribution that certain policy measures would have, but the available data is insufficient for such a fine-grained analysis.

Laclé (2012) conducted a household survey, randomly selecting households from each neighbourhood to obtain a representative sample of the Bonairean population. This survey was administered to 400 households, of which 385 respondents were considered reliable enough to use in the analysis. It included a choice experiment, which elicited the willingness to pay (WTP) for an increase in fish catch and the WTP for an avoidance of a decrease in catch. This per person WTP can be used to calculate the total WTP for recreational and subsistence fishing.

We use data from Johnson (2011) to calculate the value of commercial fishing. Johnson (2011) extensively interviewed fishers and people working in the diving industry to gain information on landings, earnings, fishing gear, sustainability, trends, time preferences, etc. She interviewed 51 fishers from Bonaire, who are estimated to represent 65% of the island's full and part-time fishers. Not all of these respondents were used for the analysis, because the necessary income questions were not answered. The dataset contains information about incomes, catches, and frequency of fishing trips, which makes it possible to calculate the fishing income by multiplying the quantity of fish caught by fish prices. The dataset also contains the reported average income per week, which enables us to cross-check the response of each fisher for consistency. Local experts, including the marine park manager and a representative of the Ministry of Economic Affairs) (e.g. the ministry concerned with fisheries), and an additional 7 local fishers were also interviewed to check for consistency and provide some extra information on the operational costs of fishing.

We endeavoured to minimize overlap between these two datasets. It is possible that Laclé's study of recreational/subsistence fishing included some of the same interviewees as Johnson's study that was focused on professional fishers. Based on the data, the best way to separate these data sets is based on the average number of fishing days per week. Every fisher who fishes 2 days or more per week is dropped from the recreational survey. Every fisher that fishes less than 2 days per week is dropped from the commercial data. As visible in Figure 2.1 this leads to the smallest possible number of dropped respondents. 35 commercial fishers remain in the sample and 115 recreational fishers. While this method may not completely reflect the distinction between commercial, recreational and subsistence fishers, there is no variable that can occur in both datasets that can be used for separation. However, since 7% of the remaining recreational fishers fishes to sell the catch, and 70% of the catch in the final commercial dataset is sold, the separation seems successful. It is also important to note that the line between commercial and recreational fishing on Bonaire is blurry: almost all fishers consume at least part of their own catch, which makes them partly subsistence fishers; and most commercial fishers also fish for enjoyment, while some recreational fishermen also sell part of their catch.

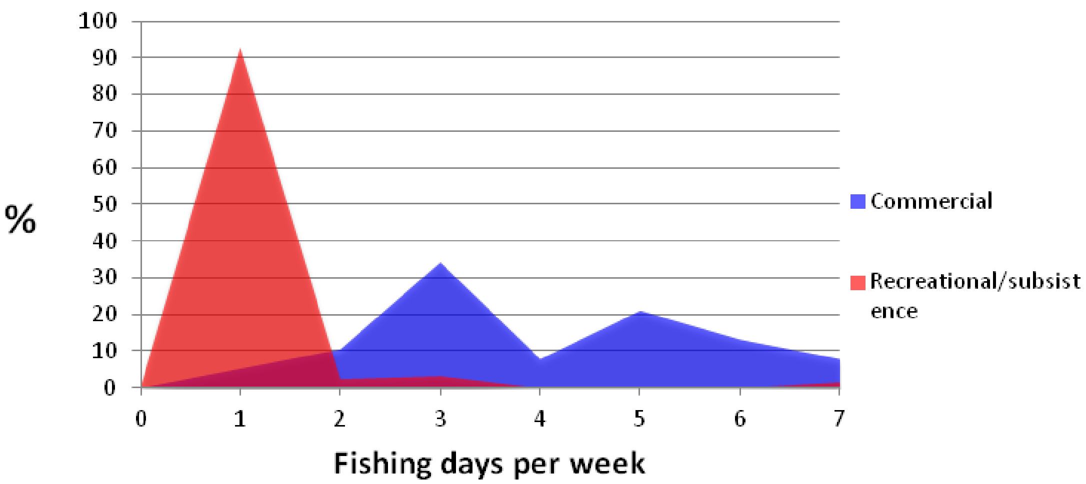

Figure 2.1 Distribution of average fishing days per week for data from Johnson (2011) and Laclé (2012).

2.3 Methodology

The fishery values, commercial as well as recreational, are estimated by combining data from two studies on the fisheries of Bonaire (see Figure 2.2). Jonhson (2011) interviewed 65% of active fishers on Bonaire and Laclé *et al.* (2012) surveyed 400 households asking questions on recreational fisheries. During these interviews fishermen with subsistence motives are found in both categories. However, the importance of the incentive varies between fishermen. To calculate the value of commercial reef-fishing in Bonaire, the net factor income approach is used, in which the capital costs are subtracted from the revenue of commercial fishing. The recreational value of reef-fishing is calculated based on the Willingness to Pay (WTP) of fishermen to prevent decreases in fish catch. A separate value is calculated for the commercial value of the catch based on the market-price technique.

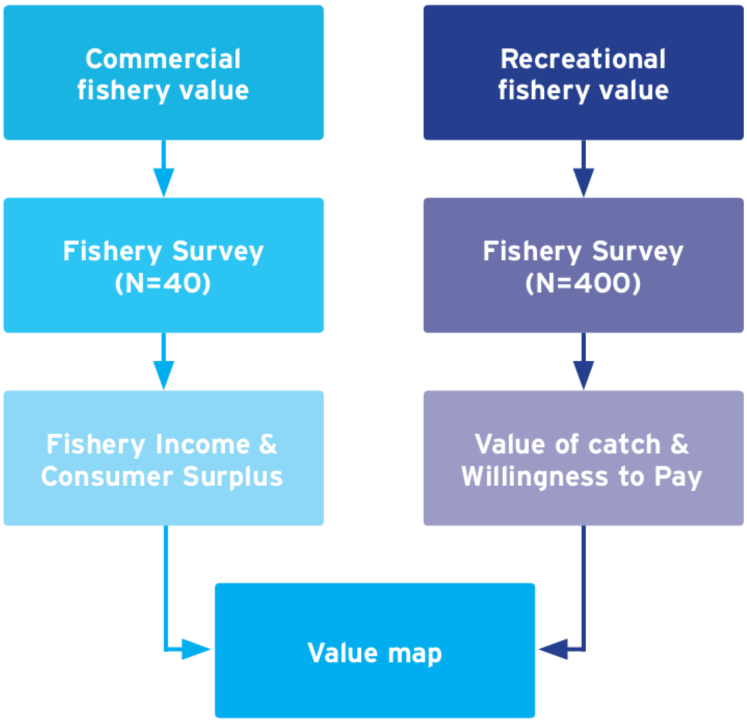

Figure 2.2 Methodological framework for the calculation of the total fishing value and creation of a value map. PS = producer surplus; CS = consumer surplus; WTP = willingness to pay.

2.3.1 Commercial fisheries

Commercial fisheries consist by our definition of fishers who have a financial incentive to fish, who sell at least a part of their catch and fish for 2 or more days a week. As determined by our literature review, the best way to capture the value of the eco-system service exploited by commercial fishers is to look at consumer and producer surplus created in the fish market. The added value of commercial fisheries, which is defined as the difference between costs of inputs in the fishing sector and the total revenue, reflects the producer surplus. This method is also called the net income benefit method. So, in order to calculate the commercial fishing value, the revenue and the costs of fishing are required. The idea is that every input in the production function is valued for its benefit. Since the producer surplus is the benefit that is not attributed to anything, it can be attributed to the ecosystem.

Based on data from Johnson (2011) we can estimate fishing revenues. However, information on fishers' expenses is not available in that dataset, so 7 interviews were conducted with local fishers to obtain the information necessary to estimate the costs of fishing. There are two primary types of fishing vessels on Bonaire: boats smaller than 8 meter with an outboard gasoline engine, and boats longer than 8 meter with an inboard diesel engine. Fishers with both types were interviewed to investigate the operational costs.

To get the most reliable estimate of the commercial fishing PS, we calculated annual revenues with four different methods, the first three of which use data from Johnson (2011), and then took the average. First, we simply used fishers' reported average weekly fishing income. Second, we used on the number of reported good, bad, and normal fishing weeks, and reported estimated income during each type of week. Third, we used the average number of kilograms of fish sold multiplied by the average sale price. And fourth we used data from interviews with fishery experts and local fishers who estimated income per fishing vessel, which we then multiplied by the number of boats.

Again, our particular interest here is reef-related fisheries. Unfortunately, the Bonairean fishing industry does not keep track of its landings, nor do fish markets keep track of their sales in terms of species. However, expert interviews indicated that the pelagic species were only targeted during specific seasons. The so called “dorado season” and “wahoo season”, named after the target species, last for a little less than four months a year. Outside those pelagic seasons, mainly reef-related species are targeted. We also consider average size of the catch during different seasons, which enables a division between reef and pelagic related fisheries.

The collection and analysis of the aforementioned information provides us with the PS of the commercial fisheries. However, calculating the total welfare created by the ecosystem service requires the consumer surplus as well. Laclé’s choice experiment (2012), investigating the average WTP of the Bonairean population for a fee that maintains the current fish catch, enables this calculation. This WTP provides a good estimate of the consumer surplus: the difference between the market price and the highest price people are willing to pay; the additional willingness to pay for a good.

2.3.2 Recreational fishing

The value of recreational fishing is difficult to determine as it is based on enjoyment of the activity, an aspect that is hard to quantify. Subsistence fishing value is also difficult to quantify because it is done for nutritional purposes (i.e., to obtain food), not financial, and people are not paying for the fish they catch. There are quantifiable expenses involved in both, but the most important cost is the opportunity cost of the time that is invested in fishing. Unfortunately, data on time spent on these types of fishing is not available.

Based on the data collected by Laclé, it is possible to determine WTP related to changes in quantity of fish caught by recreational and subsistence fishing. However, WTP is related to the ability to pay. Since subsistence fishing is mostly done by people with a low ability to pay, the calculated WTP likely underestimates the value of recreational/subsistence fishing. The market value of the catch provides a more suitable estimate of the value of fishing to subsistence fishers, as it is an estimate for the addition to their income that is created by subsistence fishing. Recreational fishers, on the other hand, depend less on fishing for their livelihood; rather their main incentive to go fishing is enjoyment, so the market value of their catch is of minor importance.

Here we calculate both WTP and the market value of the catch. To determine the WTP, we use Laclé’s choice experiment (2012), which consisted of six rounds of questions and three different proposed scenarios. The scenarios reflected different values of 6 attributes: reef quality, terrestrial quality, quantity of fish catch, the freedom of roaming goats, public access to the beach, and an environmental fee. In each round, the respondent had to choose between three alternatives, which were tradeoffs between the different attributes. If all attributes were to be equal for a respondent, there would be no best alternative, and a choice would be made on a random basis. However, since most people have a preference for specific attributes in the scenarios, the choices of the respondents reveal these preferences. If a respondent values attribute A more highly than attribute B, the state of attribute A would exert greater influence the decision of the respondent than the state of attribute B. The choices of the respondents can be analyzed using a Multinomial Logit Model (Laclé, 2012), which makes it possible to relate all attributes to the environmental fee (one of the attributes in the experiment). Thereby, a WTP can be constructed for each specific attribute.

Differences between the two valuation approaches can be informative. If the WTP approach produces a higher value estimate than the market-based approach, this indicates that the recreational aspect is very important, since buying the fish on the market would be cheaper than going to catch it. If the market value approach produces a higher estimate that indicates that fish as a cheap food source (subsistence fishing) is probably a very important reason to go fishing. Furthermore, the combined WTP for subsistence and recreational fishing might still be lower than the market value of the catch. This might be caused by an ability to pay that is too low (Arrow *et al.* 1993). However, only 2 out of the 126 recreational fishers in the dataset responded that the fees in the choice experiment were not affordable, so that seems unlikely.

Determining the part of the fisheries that is reef related is easier for recreational fishing, using Laclé's (2012) data on catch composition. Charter fishing boats are not included in the valuations. While tourists pay high amounts of money in order to go on recreational fishing trips the sector is economically significant, but trips are primarily concerned with catching large pelagic predators, especially species of marlin, so the values are not attributable to the coral reefs.

In line with the other values that are calculated, we calculate an annual value, with which it might be possible to calculate discounted values for additional future years. However, one must consider that these values are often based on current situations. Ecosystem services tend to vary in the quantities and qualities they provide, according to different scenarios.

2.3.3 Value mapping

Aggregating the final values provides us with a total value for fishing on Bonaire. However, we seek further to examine the spatial allocation of this fishing value. Van Beek (2011) provides us with a study that identifies the abundance of sea life on the reefs of Bonaire. This provides us with a spatial division of reef production, but only for half of the island and the other part of the island is also an important area. Both commercial and recreational fishers make use of the western/leeward reefs. Some larger commercial vessels fish on the eastern/windward reefs, but smaller boats are often unable to access those areas due to large waves and swell. However, there is substantial recreational shore fishing on some areas of the eastern coast.

To examine the spatial distribution of reef-related fishing effort, both commercial and recreational fishers were asked in the additional interviews to indicate their favourite fishing grounds. Unfortunately, it was not possible to obtain spatial data for the entire reef extent (only the west-coast reef). Luckily, the reefs around Bonaire are comparable. Although the reefs in the west (leeward) have steeper drop-offs, the eastern (windward) reefs have about the same extent. On average, the reefs seem to extend approximately 150 meters from the coastline (STINAPA, 2012); therefore we use a buffer zone of 150m around the island in the ArcGIS software to represent Bonaire's reef extent. The ArcGIS data used for the spatial allocation comes from Buro Vijn and was used for the spatial development plans on Bonaire.

Using this data we created a raster data layer for both recreational and commercial fisheries. Adding the values of both raster layers with an overlay function creates a final fisheries value map, where both recreational and commercial fishing are summed up in each overlaying raster.

3 Results

These two values on commercial and recreational provide informative comparisons. Once the two methods for both value categories are reconciled, then the final recreation and commercial fisheries value are combined to calculate a total annual reef-fisheries value. This number is then combined with spatial, fisheries production data to create a fisheries value map (see Chapter 4).

3.1 Commercial fishing

This section explains the calculations and results of the different methods that are used to calculate the fishing income. These values are then combined into an average fishing income per fisher. The number of commercial fishers is estimated, with which a value for the total fishing industry is calculated. Next, the importance of reef dependent species is estimated and the operating costs are calculated in order to estimate the total value of reef-dependent commercial fishing.

In Johnson's data (2011), fishers reported their average weekly income and the number of weeks per year they fished. Based on those data, we calculate an average annual income of 24,122 Antillean guilders (ANG, see Table 3.1). Based on the number of good, bad and average fishing weeks that fishers report, with the respective incomes in these types of weeks, calculated average yearly income comes to 33,656 ANG. Additionally, we calculate annual income by multiplying the average catch in kilograms with the reported prices per kilogram, resulting in an estimate of 35,511 ANG.

Table 3.1 Average annual revenue per fisher in Antillean guilders (ANG) according to the data collected by Johnson (2011).

Average annual income for commercial fishermen		
Reported*	ANG	24,122
Based on good and bad fishing weeks**	ANG	33,656
Based on reported catch sold and prices***	ANG	35,511

* The average annual fishing income of all respondents.
** Number of good fishing weeks x earnings during a good fishing week + number of bad fishing weeks x earnings in a bad fishing week + number of average fishing weeks x earnings in average fishing weeks.
*** Sold catch in KG x Price in ANG.

Since none of the fishers (with one exception we know of) keep track of their catch, precise determination of annual incomes is difficult. Most of the fishers seem to live from day to day and income fluctuates a lot from season to season. We found it prudent to use average of the three income estimates in Table 3.1, in attempt to minimize the impact of respondent errors or bias.

Johnson (2011) interviewed approximately 65% of the fishers on Bonaire. If we assume that our commercial fishers definition applies to the same percentage of fishers in the population as in the sample, a total of 54 fishers[2] are active in the commercial sector. Based on the additional interviews with local fishers and other fisheries experts, and counting the number of fishing vessels on the island, we come to a very similar conclusion. Table 3.2 shows the calculations based on the expert interviews Schep

[2] 35 fishers in the sample/0,65=54 commercial fishers.

conducted on the island, which add up to 49 fishers. For the further calculations we use Johnson's estimate of 54 fishers because her more extensive interviews imply that may be a more reliable number.

Table 3.2 Estimation of the number of commercial fishers on Bonaire. Boat numbers are averages based on expert interviews. Average number of fishers per boat is based on our observations and expert interviews. The number of fishers using big and small boats is the product of the first two columns, and the grand total is the sum of those.

	Fishermen per. boat	Number of boats	Number of fishermen
Big boats	2	11.5	23
Small boats	1.5	17.5	26.25
Total	N.A.	29	49.25

Using the annual income estimates from Table 3.1 and the number of fishers from Table 3.2, we calculate the total annual revenue in Table 3.3. Average annual revenue Table 3.3 shows the average yearly revenue per fisher based on the three calculations of yearly income. The average income of 30,435 ANG leads to a total revenue of 1,643,539 ANG. Based on the exchange rate at the time of the ANG to dollar transition, which was 1.79 ANG for 1 USD (DNB 2011), the annual revenue becomes $918,178. Based on the expert interviews conducted it is also possible to calculate the annual revenues for the commercial fisheries, as shown in Table 3.4. Based on the average catch per season per boat type the total revenue is somewhat lower: $744,138.

Table 3.3 The average of the calculated incomes in Table 3.1 multiplied by the number of commercial fishers.

With 95% confidence interval	From	To	Average
Average income (ANG)	18,555	42,316	30,435
Total income (ANG)	1,002,002	2,285,075	1,643,539
Total income (USD)	**559,778**	**1,276,78**	**918,178**

Note: Calculations based on 54 fishermen and an exchange rate of 1.79 ANG = 1 USD.

Table 3.4 Total revenues estimated from information collected in expert interviews

	Total Catch $	Reef-related catch $	% reef-related catch
Small Boats	$200,900	$121,597	60.5%
Big Boats	$543,239	$239,025	44.0%
Commercial fisheries	**$744,139**	**$360,622**	**48.5%**

Note: Revenue generated by catch of reef-related fish, calculated using average earnings per season. It is assumed that only pelagic fish are caught during the pelagic seasons and reef fish during the low season. The part of the revenue that is earned in the reef season, the reef related catch is estimated.

From the expert interviews it is also possible to determine seasonality catch. For simplicity, we assume that the catch consists exclusively of reef fish in the "low season" and exclusively of pelagic fish in the "high season." The total reef-related catch is the amount earned in the reef season divided by the amount earned annually, which is 48.5% of the total catch. Using the total annual revenue based on Johnson's data (2011), and the 48.5% based on expert interviews, we estimate the value of the reef related portion of the total catch to be a $445,317 as displayed in Table 3.6.

The costs associated with fishing are the final component required to calculate the net income value of coral reefs for the fisheries sector. We conducted additional interviews with local fishers provided insight in the operational costs of a fisher, because the cost data collected by Johnson is not specific enough for these calculations. Average costs for small boats and big boats are calculated separately for the high and low seasons. Fixed costs, which include maintenance, fishing gear costs and depreciations on investments are divided according to the percentage of the total revenue that is made in each season (Table 3.4, last column). The fuel costs are divided according to the amount of fuel that is used in each season. See Table 3.5 for the calculation of the total fishing costs.[3] Since the data is from 2010 an inflation rate of 1.18 is used to estimate diesel costs (Curoil, 2012, Wikipedia 2012). This results in a total cost of $192,877 for the reef related fisheries, which is 62.3% of the total costs of fishing overall.

Table 3.5 Calculation of total fishing costs per year. First two rows represent the average costs per boat. The final row is the estimation of total fishing costs for the entire commercial fishing industry.

Boat type	Item	Pelagic Season	Reef Season
Big boat	Total costs per boat	$6,678.	$7,885
	% of total costs	45.9%	54.1%
Small boat	Total costs per boat	$2,272	$5,839
	% of total costs	28.0%	72.0%
All boats	Total costs	$116,575	$192,878
	% of total costs	37.7%	62.3%

Note: For the aggregation of the average costs an estimation of 11.5 big boats and 17.5 small boats is used.

Using this cost estimate we calculate the net commercial fishing value, as shown in Table 3.6. First, the reef-related portion of the total revenue is calculated. Second, the costs attributed to the reef-related portion of the catch are subtracted from the reef-related revenue in order to determine the total net value of the coral reefs as eco-system service providers. This brings us to the final value attributable to the eco-system service of commercial reef fisheries, which is a little over $250,000 annually. This is the producer surplus. The consumer surplus will be calculated after the section about recreational fisheries, since some of those results are required for the calculation.

3 More information on the calculation of fishing costs can be found in the appendix.

Table 3.6 Calculation of the value of the producer surplus of the commercial fisheries.

	Value
Total annual revenue	$918,178
% of fishing reef related	48.5%
Reef-related annual revenue	$445,317
Reef-related annual costs	$192,878
Net annual commercial reef fishing value (producer surplus)	**$252,439**

Note: Total revenue – pelagic oriented revenue – costs that are incurred by reef fishing = Commercial fishing value.

3.2 Recreational fisheries

The second step towards the valuation of the ecosystem services that are provided by the coral reefs around Bonaire is the valuation of the recreational fisheries. This section starts with the calculation of the market value of the catch, as an indicator of the importance of recreational fishing as a provisioning service. Then we provide an explanation of the results from the choice experiment.

The calculation of the market value of the catch is very similar to the calculations of the commercial fishing value. However, as indicated by the data of Laclé (2011) 80% of recreational fishing is done from land and 20% from small (mostly rowing) boats. So, the costs of fishing are assumed to be negligible. This makes the calculation very straightforward:

So, the catch in kilogram is multiplied by the market price for fish, which gives the total market value of both pelagic and reef-related fish. To calculate the reef-related value, this total market value is multiplied by the percentage of kilograms that are considered to be reef-related, which gives the market value of the reef related fisheries. Both the catch and the percentage of reef fish can be calculated based on Laclés (2012) household survey data. Johnson's (2011) data provides an average market price of 6.95 $/Kg [4]. The average amount of fish catch is per trip is estimated at 7.7 kilograms. However, the distribution of this fish catch is skewed to the right, due to some dubious exceptional outliers – two the respondents reported average catches of 90 and 100 kilogram per trip. Given that the commercial fishers sell on average 18 kg per day, these values are considered unreliable. Therefore, an estimation built on the median catch per trip seems more appropriate in this case: 2 kg per fishing trip. The average number of fishing trips per month is 1.8. Multiplying the latter two with each other and by the number of months in a year, gives the yearly catch in kilogram per fisher. Based on the market price of a kilogram of fish, this is worth a $300 (see Table 3.7).

[4] The dollar amount is based on the same exchange rate as in the commercial fisheries section: 1.75 ANG/USD.

Table 3.7 Variables used to calculate the market value of recreational catch. Both median and average kilograms per trip are given, but only the median is used to calculate the annual catch.

Fishing trips per month	Catch per trip	Price in	Yearly catch per fisherman	Market value of yearly catch
1.8	2 (median)	6.95 $/Kg	43.2 Kg	$300

The second method to determine the value of the recreational fisheries is by looking at WTP. WTP is estimated using the choice experiment results provided by Laclé *et al.* (2012) (see Table 3.8). However, results are calculated separately for recreational fishers in this study. The attribute of interest is fish catch. The WTP data was collected for "no change in fish catch" and "fish catch is 20% higher" and represents the WTP to go from a situation of a 20% decrease to respectively the current situation (no change) or a better situation (20% increase). The WTP is compared to a situation where the fish catch is 20% lower. As expected, the WTP for an increase in fish catch is significantly higher than it is for an unchanged catch quantity. Strangely though, there is no significant difference between the WTP of recreational fishers and the average WTP of the total Bonairean population for avoidance of a 20% decrease in fish catch (both $6.34, for the "no change in fish catch" attribute).

This is surprising for two reasons. One, since recreational fishers are the ones that catch the fish, it is expected that they are more concerned with the quality of their fishing experience (including the quantity and size of fish they catch) than they are with the market value of that fish. A possible explanation is that recreational fishers have a lower ability to pay, but we don't have the data to determine whether that is the case, nor is it clear why that would be the case. Second, WTP for an increase in catch is much higher. So a decrease of catch is relatively less important to the fishers than an increase. In other words, fishers are willing to pay more to catch a fish, if the fish are more abundant. This is not in line with the general economic theory about scarcity, which states that average values go up if something is less abundant.

The fish catch considered to this point consists of both pelagic and reef dependent species. Luckily, Laclé (2012) inquired about the composition of the recreational fish catch. Using a card that displays all the commonly caught fish on Bonaire, the interviewers asked which fish were caught and in what quantities. Based on the responses in that household survey, the author states that only 10% of the recreational catch is pelagic. The rest of the catch (90%) is dependent on the reefs around Bonaire.

The final variable that is required to calculate the value of recreational fishing is the number of recreational fishers. The total population of Bonaire was estimated at 16,541 in 2012. Based on the household survey, between 15.7% and 23.8% of the population practices recreational fishing. That leads to between 2,488 and 3,772 recreational fishers. The estimates are derived from two different questions in the survey. "How many people practice fishing in your household?" and "Do you practice recreational fishing?"

Table 3.8 All attributes of the choice experiment and the WTP for each attribute.

	Coefficient	SE	P	Average WTP of Bonairean population($)	WTP recreational Fishers ($)
Alternative specific constant	0.840	0.135	0.000	25.95	25.95
Reef quality medium	0.530	0.071	0.000	16.38	16.38
Reef quality high	0.707	0.070	0.000	21.85	21.85
Terrestrial quality medium	0.183	0.071	0.009	5.67	5.67
Terrestrial quality high	0.295	0.069	0.000	9.11	9.11
Fish catch no change	0.205	0.079	0.010	6.34	6.34
Fish catch 20% higher	0.420	0.078	0.000	12.99	25.67*
No grazing	-0.492	0.049	0.000	-15.19	-15.19
Beach access 10% lower	0.267	0.076	0.001	8.26	8.26
Beach access no change	0.313	0.075	0.000	9.68	9.68
Fee	-0.032	0.004	0.000		
Rec. Fish * Fish catch no change	-0.027	0.186	0.886		
Rec. Fish * Fish catch 20% higher	0.411	0.18285	0.0248		
N	2232				
R2 Pseudo	0.0744				

Note: The last column represents the WTP of recreational fishers, and the second last column the WTP of the whole Bonairean population. Every WTP presented here is significantly different from 0. Difference in WTP between recreational fishers and the general population is only significant for the 20% increase in fish catch, as denoted with "*". The alternative specific constant (ASC) represents the WTP to avoid the "no management" scenario that is not explained by the attributes. So a positive ASC can be interpreted as the demand for additional environmental management.

Table 3.9 shows WTP and market value of the recreational fish catch for the entire recreational fishing population. Interviews with local experts indicated that the lower estimates were probably much more reliable. So, to be conservative, the lower estimations of $79,000 for the WTP value and the $750,000 market value are considered to be the most reliable estimates for the total economic value of fisheries. This difference can again be explained by a low ability to pay of recreational fishers, but that is not very likely, since only a few of the respondents reported that the fees in the choice experiment were not affordable. It is also possible that the beneficiaries of the catch of recreational fishing extend beyond the fishers themselves to their family and friends.

Table 3.9 Final calculation of the total WTP and total market value of the catch of recreational fishing on Bonaire.

	WTP	Market value
Average value of the catch	$31.70	$300
Recreational fishers population (% of Bonairean population)		
Low estimate	15.70%	
High estimate	23.80%	
Aggregate reef-related value		
Based on 15.7%	$70,991	$672,377
Based on 23.8%	$107,617	$1,019,272

3.3 Consumer surplus of the commercial fisheries

The WTP of the entire population for the total fish catch (both commercial and recreational) is $507,000. This can be considered the overall WTP to maintain the current situation.[5] Commercial fishing is responsible for 55% of Bonaire's entire annual catch, of which 48.5% is reef-related. So a 27% of the entire catch is reef-related commercial catch. The WTP of the population for a fee to maintain the commercial reef-related fish catch would therefore amount to $135,250, if recreational and commercial fishing are given equal weight. This is the amount of money that people are willing to pay for the catch, but do not actually pay: the consumer surplus. Total welfare created by the commercial fisheries, that is, the total fishing value, is the sum of the producer and consumer surplus, as shown in Table 3.10.

Table 3.10 Calculation of the fishing value by the sum of producer and consumer surplus.

Value component	Amount
Producer surplus	$252,439
Consumer surplus	$135,250
Total commercial fishing value	**$387,689**

[5] Calculation done in the same way as for the total WTP of recreational fishers.

4 Value maps

4.1 Recreational/subsistence fisheries

In order to allocate the total recreational fishing value spatially, it is necessary to determine an allocation function that can be used to divide the total value between different parts of the reef. According to WRI (2008), this can be calculated based on reef production: the higher the reef production, the higher the value allocated to the reef. Unfortunately, spatial information about the state of the reef is needed to determine reef production is only available for the leeward reefs, which makes this approach impossible.

Instead we use a spatial allocation based on the area where the fish are caught. Depending on the species and location, reef fish might be forming more open or more closed populations. However, the current academic perspective seems to be shifting towards the idea that reef fish populations are much more closed than previously thought, although there is limited empirical evidence to support this (Mora and Sale, 2002). For our calculations, we therefore assume, that fishers fish at the parts of the reef where fish are abundant and that those parts of the reef are important for the fish production. However, if the fish populations are relatively open, this allocation method might prove to be a poor estimate. Ideally more research would be available for the true value allocation based on the production capacity of the reefs.

Table 4.1 shows the calculations of the dollar per square meter value for recreational fisheries for each part of the reef. The allocation for the recreational fisheries is straightforward. Around the location of the activity, a buffer of 2km was used to determine the reef area attributable to the value. The function “extract by mask” in ArcGIS was then used to extract the reef area attributable to the function. So, the reef area within 2km of the recreational fishing spot is the area used for the calculations. Figure 4.1 shows the result of the allocation according to the market value of the recreational fisheries.

Table 4.1 Calculations of the dollar per square meter per year values for each area that is important for recreational fisheries. When respondents did not specify an areas that is listed as "unspecified reef locations"

Name Loc:	Percentage of fishing	Market value	WTP	Latitude	Longitude
Playa Palu di Mangel	4.71%	$31,185	$3,341	12.134358	-68.280715
Sorobon Beach	22.35%	$148,133	$15,868	12.092703	-68.235054
Bachelor's Beach	1.18%	$7,796	$835	12.126217	-68.287883
Playa Sarna/Playa Pàbou	2.35%	$15,593	$1,670	12.162046	-68.284946
Playa Lechi	2.35%	$15,593	$1,670	12.166013	-68.287228
Pink Beach	7.06%	$46,779	$5,011	12.064333	-68.283267
Boulevard	1.18%	$7,797	$835	12.154486	-68.279170
No Name Beach	2.35%	$15,593	$1,670	12.168717	-68.305150
Tolo	1.18%	$7,797	$835	12.214883	-68.337900
Playa Frans	8.24%	$54,575	$5,846	12.246139	-68.414086
Cai	8.24%	$54,575	$5,846	12.103314	-68.222582
Karpata	3.53%	$23,389	$2,506	12.218967	-68.352383
Playa Funchi	8.24%	$54,575	$5,846	12.282367	-68.414900
lagoen	2.35%	$15,593	$1,670	12.182289	-68.211622
Salt company	5.88%	$38,982	$4,176	12.079433	-68.282200
Playa Benge	3.53%	$23,389	$2,506	12.290024	-68.414611
Reef scientifico	1.18%	$7,796	$835	12.168645	-68.288011
BOPEC	1.18%	$7,796	$835	12.218562	-68.383541
Unspecified reef location	12.94%	$85,761	$9,187		
Total	**100.00%**	**$662,702**	**$70,991**		

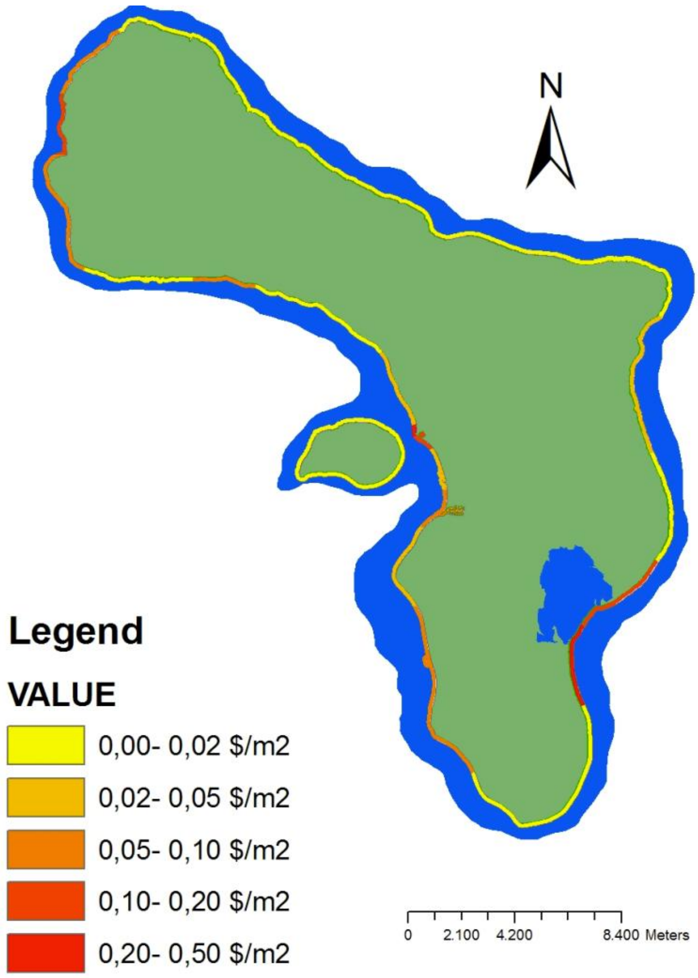

Figure 4.1 Spatial distribution of recreational fishing value.

4.2 Commercial fisheries

The allocation for commercial fisheries is based on interviews with local fishers and other fisheries experts. In these interviews it became clear that basically all large boats fish on the eastern reefs, while the smaller boats fish mainly on the western side and around Klein Bonaire. Based on the interviews we are able to divide the value of commercial fishing between the large and small boats. We know what large boats catch, what small boats catch and how many small and big boats there are, which makes the division possible. By dividing the fishing value that is attributed to a specific part of the reef by the area of that part of the reef, a dollar per square meter value is calculated (Table 4.2 and Figure 4.3)

Table 4.2 Spatial distribution of the commercial fishing value.

	Klein Bonaire & West-Coast	East-Coast	Totals
% of total reef catch	33.7%	66.3%	100.0%
Part of commercial fishing value	$130,723	$256,965	$387,689
Area in square meter	9,262,500	7,472,868	16,735,368
$ per square meter	$0.0141	$0.0344	

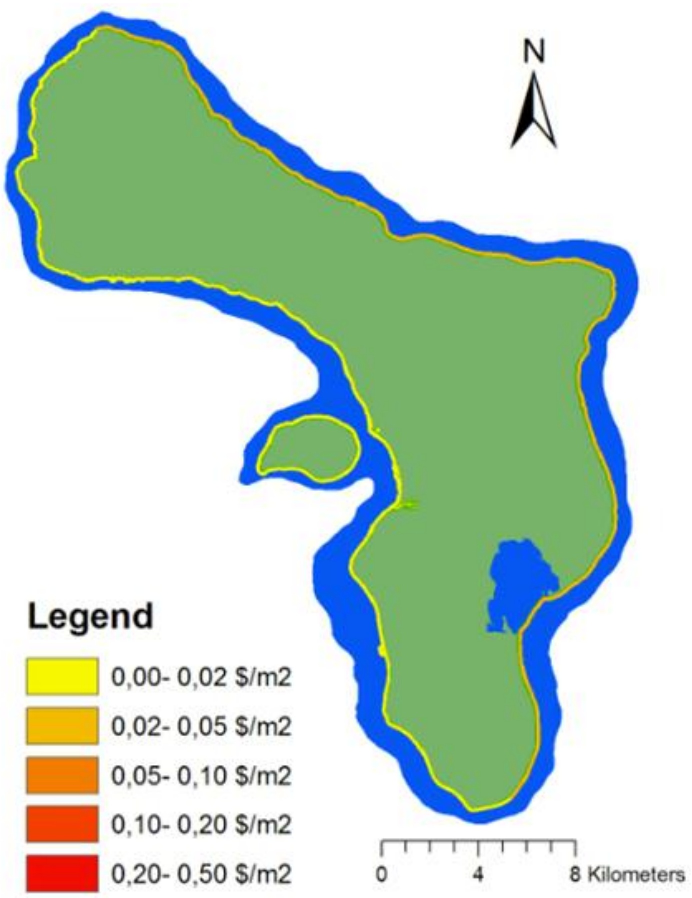

Figure 4.2 Spatial allocation of the commercial fishing values.

4.3 Total fishery value allocation

By overlaying the recreational and commercial fishing layers the final fishing layer is calculated. Rasters of both layers were snapped to the same raster layer (each cell of a layer fits exactly the overlaying cell of the other layer). This enables to sum the values of both raster layers to calculate the final fishing value per square meter, as displayed in Figure 4.3. There appears to be a high-value hotspot area around Sorobon and Lac Cai, and to a lesser degree around salt pier in the Southwest. Kralendijk is well-used area, as expected due to the higher population density of that urban area. The high-value hotspot in the Northwest is less straightforward, as that area is far away from residential areas and deep into the national park Washington-Slagbaai. Since the survey only investigated the favourite locations for fishing, but not the frequency, it is possible that many recreational fishers go there, but not very often. However, that cannot be determined from our data. Notably, the high-value hotspots are mainly determined by the concentration of recreational and subsistence fishing, not driven by commercial fishing.

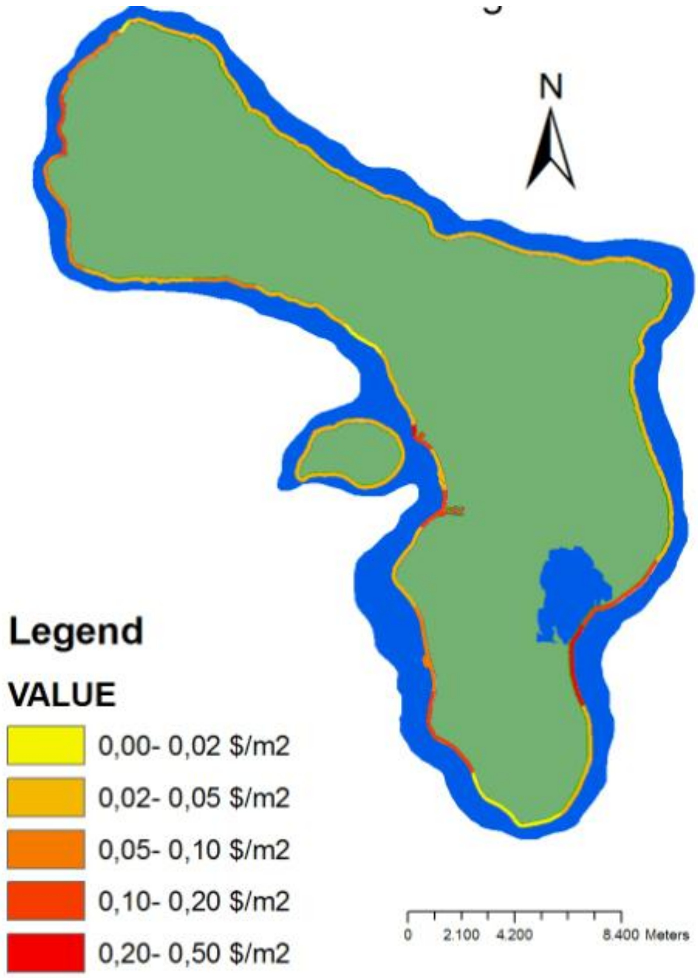

Figure 4.3 Spatial allocation of the sum of the commercial and recreational layers.

5 Conclusion

In this study, we estimate the values of commercial and recreational fisheries on Bonaire. Since it is difficult to determine the value of subsistence fishing, the market value of recreational fishing is used for the final calculations and the value map. As the WTP was much lower than the market value of the catch, the importance of fishing as an open access food source seems to be significant as does the benefit of fishing to Bonaireans who do not practice recreational fishing. In local interviews it became clear that fishing was used as a way to reduce food expenses. Of the recreational fishers, 93% chose “I enjoy fishing” as an important motivation to go fishing and 88% chose food. Both incentives can simultaneously be important for the same fishers, making it impossible to neatly and distinctly characterize their motivations. The commercial fisheries are valued by estimating the size of consumer and producer surpluses in order to calculate the total economic welfare that is created.

It is important to keep in mind that the calculated values are annual values, and that these values are determined by the state of the ecosystem, which is dynamic. Coral reefs are very sensitive to human influences and threatened by climate change (Hoegh-Guldberg *et al.* 2007; Sandin *et al.* 2008), thus these values are liable to change. Based on two questions answered by respondents in the commercial fisheries dataset (Johnson 2011), it is possible to get an idea of the extent to which fish stocks around Bonaire are overexploited: What was your best year in terms of fishing ever? What was your worst year of fishing ever? Figure 5.1 shows the results based on age categories. The average worst year reported was 2009, while the average best year was 1998. Furthermore, the best years are on average longer ago for older fishers. This data is a strong indication that catches, and implicitly fish stocks, are declining or a long time already, with clear negative ramification on the commercial, recreational, and subsistence values of fishing.

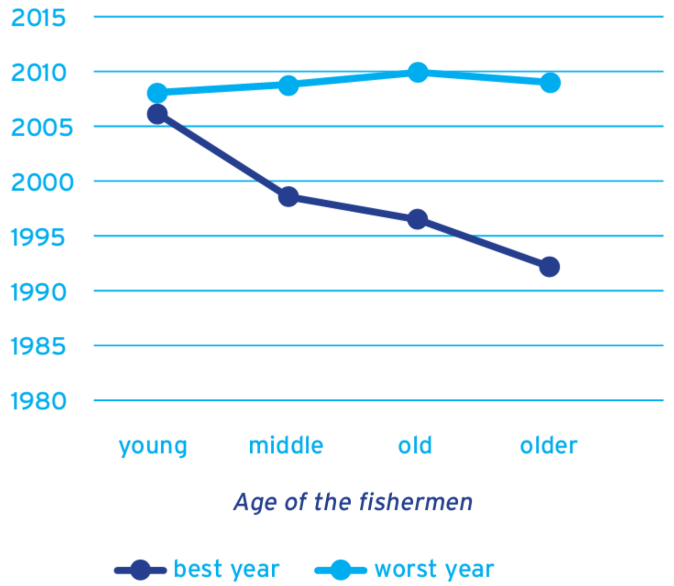

Figure 5.1 Average best vs. average worst year per age category. The best years are below the worst years for every age category. Data was collected in 2010-2011, thus worst years are generally very close to the interview year, while the best years are further in the past. Data from Johnson (2011).

The lack of data on catch composition was a challenge for this analysis. The division between reef and pelagic fisheries is a rough estimate, and the impact of the fisheries on the local ecosystem is very hard to determine based on interviews with local fishers. More detailed data is required to determine the state of fish stocks, to evaluate the sustainability of the fisheries, and to produce a more accurate calculation of the socio-economic value of fishing. Some of the fishers stated in interviews that their practices are sustainable because they mainly fish with hand or draglines and do not anchor on the reefs. While this might be the case, there is no empirical evidence for this assertion of sustainability. To determine the sustainability would require a recording system to monitor current catches and by-catches (also by lost fishing lines), as well as data on catches in previous decades, and data on changes in fishing effort over time in order to quantify how catches per unit of fishing effort have changed over time. This is not an easy task, the data is not readily available, and local fishers do not seem very eager to work with the government on organizing the fisheries. Starting such a recording system, however, would make the investigation easier in the future.

On the other hand, the data presented here represents the most thorough assessment that has yet been conducted on Bonaire's fisheries, and according to Sandin *et al.* (2008) local pressure by fisheries can form an important pressure on the coral reef as an ecosystem. In order to sustainably manage reef resources, it is critical to quantify this pressure and manage the socio-economic drivers behind them. While the calculations in this analysis could be improved with additional data at a finer resolution, we provide a useful estimate of the magnitude, market value and spatial distribution of Bonairean fisheries that can be used to inform management decisions.

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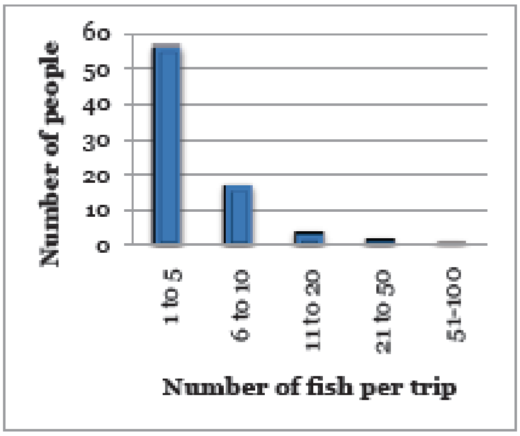
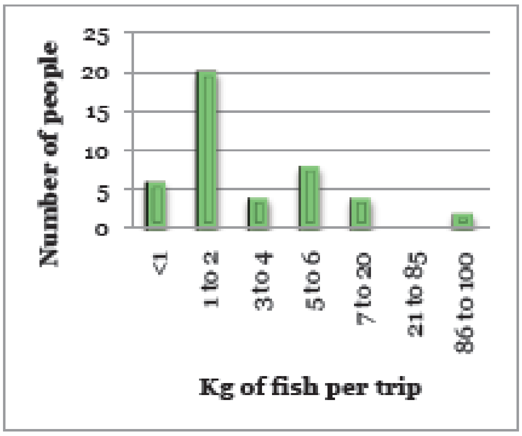
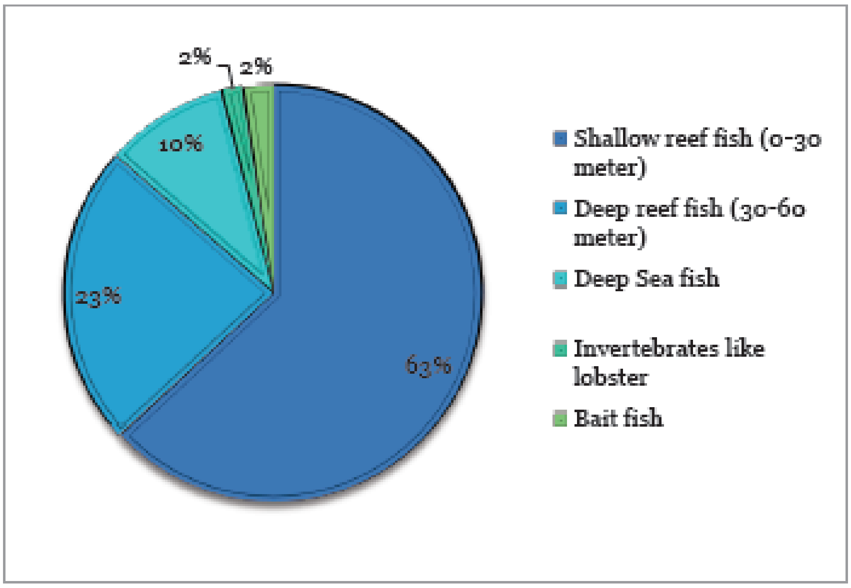
Annex A Survey outcomes (Laclé, 2012)



Graph 10: The average number of fish caught per trip



Graph 11: The kg of fish caught on average per trip



Graph 9: Composition of fish catch by inhabitants

Annex B Specific cost estimates

Table C.1 Big boat

			Average	Per year*	
Capital investment	New engine (from Miami) (overhaul)	1,500	2,250	225	
	New engine (from Curacao) (overhaul)	3,000			
	Boat	12,500		1,250	
	Fishing equipment	3,500		350	
	Sub-total				**1,825**
			Season	Corrected for inflation	
Fuel	Diesel High per day	75	3,992.72	4,711	
	Diesel low per day	50	5,372.79	6,340	
	Sub-total				**11,051**
Maintenance	Equipment	500			
	Engine	500			
	Big maintenance	688			
	Sub-total				**1,688**

Table C.2 Small boat

			Per year*	
Capital	Boat	2,057	206	
	Engine	3,600	360	
	Sub-total			**566**
Maintenance			1,200	
	Sub-total			**1,200**
Fuel	High season per day	29.6	1,576	
	Low season per day	44.4	4,771	
	Remaining	37	0	
	Sub-total			**6,347**

Annex C Example of a choice experiment card