TOTAL ECONOMIC VALUE

OF

BERMUDA'S CORAL REEFS

Valuation of Ecosystem Services

Edited by

S. Sarkis, P. J.H. van Beukering, E. McKenzie

Total Economic Value of Bermuda's Coral Reefs:

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Cover Photo: Bermuda's reefs, Jan Locke

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An electronic version of this report will be made available at www.conservation.bm

Technical Report, Department of Conservation Services, Government of Bermuda, Bermuda, 2010

PREPARATION OF THIS DOCUMENT

This report is a compilation of economic valuations conducted on goods and services provided by Bermuda's coral reefs, resulting in the Total Economic Value of this ecosystem. The study was initiated and coordinated by Dr. Samia Sarkis of the Department of Conservation Services (Government of Bermuda). It was implemented with the expertise of the Institute for Environmental Studies (IVM) of the VU University (NL), in close collaboration with the Joint Nature Conservation Committee (U.K.), Department of Marine & Ports, Department of Environmental Protection, Department of Statistics, Bermuda Institute of Ocean Sciences, Bermuda Zoological Society, Department of Tourism, Department of Forward Planning, Sustainable Development Unit, and Rego Realtors (Bermuda).

Implementation was conducted through the close collaboration of a Bermuda-based team, composed of scientific experts, government officials, and professionals in the relevant private sectors, and an overseas environmental economist team led by Pieter J.H. van Beukering, composed of economists and graduate students. A sound analysis of the Total Economic Value of Bermuda's coral reefs was achieved and presented here. The report is divided into 8 chapters, the first providing an introduction to Bermuda's case study, followed by five chapters each focusing on the value of key ecosystem goods and services, leading to the Total Economic Value assessment in Chapter 7. In conclusion, Chapter 8 provides recommendations for integrating the coral reef value in Bermuda's marine policies.

A substantial part of the work was conducted by three graduate students, completing their Master theses at Vrije Universiteit in Amsterdam, Netherlands. Lastly, a 16-page policy brief was written based on the current report, presenting recommendations on marine policy improvement in Bermuda; all recommendations were approved by the Bermuda Cabinet in September 2010.

The project was funded by the Overseas Territories Environmental Programme (OTEP BDA 402), XL Foundation in Bermuda, and the Department of Conservation Services, Bermuda.

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EXECUTIVE SUMMARY

This project was initiated and coordinated by the Department of Conservation Services, Government of Bermuda, in collaboration with environmental economists from the Joint Nature Conservation Committee (U.K.); the economic valuation was implemented by the Institute for Environmental Studies (IVM) of the Vrije University (Netherlands) supported by a Bermuda-based scientific team for all biological analyses. The Department of Conservation Services contributed financially to the development of the research framework, and the study was funded by the Overseas Territories Environmental Programme (OTEP, U.K.) and XL Foundation in Bermuda. The study's progress was overseen by a Steering Committee composed of Bermuda government representatives (Departments of Marine & Ports, Tourism, Finance, Environmental Protection, Forward Planning, Conservation Services, and Sustainable Development Unit), and well respected members of the community.

This environmental economic study seeks to address the lack of environmental consideration in current policy and decision-making for the marine environment, by providing a means of recognizing the value of the range of ecosystem services provided by Bermuda's coral reefs. Bermuda is one of the most densely populated countries in the world, with an economy supported by international business and tourism; increasing coastal development places intense pressure on the island's natural resources, namely on the marine environment and more specifically on the northernmost coral reef system in the world. The policy issues affecting Bermuda's coral reefs involve the lack of formal procedure when "planning" or "developing" in the marine environment, and the absence of a mechanism for integrating environmental values into those decisions.

Bermuda currently supports what is considered one of the "healthiest" coral reef systems of the Wider Caribbean Region. Coral cover- or coral density- varies among the different reef types, ranging from 22% to 70%. This creates habitats for an array of reef fish and invertebrates. As noted in the Biodiversity Strategy and Action Plan, Bermuda's reefs are of global importance, being the northernmost reef system due to its proximity to the Gulf Stream. The northerly latitude of Bermuda's reefs has benefited the health of the reefs by mitigating certain climate change impacts, such as increased "bleaching" events.

The immediate threats faced by Bermuda's coral reefs relate to the increasing maritime traffic associated with the import of goods to the island, and to the changing tourism industry. The developments necessary to accommodate larger ships have potential direct and indirect impact on the reef system. This may in turn lead to the loss of ecosystem goods and services provided by coral reefs to Bermuda's community.

Coral reefs provide both commercial and non-commercial goods and services. Estimating the economic value of coral reefs is complex. This value can be divided into use and non-use values; the latter are difficult to measure quantitatively and have the greatest uncertainty attached to them. In this study, the approach used to determine the Total Economic Value (TEV) focuses on 6 key ecosystem goods and services:

1) Coral reef-associated tourism 2) Reef-associated fisheries, 3) Amenity or reef-associated surplus value on real estate, 4) Physical coastal protection, 5) Reef-associated recreational and cultural values and 6) Research and educational values.

Each of these six values is quantified using specific valuation techniques, the sum of all providing the TEV.

Total Economic Value

The value of the sum of compatible uses of the above goods and services constitutes the 'Total Economic Value' (TEV) of coral reef ecosystems. It is worth noting that although TEV is known as 'Total' Economic Value, this analysis has not included all goods and services provided by Bermuda's coral reefs and that some aspects of coral reefs may be 'invaluable' i.e. they have intrinsic value, beyond any benefits provided to people. Hence, the TEV estimated here is likely to under-estimate the true 'total' value of Bermuda's coral reefs.

Table 1 outlines the value in USD for each ecosystem service provided by Bermuda's coral reefs, the resulting Total Economic Value of the reef system in Bermuda, and the contribution of each ecosystem service to the overall TEV. Please note that the values given are **annual** values, based on 2007 data and prices.

TABLE 1. THE ANNUAL TOTAL ECONOMIC VALUE OF BERMUDA'S CORAL REEFS BASED ON THE VALUE OF SIX ECOSYSTEM SERVICES PROVIDED BY THE ISLAND'S REEF SYSTEM.

Ecosystem Service	**Average value (million USD)**	**Contribution to TEV**
Tourism	405.9	56%
Coastal protection	265.9	37%
Recreation & Cultural	36.5	5%
Amenity	6.8	1%
Fishery (commercial & recreational)	4.9	0.7%
Research & Education	2.3	0.3%
Total annual value (TEV)	**722.4**	100%

The average annual value of the coral reef ecosystem amounts to **$722 million**. This high number certainly suggests that this ecosystem is highly valuable and worth conserving from an ecological, social and economic perspective. Lower and upper bound estimates were determined for each ecosystem service recognizing the uncertainty surrounding the economic analysis, resulting in a **TEV ranging from $488 million per year to $1.1 billion per**

year. The contribution of ecosystem services to this value are in order of importance: 1) Tourism (56% of TEV), 2) Coastal Protection (37%), 3) Recreational and Cultural (5%), 4) Amenity (1%), 5) Fishery (0.7%), and 6) Research and Education (0.3%).

The TEV of coral reefs of Bermuda depends on the ecological integrity of the coral reefs (which affects the level of service provision), and socio-economic conditions. Degradation of the reefs is likely to lead to a loss of ecosystem service provision and a reduction in the TEV. Using a discount rate of 4% for a 25-year period, it is evident that preserving the coral reefs (or delaying their degradation) in Bermuda pays off in economic terms. To place the TEV of coral reefs in context of the economy of Bermuda: in 2007, the Gross Domestic Product (GDP) of Bermuda amounted to US$5.85 billion in 2007 (Government of Bermuda 2008). Based on this, the **TEV of coral reefs constitutes 12% of Bermuda's GDP**.

Recommendations: Policy applications

Environmental valuation provides a tool to assist policy- and decision-makers in incorporating environmental considerations in future marine and/or coastal developments. The following policy recommendations are made on the basis of the findings of this study:

> *Recommendation 1:* Prioritize potential policy interventions in an economically sound manner.

A. Of immediate concern is the lack of "formal" procedure when assessing developments that have potential to affect the marine environment. Although legislation currently exists for developments originating from the coast and extending to the marine environment under the Planning Act, there is no legislation for developments in the marine environment - such as the destruction of reefs for enhanced ship passage. Strategic environmental assessments (SEA) are a good practice for policies, plans, and programmes taking an ecosystem-based management approach. The development of a formal standard procedure for conducting SEA, supported by legislation requiring SEA for major developments in the marine environment, will enable more informed and sustainable decisions. The TEV demonstrates the urgency and importance of implementing new legislation that accounts for the full economic value of marine resources, in order to sustain valuable ecosystem services. This TEV study can:

- Help to screen whether a development requires detailed assessment (e.g. a full strategic environmental assessment), on the basis of the likely scale and location of ecosystem service impacts.
- Inform detailed assessments of the impacts of developments, although for major developments this will require additional cost-benefit analyses.
- Inform the design of programmes for ecosystem service monitoring and enforcement of legislation.

B. The efficient utilization of limited funds requires an economically sound decision support tool to facilitate prioritization and selection procedures. Prevalent options for improved marine management are: (1) improving the transparency of decisions affecting the marine environment, such as the choice of the route for incoming mega-cruise ships in Bermuda, by developing an **extended cost-benefit analysis** incorporating the economic costs of damage to coral; (2) developing a standard **damage cost procedure** for marine vessel groundings and other forms of injury to the reef in Bermuda (e.g. anchoring damage), accounting for the wide range of lost benefits, which will on the one hand encourage preventative behaviour by potential violators while on the other hand guarantee sufficient funds for reef restoration and damage compensation.

> *Recommendation 2:* Make use of the cultural importance residents place on marine ecosystems to improve coral reef management.
>
> *Recommendation 3:* Actively involve the tourism industry in the development of sustainable coral reef management.

Recommendations 2 and 3 refer to the potential use of the information obtained in this study, as a starting point for the design of revenue raising mechanisms to generate funds for coral reef management. Currently, monies obtained through grants, donations and courses specific to coral reef ecosystems amount to US$2.3million (based on 2007 data); this 'research and education value' encompasses work conducted by NGOs and government departments, but excludes management and enforcement costs. Results of this study indicate that the engagement of the residents and tourists may potentially lead to a conservation fund of **$50 million per year**. Although the securing of funds from the resident community is a challenging issue in Bermuda, it is strongly recommended that policy-makers establish the vehicle for enabling community support for environmental conservation; this has the potential to generate $36 million per year, and **allow for the use of funds currently put into the marine environment for other socio-economic needs**. Through the comprehensive household surveys conducted during the course of this study, Bermudans have expressed their concern for the human induced impacts on their environment. Increasing awareness and education by incorporating environmental economics in the national school curriculum will ensure sustained concern and motivation for financial contribution to environmental conservation and management.

On the other hand, the Tourism sector can provide the critical mass needed to generate sustainable funding for coral reef management. The establishment of an **environmental tourist tax, and/or user fees** for divers and snorkelers is a means used by other jurisdictions of raising revenue from this group; given the small share of such contributions to the total expenses incurred by visitors, it is unlikely that such taxes and fees will discourage tourists from coming to Bermuda. An alternative mechanism for raising revenue is to engage the Tourism sector through a **Tourism/Conservation Partnership**; this has been successfully demonstrated in other jurisdictions, and entails the collaboration of the Tourism Board, tourist operators and the National Trust. Establishing such mechanisms and partnerships is strongly recommended and will enable the raising of a potential $16 million per year through voluntary contributions of tourists to fund restoration activities on impacted reefs. Examples of activities ensuring reef preservation are given in the next section.

> *Recommendation 4:* Balance consumptive and non-consumptive uses of coral reefs by strategizing spatial management and protecting critical marine areas.

The revenues generated by the commercial fishing industry are small compared to the contribution that non-consumptive coral reef services provide to Bermuda's economy. Marine Protected Areas (MPAs) provide an effective way of sustaining the tourism, recreational and cultural benefits provided by the coral reef system. They have been shown, in other jurisdictions, to act as a refuge for marine populations and enhancing in some cases fish catch outside of MPAs. The comprehensive assessment of MPAs critical to the ecosystem is a fundamental action in the long term sustainability of marine populations.

This study shows the importance of the reefs in sustaining fish and shellfish populations critical to sustaining local livelihood and culture. These consumptive and non-consumptive uses of the reefs can only be sustained through the protection of critical zones of the ecosystem. In this way, the high economic value of a live fish generated through diving and snorkeling activities, will remain balanced with revenues generated by the commercial fishing industry and the cultural value gained by recreational fishermen.

Prioritizing strong enforcement and protection of these zones by engaging boat and dive operators has proved successful in other jurisdictions; this has led to the establishment of self-financing MPAs through diver fees or user fees. The income generated covers the salaries and operational costs of the marine park. This may serve as a template for successful protection in Bermuda.

Coral Reef Research and Management Needs

In future work, economic analysis could be effectively used to evaluate the feasibility of the potential measures recommended above. In addition, increased funding earmarked for coral reef ecosystem sustainability would allow for the assessment of research and management needs, and their implementation. This is required to ensure the continued provision of valuable ecosystem services to Bermuda's community. Some examples are:

- Monitoring and early detection of natural/human-induced changes;
- Enhancing enforcement capacity on the Bermuda platform;
- Developing and implementing mitigation measures of foreseen changes – i.e. due to climate change and/or coastal development;

- Researching coral restoration and growth, connectivity between fish productivity and coral reef habitats;
- Predicting wave impact on Bermuda's coastline and identifying flood zones-including collecting wave information during storms and hurricanes.
- A better understanding of coastal erosion parameters required for mitigation measures of natural and human induced erosion processes.

The TEV and resulting recommendations for Bermuda's coral reefs are based on sound economic analyses. Only those ecosystem services that lent themselves to robust valuation techniques and deemed feasible given the existing available data were valued in this study. Although this leads to an underestimation of the TEV, it results in a final value that can be fully explained and justified. The valuation techniques and final results for each of the six ecosystem services are summarised below.

Tourism

Data was collected through available documentation and two surveys developed for the study – 1) a reef-associated tourist operator survey providing revenue data, and 2) a tourist exit survey assessing the importance of coral reefs to the visitation experience. The economic analysis for estimating the reef-associated tourism value involves three methods: a) the travel cost method, resulting in the "consumer surplus", or the value of the coral reefs to tourist recreation from the visitor's perspective, b) the net factor income method, resulting in the "producer surplus", or the value of coral reefs in the production of a marketed good generated through paid activities such as SCUBA diving and snorkeling, and c) the contingent valuation method, providing a "Willingness to Pay" value for coral reef conservation, an additional measure of "consumer surplus".

Current Bermuda Tourism Market

The cruise ship tourism sector in Bermuda forms a substantial part of the total tourism sector; in 2007, 53% of the total 663,767 visitors to the island, arrived by cruise ship. A total of 407 tourists were interviewed for this study, distributed evenly between cruise and air tourists. Survey results indicate that 38.3% of the tourists interviewed are motivated to visit Bermuda for a coral reef-associated reason, with snorkeling and touring the reef being the most popular activities. Bermuda's "pristine" reefs are evidently well appreciated and 14% of the tourists interviewed confirmed they would not come to Bermuda, should the coral reefs lose this quality**. This translates into a loss of 90,000 tourists per year if coral reef health declines**. Degradation in coral reef health would lead to a reduction in coral cover and associated losses in species diversity and abundance, due to physical damage or disease.

Operator survey

Thirteen of the existing forty reef-associated tour operators in Bermuda were interviewed, including all dive operators, and a sample of glass bottom and rental boat operators, as well as charter boat operators. The reef-associated tourism gross revenue for Bermuda is estimated at $7.4million (in 2007), with a profit margin estimated at 28%. Results concur with the tourist survey in that reef quality is important to the business, and that most visitors to Bermuda are sensitive to the health of the environment.

Consumer Surplus- Visitor's perception of coral reef value

The reef-associated tourism value is estimated based on the percentage of reef-associated recreation, stemming directly (such as diving) and indirectly (such as beach enjoyment) from the coral reef ecosystem. The consumer component of the coral-reef related tourism value of Bermuda's coral reefs in 2007 is calculated to be US$343 million, approximating US$190 million for the cruise ship tourism sector and US$154 million for the air tourism sector.

Producer Surplus- Value of marketed goods provided by coral reefs

The producer surplus is calculated based on the expenditures of tourists visiting coral reefs, minus the cost of production. The producer surplus of reef-associated operators is based on the reported tourist expenditures for both air and cruise ship tourists. The producer surplus for air visitors is estimated at US$139 per tourist and at US$55 per tourist for cruise ship passengers. Based on 663,767 visitors in 2007, the reef-related producer surplus value totals US$62.5 million in that year, the greatest part being attributed to the air tourism sector amounting to $42.9 million per year, more than twofold the value of $19.5million per year contributed by the cruise ship tourism sector.

'Willingness to Pay' by Tourists

Results indicate that 68% of all tourists visiting Bermuda are- in principle – willing to pay in addition to their current expenses, to fund activities to preserve Bermuda's coral reefs. The average cruise ship tourist is willing to pay US$28 per visit to Bermuda and the average airplane tourist is willing to pay markedly less, US$19. Extrapolating this information to a yearly basis, using the number of visitors recorded in 2007, a total sum of US$15.6 million - US$5.9 million from the air tourism sector, and US$9.7 million from the cruise ship sector-, is potentially available for the conservation of Bermuda's coral reefs.

Total Tourism Value

The total tourism value of coral reefs in Bermuda is the sum of the **consumer surplus** (based on travel costs), and the **producer surplus** (based on tourist reef-associated expenditures). All tourists add substantial reef related value to the island's economy; the total tourism value of Bermuda's coral reefs per visitor is US$611 per tourist. This value is slightly lower for cruise ship tourists (US$591 per visitor) than for air tourists (US$635 per visitor). This difference is due in great part to higher on-island expenditures incurred by air visitors, resulting in a twofold producer surplus spent by this sector; air tourists add US$43 million per year to the island's reef-related economy, compared to less than half that added by cruise ship tourists (US$20 million per year). However, because of the higher volume of cruise ship visitors, the resulting reef-associated tourism value for cruise ship tourism (US$197 million) is equivalent to that of air tourism (US$209 million). In addition, appreciation of the reefs by cruise ship tourists is similar to that of airplane tourists, reflected in their '**Willingness to Pay'** for conservation (US$9.7million for cruise ship and US$5.9 million for air visitors). The **reef-associated tourism value** for Bermuda's coral reefs is **US$406 million** per year (calculated in 2007). The **Willingness to Pay** extra for ensuring the preservation of reefs per year by all tourists is **US$16 million**.

Fishery Value

Coral reefs are a crucial habitat for fish stock and in this way also provide important ecosystem services through the commercial and recreational fishery sector. The value of coral reef-associated fisheries encompasses both direct and indirect values. The direct value of coral reef-associated fisheries refers to the market value of the fish catch and the indirect value refers to the cultural and recreational importance of fishing in Bermuda. The direct value was obtained through existing data from the Marine Resources Section (Government of Bermuda) and from face-to-face interviews with fishermen. The indirect value was obtained through a survey designed and administered for the purpose of this study, where 400 households were interviewed face to face. The valuation focuses on fisheries that depend directly on coral reefs for at least one portion of their life cycle, and is from hereon referred to as "reef-associated". The fisheries value includes 1) commercial fisheries and 2) recreational fisheries. To avoid overestimation of the fishery value, a distinction is made between reef-associated and non reef-associated catch.

Commercial fisheries

Based on existing records, 42% of the total commercial catch is considered reef-associated. Reef-associated catch for finfish ranges from 257,000 to 375,000 lbs., resulting in a value ranging from US$1.6 million to US$2.5 million; note that these data exclude the catches recorded for pelagic and sharks, which would increase fin fisheries value to a maximum of US$5.1 million. The gross value of the whole reef-associated commercial fisheries including finfish and lobster species ranges from US$2.5 million to US$3.2 million, with a mean of US$2.9 ± 0.3 million. Net values for the reef-catch were calculated by deducting estimated fishing costs. Total fishing costs were estimated at 40% - 80 % of the gross value of the total catch; due to the small sample size (n=6 fishermen), this should be considered as a very preliminary estimate. The **final net values of the commercial reef-associated catch**, for both finfish and lobster is calculated to be **US$0.6 ± 0.06 million to US$1.8 ± 0.2 million** based on a 20% to 60% profit margin.

Recreational fisheries

To date, a recreational fishing license is only required for lobster diving in Bermuda; for this reason, there is no statistical record of recreational finfish catch. This study provides the scope for a first assessment of recreational fisheries in Bermuda, based on responses of local residents during a face-to-face interview. Details of the demographics of the household interviewed are given within the Recreational and Cultural Value section of the main document. Of the 400 households interviewed, 30% indicate that one or more household member fishes recreationally. This translates into a total of almost 16,000 recreational fishermen on Bermuda in 2007. Based on interview results, the motivation for this activity by Bermudans is foremost the strengthening of bonds with friends and family, and enjoyment, rather than fishing for food. Details on fishing periods, fishing methods and preferred sites are provided by the survey. On average, 72% of the catch is made up of shallow reef fish. Deep “reef” fish (>26m depth) and deep sea fish (e.g. Tuna) are targeted by a minority of recreational fishermen. Bait fishing is recorded as being only 4% of the recreational total catch. Lobsters and mussels are reported to be least targeted by the fishermen interviewed, and make up <1% of the recreational total catch.

Results indicate that the average reef finfish catch per fishing household, i.e. a household in which at least one of the members is a recreational fisherman, is 50 ± 53 pounds per fishing household. The large standard deviation illustrates wide differences among fishermen’s catch success, with a few fishermen catching much more than the main group. This total reef-associated finfish catch is estimated at 387,000 pounds (in 2007), or 68% of the total (i.e. commercial and recreational) finfish catch. The lobster recreational catch ranges from 2,720 lobsters in 2000 to 2,973 in 2007 (with a total of 556 registered recreational lobster divers in 2007). Based on the same market prices as those used for the commercial fishery value, the recreational reef-associated value is estimated to be US$3.5 million for finfish (excluding big game sport fishing), and US$ 0.1 million for lobster. This results in a **total recreational reef-associated fishery value of US$3.7 million** for 2007. There are no costs deducted to estimate the net value as this activity is done for enjoyment and not with a financial goal; for this reason, the recreational fishery value seems high in comparison to the values of the commercial sector. The reef-associated fishery is an important component of the total recreational fishery, comprising 79% of the total value in 2007.

Recreational fishermen caught 40% of the total finfish catch in weight in 2007. Taking into account the total reef-associated catch for finfish (i.e. both commercial and recreational), recreational fishermen are responsible for 53% of the total catch in weight (2007 data). Recreational lobster diving accounts for 9% of the total lobster catch (2007).

The **sum** of **the reef-associated commercial fishery** (both finfish and lobster) and of the **reef-associated recreational fishery** (finfish and lobster) result in a fishery ecosystem value estimated at **US$5 million** per year.

Amenity Value

The environmental amenity of Bermuda's coral reefs potentially adds value to residential properties. The assessment of such a value is determined using the hedonic pricing method. The underlying question is whether the proximity of coral reefs, assessed by the view from the house, access to the beach, or pristine waterfront is perceived as an important attribute affecting the purchase price. Should a higher house price be attributed to a coral reef-related characteristic, the additional value is an estimate of the amenity value given to this environmental ecosystem by a homeowner. This study is one of few using this methodology; it is a complex analysis, requiring a large data set of house sales. A number of challenges and limitations were encountered in the valuation of this service, among which was the difficulty in accessing house sale data, and in establishing a coral reef attribute adequately reflecting the relationship between house prices and the coral reef ecosystem. Following a series of analyses, distance from house to beach, was accepted as the coral reef attribute best associated with house price. Beaches in Bermuda can be considered as a coral reef variable, because of their coralline origin, tightly linking their existence to the status of coral reefs.

The dataset made available included 593 houses, consisting of 50% condominiums and 50% houses. The average price of a 2.6 bedroom/2.2 bathroom house was of $1.5million. Approximately 14% of houses bought were located on the waterfront, and on average residences were less than 1km away from beach or coral reef, and always less than 3km; this proximity is due to the nature of Bermuda's coastline.

The amenity value is based on the estimated non-linear relationship between house prices and beach distance. The analysis reveals a quadratic relationship; unexpectedly, house prices are directly proportional to the distance from the beach up to 1.1km- i.e. house price increases with distance from the beach-, with a change in trend beyond 1. km, where as expected, house prices decrease with distance from the beach.

The total amenity value is calculated as the difference between: 1) The total price of the houses sold in the dataset ($890 million) and 2) The extrapolated calculation of the house prices in a "deterioration" scenario- or should beaches disappear (US$ 728 million). This yields an amenity value of US$221,000 per house, and when extrapolated for all houses in Bermuda, a total amenity value of US$5.6 billion. Converting this value into equal annual amounts generates an **amenity value of coral reefs** in Bermuda of around **US$6.8 million** per year.

This leads to the conclusion that Bermudans implicitly enjoy the ecosystem services derived from coral reefs but because of its invisibility, they do not explicitly consider such an amenity when buying a residential property. Living close to a beach does not appear to be a determinant characteristic in the purchase of house in Bermuda, probably due to the island's narrowness (1.5 km at the widest point) and hence the natural proximity of residences to beaches. However, **should coral reefs and beaches become scarce** due to degradation of this valuable ecosystem, **the economic value in terms of a surplus on house prices is likely to become more apparent**.

Recreational and Cultural Value

Residents of Bermuda appear to place a high value on their coral reef resources, made apparent by the significant number of people using the island's marine environment for recreational purposes. Because most residents do not depend on the ocean for subsistence or livelihood, the relationship between Bermudans and the coral reefs can be described as predominantly recreational and cultural.

A large-scale resident survey was developed and administered in order to have a better understanding of what connects Bermudan households to their reefs. A special valuation technique, choice modeling, was used to quantify recreational and cultural values related to coral reefs. In total, 400 households collaborated in a face-to-face interview, statistically representative of Bermuda's population.

The questionnaire includes seven sections concerning the following: background of respondent; recreational use of reefs; environmental awareness; choice model; demographic characteristics; recreational fishing; diving and snorkeling. *Note that the recreational fishing section was added for the benefit of the Fishery value, and is not discussed within the context of the recreational and cultural value, but in the Fishery value section.* In the choice model section, each respondent was repeatedly asked to choose between complex, multi-attribute profiles describing various changes in Bermuda's coral reefs. The selection of coral reef attributes is specific to this case study and determined by consultation with focus groups and experts.

Choice Model Development

Three focus group discussions and one expert consultation were held. The three focus groups were: (1) *Recreational fishers*, comprising Bermudan residents who fish recreationally; (2) *Snorkelers and scuba divers*, comprising Bermudan residents who scuba dive and snorkel; and (3) *Bermuda Residents*, comprising both ex-patriots and Bermudans, who do not fish or scuba dive. Lastly, an expert consultation was held with coral reef and fishery experts, from governmental departments (Conservation Services and Environmental Protection) and the Bermuda Institute for Ocean Science (BIOS), a local NGO.

Selection of attributes was based on the ability to determine the residents' use values for the coral reef ecosystem and enable the measurement of non-use values. Five attributes were identified: (i) recreational fishing, (ii) coral diversity/fish diversity (or fish abundance), (iii) recreational activities (scuba diving/snorkeling), (iv) water quality (described as coral diversity, fish diversity, water clarity, and swimming restrictions), and (v) a payment vehicle (described as an environmental levy).

Socio-demographic characteristics

A comparison of results obtained in this study was made with the 2004 Expenditure survey (Department of Statistics, Bermuda), indicating a similar ethnic composition (black=59%, mixed=8% and white=27%), and household income. The majority (82%) of respondents were born in Bermuda. The level of educational attainment in the sample was normally distributed with 94% of the respondents having achieved, senior, technical or University level education. The average annual household income was US$124,900.

Reef-related activities

Swimming is by far the most popular marine-related recreational activity of the interviewed households. Beach picnic is also a popular leisure activity. While half of the respondents still participate in water sports such as sailing, surfing, and boating, only 20 percent of the households go out snorkeling and/or diving. For the latter, seeing fish and coral species are the top two pleasures during the trip.

Environmental awareness

The results of the survey indicate that Bermudans are concerned with the environment of their island. "Marine pollution" ranks a close second after the overarching concern of "Trash/littering and illegal dumping on the island"; the "Degradation of coral reefs ranks 4th after "Increased development and lack of open space".

'Willingness to Pay' by Residents

Bermudan residents hold significant positive recreational and cultural values related to Bermuda's coral reefs and marine environment. Although there are issues associated with the payment of an environmental levy, residents are willing to pay to preserve their marine environment. Minimizing marine pollution, translated as the ability to swim anytime, anywhere was first and foremost, yielding an average 'Willingness to Pay' (WTP) of US$42 per month per household. Second was maintaining coral reef quality (i.e. coral and fish diversity), resulting in an average WTP of US$32 per month per household. Third, water clarity (maintained by a healthy coral reef system) was considered important and respondents were willing to pay on average US$27 per month to preserve or improve this attribute.

This implies that marine management policies resulting in improvements across all four environmental attributes (i.e. maintain/improve coral reef quality, avoid swimming restrictions, increase fish catch, and maintain/improve water clarity) would generate substantial benefits to the Bermudan population; more specifically, they would result in a welfare improvement equivalent to an increase in average monthly household income of around US$113. In aggregate terms, these improvements would be worth over **US$37 million** per year to the population of Bermuda, and considered to be the **total recreational and cultural value** of coral reefs to Bermuda.

Less than half of the respondents indicated that they would be willing to pay an environmental levy. This share is unusually high, compared to similar studies. The results of the choice experiment suggest that most Bermudans are actually willing to make clear trade-offs between levies and the non-monetary attributes. The contribution by residents for the preservation of the coral reef ecosystem enables the implementation of conservation and management measures.

Coastal Protection

Coral reefs absorb much of the incoming wave energy, functioning as natural breakwaters and helping to protect the shoreline from erosion and property damage. Awareness about the vital role of the rim and boiler reefs in protecting Bermuda's shoreline is raised in earlier coastal vulnerability assessment studies. However, the economic value of this ecosystem service, has not yet been estimated. In this study, the "avoided damages" approach is used to value this service. This involves the estimation of the potential damage (and associated economic losses) to the Bermuda coastal area from a given storm event, with and without the presence of a reef.

The current study is one of the few examples of the valuation of coastal protection services provided by coral reef ecosystems. Not all of the required parameters were available for Bermuda at the time of analyses. The value for coastal protection in this case was obtained by combining local information about the island's coastal profile, the storm regime for Bermuda, historic information on property damage caused by storms, flood zones susceptible for high waves, coral reef locations, shoreline stability and the role of coral reefs, and property values for land areas.

Property damage information is based on reports for Hurricane Fabian, a Category 3 (bordering Category 4) storm, hitting Bermuda directly in 2003. This results in an average damage share of 27.5% - in other words, for a storm category 3 or 4, damage to property can be as high as a quarter of the property value -. Given the lack of reporting, damage in this study relates only to properties and excludes infrastructures (such as roads). It is recommended that further modeling and data gathering are conducted to improve on the existing calculations, as this value is based on numerous simplifying assumptions, and underestimates the true value.

The economic value of the **coastal protection** function of coral reefs in Bermuda is determined at **US$266 million** per year.

Research and Education Value

The research and education value of Bermuda's coral reefs is simply based on budgets of both governmental and non-governmental institutions in Bermuda. Only research and education budgets relating to the coral reef ecosystem are incorporated within this ecosystem service. Available data did not include monies invested in management and/or enforcement of coral reef-associated resources. The sum of all **research and education** activities associated with coral reefs in Bermuda amounts to **US$2.3 million** in 2007.

Conclusions

This first environmental economic valuation for Bermuda has paved the way for an alternative approach to conservation of natural resources. The findings will generate awareness among the general public of the valuable ecosystem services provided by Bermuda's coral ecosystem. Environmental valuation also provides a tool for government policy and decision-makers, and local businesses, to integrate the value of the coral reef ecosystem into marine public policy and decision-making, and business strategies. The general community and tourists value coral reefs, evident by their willingness to trade off monies for preservation of this natural resource. It is hoped that these results on the TEV of Bermuda's coral reefs will encourage and facilitate marine policies that ensure the sustainability of the northernmost coral reef system in the world.

ABBREVIATIONS

Abbreviation	Definition
BIOS	Bermuda Institute for Ocean Science
BMD	Bermudan Dollar
CBA	Cost Benefit Analysis
CPUE	Catch Per Unit Effort
CS	Consumer Surplus
CVM	Contingent Valuation Method
FY	Fiscal Year
GIS	Geographical Information System
GOB	Government of Bermuda
HP	Hedonic Pricing
JNCC	Joint Nature Conservation Committee
MPA	Marine Protected Area
N/A	Not Applicable
NPV	Net Present Value
PS	Producer Surplus
TC	Travel Cost
TCM	Travel Cost Methods
TEV	Total Economic Value
VAT	Value-added tax
WRI	World Resources Institute
WTP	Willingness to Pay

ACKNOWLEDGEMENTS

First and foremost, our grateful thanks to the Overseas Territories Environmental Programme (OTEP) who generously contributed to the funding of this project, and to the XL Foundation who supplemented our financial needs in the second year of the study. The latter could not have been possible without the help of Sonia Whayman and Amanda Cox. The support and assistance of the Steering Committee members in the development of this project was invaluable. For this, our heartfelt thanks to Richard Winchell, Craig Simmons, Ralph Richardson, Francis Richardson, Tammy Trott, Jack Ward, Brian Franklin, Erica Smith, Charles Brown, Amanda Cox, and Adam Barboza who donated many lunch hours for intense discussions assisting to solve issues and maintain the project in the right direction.

Data collection was made possible through the collaboration of many individuals, Bermuda-based companies, and government officials. The Department of Tourism was invaluable in providing data on tourist expenditures and statistics; several members of the Department of Conservation Services were involved not only in the supply of accurate and comprehensive biological data, but also in the development of the most important reef attributes. Our thanks go to Thad Murdoch, Sarah Manuel and Kathy Coates for their willingness to share their coral reef data, and to Mandy Shailer for her time spent on GIS mapping especially important for the Coastal Protection and Amenity value assessment. Her efforts in developing a model specific to Bermuda characteristics during the latter are especially recognized. Tammy Trott, Joanna Pitt, and the Fisheries Wardens of the Department of Environmental Protection (namely John Edmunds, Mark Moran and Mark Siese) were extremely helpful in developing the Recreational Fisheries questionnaire, and helping us extract valuable information from the commercial fisheries database. Special thanks to Tammy Trott, Senior Fisheries Officer, who took the time to edit the Fisheries chapter for us. It is hoped that some of the information which came to light on recreational fishing will be of use to the Marine Resource Division as anticipated.

The amenity value for Bermuda's coral reefs could not have been calculated without the cooperation of Rego Realtors; our heartfelt gratitude for their willingness to share their database. In addition, their professional services were instrumental in providing the data necessary for the evaluation of the surplus value associated with coral reefs. This study is one of the few which has attempted using hedonic pricing to determine the amenity value of coral reefs; thank you for your input, it is very much appreciated.

Mark Guishard of the Bermuda Aviation Service-SERCO is gratefully thanked for his help in evaluating relevant data on storms and hurricanes in Bermuda. His interest and observations were extremely valuable in assessing the coastal protection service for

Bermuda's coral reefs. Thank you to the Department of Works & Engineering for providing us with previous documentation.

The professional services of Total Marketing in the interviewing of tourists for the exit surveys developed for the purpose of this study are gratefully acknowledged. The face-to-face interviews of 400 Bermudan households would not have been possible without Research.bm, and their well-trained interviewers. Thank you for your high quality work. This section would not be complete without thanking all those who responded to the interviews, both tourists and residents; your input has given us a first insight into your perception of our beautiful coral reefs.

The time taken by many individuals, especially the dive operators of Bermuda was very much worthwhile, and we are extremely grateful to you for sharing your views and your knowledge. Our thanks also go to JP Marteens, General Manager of Grotto Bay Hotel, for the use of his hotel as a pilot site for interviewing tourists. And last, but not least, all those individuals who contributed to the development of the resident questionnaire, attending focus group meetings during their lunch hour, and doing their best in representing Bermuda's diverse residents are truly thanked, as their input allowed for a comprehensive and meaningful analysis of the importance of coral reefs to the residents of this island.

1. Valuing Bermuda's Coral Reefs: An introduction to the ecosystem and to the valuation exercise

Samia Sarkis, Emily McKenzie & Pieter van Beukering

Bermuda, a 55 sq. km land mass in the middle of the Atlantic Ocean (32ºN, 64ºW), is one of the most densely populated countries in the world (1,145 people per km^2), experiencing tremendous economic growth over the last quarter of a century due to two main industries: international business and tourism. Economic development is consequently required to accommodate the needs of people living in Bermuda. Increased marine traffic, necessary for the import of goods and tourism, ensues from such development, placing in turn intense pressure on Bermuda's natural resources, both terrestrial and marine. An immediate concern is the lack of "formal" procedure for assessing developments that impact the marine environment, namely the coral reef system surrounding the island. Bermuda's marine zone includes the northernmost coral reef system, due to the proximity of the Gulf Stream, making it globally unique.

This environmental economic study seeks to address the lack of environmental consideration in Bermuda's current policy and decision-making for the marine environment, by analysing the value of the ecosystem services provided by Bermuda's coral reefs. The analysis gives information relevant to a number of different stages of the policy cycle. It identifies that the value of Bermuda's coral reefs is considerable, suggesting that greater policy focus should be devoted to preserving this natural asset. This may require increased resources for conservation and improved environmental assessment procedures for evaluating policies, projects and plans that affect coral reef health. By attempting to attribute a monetary value to the benefits that natural resources provide to people; an environmental valuation enables the integration of environmental concerns in policy and decision-making processes by placing these on a comparable basis with economic and social impacts. In this way, it provides a tool for the long-term conservation of natural resources and helps to identify and implement more sustainable policies and activities, thus balancing environmental, social and economic goals.

The strategy for this two-year project was initiated and developed by Dr. Samia Sarkis at the Department of Conservation Services in Bermuda in collaboration with environmental economists from the Joint Nature Conservation Committee (JNCC), in the U.K., and van Beukering Consultant firm in the Netherlands. Data was compiled under the supervision of Dr. Sarkis with the support and collaboration of a Bermuda-based scientific team. All economic analyses were completed by van Beukering Consultants Ltd. The entire project was coordinated by Dr. Sarkis and overseen by a Steering Committee made up of Bermuda government department heads and well recognized members of the Community.

The first year of the project was dedicated to data gathering and analysis, whilst the second year focused on providing a strategy for the promotion of the integration of economic valuation in policy-making.

1.2 The Benefits of the Coral Reef Ecosystem to Bermuda

Coral reefs provide a wide range of goods and services, both commercial and non-commercial to Bermuda's community. Coral reefs, supporting a high diversity of fish and other marine creatures, and the source of the island's famous pink beaches, are one of the primary tourist assets in Bermuda. This ecosystem also supports both commercial and recreational fisheries, providing food and enjoyment to the residents of the island. Real estate value is high in Bermuda, due to the excellent standard of economic welfare, but also to the spectacular views of turquoise waters associated with the corals beneath. The proximity of buildings to the shoreline, given the narrow width of the island (a maximum of 1.5km), render these properties vulnerable to storm surge and wave damage during the winter and hurricane period; the presence of the coral reef lagoon on the North Shore acts as an important coastal barrier, protecting the land mass and its residents. Bermuda's residents enjoy a superior quality of life, an attraction to workers from other countries and the pride and joy of Bermudans themselves; much of this enjoyment is attributed to the pristine marine environment allowing a wide range of year long leisure activities for all. Bermuda's coral reefs not only provide a playground for residents and tourists, but also support marine biodiversity used as an education tool for local and foreign students, as well as providing the capacity for internationally recognised marine research.

It is hoped that gaining an understanding of the Total Economic Value (TEV) of Bermuda's coral reefs will enable and assist policy-makers in making decisions, accounting for the important benefits that reefs provide to Bermuda's citizens and visitors. In addition, recognizing the value of the coral reef ecosystem will raise awareness in the general public and among the business community, building support for conservation and management of this natural resource. More specifically, results of the study will be highly relevant to the tourism and real estate sectors, and be useful for establishing sustainable finance schemes.

1.3 Bermuda's Coral Reefs: Description of the Study Site

Often regarded as a Caribbean island, Bermuda lies over 1,200 km to the north of its nearest Caribbean neighbour (the Bahamas), with the closest continental point of land being Cape Hatteras, North Carolina, 965 km to the west.

Bermuda lies on the southern rim of the largest of three steep-sided sea-mounts. On top of the volcanic pedestal the shallow-water Bermuda platform comprises a limestone cap, encompassing an area of approximately 1000 km^2. The study area, estimated to be 400 km^2, is illustrated in Figure 1.1, and does not include reefs on the outer edge of the North Lagoon. Bermuda's reefs are typical of high latitude reefs, with a low level of live coral coverage; the average surface coral cover on the North Lagoon is less than 44%; this only reflects the surface cover for hard corals, and does not consider soft coral species or coral growth on the sides of the reefs (Murdoch, 2007)

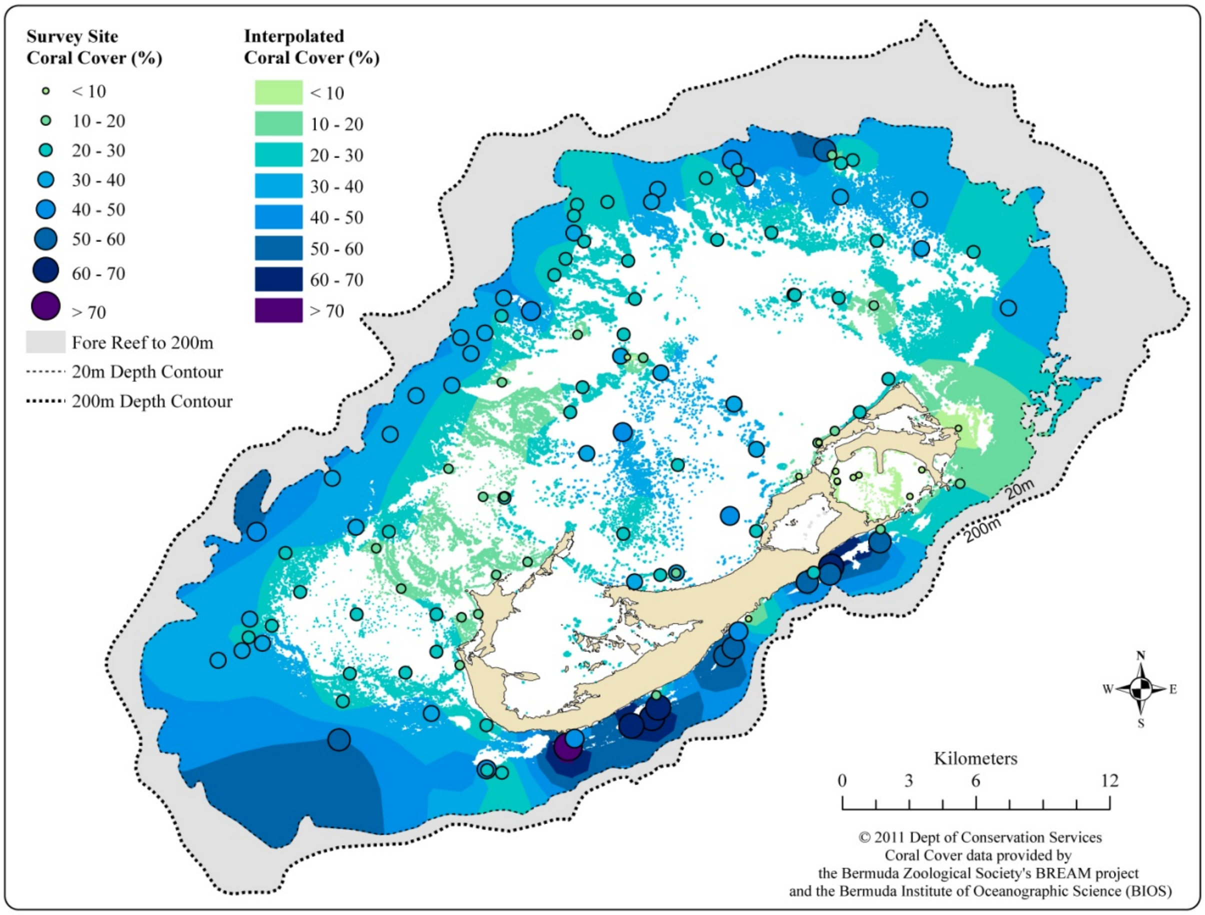

FIGURE 1.1. BERMUDA'S KNOWN CORAL REEF COVER FOR HARD CORAL SPECIES ONLY, EXCLUDING SOFT CORALS. DATA GIVEN REFLECTS TOP COVER (EXCLUDING SIDES) OF REEFS.

Coral cover illustrated in Figure 1.1 is based on surveys conducted by Murdoch (2007), and the Bermuda Institute of Ocean Sciences (2004-2007), on selected sites. The circles represent the specific site surveyed and the size of the circle represents the percentage of coral cover assessed at that site for the top of reefs only; this is therefore an underestimate of true coral cover as sides of reefs are excluded. The interpolated coral cover values were calculated using the Spline method in ESRI's ArcGIS Spatial Analyst (M. Shailer, Department of Conservation Services, Bermuda). **Please note that care must be taken in the interpretation of this map; interpolated values beyond the survey sites have not been validated. Coral reef data is available only for those sites surveyed (identified by circles), and for this reason, further surveying should be conducted for a precise assessment of coral reef cover in any**

other area outside of these sites. For further information on survey methods used and results, please refer to publications cited above. Appendix VI provides an overlay of the Bermuda platform, survey sites and interpolated coral reef cover, with a more detailed explanation on the approach taken to interpolation.

The study area excludes the fore-reef slope reefs, situated outside of the platform margin from 20-50m depth. As shown in Figure 1.2, the geographical boundaries of the study comprise: 1) The main terrace reefs, extending from 10-20 m seawards from the annular rim reefs, consisting in great part of a *Diploria-Montastrea-Porites* reef-building community, with coral cover reaching 50%; 2) The rim reefs encircling the North Lagoon are the most visible, grading into the main terrace reefs and extending towards the lagoon, and lying at depths of 15 m to 2 m. The corals comprising the rim reefs are more diverse than those in deeper water, although the main reef building corals are still dominant. Despite a lower coral coverage (22% average) than for the terrace reefs, the rim reefs remain the most diverse and healthy, showing little effect from bleaching and anthropogenic influences; 3) The lagoonal reefs, lying landward of the rim reefs in the North Lagoon. These comprise patch reefs of many sizes and shapes, the tops of which are close to the surface with steep flanks grading to depths averaging 20m; coral cover is generally less than 40% on the tops, reaching 70% on the flanks; 4) The "boiler" reefs lying to the south of Bermuda are constructed mainly of crustose coralline algae and the marine vermetid gastropod. These reefs extend approximately 1.5 km from the coast. Scientifically referred to as algal-vermetid cup reefs, they represent an unusual reef type to that found globally.

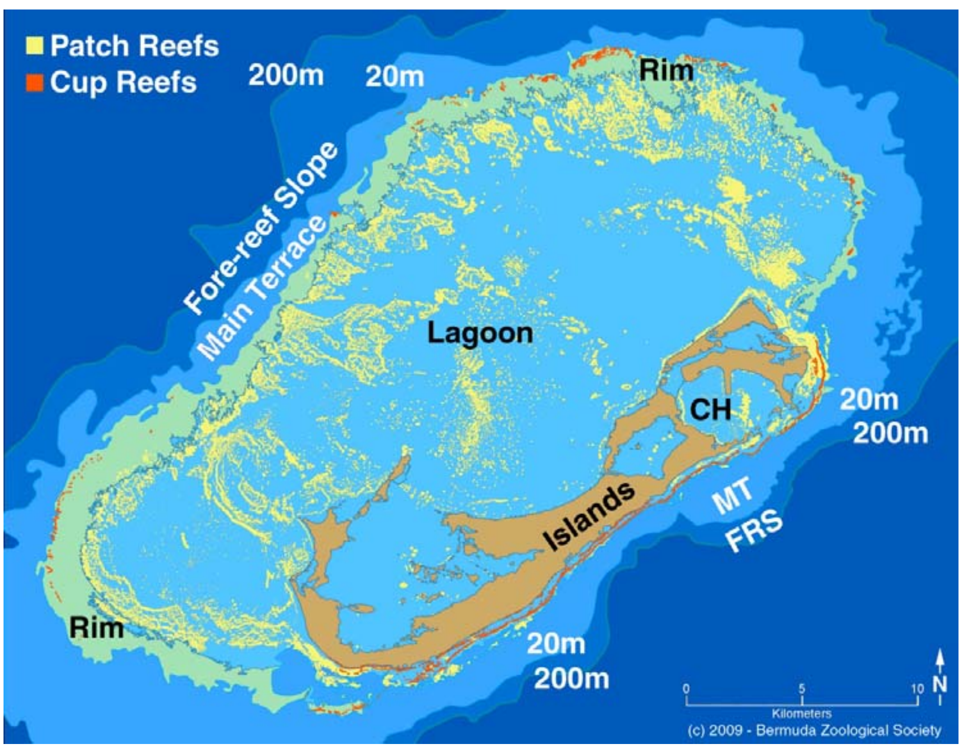

FIGURE 1.2. BERMUDA REEF CHART IDENTIFYING DIFFERENT REEF TYPES AND BOUNDARY OF STUDY.

The geographical boundary selected for this study was based in part on the description of fishing grounds, and tourism use. In addition, substantial biological data is available within this boundary, including reef species richness, providing a sound scientific basis and enabling a more comprehensive analysis of the economic value for Bermuda's coral reefs.

1.4 Policy Issues and Threats to Coral Reefs

Bermuda's coral reefs have a long history of protection. In 1966, Bermuda passed the Coral Reef Preserves Act. In 1978, the Bermuda government responded to the increasing popularity of bleached corals as curios with a protected species order that completely banned the harvest of any coral, stony or soft. Conservative measures in fisheries management and the protection of coral reefs have resulted in a healthy reef; in spite of this, Bermuda's reefs are ranked worldwide as being at "high risk" by the World Resources Institute (Burke *et al.,* 2008). This is attributed in great part to the island's high population density existing within 20km of the coral reefs, and the increasing threat potential associated with shipping traffic and coastal development. Impacts on Bermuda's reefs have been observed in the past during such events as the dredging of Castle Harbour for the airport construction, ship groundings and pollution and sedimentation in shipping channels.

Many of the policy issues adversely affecting Bermuda's coral reefs result from the lack of formal procedure when "planning" or "developing" in the marine environment. Although Bermuda is essentially a coral reef preserve under the current legislation, activities or developments are allowed through special permit issued by the Minister of the Environment. Additionally, environmental impact assessments are not mandatory and only recommended for larger developments by the Marine Resource Board, an advisory board to government. Finally, community support is virtually non-existent when reefs are threatened by marine developments, unlike that witnessed for terrestrial activities, due to the nature of the marine environment, where there is often no immediate, direct or visible impact on residents.

Due to the lack of policy safeguards and environmental assessment procedures regarding developments in the marine system, and the absence of a mechanism for integrating long-term, multiple environmental values into policies, plans and projects, decisions are typically driven by short-term tourism or business interests. This yields little consideration for the long term multiple benefits provided by the marine environment and servicing many community groups.

The threats faced by Bermuda's coral reefs can be summarised as follows:

1. Increasing marine transport/advent of larger and greater number of ships: Marine transport is crucial to Bermuda's sustainability, as there are limited resources on the island, and most equipment, materials and food are imported on cargo ships. The increasing development and level of consumption results in increased transport and hence the need to improve the management of marine transport, namely the modification/building of new docks, the passage of cargo ships, etc. In addition, the changing cruise ship industry, tending towards larger ships, calls for modifications to the coastal and marine environment. Shipping channels need to be modified for safe passage, and berths need to be increased in size to accommodate larger ships. Thus, increased shipping activity and size of ships results in the dredging of channels and coastal development. The potential impacts of increased marine transport have been identified as follows: (a) Destruction of reefs for enhanced passage; (b) Pollution and sedimentation of shipping channels; (c) Impact on recreational and commercial fisheries; (d) Increased potential in grounding of boats with associated destruction; and (e) Tourism repercussion- quality of visiting experience declines with poorer reefs.

2. Recreational boating: Impacts of this human activity on reef systems include anchor damage, and mooring effects. In addition, building of private docks negatively affects surrounding coral and sea grass species.

3. Other threats: Leaching of nutrients from domestic cesspit tanks has been associated in the past with ecological changes in the inshore waters (Bodungen *et al.*, 1982). In addition, effluents of corporation sewage plants are often nearby coral reef systems and potentially impact the surrounding systems. Although, to date there has been little cause for concern due in part to the high energy nature of some of these sites. Similarly, chemical contamination into inshore waters is a possibility through land run-off following heavy rains. The use of pesticides, especially on golf courses, is one of the identified sources, but has to date been shown to be a greater matter of concern for groundwater and ponds, than for reef systems.

The more immediate threat to Bermuda's coral reef system relates to the change in maritime transport mentioned above; more specifically, this involves the renewed use of the existing North Channel on the outer rim of the lagoon. This passage has been rarely used until recently, and has remained for this reason a pristine coral reef. The issue lies in that the larger ships (namely the mega cruise ships) cannot physically pass through the commonly used South Channel, a passage located approximately 1.5km offshore. Frequent and regular marine traffic in this passage has resulted in repeated sedimentation affecting the health of the coral reefs. Limited by depth and width of this passage, mega cruise ships have been coming into the West point of the island using the pristine North Channel since 2005. However, ship agents are concerned for the safety of the boat, as the passage remains narrow and extremely difficult in windy conditions. In addition, a more direct passage from the North Channel to the docking area is called for by ship agents, requiring the cutting of the reefs in certain locations. There is therefore, a need to expand either the North or South Channel to ensure safe passage of larger ships and in the case of the former, reduce travel time. The Department of Marine & Ports is considering a Cost Benefit Analysis (CBA) of the modifications required for both channels; the incorporation of the Coral Reef Total Economic Value at this time would introduce the environmental cost in this analysis. Environmental values of the services provided by coral reefs should definitely be included in this Cost Benefit Analysis, and thus be directly considered in a key policy decision.

1.5 Valuing Bermuda's Reefs

Many of the activities that damage coral reefs—including overfishing, dredging, or discharge of sewage near reefs—occur because an individual or group seizes an immediate benefit, without considering the long-term consequences. Often, the party that gains is not the one that bears the cost. A new development may pollute and degrade an offshore reef, but those who suffer are the fishers or the divers who use that reef. Shortcomings in management practices often stem from inadequate information on the economic and social impacts of different activities, and a focus on short- rather than long-term benefits. When the benefits coral reefs provide to the economy of the island are under appreciated by policy-makers, decisions remain business driven for the short-term, and long-term sustainability of the services provided to the Community is jeopardized.

The economic valuation of ecosystem goods and services is increasingly used worldwide, gaining popularity because it offers a useful means of inserting the concept of ecosystem value into policy discussions and decision-making (Van Beukering and Slootweg, 2010). By quantifying—even imperfectly—the value of an array of environmental goods and services under different development scenarios or policy options, the total costs and benefits (as well as the "winners and losers") are made explicit. It is hoped that an increased awareness of the economic values of ecosystems will lead to more sensible, far-sighted decision-making than is currently the case in coastal areas around Bermuda.

Estimating the economic value of coral reefs in supporting the well-being (including both social and financial benefits) of local people is neither easy nor straightforward. The methodology used for determining the Total Economic Value (TEV) is diverse among studies, and makes comparisons among sites difficult. The TEV framework divides the value of ecosystem goods and services into use and non-use values. Use values are further broken into direct use, indirect use and option values. Direct use values include consumptive uses – such as fish for food- and non-consumptive uses, such as tourism and recreation. Indirect use values include ecosystem services such as shoreline protection. Non-use and option values are the most controversial elements of TEV; they are the most difficult to measure quantitatively and have the greatest uncertainty attached to them. This is explained in detail in Chapter 7.

The greatest part of the TEV obtained for Bermuda's reefs refers to the more tangible direct and indirect use values. The study focused on these values in order to deliver a TEV which is understood by all, widely accepted throughout the community and the government, and ultimately used in future policy and decision-making. The approach used here focuses on six key ecosystem goods and services: (1) Coral reef-associated tourism, (2) Reef-associated fisheries, (3) Amenity or reef-associated surplus value on real estate, (4) Physical coastal protection, (5) Reef-associated recreational and cultural values, and (6) Research and education value. The approach used to quantify the values for each of the six ecosystem services in the current study is summarised in Figure 1.3, including both data collection and valuation techniques. Each approach is explained in detail in the following chapters.

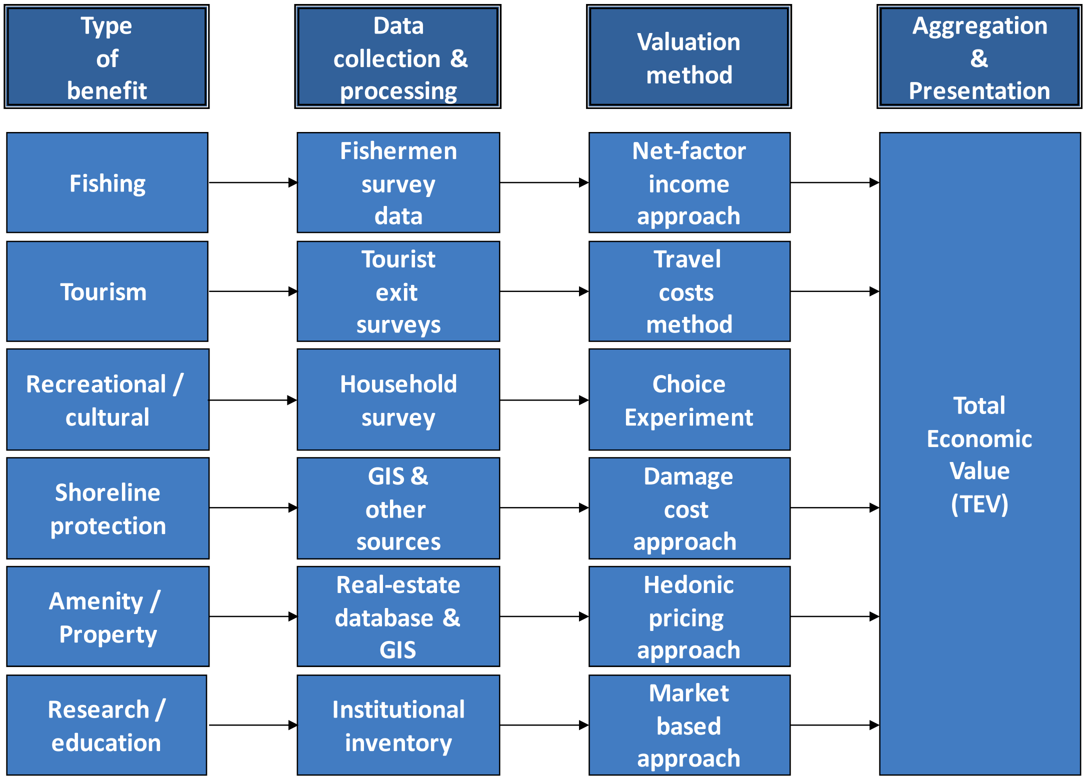

FIGURE 1.3. SERVICE AND VALUATION TECHNIQUES USED IN DETERMINING TEV FOR BERMUDA'S CORAL REEFS.

1.6 Expected Outcomes

Economic valuation has a wide range of policy applications. In Bermuda, we expect this coral reef valuation to contribute to policy and decision-making by:

- Estimating the economic value of coral reef goods and services that can be incorporated into cost-benefit analyses that compare different development or management scenarios, such as those required for the accommodation of safe ship passage, residential and tourist developments, or different types of sewage treatment;

- Evaluating the costs and benefits of different levels of investment in coastal management, fisheries management, or marine protected area (MPA) management and enforcement of regulations;

- Raising awareness by estimating the economic value that Bermuda's coral reefs contribute to the wellbeing of Bermuda's citizens and to the island's economy. This could argue for increased investment in maintaining coastal water quality or managing coastal development;

- Identifying sources of financial support- such as setting tourist fees for recreational diving, establishing an environmental levy;

- Estimating coral reef value to underpin fines or other forms of compensation for coral reef damage from marine vessel groundings, anchors, oil spills, etc. (Damage compensation usually includes the cost of assessment, monitoring, and restoration, as well as the lost revenue / value of services, while the reef is degraded).

There are examples worldwide of the successful application of environmental economic valuations to policy decisions. One such example is in Bonaire, Netherlands Antilles, where the 'Willingness to Pay' (WTP) by scuba divers was used to support a fee of US$10 per diver in the Bonaire Marine Park (Dixon *et al.*, 1993). This fee was later increased to US$25 per diver and US$10 per visitor for other users, and generates a cash flow sufficient to cover the costs of park management and enforcement of regulations. As a result, Bonaire has some of the best managed and healthiest coral reefs in the Caribbean. It is hoped that results of the Bermuda coral reef economic valuation study will provide the necessary information to assist sustainable environmental policies.

The report is divided into the following seven Chapters: Tourism, Fisheries, Amenity, Recreational and Cultural, Coastal Protection, Total Economic Value and Conclusions. Each of the reef-associated chapters includes the methods used, results and monetary value for the service. The Total Economic Value chapter synthesizes all values into one. Finally, the last chapter summarises the lessons learnt, as well as recommendations on the means to integrate the Coral Reef Total Economic Value into decision-making during future development scenarios. It is worthwhile adding that a policy brief is also produced in conjunction with this report for the benefit of the Government of Bermuda.

2. Tourism value

Loes Looijenstijn-van der Putten & Pieter J.H. van Beukering

2.1 Introduction

The tourism sector is one of the most important industries of Bermuda. In 2007, over 660,000 people visited Bermuda (Bermuda Department of Tourism, 2007a). This study aims to assess the contribution of reef-associated tourism value to the island's overall economy. In order to achieve this, the importance of the coral reef ecosystem to the visitor's experience is investigated, taking in consideration that not all visitors come to Bermuda for a reason related to coral reefs. In addition, the contribution from both cruise ship tourism and air visitors to the reef-associated tourism value is distinguished. Data was gathered through available documentation published by the Department of Tourism, and through empirical research. For the latter, two surveys were designed and distributed specific to this study: 1) A reef-associated tourist operator survey providing revenue data, and 2) a tourist exit survey giving insight into the motivations of tourists for visiting Bermuda, expenses incurred during the visit, and the 'Willingness to Pay' for reef conservation.

The economic analysis used to estimate the tourism value of Bermuda's coral reefs involves three methods, including both revealed and stated preference methods:

- The *travel cost method* is a revealed preference method resulting in what is termed the "consumer surplus", or the value of ecosystems to tourist recreation from the visitor's perspective. The method is based on the assumption that travel expenses incurred by tourists to visit a site represent the price of access to the site (Van Beukering *et al.,* 2007a). Based on the travel cost information of visitors, the demand for the services provided by the site can be estimated.

- The *net factor income* yields a value for "producer surplus", or the value of the ecosystem in the production of a marketed good, generated through paid activities such as SCUBA diving and snorkeling. The net factor income relies on determining the percentage of profit made which can be considered as value added to the coral reef services. For air visitors, the value added is extrapolated from other studies; for cruise ship tourists, there is no such documentation and the value added has to be to be calculated for this study.

- The *contingent valuation method* results in a 'Willingness to Pay' value for the conservation of the ecosystem, and thus estimates the potential additional consumer surplus.

All three methods and values, summarised in Figure 2.1, are used to estimate the reef-associated tourism value and are explained more thoroughly in Appendix I.1.

FIGURE 2.1. METHODS USED TO VALUE CONSUMER SURPLUS, PRODUCER SURPLUS AND 'WILLINGNESS TO PAY' CONTRIBUTED TO BY TOURISTS FOR CORAL REEF-ASSOCIATED ACTIVITIES.

2.1.1 Challenges and Limitations

I. Common practice in calculating travel costs is to account for the time tourists spend in reaching their destination. In the case of cruise ship passengers, it is difficult to assess and separate travel costs from the costs of staying on Bermuda. Therefore, in the current study, the monetary costs of travel to the site, the time costs of travel and the monetary costs of staying (i.e. accommodation and meals) are included. This is explained in detail further.

II. A tourist may have several reasons to visit a location. In this instance, the percentage of travel costs and travel expenditures allocated to the coral reef value is estimated by assessing the percentage of anticipated reef-related activities contributing to the motivation for travelling to Bermuda.

III. The share of costs incurred by travel attributed to the destination is different for air tourists and cruise ship visitors. For the latter, the travel time at sea is considered as "half the pleasure" of the trip, and hence not related to the destination; for this reason, it is considered as contributing only 50% to travel costs incurred to visit coral reefs. On the other hand, for tourists arriving by air, travel time is functional and not part of the pleasure.

IV. In some instances, Bermuda is only one of four destinations during a given cruise. In such cases, travel costs incurred to visit Bermuda are assumed to be one fourth of total travel costs related to the destination. On the other hand, for air tourists, all airplane trips are considered as single-destination trips. For these visitors, 100% of the travel costs are related to the destination itself, however, the coral reef-related share of the trip is thereafter estimated and the travel cost amount is discounted accordingly.

2.1.2 Reef-associated Tourism Activities

Note that all information presented here considers strictly international tourist use of the coral reefs. The reef-associated international tourism activities include:

- *Travel*: Travel to Bermuda, as well as local transportation to reef-associated activities is taken into account. Various sources of information were used to collect this information such as travel agents, ticket booking websites (e.g. www.travel-o-city.com), as well as local cost estimates (e.g. fuel, rental).

- *Accommodation*: Reef-associated share of accommodation expenditures is identified. This information was compiled through the tourist exit survey.

- *Reef recreation*: Reef recreation includes tourist use of coral reefs for snorkeling, diving, boat tours and recreational fishing. Data was obtained both from boat operators, and from the tourist exit survey.

- *Additional miscellaneous expenditures*: Visitor expenditures on other activities such as restaurants, shopping, etc. are taken into account. This information is compiled from the tourist exit survey, and used to accordingly adjust the reef-related tourism value.

2.2 Bermuda Tourism Market

Bermuda is an attractive tourism destination, due in part to its excellent infrastructure, easy access, and natural beauty. In 2000, although visitor numbers were only half of what they were in 2007, Bermuda ranked first among all tropical islands worldwide on the basis of tourism density (i.e. the number of tourist days divided by the total land area) (McElroy, 2003).

2.2.1 Cruise Ship Tourism Sector

The cruise ship tourism sector in Bermuda forms a substantial part of the total tourism sector of the island. Data from the Department of Tourism indicates that in 2007 a total of 195 cruise ships called in Bermuda carrying 354,024 passengers, a 5.3% increase compared with 2006. Based on a total of 663,767 visitors in 2007, the cruise ship sector was responsible for more than half of the total number of visitors that year (Bermuda Department of Tourism, 2007a). The cruise ship season in Bermuda runs from April to November, with most frequent ships originating from the Northeast and Mid-Atlantic coasts of the USA. Ports of origin include: Cape Liberty, New York, Philadelphia, Boston and Baltimore. Bermuda is a destination of choice for these ships, because of its relative proximity to the Eastern coast of the U.S. compared to other Caribbean island destinations. Usually, Bermuda is the only destination for these cruise ships, but occasionally, part of a small eastern Caribbean cruise. Total cruise duration, is generally five to nine nights, with an average of two to four nights spent in Bermuda's ports (IEc and Price, 2006). According to reports by the Bermuda Department of Tourism, key on-island activities in 2007 of cruise ship passengers on Bermuda are shopping (65%), visiting beaches (41%), swimming (34%), snorkeling (11%) and touring around the island (9%). Key attractions while on the island are the Royal Naval Dockyard (54%), the town of St. George's (41%), Horseshoe Bay (30%), Tobacco Bay (14%) and Dockyard (13%). Approximately, 31% of all cruise passengers purchase an on-island package tour. Most packages are purchased onboard the ship (72%). Glass bottom boat tours are among the most popular tours, closely followed by tours around the island (Bermuda Department of Tourism, 2007b). The nationality of cruise ship tourists is primarily American (Table 2.1).

TABLE 2.1. NATIONALITY OF BERMUDA'S VISITORS IN 2007

	Air travelers	**Cruise ship tourists**
USA	75%	91%
Canada	9%	3%
UK	10%	2%
Rest of Europe	2%	2%
Rest of world	4%	1%

Source: Bermuda Department of Tourism (2007a)

2.2.2 Air Passenger Tourism Sector

The majority of air passengers also come from the U.S.A. as seen in Table 2.1, although the percentage is less than that seen for the cruise ship sector (75% for air). Approximately, 25% of the air passengers come from other parts of the world, namely from the U.K. and Canada, compared to 8% for cruise ship visitors (Table 2.1). Compared to cruise ship passengers, air visitors spend more time on the island (i.e. 5.4 nights). Over 60% of all visitors arriving by airplane are older than 40 years (Bermuda Department of Tourism, 2007a).

2.2.3 Tourism Expenditures

For a better understanding of the overall size of the tourist market in Bermuda, reported on-island visitor expenditures for both air and cruise tourists are given in Table 2.2. Although cruise ship arrivals constitute more than half of total arrivals in Bermuda, the on-island expenditures of cruise ship tourists amount to only 9% of air tourists' expenditures in 2007. According to the Bermuda Department of Tourism (2007), an average air visitor spends US$ 1,316 of which 57% is on accommodation, and 22% on meals and beverages. On the other hand, an average cruise visitor in the same year spends only US$107 of which 18% is spent on meals and beverages, 52% on shopping and 32% on on-island activities. The decrease in expenditures of cruise ship tourists between 2006 and 2007 can be attributed to the increase in one-day layover ships, whose passengers traditionally spend less money (Bermuda Department of Tourism, 2007a).[1]

TABLE 2.2. AVERAGE ON-ISLAND VISITOR EXPENDITURES 2006 AND 2007

	Total 2006 (million US$)	**Total 2007** (million US$)	**Per visitor 2006** (US$)	**Per visitor 2007** (US$)
Air arrivals*	351	403	1,174	1,316
Cruise arrivals**	41	38	123	107

* *Note that throughout this chapter air visitors and air tourists are used alternatively and business visitors are excluded from the analysis.*

*** Excluding visitor's head tax*

Source: Bermuda Department of Tourism (2007a)

2.3 Tourist Exit Survey Data Summary

2.3.1 Bermuda Tourist Profile

A tourist exit survey additional to that routinely administered by the Department of Tourism, and developed specifically for this study was conducted in July/August 2008 (see Appendix I.2 for the complete questionnaire). A total of 407 questionnaires were given, surveying 201 (49.4%) air tourists and 206 (50.6%) cruise ship tourists. The tourist profile is therefore generated from a relatively equal number of cruise ship and air passengers. Surveys were carried out in the departure lounges of the International Airport as well as at the three existing cruise ship terminals. They were conducted face-to-face by trained interviewers, in order to optimise survey quality. Only visitors coming to Bermuda for leisure were surveyed; all those whose primary purpose was business related were excluded, based on the unlikelihood that such visitors derive any benefit from Bermuda's reefs.

A full description of the survey results on the tourists visiting Bermuda, their origin, and the description of their trip is given in Appendix I.3. Data is summarised in Box 2.1.Results relating to tourists origin are in agreement with those reported by the Department of Tourism (2007a) but differ slightly for the length of stay on Bermuda. The survey below indicates that air passengers stay 7 days (rather than 5.4) and cruise ship passengers stay 2 days (rather than 4) (Department of Tourism, 2007a).

[1] Cruise ships contribute to the Bermudan economy by : (1) On-land expenditures of cruise ship passengers; (2) Service fees to the Department of Marine & Ports (US$8,000 – US$10,000 per ship per week); (3) Docking fees to the corporations (length of ship times US$6,50 times number of days); and (4) Passenger tax (US$ 150,000 per ship).(IEc and Price, 2006)

BOX 2.1 SUMMARY OF TOURIST INFORMATION RESULTING FROM THE EXIT SURVEY JULY 08

General description

- 48% of tourists are female and 52% are male.
- 50% have a university or college degree and 28% have a master or other advanced degree.
- 80% are employed and 19% are not in the workforce (most of them retired).
- The average age is 48 years.
- The average household composition is 2 adults and 0.8 children under 18 years.
- The average gross income is US$120,000 (net income US$95,000).

Origin

- Most tourists come from the East Coast of the U.S.A.
- 95% of cruise ship tourists are from the East Coast of the U.S.A. (91% as per Department of Tourism exit survey)
- 71% of all air tourists originate from the USA (75% as per Department of Tourism exit survey), and 23% from Europe

Trip description

- Air tourists stay 7 days in Bermuda and cruise ship tourists a little more than 2 days (Department of Tourism exit survey: 5.4 and 4 days respectively).
- Repeat tourism: Air tourists surveyed were in Bermuda for the 4th time and cruise ship tourists for the 2nd time.
- 33% of air tourists booked their trip as a package. Most packages (76%) include flight and accommodation. 100% of all cruise ship tourists' travel arrangements are packages

2.3.2 Travel Costs and Expenditure Data

Average travel costs, based on the tourist exit survey, incurred by visitors to Bermuda differ between air and cruise ship tourists, as seen in Table 2.3. Results indicate that accommodation is the largest expense incurred, followed by the flight, meals, and shopping for air passengers. On the other hand, cruise ship passengers spend a large sum on their package trip, prior to the departure, and spend much less during their stay in Bermuda. However, the amount spent for reef-associated activities between the two types of tourists is comparable, with air visitors spending more for diving. In total, cruise ship tourists spend almost half as much as air tourists. The average travel costs, when pooling results from both the cruise ship and air tourism sectors, amounts to US$1,925 (inclusive of all costs).

TABLE 2.3. AVERAGE TRAVEL COSTS TO VISIT BERMUDA FOR BOTH THE AIR AND CRUISE SHIP SECTORS.

	Air	Cruise
Package*	$405	$1,089
Flight	$569	$6
Accommodation	$661	$122
Diving	$19	$5
Snorkeling	$12	$17
Touring the reef	$7	$11
Shopping	$229	$84
Local transportation	$99	$20
Meals	$383	$38
Other	$46	$29
Total	$2430	

** The travel costs are averages of the total sample (i.e. the average travel cost of a package for air travelers that actually bought a package is US$1,626). There is no overlap between travelers travelling with a package and travelers that individually arranged their trip.*

Pre-paid travel costs, made at home prior to travelling, as estimated from the tourist exit survey are given in Table 2.4.

TABLE 2.4. TRAVEL-ASSOCIATED COSTS PRE-PAID PRIOR TO TRAVELLING

	Air	Cruise
Package*	$405	$1,089
Flight	$569	$6
Accommodation	$348	$122

* *The travel costs are averages of the total sample (i.e. the average travel cost of a package for air travelers who purchased a package is US$1,626). There is no overlap between travelers with a package and travelers who made individual arrangements*

As shown in Table 2.5, when considering on-island expenditures only, air tourists spend more than five-fold the amount spent by cruise ship tourists. This is in accordance with results from Bermudan government exit surveys, reporting US$1,316 for air tourists and US$107 for cruise ship tourists (see Table 2.2, Department of Tourism, 2007a). This implies that on-island expenditures by visitors –i.e. directly benefiting the island's economy- are mainly contributed to by the air tourism sector, with only 7%-9% coming from the cruise ship tourism sector.

TABLE 2.5. ON-ISLAND EXPENDITURES FOR AIR AND CRUISE SHIP VISITORS

	Air	Cruise
Accommodation*	$313	
Diving	$19	$5
Snorkeling	$12	$17
Touring the reef	$7	$11
Shopping	$229	$84
Local transportation	$99	$20
Meals	$383	$38
Other	$46	$29
Total	$1,107	$204

**Please note this only relates to on-island expenses for accommodation; approximately 50% is pre-paid (see Table 2.3)*

2.3.3 Coral Reef-associated Activities for Tourists

There are a number of reasons or motivations for tourists to choose a destination, as listed in Table 2.6. The percentage use of the coral reefs by tourists is estimated through the following activities: Snorkeling, diving, touring the reef and – because Bermuda's beaches are 100% coralline relying completely on coral reefs for their formation– visiting the beach. Survey results indicate that 36.8% of the motivation of airplane tourists is associated with the coral reefs with a slightly higher percentage for cruise ship tourists of 39.7% (Table 2.6). Visiting the beach is the highest reef-associated motivation for Bermuda's tourists in general; 15.8% of visitors come to Bermuda for its beaches. Snorkeling and touring the reefs appeal to 8.6% and 8.3% of all visitors respectively, contributed to in greater part by cruise ship visitors. SCUBA diving motivates 5.7% of all tourists to visit Bermuda, with a comparable contribution by the air and cruise ship sector.

For the purpose of the current economic analysis, tourists can be arbitrarily classified as "active" or "inactive" users, where the former includes tourists who have dived and/or snorkeled previous to their current trip. Air tourists are slightly more "active" than cruise ship tourists according to this study's survey; the former average 20 dives and 34 snorkel experiences, compared to 14 dives and 26 snorkel experiences reported by cruise ship tourists (see Appendix I.3 for more detail). This potential effect on the amount of money spent on these activities is not reflected in the results of this survey. Recreational fishing is the least motivating factor for tourists to visit Bermuda (4.9% in total).

Travel costs for diving and snorkeling are generated from a total of 130 tourists surveyed, who spent time diving and/or snorkeling (41 and 89 respectively).

TABLE 2.6. MOTIVATION TO VISIT BERMUDA FOR AIR AND CRUISE SHIP TOURISTS

	Air	**Cruise**	**Total**
Visiting the beach	16.1%	15.4%	15.8%
Sightseeing	13.7%	15.3%	14.5%
Eating and drinking	16.0%	11.5%	13.7%
Shopping	11.1%	11.3%	11.2%
Snorkeling	7.3%	9.6%	8.6%
Touring the reef	7.4%	9.1%	8.3%
Sailing	6.2%	6.6%	6.4%
Diving	5.9%	5.5%	5.7%
Playing golf	5.5%	5.4%	5.4%
Fishing	4.6%	5.2%	4.9%
Business	4.5%	4.3%	4.4%
Other	1.5%	0.7%	1.1%
Total	100%	100%	100%
Total reef-related	**36.8%**	**39.7%**	**38.3%**

The importance of the "health" and pristine appearance of coral reefs in Bermuda, was reflected in the survey responses; both air and cruise ship tourists consider the coral reefs (rather than associated fauna) as the largest attraction by visiting divers and snorkelers (see Table 2.7).The sighting of reef fish ranks a close second as a tourism asset. For reasons of simplification, it is assumed that wrecks are not necessarily reef-related although several wrecks in Bermuda are located in reef areas and attract reef fish. It is interesting to note that there is little difference between responses from active and non-active user (Table 2.7), when assessing the relative importance of coral reefs themselves as a tourism asset. However, given the small sample size for non-active users (n=12), this needs to be verified. It is worthwhile noting that of the tourists surveyed, 14% would not have come if coral reefs were known to be dying or damaged. Extrapolating this percentage to a total of 660,000 visitors reported on the island in 2007, this translates into a potential decrease of more than 90,000 tourists per year. More specifically, 19% of cruise ship and 8 % of air tourists would not have visited Bermuda, corresponding to over 66,000 fewer cruise ship passengers and 24,000 fewer air arrivals.

TABLE 2.7. RELATIVE IMPORTANCE OF CORAL REEF ASSOCIATED SIGHTINGS FOR AIR AND CRUISE SHIP DIVERS AND SNORKELERS

	Active divers/snorkelers (n=139)	**Non-active divers/snorkelers (n=12)**
Coral reef	35%	33%
Fish	31%	29%
Wrecks	20%	21%
Sharks	11%	9%
Other	3%	8%
Total	100%	100%

2.3.4 Reef-associated Direct Value (Tour Operator Survey)

There are 40 reef-associated tour operators in Bermuda, categorized as follows:

1. Diving (including rent of snorkeling gear) and helmet diving
2. Glass bottom boat operators
3. Small boat rental operators (including rent of snorkeling gear)
4. Boat charter operators (including rent of snorkeling gear)

Data on the direct value generated from coral reef tourism was compiled from information given by tour operators. Thirteen reef-associated tourist operators were interviewed face –to-face, all dive operators (n=5), three glass bottom and rental boat operators, and two charter boat operators. The questionnaire (see Appendix I.4) was designed to obtain data on the gross revenue and costs associated with reef recreation, a measure of the type of tourists attracted to reef-related activities, and an additional estimate of the perceived threats and solutions to ensure continued visitor satisfaction. The 'Willingness to Pay' for conservation of the coral reefs by tourists benefiting from this ecosystem was also estimated within the scope of the survey.

Detailed results of the survey are provided in Appendix I.5. In summary, prices charged for reef-associated activities were found to be relatively equal among operators. The majority of tour operator customers (69%) are from the USA. A little more than half of all foreign customers arrive in Bermuda by air (56%); a large proportion (46%) comes by cruise ship, and only 1% arrives by personal yacht ('yachties'). According to tour operators, most international visitors show sensitivity to the environment –for example, demonstrate concern for fish and coral preservation, or show responsible behaviour in waste disposal. Air visitors appear slightly more sensitive than 'yachties' and cruise ship tourists (Figure 2.2). The health of the coral reefs and its associated fish fauna is reported to be an important component of the reef visitation experience.

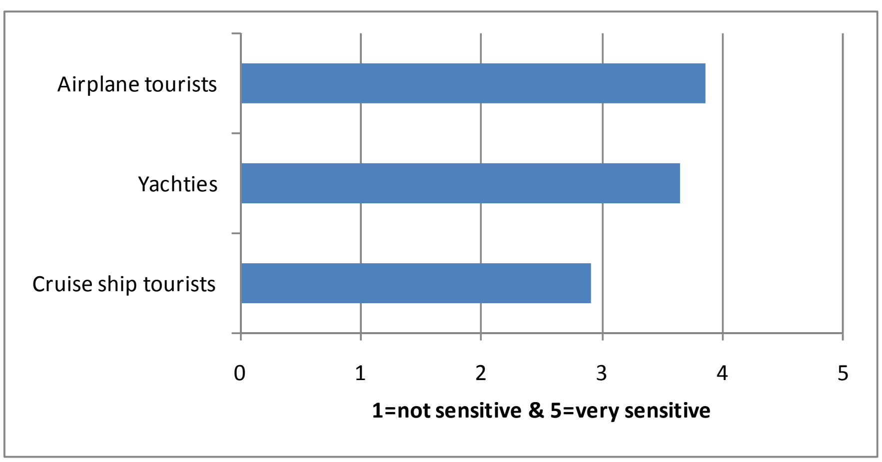

FIGURE 2.2. ENVIRONMENTAL SENSITIVITY OF VISITORS AS PERCEIVED BY TOUR OPERATORS IN BERMUDA.

According to the tour operators, the quality of the coral reefs has a high impact on their business. Most of the operators (58%) report that the quality of Bermuda's coral reefs has improved during the last five years, whereas 25% experienced no change, and 17% experienced a decline in quality. As seen in Figure 2.3, tour operators consider overfishing- both recreational and commercial- as the most important threat to coral reefs, followed by sewage disposal. The impact of cruise ships and coastal development are considered minor threats. Improved environmental education, enforcement and legislation were suggested as means to minimise threats; restriction and/or prohibition of jet skis, and the establishment of marine parks were given as examples to ensure preservation of this natural resource. Only one third (33%) of all operators are in favour of an extra visitor fee paid towards the protection of coral reefs; the lack of support for this concept is due in great part to the feeling that water sports bear minimal impact on the reefs; hence, operators hold minimal responsibility, and yet fear that the financial burden of reef protection will become theirs (Appendix I.5 for detailed survey response)

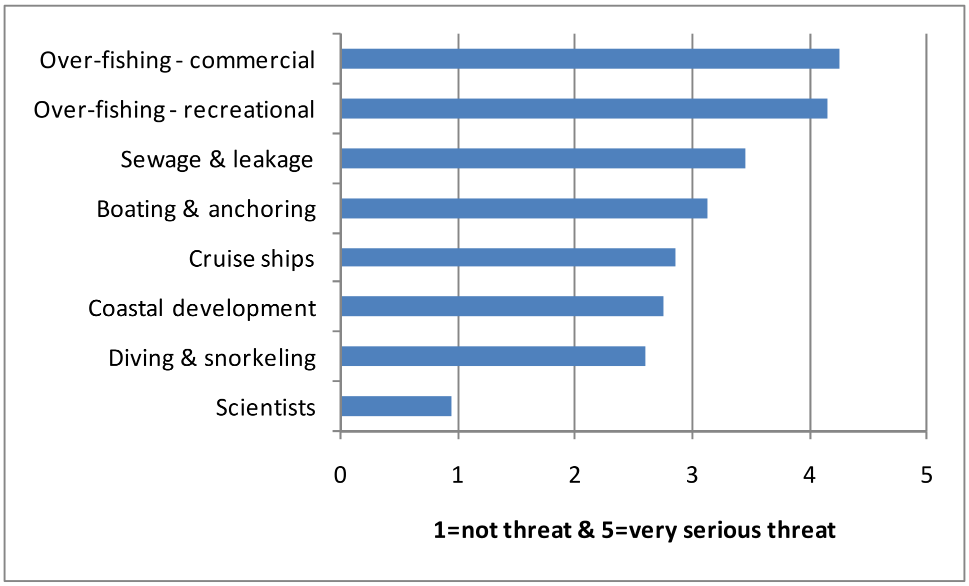

FIGURE 2.3. PERCEPTION OF TOUR OPERATORS ON RELATIVE IMPORTANCE OF THREATS TO BERMUDA'S CORAL REEFS (N=13).

The reef-associated tourism gross revenue for Bermuda–extrapolated from the data set compiled from 13 reef-related operators – is estimated at US$ 7.4 million (Table 2.8). The profit margin is estimated to be 28%, based on the costs reported by tour operators interviewed. Personnel, boat maintenance and fuel are the three most important costs (41%, 20% and 17%), amounting to 78% of total business costs. Diving and Glass bottom boat operators generate the most important revenue amounting to 69% of the total reef-associated gross revenues. According to the operators, the market growth, in terms of customers and revenues, during the last 5 years is estimated at 13%. Note that if this aggregated sum would also include non-reef associated revenues, the total gross revenue adds up to approximately US$ 10 million in 2007 which is in line with earlier estimates by the Ministry of Environment (2000) ranging between US$ 7.5-US$ 11 million per year.

TABLE 2.8. EXTRAPOLATED REEF-ASSOCIATED GROSS TOURISM REVENUE IN BERMUDA (2007)

	Number of operators	Total revenues (US$)
Diving and helmet diving operators	5	2.7 million
Glass bottom boat operators	5	2.4 million
Small boat rental operators	5	1.0 million
Boat charter operators	25	1.3 million
Total		**74 million**

2.4 Consumer surplus

To assess the value of coral reefs used for recreation in Bermuda, the zonal travel cost method was used, based on the assumption that the travel expenses incurred to visit a site represent the price of access to the site (Van Beukering *et al.,* 2007a). Ten zones were defined, based on travel time to Bermuda (Table 2.9). Given the number of visits to Bermuda and the population for each zone, visitation rate- i.e. the number of visits to Bermuda per thousand inhabitants for each zone- can be calculated. Average travel costs incurred by tourists to visit Bermuda, as given in Table 2.9, were calculated based on the five components outlined in Table 2.10.

TABLE 2.9. TRAVEL ZONES FOR VISITORS TO BERMUDA WITH ASSOCIATED TRAVEL COSTS.

Zone	Number of visits	Population	Visitation rate*	Travel costs (USD)
East coast	500,708	118,417,689	4,2283	1,197
Mid East	57,647	106,619,715	0,5407	1,340
Mid West	9,882	44,354,903	0,2228	3,933
West Coast	13,177	63,372,845	0,2079	1,466
Alaska	1,647	5,143,364	0,3202	1,628
South America	0	576,000,000	-	-
Europe	77,412	736,000,000	0,1052	3,906
Africa	0	967,000,000	-	-
Asia	1,647	4,052,000,000	0,0004	3,627
Oceania	1,647	35,000,000	0,0471	2,813
Total	**663,767**			**1,582**

** Visits per 1,000 inhabitants*

Source of population: World Development Indicator (2008)

TABLE 2.10. FIVE TYPES OF TRAVEL COST (PER TOURIST)[2]

Cost category	Air (USD)	Cruise (USD)
Flight and/or cruise, accommodation, meals (TC1)	$2,153	$1,308
Other expenses in Bermuda including activities (TC2)	$275	$113
Travel cost to port of embarkation (TC3)	$0	$106
Cost of travel time to port, flight and at sea (TC4)	$141	$365
Cost of travel time in Bermuda (TC5)	$617	$238

Data for TC1 (flight/cruise, accommodation, meals) and TC2 (other expenses in Bermuda) were obtained from the current study's tourist exit survey. TC1 is a combination of transportation costs to the destination, accommodation and meals; it is difficult to separate these three costs for tourists travelling on a package- especially true for cruise passengers. TC2 includes travel costs within Bermuda, expenses for tours (e.g. snorkel and dive trips), and other costs (e.g. souvenirs). TC3, TC4 and TC5 are calculated on the basis of the place of residence of the respondent, port of embarkation, type of transportation to Bermuda, household income and working hours (Table 2.10). Costs of travel time are considered relevant for those tourists who are employed only, as travel time is an opportunity cost if holiday time is limited. For respondents who preferred not to disclose their income an estimate of US$ 100,000 was used, representing the average income of the survey sample. The means of all five types of travel costs are substantially different for airplane tourists and cruise ship tourists.

Based on the travel cost information above, the demand for the services provided by coral reefs can be estimated by calculating a demand-curve for the individual visitor, extrapolating results over the total population to derive the measure of total benefits. To estimate the demand curve, two steps are required: (1) Regression on visitation rate per zone and average travel costs incurred by visitors of the zone, and (2) Demand or regression function (see Appendix I.1 for more detail on methodology).

<u>Step 1: Visitation rate vs Travel cost</u>

In Step 1, a linear regression (SPSS 13 for Mac) is run on the visitation rate (independent variable from Table 2.8) and the travel costs (dependent variable), where the 'Travel costs' is the sum of TC1 (flight, accommodation and cruise), TC3 (travel cost to port of embarkation) and TC4 (travel time to port, flight and sea). For cruise ship tourists, the travel costs are 50% of the calculated sum, given that only half of the travel costs are related to the destination itself (Bermuda). The other half of travel costs by cruise ship tourists is related to the pleasure of being at sea.

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[2] Assumptions underlying the calculations: Distances and cost of travel by car and cost of travel by airplane have been retrieved from www.convertunits.com and www.cheaptickets.com, respectively. If respondent lives more than 500 km from port of embarkation he/she is assumed to take the airplane to port, otherwise the tourist will travel by car. The average waiting time at airport is 2 hours one way. Cost of flying is based on return ticket between 15 and 22 October. Since prices are usually higher in the peak season, this assumption may lead to an underestimation of the final travel costs. Note also that actual airfares, rather than travel agent airfares, are used. This may lead to an overvaluation. Both effects possibly outweigh each other.

Unfortunately, it did not prove possible to differentiate air and cruise ship data during the analysis. This is due to the fact that almost all cruise ship tourists originate from the same zone (U.S. East coast), and hence incur similar travel costs to Bermuda when using the zonal travel cost method. This homogeneity in data yields no significant relation between travel costs of cruise ships and the visitation rate. Air and cruise ship tourist travel cost data is therefore pooled. Results show no significant relationship between travel costs and visitation rate (t-value is 0.97 and significance is 0.37), attributed to the lack of variation in the travel costs within the US sample. It is expected that with more observations, other destinations may stand out in the dataset, thereby increasing the range of values in the dataset and subsequently strengthening the relationship. Despite the weak link between actual travel costs and the visitation rate, the coefficients generated were used to calculate the following function for this study:

*Travel costs = 3,434 – 624 * Visitation rate*

Step 2: Demand function

Step 2 involves the calculation of the demand function, based on the above regression function. The function is based on the total number of tourists that visit Bermuda at the current travel costs, and expanded by estimating the number of coral reef visitors with different additional travel costs. The demand function for Bermuda is:

*Additional travel costs = 2.700 - 246 * Visitors*

Demand curve

The demand-curve obtained for Bermuda is illustrated in Figure 2.4, enabling the calculation of the consumer surplus - equal to the area under the curve (see the triangle labeled “CS”). These calculations result in a total consumer surplus for Bermuda of US$ 896 million, yielding a consumer surplus of US$ 1,350 per tourist. This represents the total tourism value of Bermuda, including reef-associated and non reef-associated value.

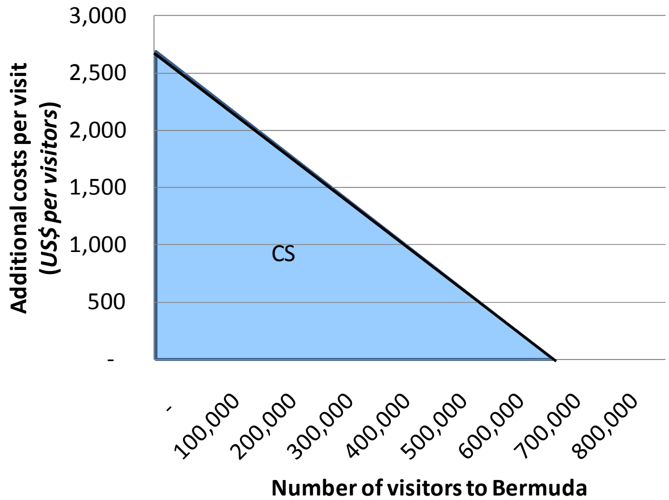

FIGURE 2.4. A DERIVATION OF THE CONSUMER SURPLUS BASED ON THE VISITORS – TRAVEL COSTS RELATIONSHIP FOR BERMUDA'S TOURISTS.

The reef-associated tourism value is estimated based on the percentage of reef-associated recreation, stemming directly (such as diving) and indirectly (such as beach enjoyment) from the coral reef ecosystem. These shares are given in Table 2.6 and are combined with the specific visitor information for air and cruise passengers. The results are shown in Table 2.11. The reef -associated tourism value from a consumer perspective for the cruise ship sector only, approximates US$190 million, amounting to US$40 million more than for the air tourism sector. The total (both air and cruise) consumer component of the coral-reef related tourism value of Bermuda's coral reefs in 2007 is calculated to be US$343 million.

TABLE 2.11. CONTRIBUTION OF TRAVEL COSTS INCURRED BY AIR AND CRUISE SHIP TOURISTS IN BERMUDA TO ACCESS CORAL REEFS FOR RECREATION, GIVEN AS CONSUMER SURPLUS.

	Air	**Cruise**	**Total**
Visitors in 2007	309,743	354,024	663,767
Consumer surplus	$1,350	$1,350	$1,350
Percentage reef-related	36.8%	39.7%	38.3%
Reef-related consumer surplus	$496	$536	$517
Total reef related per year	**$154 million**	**$190 million**	**$343 million**

2.5 Producer surplus

Coral reefs are an attractive asset to tourists, and lead to the provision of a service that can be sold, hence these may be considered a marketed good, with a monetary value. The producer surplus is calculated based on the expenditures of tourists visiting coral reefs, minus the cost of production. The producer surplus of direct and indirect reef-associated operators is based on the reported tourist expenditures for both air and cruise ship tourists (Appendix I.3). Note that expenditures incurred prior to arrival in Bermuda are not considered in the calculation of the reef-related producer surplus, neither are non reef-associated expenditures, such as those incurred during shopping.

In order to estimate the producer surplus of tourism related coral reef services, the net factor income approach is applied (see Appendix I.1). For this, a percentage of each type of expenditure or activity needs to be defined. Due to the lack of information on added value for a number of recreational activities in Bermuda, values are adopted from a similar study on Hawaii's coral reefs (Cesar *et al.*, 2001). The following value added levels are assumed for the current study: 25% for all direct reef - related expenditures on the island; 25% for expenditures indirectly related to the reef, and 2% for flight expenditures. For the expenditures indirectly related to the reef, the added value percentage is applied to only a limited part of the expenditures (Tables 2.12 and 2.13). Not all tourists visit for a single purpose of diving or snorkeling, and hence, similarly to the consumer surplus, the proportion of total expenditures is based on the relative importance of the reefs as assessed by the tourists' motivations to visit Bermuda (36.8% and 39.7% for air and cruise ship tourists, respectively).

TABLE 2.12. PRODUCER SURPLUS AIRPLANE TOURISTS

Item	Average costs	% Value added	% Reef related	Producer surplus
Flight	$771	2%	36.8%	$6
Accommodation	$862	25%	36.8%	$79
Diving	$19	25%	100%	$5
Snorkeling	$12	25%	100%	$3
Touring the reef	$7	25%	100%	$2
Local transportation	$99	25%	36.8%	$9
Meals	$383	25%	36.8%	$35
Total	**$2,153**			**$139**

Assumption: 50% of the costs of a package is 'flight' and 50% is 'accommodation'.

TABLE 2.13. PRODUCER SURPLUS CRUISE SHIP TOURISTS

Item	Average costs	% Value added	% Reef related	Producer surplus
Cruise package	$1,089	9%	39.7%	$39
Diving	$5	25%	39.7%	$0
Snorkeling	$17	25%	100%	$4
Touring the reef	$11	25%	100%	$3
Local transportation	$20	25%	100%	$5
Meals	$38	25%	39.7%	$4
Total	**$1,180**			**$55**

No documentation is available on the value added percentage for the fare of a cruise ship voyage, and is calculated as follows for the purpose of this study: As shown in Table 2.14, revenue generated by cruise ship tourism also includes the fees and taxes paid by cruise ships to Bermuda. Therefore, it is assumed that a minimum of US$ 87 of the costs of the cruise ship flows into the Bermuda economy, corresponding to 9% of the average cruise trip price (see US$ 1,089 in Table 2.13). Therefore, 9% is applied as the producer surplus proxy for the value added of the cruise ship passengers.

It should be noted that this is a high estimate since the costs incurred by the Bermudan government for the required infrastructure to accommodate cruise ships – i.e. building docks and other facilities – are unknown and therefore not taken into account. The real value added of the average cruise ship price to the Bermudan economy is therefore likely to be lower than 9%.

TABLE 2.14. FEES AND TAXES PAID BY CRUISE SHIPS TO THE BERMUDAN GOVERNMENT

Item	Comment	Per ship	Per passenger
Service fee	10,000 per ship per week	$10,000	$5
Docking fee	Length x 6.50 x no. of days	$13,650	$7
Passenger tax	150,000 per ship	$150,000	$75
Total		**$173,650**	**$87**

Source: IEc and Price (2006)

Assumptions: average stay in Bermuda 3 days, average number of passengers per vessel is 2,000

Based on the above calculations, the producer surplus for air visitors is estimated at US$139 per tourist and at US$55 per tourist for cruise ship passengers (see Table 2.15). Based on 663,767 visitors in 2007, the reef-related producer surplus value totals US$62.5 million in that year (Table 2.15), the greatest part being attributed to the air tourism sector amounting to US$42.9 million per year, more than twofold the value of US$19.5million per year contributed to by the cruise ship tourism sector.

TABLE 2.15. TOURISM VALUE OF BERMUDA'S CORAL REEFS FROM PRODUCER PERSPECTIVE

	Air	Cruise	Total
Visitors in 2007	309,743	354,024	663,767
Reef related producer surplus (US$ per visitor)	$139	$55	$94
Reef-related producer surplus per year (million US$)	**$42.9**	**$19.5**	**$62.5**

2.6 Willingness to Pay (WTP)

There is a potential for an additional consumer surplus, based on the willingness of tourists to pay for coral reef conservation. Such 'Willingness to Pay' (WTP) stems from the desire to continually ensure a high quality reef-associated visitation experience, and is evaluated through the tourist exit survey. Tourists interviewed are introduced to this WTP concept in the following way:

"Currently, coral reefs around Bermuda are beautiful and healthy. However there are some threats caused by human activity which can change that. One of them is the increased pressure from tourism. If these threats are not dealt with, they can damage the reefs. This would ultimately mean losing Bermuda's pink beaches and blue waters. To help preserve the coral reefs of Bermuda, extra funds may be needed for which tourists may be asked to pay."

Results indicate that 68% of all tourists visiting Bermuda are, in principle, willing to pay in addition to their current expenses, to fund activities to preserve Bermuda's coral reefs (see Table 2.16). It is worth noting that less air visitors are willing to pay for conservation (60%) than cruise ship tourists (76%).

TABLE 2.16. 'WILLINGNESS TO PAY' BY TOURISTS FOR CONSERVATION OF REEFS IN BERMUDA (NUMBER OF RESPONDENTS AND SHARE BETWEEN BRACKETS)

Answer	Air	Cruise	Total
No	80 (40%)	49 (24%)	129 (32%)
Yes	121 (60%)	157 (76%)	278 (68%)

In a further analysis of the results, it can be seen that the highest percentage willing to pay is found among the "user" group of the cruise ship sector, followed closely by the "user" group of air visitors (79% and 70% respectively)(Table 2.17). The least willing are the "non-user" group of the air tourists, with 45% refusing to pay for coral reef preservation. It is worth noting that 74% of cruise ship passengers who are not actively using coral reefs are still willing to pay extra for the conservation of this ecosystem.

TABLE 2.17. 'WILLINGNESS TO PAY' FOR CONSERVATION OF CORAL REEFS IN BERMUDA BY USERS AND NON-USERS OF REEFS (NUMBER OF RESPONDENTS AND SHARE BETWEEN BRACKETS)

Respondent	Answer	Air	Cruise	Total
Non-users	No	59 (45%)	29 (26%)	88 (37%)
	Yes	71 (55%)	82 (74%)	153 (63%)
Users	No	21 (30%)	20 (21%)	41 (25%)
	Yes	50 (70%)	75 (79%)	125 (75%)

Reasons for the unwillingness to pay by tourists were investigated and are presented in Table 2.18. Most tourists who are unwilling to pay feel that conservation is the responsibility of Bermuda (39% for air tourists and 21% for cruise ship tourists) and that their activities have no impact on coral reefs (36% for air tourists and 19% for cruise ship tourists). Limited funds was a factor for both air and cruise ship tourists, as the air visitors felt they could not afford any extra payment, and cruise ship passengers felt that enough funds had been put towards the trip itself. Interestingly, many cruise ship tourists prefer to donate to other projects. There is also a noticeable percentage of tourists (both air and cruise ship sector) who were unsure as to whether they would be willing to pay (12%).

TABLE 2.18. REASONS FOR THE UNWILLINGNESS TO PAY BY TOURISTS

	Air (n=80)	Cruise (n=48)	Total (n=128)
Conservation is responsibility of Bermuda	39%	21%	32%
My activities have no impact on coral reefs	36%	19%	30%
I cannot afford	13%	17%	14%
Trip is expensive enough	1%	13%	5%
Prefer to donate other projects	0%	13%	5%
No need for management of coral reefs	1%	0%	1%
Conservation program would not be effective	1%	0%	1%
Other	0%	4%	2%
Don't know	9%	17%	12%

Over half of the tourists (57%) who demonstrate 'Willingness to Pay' prefer to pay per visit to Bermuda, rather than per reef-related activity or on a yearly basis (Table 2.19).

TABLE 2.19. PREFERENCE OF PAYMENT OPTIONS OF TOURISTS 'WILLING TO PAY' FOR REEF CONSERVATION

	Air (n=121)	Cruise (n=157)	Total (n=278)
Per visit to Bermuda	57%	57%	57%
Per reef related activity	36%	22%	28%
Per year	3%	5%	4%
No preference	2%	15%	10%
Don't know	2%	1%	1%

The option of a voluntary payment or mandatory payment is relatively equally distributed among tourists willing to pay, with a small majority preferring the voluntary payment (Table 2.20). Responses differ little between air and cruise ship tourists, with a slightly higher number of air passengers preferring the voluntary payment over the mandatory payment.

TABLE 2.20. VOLUNTARY OR MANDATORY PAYMENT FOR CONSERVATION OF REEF

	Air (n=123)	*Cruise (n=156)*	*Total (n=279)*
Voluntary	51%	49%	50%
Mandatory	42%	49%	46%
Don't know	7%	3%	4%

The average 'Willingness to Pay' (in USD) for the conservation of coral reefs in Bermuda by tourists arriving by air or cruise ship is illustrated in Table 2.21. The "Protest" column relates to the fact that the unwillingness to pay is associated with the design of the hypothetical situation; tourists may be willing to pay if the situation was designed differently. For the purpose of mathematical calculations, "protest reasons" are considered as missing values and not included in the analysis, and "unWillingness to Pay" without any protest reasons are attributed a willing to pay value of $0.

The average cruise ship tourist is willing to pay US$28 per visit to Bermuda and the average airplane tourist is willing to pay markedly less, US$19. Extrapolating this information to a yearly basis, using the number of visitors recorded in 2007, a total sum of US$ 15.6million - US$ 5.9 million from the air tourism sector, and US$9.7 million from the cruise ship sector-, is potentially available for the conservation of Bermuda's coral reefs.

TABLE 2.21. AGGREGATION OF THE 'WILLINGNESS TO PAY' ESTIMATES ACROSS ALL VISITORS

	Air	Cruise	Total
Visitors in 2007	309,743	354,024	663,767
WTP (US$ per visit)	US$19	US$28	US$24
Conservation consumer surplus	US$5.9 million	US$9.7	US$15.6 million

There is a significant correlation between the amount tourists are willing to pay and their gross income (t-value is 2.1 and significance is 0.036), as well as between the amount to pay and the "active reef user" variable (t-value is 1.9 and significance is 0.05). This confirms the results presented in Table 2.17 showing that tourists considered "users" of the reefs show greater 'Willingness to Pay' than tourists who are "non-users". Note that the average income of tourists coming to Bermuda indicates a relatively affluent tourist type (average gross income of US$ 120,000 and average net income of US$ 100,000).

2.7 Total tourism value

The total tourism value of coral reefs in Bermuda is the sum of the consumer surplus –based on travel costs- the producer surplus – based on tourist reef-associated expenditures, and the 'Willingness to Pay' for conservation – the potential extra value dependent on the perception of tourists. The total tourism value with the additional WTP of Bermuda's coral reefs per visitor is summarised in Table 2.22. Total tourism value (consumer and producer surplus) amounts to US$ 611 per tourist. This value is slightly lower for cruise ship tourists (US$ 591) than for air tourists (US$635), due in part to a lower producer surplus of cruise ship tourists, associated with a shorter length of stay on Bermuda. The 'Willingness to Pay' extra for conservation is estimated at US$24 per tourist, with a higher value for cruise ship tourists (US$28) than air tourists (US$19).

TABLE 2.22. TOTAL TOURISM VALUE AND ADDITIONAL WTP VALUE OF BERMUDA'S CORAL REEFS PER PERSON

Variable	Air	Cruise	Total
Consumer surplus	$496	$536	$517
Producer surplus	$139	$55	$94
Total tourism value	$635	$591	$611
WTP for conservation	$19	$28	$24

These values are extrapolated to estimate the total tourism value of Bermuda's coral reefs per year to be US$ 406 million (Table 2.23). The higher volume of cruise ship tourists accounts for an equivalent total tourism value per year to that generated by air tourists (approximating US$ 209 million and US$ 197 million, respectively). The 'Willingness to Pay' extra for conservation per year is US$ 16 million, contributed to in greater part by the cruise ship tourists than by air visitors (US$ 10 million, and US$ 6 million respectively).

TABLE 2.23. TOTAL TOURISM VALUE AND POTENTIAL EXTRA VALUE (WTP) OF BERMUDA'S CORAL REEFS PER YEAR

Variable	Air	Cruise	Total
Consumer surplus	$153.7 million	$189.8 million	$343.3 million
Producer surplus	$42.9 million	$19.5 million	$62.4 million
Total tourism value	$196.6 million	$209.4 million	$405.8 million
WTP for conservation	$5.9 million	$9.7 million	$15.7 million

3. Fishery value

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3.1 Introduction

To determine the value of coral reef-associated fisheries, both the direct and indirect value of reef-associated fishing need to be considered. The **indirect** value refers to the cultural and recreational importance of fishing in Bermuda. This valuation exercise was conducted within the scope of a broader recreational and cultural value, described in the choice modeling section (see Chapter 5). In brief, a recreational fishing module was incorporated in a household survey, disseminated to a representative sample of the Bermuda resident population (400 households) as a face-to-face 10-minute interview. This proved necessary, as there was no available data on recreational fishing in Bermuda, confirmed by the Marine Resources Section of the Department of Environmental Protection. Results provide a first estimate of the recreational fishing value for Bermuda, and are presented within this chapter as part of the overall fishery value.

The **direct** value of coral reef-associated fisheries refers to the market value of the fish catch. The financial analysis used for this component is based on the gross revenue of commercial fishing, the associated operating costs and the estimated net revenue. Operating costs usually include processing, fuel, boat maintenance, etc. In Bermuda, the only "processing" of fish sold commercially, is the filleting of fresh fish, conducted by individual fishermen. This is considered as part of the labor costs, and hence no processing costs are included in this study. Assessing other operating costs of fishing in Bermuda is difficult, due to the general lack of reporting on incomes and expenditures in Bermuda, and to the large differences in costs incurred among individual fishermen (GOB, 2000). To estimate the costs of commercial fishing for the purpose of this study, six fishermen were interviewed face-to -face.

In order to remain within the scope of this study- i.e. assessing the total economic value of coral reefs- the fishery value derived within this study relates only to fisheries depending directly on coral reefs for at least one portion of their life cycle. This is from hereon referred to as the reef-associated fishery value. This value includes (1) Commercial Fisheries, and (2) Recreational Fisheries. Both fisheries include the following groups of species: Groupers (*Serranidae*), jacks (*Carangidae*), snappers (*Lutjanidae*), tuna and mackerel (*Scombridae*), sharks (*Lamnidae*), bait fish (anchovy, fry, pilchards), grunts (*Haemulidae*), hogfish(*Labridae*), porgy(*Sparidae*), and spiny lobsters (*Panularis argus*). Spiny lobster commercial catch data are recorded separately from finfish commercial catch. Other fisheries, targeting oceanic fish, are not included here.

A detailed list of fish caught and recorded in Bermuda is given in Appendix II.

3.2 Commercial fisheries

3.2.1 Finfish Total Catch Data

Catch data used in this study was made available by the Marine Resources Section of the Department of Environmental Protection. Data is collected from licensed commercial fishermen, required to keep a daily log of their catch and effort.[3]

Two distinct fishing areas are identified around Bermuda, referred to as the Banks, and the Platform. The Banks include the Challenger and Argus Bank, two submerged volcanic peaks rising to approximately 50m of the seawater level, and located 22 km and 37km southwest of Bermuda, respectively (GOB, 2006). The Platform consists of the area surrounding the Bermuda Islands, including the North Lagoon (see Chapter 1, Figure 1.1). The reef-associated fisheries groups first need to be identified, as it is probable that the fish caught on the Banks are not all coral reef dependent.

Total catch, including both records from the Banks and from the Platform is given in Figure 3.1. Total catch ranges between 2000 and 2007, with a maximum of 925,080 pounds recorded in 2007, and a minimum of 670,205 pounds in 2001. Total catch is broken down into species groups, one of the largest being “Tuna, Mackerel, etc.” which includes most pelagic species. The marked decline recorded in 2004 is attributed in part to the effects of Hurricane Fabian, destroying part of the fishing fleet in September 2003. Recorded catch remains low until 2006 for most species, increasing again in 2007, but not to the peak levels seen in 2002.

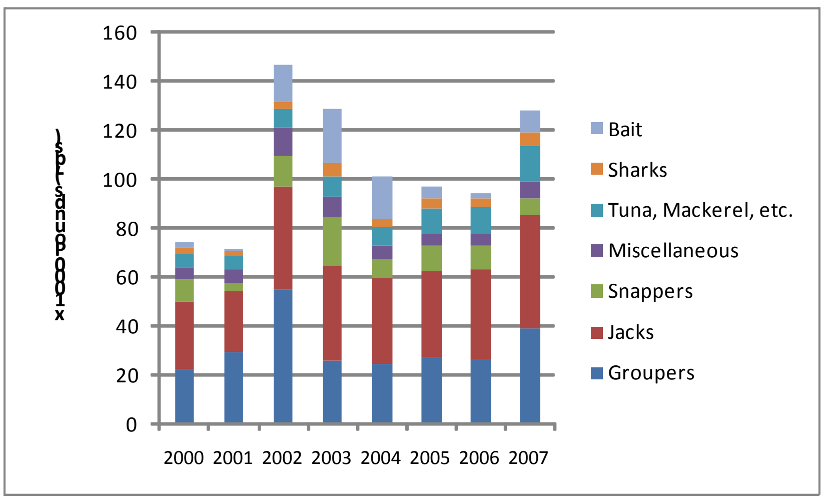

FIGURE 3.1. TOTAL CATCH SPECIFIED PER SPECIES GROUP FROM BOTH THE BANKS AND THE PLATFORM (IN POUNDS)

[3] Care should be taken when interpreting these data, since fishermen may sometimes strategically over- or underreport. Sales are not recorded in Bermuda, and data given cannot be verified.

The value of the coral reef-associated finfish fisheries may only be generated from the records of fish caught on the Platform[4]. This is based on information from the Marine Resources Section, on the assessment of species directly dependent on the coral reef system at any one given time in their life cycle (see Appendix II.2 for a complete list of reef-dependent species).

The percentage of catch on the Platform to the Total Catch for each species group is given in Table 3.1, as "share platform". In total, 59% of the total catch is caught on the platform. The species caught on the Platform that are not considered reef-dependent are excluded from this percentage, resulting in the "share platform excluding pelagic fish" values. This reduces the Platform share (in weight) of the total catch by another 17%, attributed to the reduced contribution of the "Tuna, Mackerel, etc." group (from 40% to 4%), and of the "Sharks" group (49% to 32%). This indicates that 42% of the commercial fisheries catch can be considered as reef-dependent. This percentage will be used to value the coral reef-associated commercial fisheries.

TABLE 3.1. RELEVANT SHARE OF FINFISH SPECIES GROUP CAUGHT ON THE PLATFORM (2000-2007)

Species	**Share platform**	**Share platform excluding pelagic fish**
Groupers	69%	69%
Jacks	66%	66%
Snappers	86%	86%
Miscellaneous	84%	84%
Tuna, Mackerel, etc.	40%	4%
Sharks	49%	32%
Bait	90%	90%
Total	59%	42%

Figure 3.2 illustrates the catch of reef-associated fish per species group for the period 2000-2007. Besides a disruption in catch in 2003, the year of Hurricane Fabian, and 2004, when some of the fishing vessels were still under repair, the reef-associated catch has been relatively stable.

[4] A limitation is that the division between Banks and Platform is not fully exclusive. As fishermen may opt to fish on the Banks or on the Platform on any one given day, records of the catch will reflect this choice, and fish caught on the way to the Banks, whether actually caught nearer or even on the Platform, will be recorded as "Banks". The estimated fisheries values can therefore be considered a conservative estimate.

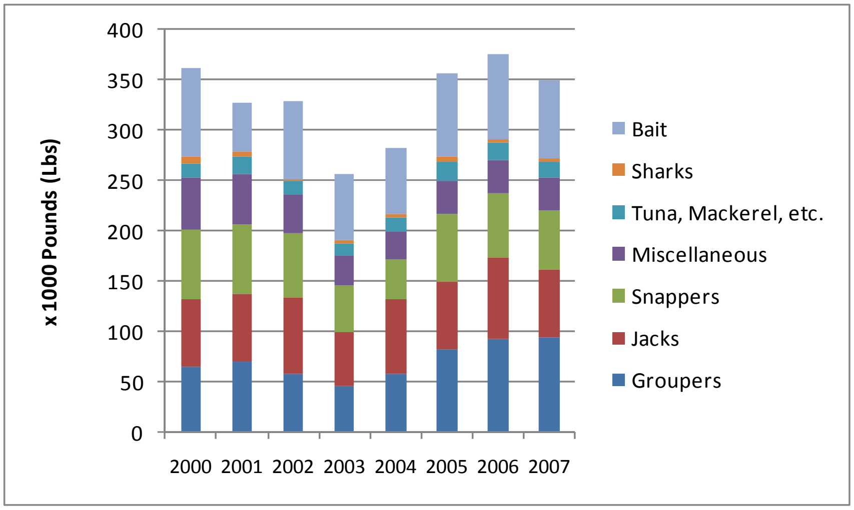

Figure 3.2. Total annual reef-associated fish catch per species group 2000-2007

3.2.2 Finfish market price

The value of the catch is calculated using market prices collected by the Marine Resources Division in the period 2001 to 2006. Comparison with earlier reported prices (GOB, 2000) and primary data collection in May 2008 shows very stable prices over the years. Therefore, the same prices are used throughout the period analysed (2000-2007), as shown in Table 3.2 for the different species groups.

TABLE 3.2. MARKET (ROAD SIDE) FISH PRICES 2000-2008

Species	Price ($/Lbs)
Groupers	10.00
Jacks	7.00
Snappers	10.00
Miscellaneous	8.00
Tuna, Mackerel, etc.	4.50
Sharks	2.00
Bait	4.00

3.2.3 Lobster Total Catch Data

The lobster fisheries are an important reef-dependent element in Bermuda's commercial fisheries, and all lobsters are caught on the Platform. Spiny lobsters, *Panularis argus*, are by far the most important lobster species caught in Bermuda, and are therefore the focus of the lobster fisheries analysis. The fishing season for spiny lobsters is open from September 1st till March 31st, with minimum size restrictions imposed (GOB, 2006). In 2007, 28 fishermen had a permit for lobster fishing. Catch data and prices are collected by the Marine Resources Section. The total catch of lobster between 1996 and 2007 is shown in Figure 3.3, and appears to be cyclic, with peak landings reported in 1999.

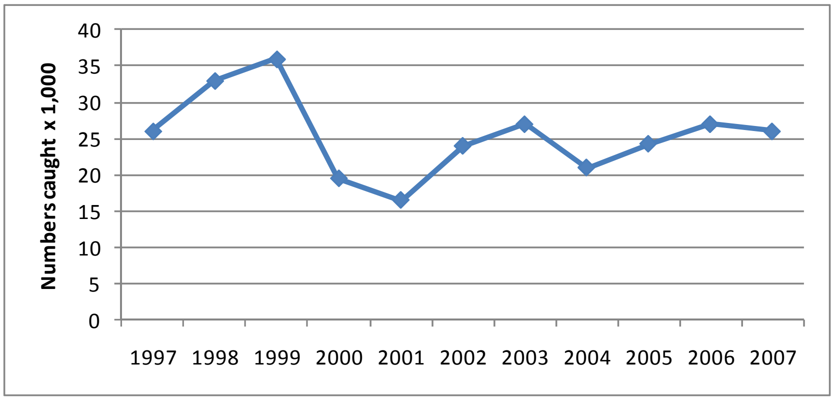

FIGURE 3.3. COMMERCIAL CATCH OF SPINY LOBSTER IN BERMUDA[5]

3.2.4 Spiny Lobster Catch Value

Lobster prices are size dependent. Table 3.3 reports the market prices used in this analysis. Prices increased in 2002, but have remained stable since.

TABLE 3.3. MARKET PRICES OF THE SPINY LOBSTER 2000-2007 IN BERMUDA (USD)

Length in mm	2000	2001	2002	2003	2004	2005	2006	2007
92-102	$20	$20	$25	$25	$25	$25	$25	$25
102-112	$20	$20	$30	$30	$30	$30	$30	$30
112-122	$25	$25	$35	$35	$35	$35	$35	$35
122-132	$30	$30	$40	$40	$40	$40	$40	$40
132-142	$35	$35	$45	$45	$45	$45	$45	$45
> 142	$35	$35	$50	$50	$50	$50	$50	$50

Length distribution of lobsters caught is estimated annually by the Marine Resources Section based on measurements from a sub-sample of 1000 to 3000 individuals. The resulting length-frequency percentages are multiplied by the total annual catch to obtain catch numbers per length class (see Appendix II.1). The annual total gross value of the lobster fishery is thereafter calculated based on catch numbers per length class and market prices (Table 3.3).[6]

5 The catch in each year reflects that of one lobster season, e.g. the year 1996 reflects the 1996-1997 lobster season.

6 The results of the measurements for the 2007-2008 season were not available at the time of writing. Therefore the average distribution over the years 2000-2006 was used instead. A table with the length distributions is provided in Appendix II.1.

3.2.5 Total Commercial Fisheries Value (Finfish and Lobster)

The total catch data and the calculated gross value for both finfish and lobster commercial fisheries are given in Table 3.4. Results for finfish fisheries are separated into the total catch and the reef-associated catch (see Appendix II.2 for composition). Reef-associated catch for finfish ranges from 257,000 to 375,000 lbs., resulting in a value of 1,599,000 USD to 2,477,000 USD; these data exclude the catches recorded for pelagic and sharks, which would increase fin fisheries value to a maximum of 5,085,000 USD. The commercial lobster fishery is valued at 405,000 USD to 968,000 USD within the period analysed. The total reef-associated commercial fisheries (including both finfish and lobster) have an estimated gross value ranging from 2,489,000 USD to 3,245,000 USD, with a mean gross value of 2,927,000 ± 343,862 USD.

TABLE 3.4. COMMERCIAL CATCH AND GROSS VALUE FOR FINFISH AND LOBSTER FISHERIES DURING 2000-2007(IN 1,000 LBS FOR FISH; IN 1000 INDIVIDUALS FOR LOBSTER)

	2000	2001	2002	2003	2004	2005	2006	2007
Catch – Physical (1,000lbs.)								
- Total catch	856	640	832	727	804	834	784	886
- Reef-ass. catch	362	327	329	257	282	357	375	349
- Lobster catch	19.1	17.4	23.4	28.1	20.4	23.8	26.7	26.1
Catch – Value[7] (x1000 USD)								
- Total catch	4,753	4,012	4,820	3,970	4,319	4,730	4,594	5,085
- Reef-ass. finfish catch	2,300	2,356	2,124	1,599	1,786	2,323	2,477	2,345
- Lobster catch	457	405	808	968	703	907	957	900
Total reef-ass. catch	2,757	2,761	2,932	2,567	2,490	3,230	3,435	3,245

Net values for the reef-catch were calculated by deducting fishing costs estimated. Limitations of this estimate are due to the large differences in costs reported by individual fishermen, and to the small sample size of fishermen willing to respond (n=6). Nonetheless, it appears that the most important cost categories are reported as fuel and gear. Total fishing costs are roughly estimated to 40% - 80 % of the gross value of the total catch, yielding a 20%-60% profit margin.[8] The final net values of the reef-associated catch, for both finfish and lobster, are given in Table 3.5. The mean net value is calculated to be 585,250 ± 64,439 USD for a 20% profit margin, and 1,756,250 ± 193,049 USD for a 60% profit margin.

7 Bait is not included in the calculations: bait is mostly re-used as input instead of being sold.

8 Based on the total catch value in 2007 (i.e. including the banks and pelagic species) equivalent to approximately 5 million USD, and 76 full time fishermen (there were 133 reporting licensed operators in 2006 of which roughly 57 were full time fishermen; counting the others as one quarter, gives 76 full time fishermen), the profit margins of 20-60% would yield an average profit range of 13,500 to 40,000 USD, of which crew wages would still have to be paid.

TABLE 3.5. TOTAL NET VALUE OF COMMERCIAL REEF-ASSOCIATED FISHERIES FOR BOTH FINFISH AND LOBSTER SPECIES DURING 2000-2007 (X 1,000 USD), BASED ON A PROFIT MARGIN OF 20-60% OF THE GROSS VALUE.

	2000	2001	2002	2003	2004	2005	2006	2007
Commercial value low*	551	552	586	513	498	646	687	649
Commercial value high**	1,654	1,657	1,759	1,540	1,494	1,938	2,061	1,947

* based on 20% profit;

** based on 60% profit.

3.3 Recreational fisheries

All data presented in this section was extracted from a household survey conducted among local residents for the purpose of this study. A copy of the questionnaire is provided in Appendix IV.3. Limitations in the data lie in the incapacity to verify the given information; Given that it is illegal to sell finfish and lobster in Bermuda without a commercial fishing license, respondents in the questionnaire may have underreported their catch; on the other hand, they may also have exaggerated their success.

As shown in Figure 3.4, of the 400 households that were interviewed 30% indicated that one or more household members fished recreationally.[9] This translates into a total of almost 16,000 recreational fishermen on Bermuda in 2007.[10]

Spring and summer months (May to September) appear to be the most popular with recreational fishermen, as illustrated by the increasing number of average fishing trips, and percentage of fishermen going out during this period (Figures 3.5 and 3.6).

[9] However, in five of these interviews, although referring to themselves as recreational fishermen, the respondents indicated never to go out fishing. They did answer the remaining questions in the fishing section of the questionnaire.

[10] It is estimated that there were 27,488 households in Bermuda in 2007. This is based on the number of households from the 2000 census and assuming an identical growth rate as in the period 1991-2000 (GOB, 2002). The total number of fishermen includes children and infrequent fishermen.

FIGURE 3.4. NUMBER OF RECREATIONAL FISHERMEN PER BERMUDAN HOUSEHOLD

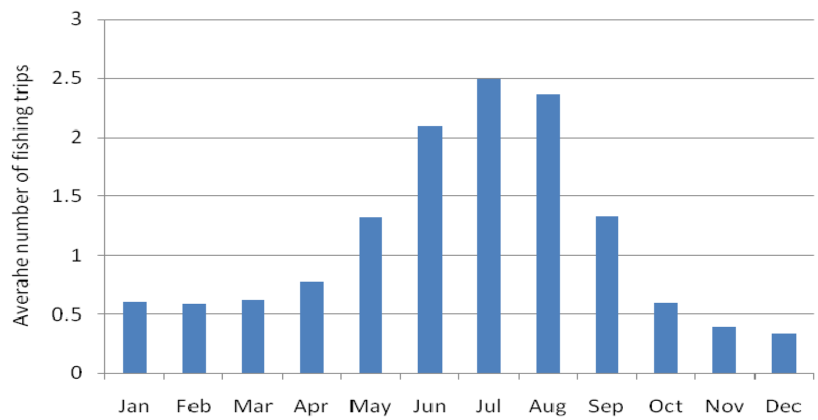

FIGURE 3.5. AVERAGE NUMBER OF FISHING TRIPS PER MONTH

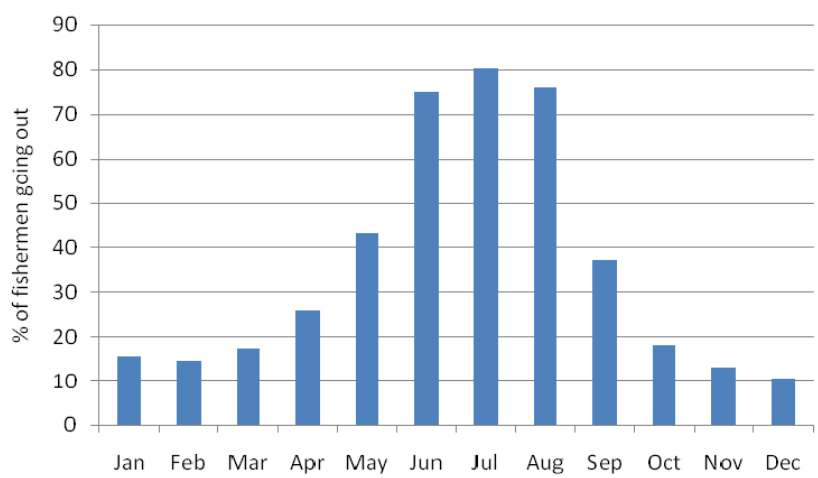

FIGURE 3.6. SHARE OF RECREATIONAL FISHERMEN GOING OUT PER MONTH

The motivation to fish recreationally was also assessed using a five point Likert scale ranging from "not important" to "very important". Results were analysed by calculating a weighted average for each motivation across the 400 respondents.

The two main reasons to go out fishing are to strengthen bonds with friends and family, and to enjoy fishing as a leisure activity (Table 3.6) . Fishing for food is the third most important reason in Bermuda. The two least important motivations are maintaining family' tradition '– i.e. fishing runs in the family – and catching fish 'to give to family and friends'. Besides the motivations provided in the questionnaire, competition was another reason mentioned.

TABLE 3.6. MOTIVATIONS FOR RECREATIONAL FISHERMEN (SHARE OF RESPONDENTS THAT SELECTED EACH CATEGORY IN PERCENTAGES) AND THE MEAN SCORE FOR EACH MOTIVATION (ON A SCALE BETWEEN 0 AND 10)

Rank	**Motivation to go out fishing**	**Not important**				**Very important**	***Mean score***
#		***0 pt***	***3 pt***	***5 pt***	***7 pt***	***10 pt***	***0-10***
1	Strengthen bonds with friends & family	4	5	16	26	50	*7.7*
2	Enjoy fishing	1	3	17	78	1	*6.5*
3	Catch for food	22	11	18	20	29	*5.5*
4	Tradition	25	16	24	13	22	*4.8*
5	To give catch to family and friends	31	17	16	16	21	*4.4*

The simple hand line proves the most popular fishing technique among recreational fishermen, used by 78 % of the fishing households interviewed (Table 3.7). The rod and reel is second most popular, used by 57 % of those interviewed. Other techniques used are also given in Table 3.7; the table does not add up to 100%, because more than one technique can be used by the same fisherman.

TABLE 3.7. APPLIED FISHING METHODS BY RECREATIONAL FISHERMEN IN BERMUDA.

Rank #	**Technique**	**% of fishermen**
1	Hand line	78%
2	Rod and reel	57%
3	Trawling	4%
4	Lobster diving	2%
5	Spear fishing	2%
6	Bait netting	4%

As seen in Table 3.8, 74% of recreational fishermen interviewed fish from shore. The most popular location for recreational fishing from shore and from boat is the East End. The other locations used by recreational fishermen on and around the island are also given in Table 3.8.

TABLE 3.8. AVERAGE FISHING TIME SPENT AT DIFFERENT LOCATIONS (IN % OF TOTAL FISHING TIME)

Location	Fishing from shore (74%)	From Boat (26%)	Total time fishing (100%)
East End	22	8	30
North Shore/Lagoon	16	5	21
South Shore	11	5	16
Inshore*	14	2	16
West End	11	4	15
Banks	n.a.	3	3

* Inshore implies fishing in and around St. George's, Castle Harbour, Hamilton Harbour, Harrington Sound, & Great Sound.

As expected when considering the preferred locations, the majority of recreational fishermen target shallow reef fish; in other words, 72 % of the catch is made up of shallow reef fish. This is in agreement with the estimate that of the recreational fishermen interviewed, only 12% reported never to fish for shallow reef species (see Table 3.9). "Deep reef fish", found at depths greater than 26m, and "Deep Sea fish", like tuna, are estimated to make up 13% and 10% respectively, of the recreational total catch. They are targeted by a minority of recreational fishermen, with 65%-79% of fishermen reporting not to be involved in this type of fishing. Bait fishing is recorded as being only 4% of the recreational total catch, with 99% of the fishermen interviewed not targeting this species group. Lobsters and mussels were reported to be least targeted by the fishermen interviewed, and made up <1% of the recreational total catch. The last column in Table 3.9 shows the share of recreational fishermen who target one group alone - i.e. 90% or more of their total catch is of one particular fish group. Fifty-five percent of the fishermen are seen to catch shallow reef fish only. The other categories are not targeted specifically by many recreational fishermen.

TABLE 3.9. RECREATIONAL CATCH CLASSIFICATION AND SHARE OF CATCH

Fish type	Average share of total catch (%)	Share of fishermen not involved at all (%)	Share of fishermen with 90% or more (%)
Shallow reef fish (< 26m)	72	12	55
Deep reef fish (> 26m)	13	65	3
Deep Sea fish (e.g. tuna)	10	79	3
Lobster	1	95	0
Bait fish	4	90	3
Mussels	0	99	0

To facilitate answering questions about the size of their catch, recreational fishermen were given the choice to report catch in pounds or numbers of fish caught. Most of them (89%) chose the latter. In order to estimate total recreational catch (pounds) and its value (USD), catch reported as numbers had to be converted to catch in pounds. A number of assumptions had to be made for such conversions, detailed in Appendix II.3.

Results on the total recreational catch indicate that the average finfish catch per fishing household - i.e. a household in which at least one of the members is a recreational fisherman, is 73 ± 97 pounds per year. The large standard deviation illustrates wide differences among fishermen's catch success, with a few fishermen catching much more than the main group. This is reflected by the median catch of only 40 pounds, markedly lower than the calculated average of 73 pounds. By extrapolating the average catch, total recreational catch for finfish in Bermuda is estimated to be 572,000 pounds in 2007, or almost two thirds of the annual commercial catch. However, this encompasses all fish caught, including pelagic finfish. As was done for the commercial fishery value, a distinction is made to assess the coral reef-associated fishery value. For this reason, the "Deep Sea Fish" category is excluded from the total recreational catch; this yields an average catch for finfish of 50 ± 53 pounds per fishing household, with a median value of 30 pounds. By extrapolating the average catch, the total reef-associated finfish catch is calculated to be of 387,000 pounds in 2007, or 68% of the total finfish catch. The catch numbers for 2000-2007 are shown in Table 3.10.[11]

Recreational lobster diving, which requires a license, is also popular in Bermuda. In 2007, there were 556 registered lobster divers. Assuming only 1 lobster diver per household, 2% of the households interviewed should include a recreational lobster diver. It follows that approximately 8 lobster divers should have been interviewed in the 400 household survey. In fact, only six were surveyed; based on this and by extrapolating the average catch reported in the survey, a total recreational lobster catch of 2,973 individuals is estimated for 2007. As the number of lobster divers in the survey is lower than expected (6 instead of 8), a second estimate is made, based on that used by the Marine Resources Section (Government of Bermuda); where, the lobster recreational catch is calculated to be 10% of the commercial lobster catch.[12] This yields a recreational lobster catch of 2,606 lobsters in 2007, a slightly lower value than that calculated in the current study document. Based on these calculations, the lobster recreational catch is estimated as ranging from 2,720 lobsters in 2000 to 2,973 lobster in 2007 (Table 3.10). The lobster catch only varies with the number of households.

The value of the recreational catch is determined using market prices. The occurrence of the different species groups (e.g. groupers, snappers) within the categories presented in Table 3.9 (e.g. shallow reef fish, deep reef fish) is assessed (see Appendix II.2 for details on species composition for each group). This enables the estimation of market prices for each catch category as used in the survey. Four price categories were generated: Shallow reef fish at 9 USD/lb., Deep reef fish at 10 USD/lb., Deep sea fish at 4.50 USD/lb., and Bait at 4 USD/lb.

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[11] The average catch value per fishing household, and the share of fishing households in Bermuda is assumed to be equal to the figures for 2007. The total catch therefore only varies with the total number of households in Bermuda, which was based on the 2000 census (GOB, 2002).

[12] Recreational lobster catch is supposed to be reported to the Marine Resources Section but the reported numbers have always been unreliably low; for this reason, a general estimate of 10% is used instead.

TABLE 3.10. RECREATIONAL CATCH FOR THE PERIOD 2000-2007 (X 1000 LBS. FOR FISH; IN NUMBER OF INDIVIDUALS FOR LOBSTER)

	2000	2001	2002	2003	2004	2005	2006	2007
# of households	25,148	25,470	25,795	26,125	26,459	26,798	27,141	27,488
Total fish catch	524	530	537	544	551	558	565	572
Reef-associated fish catch	354	359	363	368	373	377	382	387
Lobster catch	2,720	2,755	2,790	2,826	2,862	2,898	2,936	2,973

The share (or percentage) of the catch categories to the total catch of each recreational fisherman is estimated, and a value attributed by using prices above.[13] The resulting values are averaged to obtain a total fishing value per recreational fishing household (560 USD), and a reef-associated value per recreational fishing household (454 USD). By extrapolating the average values, the total recreational catch value for finfish in Bermuda, is estimated to be 4,382,000 USD in 2007 (*Please note: this excludes big game sport fishing*) and the reef-associated value is estimated to be 3,549,000 USD. Table 3.11 shows all values for the period 2000-2007.

The value of the recreational lobster catch is estimated similarly to the commercial value, and the same size frequencies and prices are applied (see Table 3.11). The recreational lobster fishery value peaked in 2005 at 111,000 USD.

Costs for recreational fishermen are not deducted from the value calculated to estimate a net value (as was done for the commercial fishery). The reason is that costs incurred by recreational fishermen are for enjoyment, and devoid of a financial goal. This yields a recreational reef-associated fishery value of 3,652,000 USD for 2007, a relatively high estimate compared to the values of the commercial sector (based on a cost margin of 40% to 80%). The reef-associated fishery is an important component of the total recreational fishery, comprising 79% of the total value in 2007. It is also worth noting that recreational lobster diving comprises only 3% of the total reef-associated fishery value in 2007.

Results also indicate that as a group, recreational fishermen caught 40% of the total (commercial and recreational) finfish catch in weight in 2007. Considering the reef-associated finfish catch only, recreational fishermen were responsible for just over half of the total reef-associated finfish catch in weight (53%). Recreational lobster diving accounted for 9% of the total (commercial and recreational) lobster catch.

[13] For instance, if a fishing household caught a total of 100 pounds, and half of this consisted of Shallow Reef Fish, and half of Deep Sea Fish, than the total value for this household is 100*(0.5*9 USD + 0.5*4.50USD)= 675USD, and the reef-associated value is just 450 USD as the catch from the Deep sea fish category is excluded.

TABLE 3.11. RECREATIONAL CATCH VALUES FOR THE PERIOD 2000-2007(X 1,000 USD)

	2000	2001	2002	2003	2004	2005	2006	2007
Total finfish catch value	4,009	4,060	4,112	4,165	4,218	4,272	4,327	4,382
Reef-ass. finfish catch value*	3,247	3,288	3,330	3,373	3,416	3,460	3,504	3,549
Total lobster catch value	65	64	96	98	99	111	105	103
Total reef-ass.* catch value	**3,312**	**3,352**	**3,426**	**3,471**	**3,515**	**3,571**	**3,609**	**3,652**

* refers to reef-associated catch value

3.4 Total fishery value

A summary of the total catch, the reef-associated catch, and the reef-associated fishery value between 2000 and 2007 is given in Table 3.12 for both the commercial and recreational fishery. Please note that **net values** are shown for the commercial fishery value.

A distinction is made in this chapter between reef-associated and non reef-associated catch. In the commercial fishery, an average share of 42% of the total finfish catch (by weight) is considered reef-associated. For the recreational fishery, using a different method, the estimated share of reef-associated finfish catch is 68%. This difference is mainly due to a different species focus between commercial and recreational fishermen. Pelagic species are an important component of the commercial fishery, both in weight and in value, but excluded for the purpose of this valuation exercise. **The reef-associated value given below for Bermuda's fishery does not therefore reflect the value of the entire fishery, but only of the portion of the fishery dependent on coral reefs.**

In brief, the valuation of the Bermuda fishery is based on commercial catch data from yearly records (Marine Resources Section, Department of Environmental Protection), and on recreational data from surveys specific to this study. There are no previous records for recreational fishing in Bermuda, and no obligation for recreational fishermen to register or report their catch. Data presented here results from the inclusion of a recreational fishing section to the household survey, conducted for the valuation of other coral reef services. This has resulted in a first dataset for recreational catch in Bermuda; results indicate the presence of 16,000 recreational finfish fishermen in 2007 in Bermuda, fishing mostly during the summer months for the pleasure of bonding with family and friends. Most recreational fishing is from the shoreline with simple fishing gear, such as a hand line or a rod and reel. This data is based on a one time survey; the increase simulated in the recreational finfish catch (Table 3.10) reflects Bermuda's growing population, and assumes that the share of commercial fishermen and the average catch per fishermen is constant between 2000 and 2007.

TABLE 3.12. OVERVIEW OF COMMERCIAL AND RECREATIONAL CATCH IN BERMUDA

	2000	2001	2002	2003	2004	2005	2006	2007
Commercial total finfish catch (x 1,000 lbs.)	856	640	832	727	804	834	784	886
Recreational total finfish catch (x 1,000 lbs.)	524	530	537	544	551	558	565	572
Total finfish catch (x 1,000 lbs.)	**1,380**	**1,170**	**1,369**	**1,271**	**1,355**	**1,392**	**1,349**	**1,458**
Commercial reef-ass. finfish catch (x 1,000 lbs.)*	362	327	329	257	282	357	375	349
Recreational reef-ass. finfish catch (x 1,000 lbs.)*	354	359	363	368	373	377	382	387
Total reef-ass. finfish catch (x 1,000 lbs.)*	**716**	**686**	**692**	**625**	**655**	**734**	**757**	**736**
Commercial lobster catch (x 1,000 individuals caught)	19.1	17.4	23.4	28.1	20.4	23.8	26.7	26.1
Recreational lobster catch (x 1,000 individuals caught)	2.7	2.8	2.8	2.8	2.9	2.9	2.9	3.0
Total lobster catch (x 1,000 individuals)	**21.9**	**20.1**	**26.2**	**30.9**	**23.3**	**26.7**	**29.7**	**29.0**
Reef-ass. commercial value low (x 1,000 USD)*	551	552	586	513	498	646	687	649
Reef-ass. commercial value high (x1,000 USD)*	1,654	1,657	1,759	1,540	1,494	1,938	2,061	1,947
Reef-ass. recreational value (x 1,000 USD)*	3,312	3,352	3,426	3,471	3,515	3,571	3,609	3,652

* refers to reef-associated catch or value. Commercial value is net value.

Finally, this study demonstrates that the Bermuda recreational fishery is an important component of the total fishery (both commercial and recreational); recreational fishermen caught in 2007, 40% of the total finfish catch in weight. In addition, the catch of recreational fishermen is very reef-dependent, and is estimated to be 53% of the total (commercial and recreational) reef-associated catch in weight in 2007. On the other hand, recreational lobster divers do not contribute much to the total (commercial and recreational) catch, accounting only for 9% of the total lobster catch.

4. Amenity Value

Mark Roelfsema, Sebastiaan Hess & Pieter J.H. van Beukering

4.1 Introduction

The environmental amenity of Bermuda's coral reefs potentially adds value to residential properties. The assessment of such a value is determined within the scope of this study using the hedonic pricing method. Buyers consider certain characteristics when purchasing a house. The question is whether the proximity of coral reefs, assessed by the view from the house, access to the beach, or pristine waterfront is perceived as an important attribute affecting the purchase price. Should a higher house price be attributed to a coral reef-related characteristic, the additional value becomes the amenity value given to this environmental ecosystem by a homeowner.

As seen in the literature review in Appendix III.1, hedonic pricing has not been used much for valuing coral reefs; it is a complex analysis and requires a large data set of house sales (see Appendix III.2 for theory of hedonic pricing). This type of valuation technique assumes that housing units are perceived by owners, as bundles of attributes, and different levels of utility are derived from different combinations of these attributes. These attributes or characteristics, which are relevant to house prices, may vary widely in their nature. The attributes considered in this study include (1) structural characteristics such as size, state of the house, number of rooms, view, etc., (2) neighbourhood characteristics such as average income and such as availability of schools, (3) accessibility characteristics such as proximity of important locations, (4) environmental characteristics describing vicinity and quality of the coral reef ecosystem to the house, and (5) other characteristics that are typical to Bermuda such as flood zones and parishes. These attributes are explained in more detail in the methodology section.

4.1.1 Challenges and Limitations

The Bermuda Real Estate database system does not facilitate data collection; for this reason, data for this study is based on information obtained from one Real Estate company only. Despite the fact that it is one of the largest companies in Bermuda, the amount of data collected is minimal for the purpose of this study, and lacks in details at times; for this reason, the validity of the dataset obtained was thoroughly and carefully verified using statistical analyses.

A number of assumptions are made in using the hedonic pricing approach to calculate the amenity value; all assumptions are checked for validity using graphical analyses and statistical tests, described in detail in Appendix III.3.

The correlation between the coral reef ecosystem and the marine environment is high in a small island like Bermuda. In order to estimate an amenity value stemming from coral reefs only, a clear distinction had to be made between coral reef-related variables and ocean-related variables (such as ocean view). It should be noted that beaches are considered as a coral reef-associated characteristic, given their coralline origin. More specifically, in Bermuda, beach formation is tightly linked to the presence of a healthy coral reef system nearby, and hence potentially severely impacted by the degradation of surrounding coral reefs. Please note that in this chapter, only the amenity value of the beaches is estimated; their recreational value is discussed in Chapter 5.

The contribution of hotels, offices and shops to the amenity value of Bermuda's coral reefs is beyond the scope of this study, and not included here. For this reason, the amenity value presented here is an underestimate.

4.2 Methodology

4.2.1 The hedonic pricing model

The house price is explained in terms of several attributes, including waterfront or proximity to the beach and coral reefs, valued as important during the decision-making process of purchasing a house. The relationship between house prices and coral reef-related characteristics is estimated using a linear regression model, where,

Dependent variable = House selling price and,

Independent variable = House characteristic deciding the owner's purchase.

Independent variables are subdivided in several subcategories. The subcategories of characteristics relevant to house prices used in this study are:

- *Structural characteristics* - size, state of the house, number of rooms, view. In Bermuda's case, the database focuses on residential houses only, excluding commercial properties (e.g. hotels, shops). Not only is there insufficient information to include this category, but commercial properties are also likely to respond very differently when used in such a model, compared to residential homes.
- *Neighbourhood* – usually includes a group of characteristics, such as availability of playgrounds, average income, etc. A low segmentation in the Bermudan housing market is expected because of its small land surface area. Therefore, standard neighbourhood characteristics are not considered in this study, and neighbourhood is defined by "parish" in Bermuda, explained below.
- *Accessibility*- related to proximity of important locations, and given in terms of distance to specific location. Locality parameters such as distance to airport, schools and supermarkets are taken into account, and are determined from available GIS data.

- *Environment*- describes vicinity of the coral reef ecosystem to the house, including:
    - clear “pristine” water
    - diversity of ocean view (turquoise water, reefs in general, boiler reefs, rocks)
    - ocean view
    - waterfront
    - possibility of mooring a boat
    - proximity and access to beach and coral reefs
- *Typical Bermudan factors:* Certain characteristics are region specific and potentially influence the price of a house. In Bermuda, some of these have been identified, and are included in the analyses as “dummy” variables. They include:
    - “Flood zones”, an extra environmental characteristic, having a negative effect to owning a house on the waterfront;
    - “Parish”, a neighbourhood characteristic, checking the parish location influences the price. Bermuda has nine parishes and two municipalities (Hamilton and St. Georges);
    - “Availability to International Purchasers”, an extra structural characteristic, based on Bermudian legislation prohibiting the sale of a house below a specified monetary threshold to non-Bermudans;
    - “Watlington Waterworks”, an extra structural characteristic, based on the supply of freshwater through a private company rather than on the standard individual collection of rainwater.

The relevance of coral reef characteristics to the house price, and hence the amenity value, are assessed to estimate the final amenity value. For example, Bermuda’s array of turquoise waters is an integral part of the island’s beauty; does a house with such a view, attributed in great part to coral reef formation, have an added value? It is the relevance of such independent characteristics to Bermuda house prices which the hedonic pricing method attempts to determine. This is conducted through a series of mathematical steps (see Appendix III.2 for details).

4.2.2 Data access, management and preparation

Data for the study was collected from a local real estate agency’s database of residential house sales, including prices and structural characteristics for houses sold between December 2003 and May 2008. All house data collected is analysed using a Geographical Information System software (GIS). Accessibility and environmental variables are determined for all properties in the database using existing GIS maps for Bermuda’s coral reefs (Source: Department of Conservation Services, Government of Bermuda). (See Appendix III.2 for details).

In estimating the value that coral reefs potentially add to the selling price of a house, it is assumed that the greater the proximity to a coral reef-related attribute, the higher the price a buyer is willing to pay. In the Bermuda case study, the following parameters are considered to determine the relevance of coral reef-related characteristics to house prices, and have relevant data available:

1.Distances from (a) house to coast; (b) coast to closest reef; and (c) house to beach. The distance from the house to the coral reef is broken down into the "distance from the house to the coast" (to distinguish ocean-related characteristics), and "distance from the coast to the reef" (to distinguish coral reef-related characteristics).

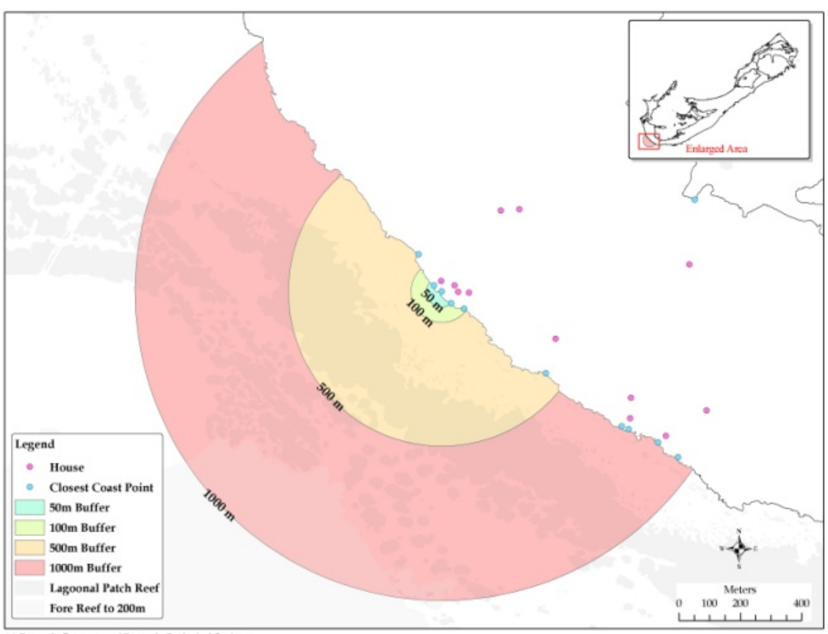
2.Reef structure. In concentric circles around the closest coastal point from every house, the following structures are considered: (a) average patchiness (covered area/total area and the total outline of the reef structures); and (b) area covered. Reef structure causes colour variations in the water, referred to as the "patchiness" characteristic.

3.Live coral cover (intervals of 20%). Coral cover refers specifically to live coral, and reflects the quality (or health) of the reef. The higher the coral cover per m^2, the higher the quality. Both coral cover and patchiness are expressed as a total and percentage calculated for concentric circles of 50 m, 100 m, 500 m and 1000 m drawn from the closest coastal point (Figure 4.1).

4.Reef type making one distinction: whether it is a boiler reef or not.

As a control for ocean related variables, *waterfront characteristics*, such as the presence of a dock and mooring are also included. The impact of removing the waterfront variable is investigated.

Reef structure causes colour variations in the water, referred to as the "patchiness" characteristic, and is investigated as contributing to coral reef amenity in this study. Coral cover, refers specifically to live coral, and reflects the quality (or health) of the reef; where, the higher the coral cover per m^2, the higher the quality. To separate the other ocean related variables from the coral characteristics, a further distinction is made between "distance to coast" and "patchiness" or "coral cover". Both coral cover and patchiness are expressed as a total and percentage calculated for concentric circles of 50 m, 100 m, 500 m and 1000 m drawn from the closest coastal point (Figure 4.1)



(c) Bermuda Government / Bermuda Zoological Society

FIGURE 4.1. CONCENTRIC CIRCLES USED FOR THE ESTIMATION OF DISTANCE FROM COAST TO CORAL REEF

4.3 Data analysis and results

As shown in Figure 4.2, the locations of houses sold during December 2003 and May 2008 based on the collected dataset are evenly distributed over the island, indicating that the dataset is representative for owner-occupied houses.

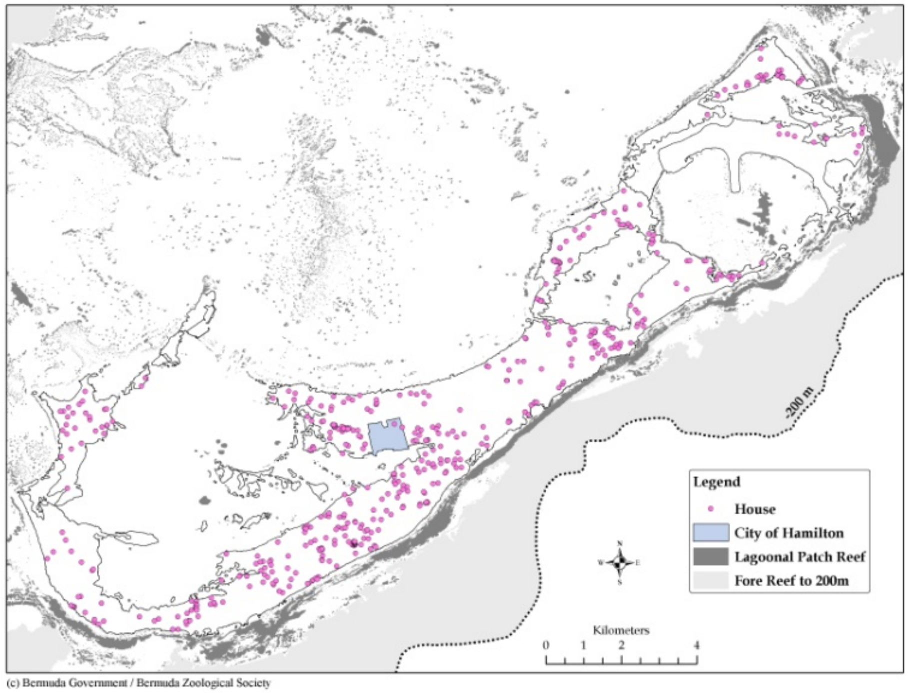


FIGURE 4.2. HOUSE LOCATIONS SOLD IN BERMUDA DURING DECEMBER 2003 AND MAY 2008 (N=593).

The dataset compiled for houses sold in Bermuda during December 2003-May 2008 is summarised in Table 4.1. The dataset consists of approximately 50% condominiums (apartments) and 50% residential houses, amounting to 593 residences in total. The average house price is $1.5 million, ranging from $325,000 to a maximum of $17.5 million. It takes on average 251 days to sell a house. Approximately 14% of houses bought are located on the waterfront, with the average house having 2.6 bedrooms and 2.2 bathrooms. The average house sold is located approximately 5.2 km from the city of Hamilton, and 10.5 km from the airport; but is located relatively close to schools, supermarket and to a National Park bordering the coast (682 m, 684 m, and 666 m respectively). The average house is located at 20.85 m elevation. Slightly more than 10% of the houses are situated in one of the flood zones identified by the Department of Works & Engineering (Government of Bermuda). On average, people live close to the beach and coral reefs (619 m and 744 m). Finally, most houses sold are located in the parishes of Paget and Pembroke; the least number are sold in the City of Hamilton, reflecting its use as the Business District of Bermuda.

TABLE 4.1. DATA SUMMARY FOR HOUSES SOLD BY ONE REAL ESTATE AGENT IN BERMUDA DURING DECEMBER 2003 AND MAY 2008 (N=593).

Category & variable	Mean	Minimum	Maximum
Sold Price	$1,477,606	$325,000	$17,500,000
No of days on market	251	3	2,366
No of beds	2.6	1	8
No of baths	2.2	0	10
Property Type	0.5	0	1
Sold Days	640	25	1,641
Listed Days	865	100	3,379
Available Inter-purchaser	0.11	0	1
Shared Tank	0.06	0	1
Pool	0.33	0	1
Waterfront	0.14	0	1
Dock	0.07	0	1
Parking	0.30	0	1
Garage	0.23	0	1
Mooring	0.04	0	1
Balcony	0.20	0	1
Well	0.16	0	1
Reverse Osmosis	0.01	0	1
Golf	0.01	0	1
Tennis Courts	0.07	0	1
Watlington Water	0.10	0	1
BD	0.95	0	1
Boiler	0.17	0	1
Accessibility			
Distance to City of Hamilton (m)	5,203	380	15,018
Distance to closest school (m)	682	40	3,680
Distance to closest super market (m)	684	34	3,042
Distance to airport (m)	10,516	1,356	19,784
Distance to closest golf course (m)	1,307	0	5,031
Distance to coastal national park (m)	666	14	1,969
Environmental characteristics			
Elevation (m)	20.85	0.15	64.49
Flood zone 1 (dummy)	0.04	0	1
Flood zone 3 (dummy)	0.06	0	1
Flood zone 5 (dummy)	0.10	0	1
Distance to Coast (m)	262	7	885
Distance from coast to closest reef	357	1	1,223
Distance to closest reef	619	42	1,736
Distance to closest beach	744	8	2,704
Price adjusted	0.21	0	1
Neighbourhood (dummy variables)			
Devonshire	0.05	0	1
Hamilton	0.09	0	1
Paget	0.14	0	1
Pembroke	0.13	0	1
Sandys	0.08	0	1
Smiths	0.09	0	1
Southampton	0.08	0	1

St. Georges	0.10	0	1
City of Hamilton	0.01	0	1

The relationship between all independent variables (structural, accessibility, neighbourhood, environmental) and the dependent variable (house price) is analysed graphically using scatter plots and histograms. A summary of the most relevant graphs and observations are presented below (see Appendix III.4 for all graphs):

- There are a few data points with relatively high prices; this is further investigated mathematically through the outlier analysis (see Appendix III.4).

- House price distribution is highly skewed to the left, as can be seen in Figure 4.3, implying that most properties sold have a selling price which is lower than the average selling price.

- When considering the relationship between the number of houses sold and "Distance to reef", and especially for "Distance to beach" parameters (Figure 4.3 and Figure 4.4), it becomes evident that the majority of houses sold are located relatively close to the reef and to the beach. This distribution is attributed in great part to the nature of Bermuda's coastline, characterized by a long and narrow land mass (35 km x 1.6 km), resulting in the majority of the houses being situated close to the coast.

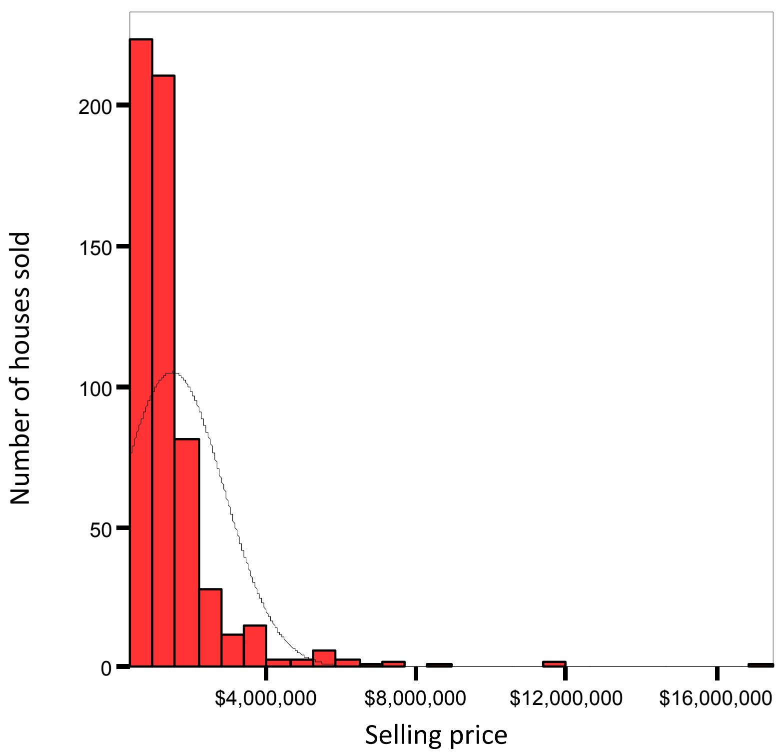


FIGURE 4.3. NUMBER OF HOUSES SOLD IN BERMUDA AND THEIR RESPECTIVE SELLING PRICE (USD) (DECEMBER 2003-MAY 2008, N=593).

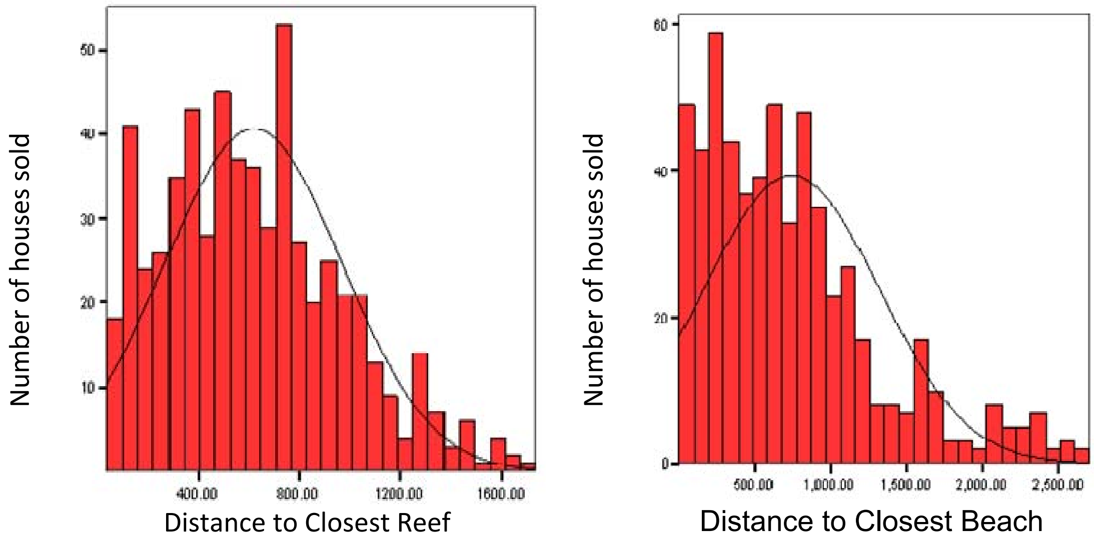


FIGURE 4.4. THE RELATIONSHIP BETWEEN THE NUMBER OF HOUSES PURCHASED AND THEIR PROXIMITY TO CORAL REEFS AND TO BEACHES (DECEMBER 2003-MAY 2008; N=593)

In order to verify that the independent variables selected are appropriate representations of coral reef attributes, the collinearity between independent variables is calculated i.e. the interdependence between some of the environmental characteristics and some of the structural characteristics. A high correlation between two variables may render a parameter estimate imprecise and thus make it difficult to separate the effects of different independent variables (see Appendices III.2 and III.3 for detail). Collinearity tests are conducted for all independent variables, and illustrated in Appendix III.3. The main results of the collinearity tests are summarised below; results for environmental independent variables are given in Tables 4.2 and 4.3. . Note that correlation coefficients higher than 0.6 indicate possible collinearity, and warrant the exclusion of the variable in the estimation of the total amenity value. According to the collinearity tests, the following variables are highly correlated and are excluded:

- *Number of bedrooms* and *number of bathrooms*.
- *Property type* and *parking*, due to the fact that condominiums often include a parking lot.
- *Distance to closest supermarket* and *Southampton Parish*. The distance from a purchased house to supermarkets is higher in Southampton than in other parishes.
- *Distance closest reef* and *Distance from coast to closest reef*. This is expected since the distance to the closest reef is the sum of distance to coast point and distance from coast to reef (Table 4.3).

Some of the environmental variables show some correlation, but are included in the hedonic pricing analyses and explained as follows:

- The *flood zones* are highly correlated among themselves. This is due to the fact that all houses in flood zone 1 (high risk area) are part of flood zone 3 (medium risk) and zone 5 (low risk) and all houses in flood zone 3 are part of flood zone 5. Therefore, only one of these three flood zones is included as an explanatory variable (Zone 1).

- Waterfront is negatively correlated with ocean related distances representing the distance that house owners need to drive to visit the coast. However, because the correlations are not very high (less than 0.6), the variable is not excluded (Table 4.3).

TABLE 4.2. CORRELATION AMONG THE WATERFRONT (OCEAN RELATED) CHARACTERISTICS.

Correlations	Waterfront	Dock	Mooring
Waterfront	1.00	0.47	0.41
Dock	0.47	1.00	0.55
Mooring	0.41	0.55	1.00

TABLE 4.3. CORRELATION AMONG CORAL RELATED AND OCEAN RELATED CHARACTERISTICS.

Correlations	Waterfront	Distance to closest reef	Distance to closest beach	Distance to coast point	Distance from coast point to closest reef
Waterfront	1.00	-0.33	-0.19	-0.45	-0.08
Distance to closest reef	-0.33	1.00	0.25	0.46	0.83
Distance to closest beach	-0.19	0.25	1.00	0.17	0.17
Distance to coast point	-0.45	0.46	0.17	1.00	-0.11
Distance from coast point to closest reef	-0.08	0.83	0.17	-0.11	1.00

Note: Values in red indicate a high collinearity between two variables.

4.4 Hedonic pricing function

The data above is used to develop a model of the relationship between house prices and coral related characteristics (see Appendix III.2 for details on model design and assumptions). This relationship is calculated through the following three steps:

1. *Full model*: All variables are included in a "full model" giving insight into the important variables and resulting in a set of relevant variables for the final regression analysis;

2. *Hierarchical model*: The relationship between house price and the relevant coral related variables is determined using a "Hierarchical linear regression". This step determines which variables are appropriate for explaining the house prices on Bermuda;

3. *Variable transformation*: Statistical transformation of variables is required to evaluate the model best reflecting the relationship determined in the previous step.

Step 1: Full model

Each regression analysis is undertaken for the three variants: (1) Distance to reef; (2) Distance to beach; and (3) Distance to coast and distance from coast to reef (including patchiness and live coral cover). Based on a previous analysis showing a log-like distribution of house prices, the full model was developed for both untransformed house prices (taken straight from the dataset) and log-transformed house prices, as the dependent variable. The latter is found to be the best choice, based on a 'best fit' test (multiple correlation coefficient criterion R^2 and verification of assumptions; normality and heteroscedacity were both checked- see Appendix III.4 for more details).

Appendix III.4 provides results of the significance of all parameters for the full regression model with and without a log-transformed house price.

Results of the log-transformed full model are given in Table 4.4. These provide the independent variables, describing structural and accessibility characteristics, which are significant. Statistical results warrant the inclusion of all three variants ('distance to reef', 'distance to beach' and 'distance to coast and distance from coast to reef') in further analysis.

TABLE 4.4. LEVEL OF SIGNIFICANCE OF VARIABLES IN THE THREE VARIANT MODELS*

Significance	**Coast-reef**	**Reef**	**Beach**
No of beds	0.000	0.000	0.000
No of baths	0.000	0.000	0.000
Distance to City of Hamilton (m)	0.001	0.003	0.004
Distance to closest school (m)	0.009	0.001	0.001
Distance to closest supermktt (m)	0.053	0.046	0.032
Distance to closest golf course (m)	0.034	0.041	0.050
Property type	0.000	0.000	0.000
Available Inter-purchaser	0.001	0.001	0.000
Pool	0.001	0.001	0.001
Waterfront	0.007	0.007	0.002
Parking	0.021	0.029	0.028
Garage	0.001	0.002	0.001
Mooring	0.016	0.016	0.018
Price adjusted	0.062	0.030	0.028

* The level of significance is $p<0.1$, and considered highly significant at $p<0.01$; and medium high at $p<0.05$.

It should be noted that the effect of the "year" (affected by factors that change over time, such as inflation) was tested but did not have a significant influence on house price in this study. The distance to the airport was, unlike for other regions, not a significant variable for Bermuda.

Step 2: Hierarchical model

In order to determine the final log-transformed model, the significant variables outlined above (Table 4.4) are incorporated with coral-related variables and other variables deemed important. This includes additional dummy variables within the category "Typical Bermudan factors" which are region-specific characteristics, namely:

- *Flood zone*: if the house is located in a flood zone and,
- *Parish*: indicating where in Bermuda the house is located.

Although these variables are not significant in the full model, they are worth investigating further; the former represents the negative effect of being located close to the coast and the second is the only neighbourhood variable.

Three regression models are determined, one for every coral-related parameter similar to the variants presented in Table 4.4. Assumptions are checked for all three models, and the use of standard mathematical transformations is verified (Appendix III) (Roelfsema, 2008). Results of several alternative models for each coral-related variant (reef, beach and coast-reef) are available in Roelfsema (2008). These indicate that:

- The expected negative relationship between house prices and the coral reef amenity is only partly found in the linear-quadratic regression with the beach variant. In all other variants for all used transformations the relationship is either not significant or does not have the expected significance.
- Adding the significant variables from the full model results in an explained variance (R^2) of the house price (i.e. dependent variable) of 0.79- considered a good fit. Thus, the model provides good insights into the determinants of the house price in Bermuda.
- Adding the variable 'distance to reef' to the regression model results in a non-significant estimate. This applies for all transformations.
- For the beach variant, both the log-transformation and the linear-quadratic-transformation result in significant variables.
- Although adding both the 'distance to coast' and 'distance from coast to reef' gives a significant result, the 'distance to coast' is not a significant variable when using the t-test. This is difficult to explain, but statistically need to be withdrawn.
- The beach variant (or 'distance from house to beach') is the only variant showing significant results, and is discussed in greater detail in Appendix III.5.
- Flood zone 1 (high risk) is a significant variable in the three variants. Its regression coefficient is positive, although unexpected, because of the increasing flood risk in these areas. The correlation between waterfront and flood zone (15%) may be the reason for this, as the addition of the flood zone variable leads to a 10% decrease in the waterfront coefficient. The flood zone variable is thus removed from the model.

'Distance to beach' variant

Log-transformation and linear-quadratic transformation analyses indicate that the beach variant is significant. Further mathematical investigations indicate that the 'distance to beach' has a linear quadratic relation with the house price. This implies that houses closest to the beach are least expensive, progressively becoming more expensive until 1.1 km from the beach; beyond 1.1 km, a decrease in house prices is once again seen. This quadratic relationship is illustrated in Figure 4.5; and shows the turning point lying at slightly over 1000 m.

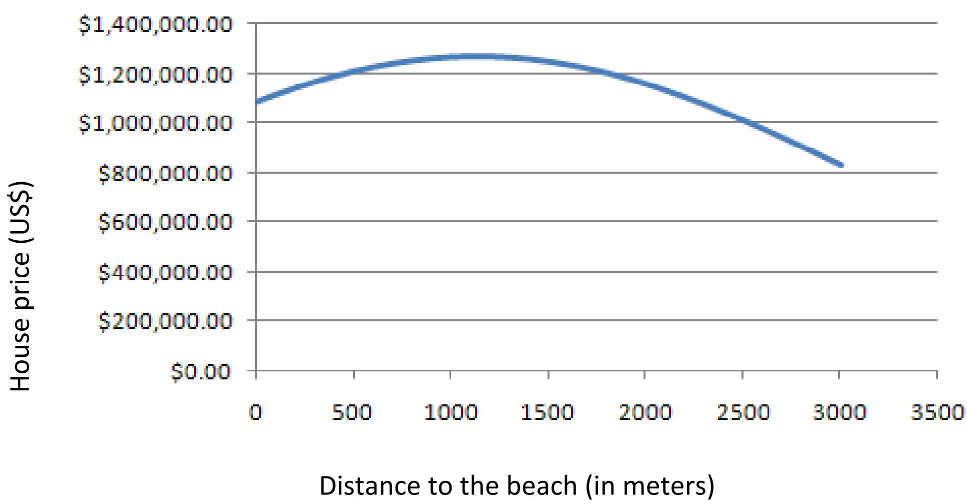


FIGURE 4.5. THE RELATIONSHIP BETWEEN HOUSE PRICE IN BERMUDA AND DISTANCE TO THE BEACH (N=593).

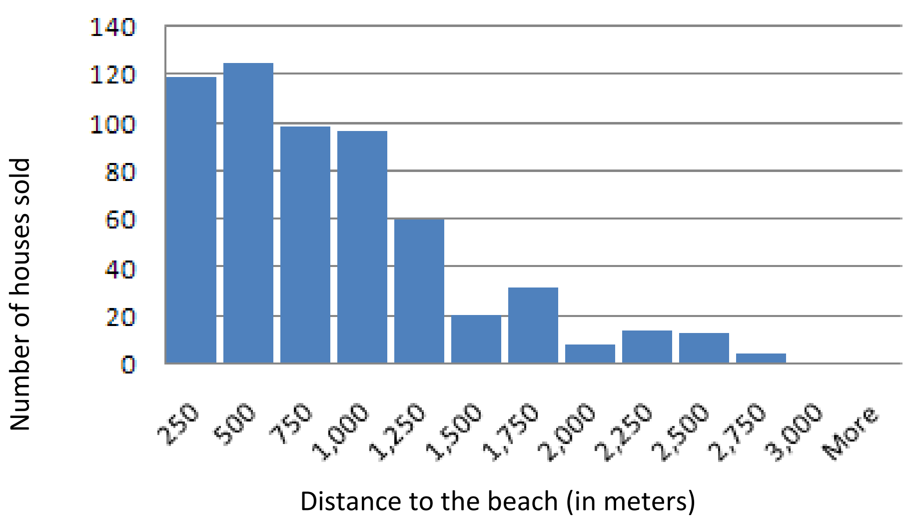


FIGURE 4.6. DISTRIBUTION OF THE SAMPLE SIZE USED FOR BERMUDA'S AMENITY VALUE WITH RESPECT TO THE VARIABLE 'DISTANCE TO BEACH'.

However, care must be taken in the interpretation, as results are based on a relatively small dataset of houses located further from the beach (n=32), as illustrated in Figure 4.6. The majority of the houses in the available dataset lies in a distance <2 km away from the beach. Although there are no reasons to consider this data erroneous, additional observations would allow for a more robust verification of the quadratic relationship found.

The statistical relationship between house prices and house price characteristics are shown in Table 4.5, given as significant ($p < 0.1$) or insignificant ($p > 0.1$). The distance to the closest golf course, supermarket and parking are insignificant, but remain included in the model. Results show that 'distance to Hamilton', and 'distance to golf courses' reflect a negative amenity –or have a negative relationship with house prices - as indicated by the regression coefficients (betas). In other words, the further a house is from a golf course or from Hamilton, the lower the selling price.

TABLE 4.5. REGRESSION RESULTS OF THE MODEL 'DISTANCE TO THE BEACH'*. REGRESSION COEFFICIENT (BETA) AND THE LEVEL OF SIGNIFICANCE ARE GIVEN.

Variable	**Beta**	**Significance**
Constant	13.1566440	0.00
Available Inter-purchaser	0.2221161	0.00
Distance to City of Hamilton (m)	-0.0000168	0.00
Distance to closest golf course (m)	-0.0000160	0.16
Distance to closest school (m)	0.0001628	0.00
Distance to closest supermarket (m)	0.0000380	0.11
Garage	0.0950128	0.00
Mooring	0.1886388	0.00
No of baths	0.1674470	0.00
No of beds	0.1575779	0.00
Parking	0.0616516	0.06
Pool	0.1173554	0.00
Price adjusted	0.0581642	0.04
Property type	-0.4167224	0.00
Waterfront	0.1622803	0.00
Distance to closest beach (m)	0.0002758	0.00
Distance to closest beach (m)	-0.0000001	0.00

*Significance is generally considered very high at $p<0.01$; medium high at $p<0.05$ and just significant at $p<0.1$.

4.5 Total amenity value

The total coral reef amenity value is based on the hedonic pricing function, resulting solely from the beach variant model. As seen earlier, the other two coral-related variables ('distance to reef' and 'distance to coast and distance to reef') are not statistically significant and are therefore excluded.

The amenity value of the beach is based on the assumption that the value of the beach can be fully attributed to the reef value: without coral reefs, there would be no beaches. This assumption is justified given that Bermuda's beaches are known to be of coralline origin. Our analysis determines the additional value in terms of a change in house prices resulting from every additional meter distant from the beach. This can be used to estimate the consumer's 'marginal Willingness to Pay' for coral reef amenity in Bermuda, as illustrated in Figure 4.7. Because the estimated relationship between distance to beach and house price is linear-quadratic, the marginal price is not constant, but varies depending on the distance to the beach.

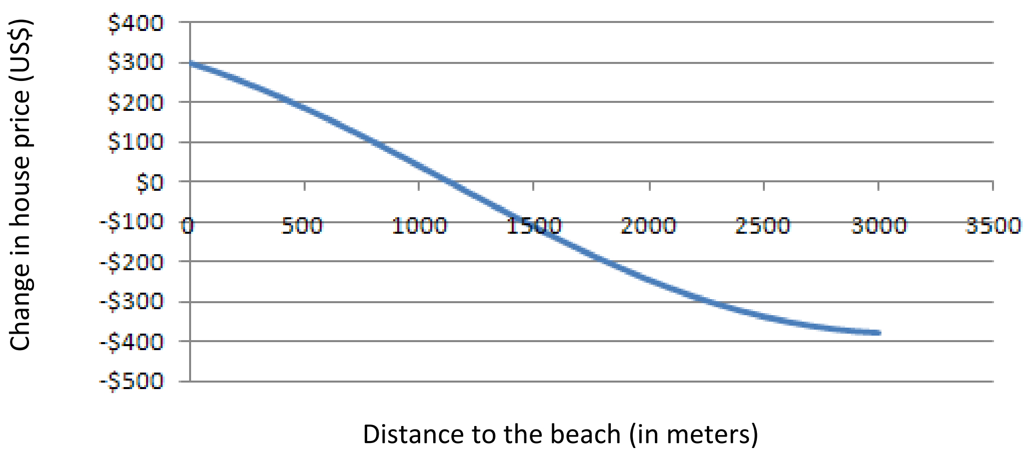


FIGURE 4.7. 'MARGINAL PRICE' (ADDITIONAL VALUE) THAT BERMUDA CONSUMERS ARE WILLING TO PAY FOR CORAL REEF AMENITY (AN EXTRA METER OF DISTANCE FROM THE BEACH).

The marginal price alone cannot be used in estimating the total amenity value, as it represents the value of a small increase in distance. The total amenity value equates the surface under the marginal demand curve, and is calculated as follows:

1) The total price of the houses sold in the sample is calculated, amounting to approximately $890 million.
2) The value of the houses in the 'deterioration' scenario in which amenity value is expected to decrease with the disappearance of the beach (Box 4.1), is calculated as follows: The relationship between price and distance is extrapolated, yielding approximately $728 million. Given results obtained, maximal distance to beach is arbitrarily attributed as 2.5 km, with no amenity value after 2.5 km.

3) The amenity value is determined by calculating the difference between *current house price* and *house price in deterioration scenario*.

4) **Box 4.1. The Deterioration Scenario**

The amenity value is based on a comparison of the value of all houses currently on Bermuda with the value of the houses in a scenario where there are no coral reefs, beaches or coast. This scenario is constructed by virtually moving the coral reef and beach away for a large distance as can be seen in Figure 1, and is referred to as the "deterioration scenario".

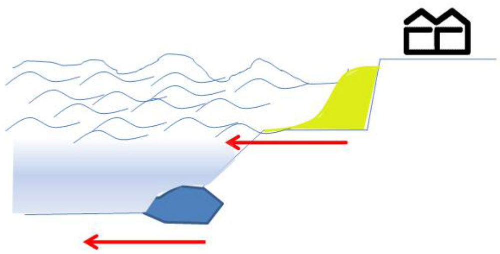


FIGURE 1 DETERIORATION SCENARIO

Based on our hypothesis, a negative relationship is expected between house prices and distance to reef, beach or coast. In other words, increasing the distance from a house to a beach should result in a lower selling price. Figure 2 illustrates this relationship. The value in the deterioration scenario is calculated by extrapolating the relationship between house price and distance for all houses in the sample. Care must be taken in extrapolating the price function, as the greater the extrapolation, the more uncertain becomes the relationship, as it is no longer based on existing data.

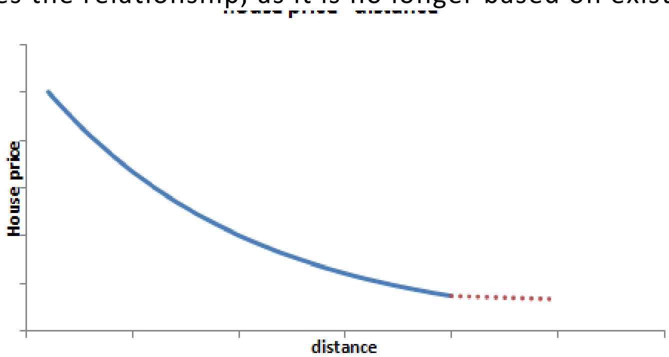


FIGURE 2 EXPECTED RELATIONSHIP HOUSE PRICES AND DISTANCE TO THE BEACH

The amenity value calculated for the collected dataset is given in Table 4.6, and extrapolated to the total number of houses on Bermuda. The total value of all houses in the dataset is of approximately $860 million; this value decreases to $728 million in a hypothetical scenario of no beach. Given that the total number of houses in the year 2000 is reported to be 25,148 (Department of Land Valuation 2008), a total beach value of $5.6 billion can be calculated for Bermuda, amounting to a value of $221,000 per house (Table 4.6).

TABLE 4.6. TOTAL AMENITY VALUE OF BERMUDA'S CORAL REEFS.

No houses (sample)	593
Value (beach)	$859,694,845
Value (no beach)	$728,428,602
Total value (sample)	$131,266,242
No of houses (Bermuda)	25,418
Total value	$5,626,518,300

The total value is a capitalized value over the total life span of the houses. Assuming a time span of 100 years, this value is converted into equal annual amounts. The results are shown Table 4.7. This results in an annual amenity value for Bermuda's coral reef of $6.8 million per year.

TABLE 4.7. ANNUALIZED AMENITY VALUE OF BERMUDA'S CORAL REEFS.

Years	100
Capitalization factors	20
(Sample) value per year (years)	$160,634
(Sample) value per year (infinite)	$159,412
(Total) value per year (years)	$6,885,309
(Total) value per year (infinite)	$6,832,950

5. Recreational and cultural value

Luke Brander, Tadzio Bervoets, Sebastiaan Hess, Pieter van Beukering & Samia Sarkis

5.1 Introduction

Bermudans have traditionally placed a high value on their maritime heritage in general, and the coral reefs in particular. Although knowledge and awareness concerning the island's reef system appears to have receded, it is still evident that residents place a high value on their coral reef resources. This is made apparent by the significant number of people that use the island's aquatic environment for recreational purposes, such as recreational fishing, swimming, diving, and snorkeling, and who enjoy the island's exceptionally clear water and the pink sand of its beaches. Because most residents do not depend on the ocean for subsistence or livelihood, the relationship between Bermudans and the reefs can be described as predominantly recreational and cultural.

In order to quantify these recreational and cultural values in monetary terms, a so-called choice model valuation study was designed and implemented specific to this study. Using a survey of Bermuda households, an attempt is made to elicit the preferences that Bermudans have for a number of characteristics related to coral reefs and the marine environment.

Choice modeling analyses public preferences towards environmental goods to estimate their economic value. Data is obtained for this study from face to face interviews, conducted in a representative sample of 400 Bermudan households. The questionnaire includes seven sections on: background of respondent; recreational use of reefs; environmental awareness; choice model; demographic characteristics; recreational fishing; diving and snorkeling. In the choice model section each respondent is repeatedly asked to choose between complex, multi-attribute profiles describing various changes in Bermuda's coral reefs. The selection of coral reef attributes is specific to this case study and determined following consultation with focus groups and experts.

The attributes selected are: i) quality of coral reef, ii) fish catch per fishing trip, iii) swimming restrictions, iv) water clarity, and v) environmental levy.

Given the complexity and specificity of the choice model design and questionnaire development, a description of the steps taken is given in the methodology section.

5.2 Methodology

The methodology used in designing and implementing the choice model valuation study involves the following steps: 1. choice model design; 2. questionnaire development; 3. survey implementation; and 4. analysis of results. A more extensive explanation of the choice modeling valuation method itself is provided in Appendix IV.1.

5.2.1 Choice model design

Designing a choice model for the valuation of recreational and cultural services provided by coral reefs in Bermuda involves a number of important steps, including the identification of key services related to Bermuda's reefs through focus group and expert consultation, selection of attributes and levels with which to describe reef services, and the representation of these attributes and levels.

5.2.2 Focus group and expert consultation

Focus groups and expert consultations are used to identify and obtain information on the most important services provided Bermuda's reefs and the main threats that they face. Focus groups have been shown to be essential in identifying and describing the most relevant attributes and their associated levels for use in choice experiments (van Beukering *et al.*, 2006).

The identification of attributes for the Bermuda choice experiment started with consultations with experts and a review of coral reef choice experiment studies. At this stage a preliminary list of five attributes were selected: (i) recreational fishing, (ii) coral diversity/fish diversity (or fish abundance), (iii) recreational activities (scuba diving/snorkeling), (iv) water quality, and (v) a payment vehicle.

Recreational activities and fishing are included in order to determine the residents' use values for the coral reef ecosystem. Coral diversity and fish diversity are suggested as attributes that would enable the measurement of non-use values. Similarly, water quality is also listed as a possible attribute that would allow for the measurement of non-use values. Water quality relates to the visible quality/clarity of the water surrounding Bermuda. With regards to the payment vehicle, in preliminary consultations held with the steering group in Bermuda, it was decided that the payment should not be described as a tax. An environmental levy is proposed as an alternative payment vehicle. It is the opinion of the steering group that Bermudans would not accept the payment of an additional tax.

On Bermuda, three focus group discussions and one expert consultation were held. The three focus groups were: (1) *Recreational fishers*, comprising of Bermudan residents who fish recreationally; (2) *Snorkelers and scuba divers*, comprising of Bermudan residents who scuba dive and snorkel; and (3) *Bermuda Residents*, comprising both ex-patriots and Bermudans, who do not fish or scuba dive.

An expert consultation was held with coral reef and fishery experts, from governmental departments (Conservation Services and Environmental Protection) and the Bermuda Institute for Ocean Science (BIOS), a local NGO. The consultation was held in order to determine the appropriateness of questions in the general survey as well as attribute selection and levels in the general survey.

5.2.3 Attribute selection

Based on the focus group discussions and expert consultations, the following attributes are selected for inclusion in the choice model (details of the considerations regarding each attribute are given in Appendix IV.2)

- *Payment vehicle*: An environmental levy tied to the monthly electricity bill etc. The four levels for this attribute are set at 5 BMD, 10 BMD, 20 BMD, and 50 BMD per month.
- *Quality of the Coral Reef*: The variety and abundance of coral, reef fish and other creatures. The three levels for this attribute are poor, medium and high quality of the reef.
- *Fish catch per trip*: Percentage increase/decrease from the present catch. The levels are set at 20% higher catch, no change in catch, and 20% lower catch.
- *Water Clarity*: Described as poor, medium or high clarity.
- *Swimming Restrictions*: Number of closures during the swimming season (the summer months when the waters are warmest). The three levels for this attribute are set at 7 days, 4 days, and zero days restrictions.

The five attributes and their respective levels included in the design are summarised in Table 5.1.

5.2.4 Choice set design and representation

The statistical design for the choice experiment (the combination of attribute levels and alternatives in each choice presented to the respondent) is generated using Sawtooth/SSI software and a fractional factorial design. Six separate choice sets, each consisting of five choice cards, are generated. Each choice card contains three alternative options: two management options and an option representing the future situation without extra management. Each respondent is asked to answer one of six sets of five choice cards (i.e. there are 30 choice cards in total).

No prohibitions on the combinations of attribute levels within an alternative are included in the design, so it is possible that apparently contradictory combinations could occur (e.g. poor water clarity with no swimming restrictions). Whether or not respondents picked-up on any contradictory combinations of attribute levels was examined in the pre-test. The design is manually checked for dominant choices, i.e. for combinations of alternatives in which the attribute levels for one alternative are all better than in the other alternative.

The attribute levels for each alternative on a choice card are represented by pictograms together with explanatory text to aid respondent understanding of the choices they are asked to make. Figure 5.1 presents an example choice card.

TABLE 5.1. ATTRIBUTES AND ATTRIBUTE LEVELS USED IN THE CHOICE EXPERIMENT

Attribute	**Level Description**
Quality of the coral reefs: This relates to the variety and abundance of coral, reef fish, and other creatures.	Poor, meaning a low variety and abundance of coral reef life Moderate, with higher variety and abundance, more or less like it is today High, with many different species and animal numbers
Catch per trip: This is the amount of fish (and other inshore species) that can be caught by a local recreation fisherman on an average fishing trip.	20% lower catch than today The same average catch as today 20% higher catch than today
Swimming restriction: In the future there may be limitations to safe swimming due to marine pollution (e.g. sewage, chemicals etc.) during the summer season. Certain swimming sites could be closed because of health risk of going in the water.	7 days of restrictions, where it is not allowed to swim in swimming sites close to shore 4 days of restrictions, where it is not allowed to swim in swimming sites close to shore No restrictions, as is usually the case today
Water clarity: This determines how far you can see into the water from the shore or when swimming, snorkeling or diving.	Poor clarity Medium clarity High clarity, as is usually the case today
Environmental levy. This levy would be paid by all Bermudans and foreign residents on a monthly basis. The proceeds of the levy would solely be used for protection and restoration of the reef and would be managed by a non-governmental organization. Specific measures include paying for rebuilding damaged reef by transplanting coral; cleaning up marine trash and pollution; and providing better and wider education campaigns to make Bermudans aware of the importance of the reef for Bermudan life.	*0 BMD* *5 BMD* *15 BMD* *25 BMD* *40 BMD*

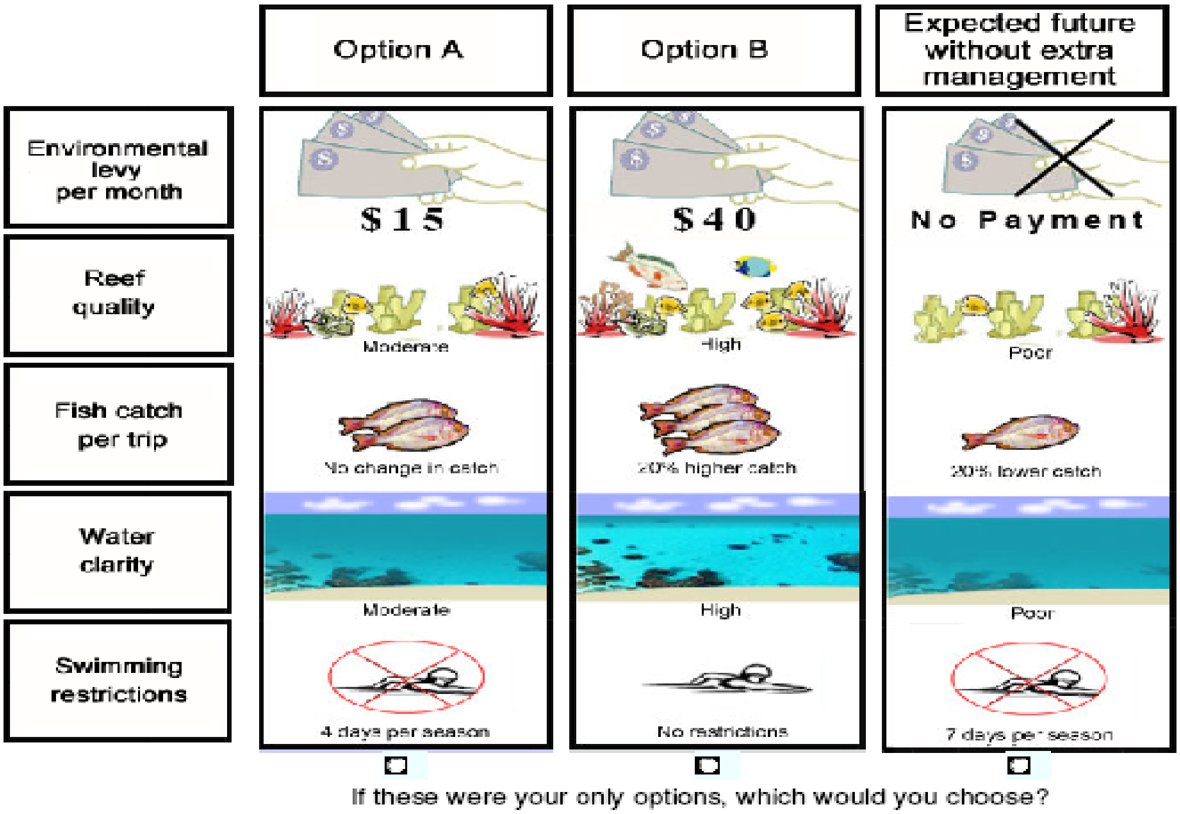


FIGURE 5.1. EXAMPLE OF BERMUDA CHOICE CARD AS PART OF THE CHOICE EXPERIMENT

5.2.5 Questionnaire development

The survey is divided into 7 sections, each dealing with a specific theme:

1. Section I includes general questions relating to the respondent's background, the length of time they have been residing on the island, and how long the respondent plans to stay on Bermuda. These questions are not only important for the analysis, but also enable the respondent to 'warm up' before engaging in the more difficult questions of the survey.
2. Section II deals with the respondent's recreational use of the reefs, i.e. how the respondent uses the reef for recreational activities. These questions are included in order to determine the level of use of the reef resource.

3. Section III focuses specifically on the level of environmental awareness of the respondent. This section includes questions on whether or not the respondent has made any monetary contributions to environmental causes or organizations, on the importance the respondent places on environmental issues, and if the respondent are, in principle, willing to pay an environmental levy contributing towards the improvement of the Bermuda environment. It is important to note that this section does not include any questions specifically on awareness of coral reef related issues; instead it focuses on general environmental awareness.
4. Section IV contains the choice experiment. This section is more involved and requires direct assistance and guidance by the interviewer. Aside from the choice questions, this section also includes follow up questions to the choice experiment. These questions are on how the respondent made his/her choices and which attributes are important to the respondent.
5. Section V includes demographic questions needed for the statistical measure of the respondent's profile. Respondents are made aware that these questions are for statistical purposes only, as some of them are considered quite sensitive. Respondents are asked to state their yearly income per household, ethnic background, level of education, and employment. These questions are included to give an insight into the values of the respondent and how they are shaped by differing demographic variables.
6. Section VI contains questions related to recreational fishing. This section opens with a question asking whether or not the respondent or anyone in the household engages in recreational fishing and if so the recreational fishing questions are completed by the respondent or the member of the household who most actively fishes. If no fishing was conducted by members of the household, the section is skipped. The fishing section, aside from questions used to determine the level of use, also includes additional questions that were specifically requested by the Bermuda Marine Resources Section (Department of Environmental Protection), as a first record for recreational fishing activity on Bermuda.
7. Section VII contains questions related to scuba diving and snorkeling. Respondents are asked whether or not they or anyone in the household snorkeled or scuba dived. If this is the case, the rest of the section is completed by the respondent or the member who most actively snorkeled or scuba dived; if not the section is skipped.

At the end of the survey respondents are given the option of including their contact information if they are interested to receive information regarding the study. Respondents are made aware both at the beginning of the survey and at the end that none of their personal information would be included in the final report and that the survey will be conducted in strict confidentiality. The questionnaire is included in full in Appendix IV.3.

The questionnaire was pre-tested on 12 randomly selected respondents in the field to test the coherency of the questions, identify any difficulties experienced by respondents, and check the understanding of the choice experiment attributes and levels. Full details of the pre-test and resulting changes made to the questionnaire are provided in Appendix IV.3 and thoroughly discussed in Bervoets (2008).

5.2.6 Survey implementation

A professional research company, Research.bm, was contracted to recruit and train interviewers, conduct the survey, and manage data entry. For the survey, each interviewer was provided with a package of material, which they were to use during the interview. This included:

1. *Questionnaire*. The questionnaire, as shown in Appendix IV.3, includes an interviewer version that differs slightly from the respondent version. The interviewer version, which functions as the response sheet for each conducted interview, includes information on the location of the interview, start time and end time; name and ID number of the interviewer, and the date the interview is conducted. The respondent version only includes the questions; it is laminated for the sake of durability and each interviewer is supplied with one. The respondent version is included in order to facilitate the information processing of the respondent by enabling him or her to read along with the questions.

2. *Instructions for interviewers*. The instructions for interviewers includes specific instructions as to how to conduct the general survey, what to bring to the interview, and the sampling strategy. The instructions for interviews are given in Appendix IV.4.

3. *Interview protocol.* Each interviewer is supplied with an interview protocol (see Appendix IV.5), which includes information specific to conducting the choice experiment portion of the survey. It also includes information to familiarize the interviewer with the interview process, what to keep in mind while interviewing, and key-words which would assist the interviewer during the course of the interview.

4. *Choice-sets.* Each interviewer is provided with a bound and laminated version of the choice-sets. Each interviewer is given all six versions of the choice sets, allowing them to use a different version with each respondent with the aim of reducing interviewer bias. The first choice card in each version is an example card, which the interviewer could use when explaining the choice experiment to the respondent.

5. *Attribute descriptions.* Interviewers are given a laminated version of the attribute description. The written descriptions are supplemented by the pictograms as they appear on the choice cards in order to facilitate information processing by the respondent.

Prior to training the interviewers, the interview trainer is made thoroughly familiar with the basic principles of the choice experiment, and how the interviewers should assist the respondents. This information is also included in the interview protocol and in the instructions for interviewers. Specific attention is also paid to the precise recording of the version number on the response sheet of each choice experiment.

Based on meetings held with the Bermuda Department of Statistics, it was concluded that a representative sample of 400 completed questionnaires would be sufficient to allow statistically significant inference from the survey results. Interviewers are instructed to sample every third household in the selected street. If a household is not at home, the interviewer should move on to the following household. Research.bm, the company contracted to conduct the survey, employed interviewers from every community on the island; this ensures a higher number of completed surveys due to the familiarity the interviewer has with his or her own community.

5.3 Data description

5.3.1 Socio-demographic characteristics

To check the representativeness of the survey results, a comparison is made with other large scale surveys conducted in Bermuda. The 2004 Expenditure survey, including a sample of more than 750 respondents, provides a good basis for comparison of several socio-demographics characteristics such as ethnicity, income and household size.

As shown in Table 5.2, the ethnic composition of both samples is quite similar. The coral reef survey has a slightly higher share of black (59% versus 52%) and mixed households (8% versus 5%), resulting in a lower representation of white households (27% versus 39%). These differences are not dramatic and thus are unlikely to affect the results. However, it is worthwhile to check whether ethnicity is a determinant of the 'Willingness to Pay' (WTP) for coral reefs protection, for reason of extrapolation to the overall Bermudan population.

TABLE 5.2. ETHNICITY OF RESPONDENTS

	Census	**Survey**
Black	52%	59%
White	39%	27%
Mixed	5%	8%
Other	5%	6%
Total	**100%**	**100%**

Since household income is often a strong determinant of the WTP for coral reef protection, it is important for the coral reef survey to be representative of the Bermuda income distribution. The coral reef survey experienced a rather high refusal rate for the household income question. Almost 32% of the respondents refused to report their income levels. If this refusal is evenly distributed across the sample, it may not affect the results very much. The income distribution patterns between the 2004 Expenditure

Survey and the coral reef survey are plotted in Figure 5.2. By eliminating the refusals from the sample for the income distribution, the patterns between the 2004 Expenditure Survey (Census) and the coral reefs become similar.

Another way of testing the difference between both surveys is to look at average household income. Income was recorded as BMD, and converted to USD for the purpose of this study. The average annual household income recorded in the 2004 Expenditure Survey was 106,270 USD, which with 4% income growth equals 124,300 USD in 2008. The coral reef survey generated an average annual household income of 124,900 USD. Given the similarity of the income distribution and average levels, it can be concluded that the coral reef sample is likely to be representative of the Bermudan population with respect to income.

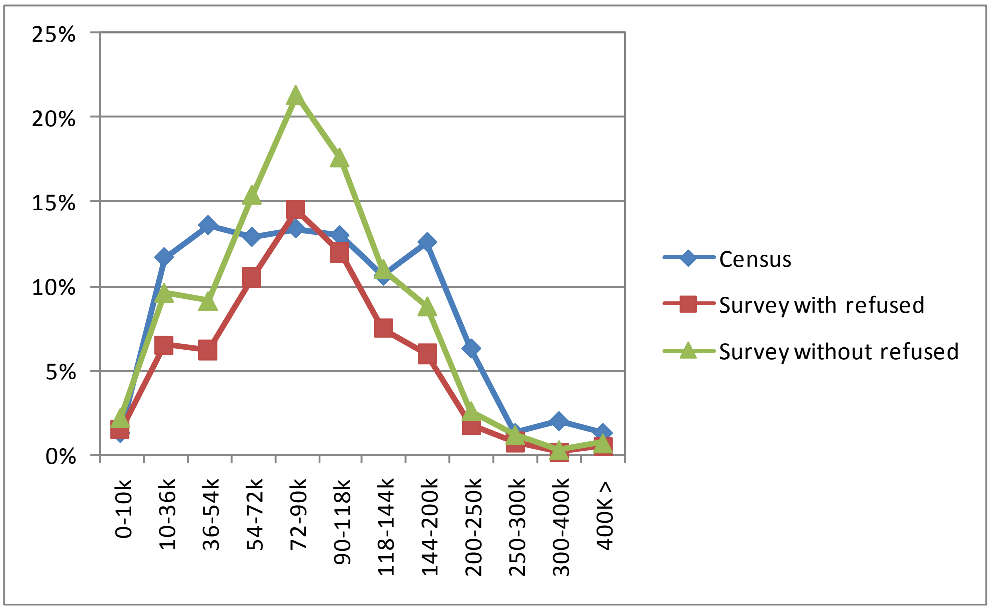


FIGURE 5.2. ANNUAL GROSS HOUSEHOLD INCOME (USD)

The educational level of the respondents is shown in Table 5.3. Since there is no precise information available regarding current educational levels for the Bermudan population, it is hard to judge whether this variable is representative for Bermuda. The levels of educational attainment in the sample appear to be normally distributed, with the majority of the respondents within the categories of Senior school, Technical/vocational and University level. There is no reason to suspect that this outcome deviates from the actual education level in Bermuda.

TABLE 5.3. EDUCATION LEVELS OF RESPONDENTS

	Share of sample (in %)
Primary	0.8
Middle school	2.5
Senior school	33.8
Technical/vocational	24.8
University	37.5
Do not know / refused	0.8
Total	**100.0**

Table 5.4 shows the country of origin of the participating respondents. Although the large majority was born in Bermuda, a substantial share of the interviewed households migrated to Bermuda from abroad. US and UK citizens are the most common migrants to Bermuda.

TABLE 5.4 ORIGIN OF RESPONDENTS

Country of origin	Share of sample (in %)
Bermuda	81.5
United Kingdom	3.0
United States	3.5
The Caribbean	2.8
Canada	2.5
Portugal/ Azores	2.0
Elsewhere, specify …	4.5
Refused	0.3
Total	**100.0**

On average, respondents who were not born in Bermuda immigrated to Bermuda nine years ago. However, as shown in Figure 5.3, the majority of the migrants came in the last six years. Knowing the long-term motives of the new-comers may also be important in determining their willingness to invest in the environment of Bermuda. People who intend to stay only briefly on the island may have less interest in protecting the island for future generations. Therefore, the respondent's intention to stay in Bermuda was also asked. Around 41% of the non-Bermudans intend to stay no longer than 5 years, 19% intends to stay between 5 to 10 years, 10% between 10 to 25 years, and 27% has no intention ever to leave the island.

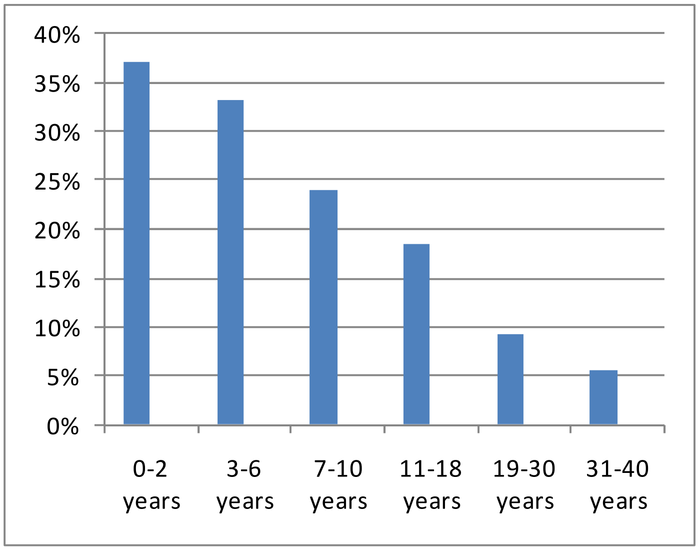


FIGURE 5.3. INTENDED LENGTH OF STAY ON BERMUDA FOR NON-BERMUDANS

5.3.2 Reef-related recreational activities

Concern about the marine environment and the willingness to contribute to its protection depends often on the level of interaction people have with coral reefs, oceans and beaches. Therefore, the survey includes a section on reef-related recreation activities of the household.

To begin with, households are asked about their ability to swim. The majority of the respondents are able to swim (83%) while the spouses of the respondent are less skilled swimmers (53%). In 38% of the families, all members of the family, including the children, are able to swim. All in all, ability to swim does not seem to be a serious obstacle to interact with the reef.[14]

Figure 5.4 shows the degree of participation of households in reef-related recreational activities. As expected, swimming is by far the most popular marine-related recreational activity of the interviewed households. Beach picnic is also a popular leisure activity. While half of the respondents still participate in watersports such as sailing, surfing and boating, only 20 percent of the households go out snorkeling and/or diving. On average, the frequencies with which each recreational activity is practiced do not differ much. Those who swim, on average do it 8 times in a year. Those who do watersports, on average go out 5 times in a year. A similar frequency is found for active snorkelers and divers (5 times in a year).

[14] In comparison, a similar study in Guam showed that only between 11% and 16% of the adult household members are able to swim, while less than 9% of the children could swim. This inability to swim is a serious handicap to interact with the reef (van Beukering *et al.*, 2007).

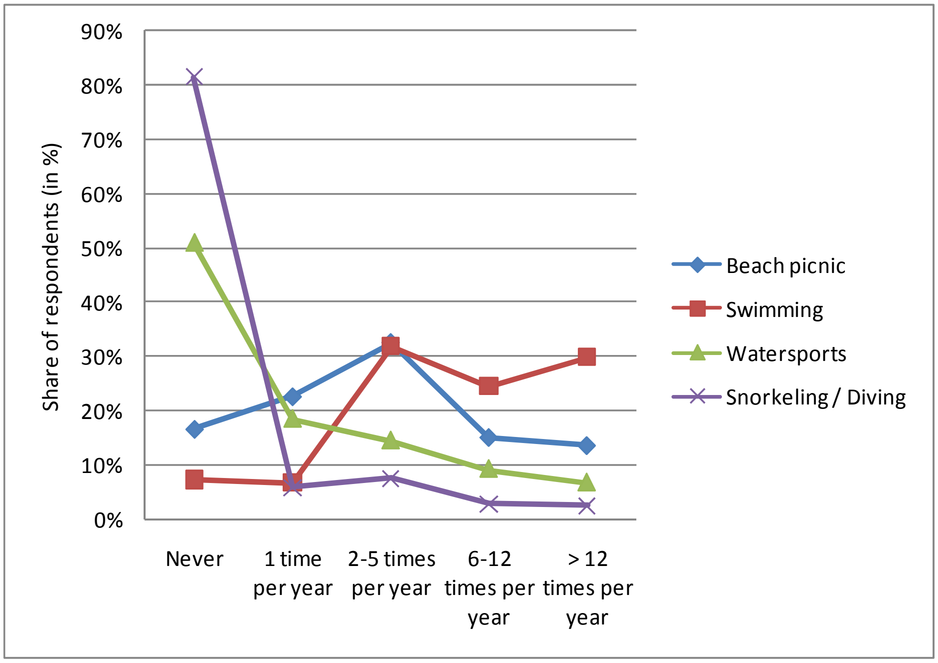


FIGURE 5.4. PARTICIPATION RATE OF HOUSEHOLDS IN MARITIME RECREATIONAL ACTIVITIES

A separate section was included in the questionnaire for those that are active snorkelers and divers. Of the 400 interviewed households, 51 households filled this section of the questionnaire. All of the 51 households are involved in snorkeling and 17 of these households scuba dive at least once a year as well. This implies that 19% of the households in Bermuda are involved in snorkeling and 6% in scuba diving. Within these active households, on average, one to two members participate in these activities. Overall, divers are somewhat less active than snorkelers in terms of number of trips in their lifetime (see Figure 5.5). This is hardly surprising, given that a snorkeling trip requires less time, effort and equipment, and is often one of several activities undertaken on multi-purpose beach visits. Residents report that 80% to 85% of their snorkeling and scuba dive experiences take place in Bermuda, and not overseas.

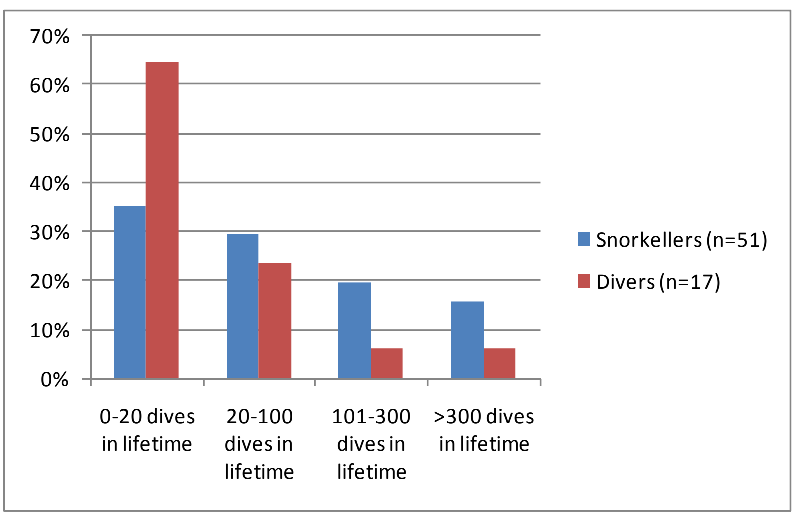


FIGURE 5.5. EXPERIENCE LEVEL OF SNORKELERS AND DIVERS

Figure 5.6 shows the popularity of the various dive sites among the total number of dives by the respondents. The most popular dive sites among Bermudan scuba divers are Snake Pit and Eastern

Wrecks. Note that these are not necessarily the same dive sites that are popular among tourists. The category other dives sites include Eastern Blue Cut, Western Wrecks, Tarpon Hole, Mills Breaker and The Cathedral.

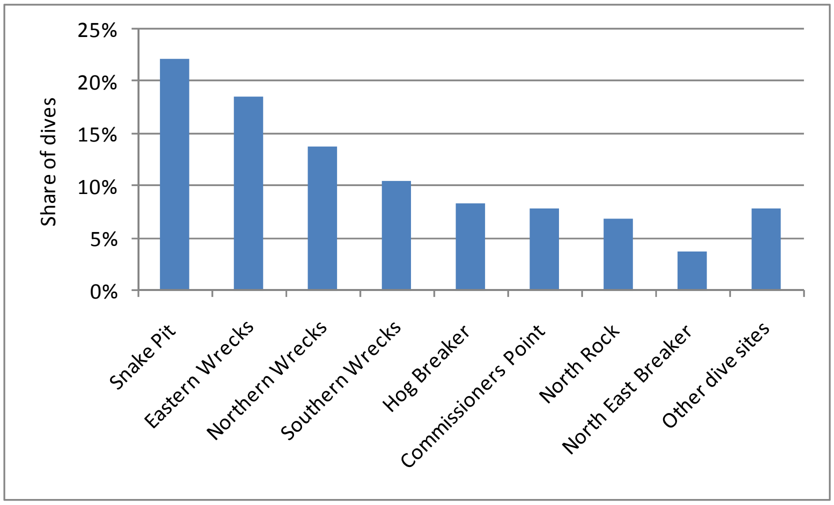


FIGURE 5.6. POPULARITY OF SELECTED DIVE SITES IN BERMUDA

Table 5.5 indicates how the respondents rated the most important attributes for diving and snorkeling. Respondents expressed their perception by choosing a score on a Likert scale between 'not important' and 'very important'. Scores are generated by calculating a weighted average for each environmental issue across the 51 active respondents. An overall score for each attribute is calculated through a weighted average procedure (weights vary from 0 points for 'not important' to 10 points for 'very important'). The last two columns of Table 5.5 give scores for snorkelers only, and for snorkelers who also scuba dive. Divers differ somewhat from snorkelers by appreciating reefs and wrecks relatively more, which are generally located at deeper depth.

TABLE 5.5. IMPORTANCE OF SEEING FISH, RARE SPECIES, CORAL AND WRECKS (SHARE OF RESPONDENTS THAT SELECTED EACH ATTRIBUTE IN PERCENTAGES) AND THE AVERAGE SCORE FOR EACH ATTRIBUTE (ON A SCALE BETWEEN 0 AND 10)

Rank #	Snorkeling/diving attributes	Not important 0 pt	3 pt	5 pt	7 pt	Very important 10 pt	Snorkel only 0-10	Dive also score 0-10
1	Fish	0	5	9	30	56	8.4	8.1
2	Coral	4	7	9	30	51	7.8	8.0
3	Rare species	14	7	19	23	37	6.4	6.5
4	Wrecks	12	19	28	19	21	5.2	6.1

In response to recreational fishing questions, the survey revealed that 30% of the interviewed households have one or more members of the household involved in some kind of fishing. Within this group of recreational fishermen, close to 2 members in the household fish actively. More detailed results of the outcome of the household survey on fisheries are given in Chapter 3, as part of the overall fishery value associated with the coral reef ecosystem.

5.3.3 Environmental awareness

Table 5.6 shows how the respondents rated the most important environment issues in Bermuda. Scores are generated by calculating a weighted average for each environmental issue across the 400 respondents, who expressed their perception by choosing a score on a scale between 'not important' and 'very important'. In a similar fashion, as was done for the attributes shown in Table 5.5, an overall score for each environmental issue is calculated through a weighted average procedure (weights vary from 0 points for 'not important' to 10 points for 'very important').

Several conclusions can be drawn on the basis of this exercise. First, Bermudans are concerned with the environment of their island. On average, only 4% of the respondents felt the issues presented are not important, while 45% of the sample indicate the issues to be very important. Second, waste problems, such as littering and illegal dumping, are perceived to be the most serious environmental issue in Bermuda by the respondents. This outcome can be explained by the fact that solid waste is a very tangible problem, which many people in Bermuda are confronted with. For the same reason, marine pollution follows closely. Third, the direct degradation of marine resources, such as damage to coral reefs and overfishing, are seen as average environmental problems in Bermuda. Besides the fact that these problems are less visible, this perception may also be a true representation of the relatively healthy state of the marine ecosystems in Bermuda; this may be attributed in part to ongoing conservation measures aiming for the protection of the coral reef platform and gear control of commercial reef fishing. Finally, despite the critical media attention on increased container and cruise ship traffic in Bermuda, the respondents do not necessarily see this as a serious environmental problem, explained in part by a lack of awareness of the consequences of such developments on the coral reef system.

TABLE 5.6. IMPORTANCE OF ENVIRONMENT ISSUES (SHARE OF RESPONDENTS THAT SELECTED EACH CATEGORY IN PERCENTAGES) AND THE AVERAGE SCORE FOR EACH ENVIRONMENTAL ISSUE (ON A SCALE BETWEEN 0 AND 10)

Rank #	Environmental issue	Not important 0 pt	3 pt	5 pt	7 pt	Very important 10 pt	Mean score 0-10
1	Trash/littering/ illegal dumping on land	1	2	7	23	68	8.8
2	Marine pollution	1	3	9	25	63	8.6
3	Increased development/ lack of open space	1	3	17	25	55	8.2
4	Degradation of coral reefs	2	5	14	30	49	7.9
5	Over fishing	8	13	32	21	26	6.1
6	Noise pollution	7	18	29	14	31	6.1
7	Increased container and cruise ship traffic	9	17	31	21	23	5.8

Whether and how much people donate for environmental organisations or causes is often a good indicator for environmental awareness as well as their 'Willingness to Pay' for the environment (Brouwer *et al.*, 2007). Therefore, one more question is added on whether the respondent donated to environmental organisations in the last 12 months.

Table 5.7 shows that one quarter of the respondents interviewed donates to environmental causes, either in terms of money and/or in terms of days offered for an environmental purpose. However, there is a clear positive relationship between the level of outdoor activity of the household and the probability of environmental donations. A subgroup is constructed by clustering 'active' outdoor households that are involved in swimming, watersports, or snorkeling and diving more than five times in a year.[15] As seen in Table 5.7, the 'Active outdoor household' group shows a higher share of donators (i.e. 39%) than in the 'passive' or 'less active outdoor' household group (i.e. 20%). In fact, for the group of active snorkelers and divers the share of donating households is as high as 76%.

TABLE 5.7. DONATIONS TO ENVIRONMENTAL CAUSES (% OF RESPONDENTS)

	Passive or less active outdoor household	**Average household**	**'Active' outdoor household**
Donates to environment	20	25	39
Does not donate to environment	80	75	61

The level of donations for an environmental cause is given in Tables 5.8 and 5.9. Typically, households are more likely to provide days of voluntary service to environmental causes (Table 5.8) than money to environmental organizations (Table 5.9). The mean value for donated voluntary services is 2.5 days per household per year and the mean value for donations to environmental causes is equivalent to 71 USD per household per year.

TABLE 5.8. DONATIONS TO ENVIRONMENTAL CAUSES IN LAST 12 MONTHS IN DAYS

Days	**Days donated (n=68)**
1 day	18%
2-3 days	22%
4-10 days	29%
11-30 days	15%
31-50 days	10%
> 50 days	6%

15 Note that of the 400 respondents 217 of them are labelled active swimmers, 64 as active watersports households, and 21 as active snorkelers or divers.

TABLE 5.9. DONATIONS TO ENVIRONMENTAL CAUSES IN LAST 12 MONTHS IN MONEY

Amount	Money donated (n=52)
1-10 USD/yr	13%
11-50 USD/yr	27%
51-200 USD/yr	29%
201-500 USD/yr	13%
500-1000 USD/yr	10%
>1000 USD/yr	8%

5.4 Preferences for marine attributes and 'Willingness to Pay'

Preferences for marine attributes and respondents' Willingness to Pay' (WTP) for changes in their provision are determined from the responses given in the choice model section of the questionnaire.

In order to identify the relative preferences that respondents hold for the attributes included in the choice experiment, a logit regression analysis of the choice data is performed. The preferred model specification is a mixed logit linear model. This specification is based on theoretical expectations and was found to have the highest explanatory power. Table 5.10 presents the parameter coefficients, their standard errors, and P-values for each attribute. All attributes have expected signs (i.e. each attribute affects the probability of an option being chosen in the expected (positive or negative) direction) and have statistically significant coefficients ($p<0.05$). The estimated coefficients represent the slope of the utility function associated with each attribute or, in other words, the change in marginal utility per unit change in the attribute value. For example, the negative coefficient on the tax variable indicates the negative marginal utility associated with a 1USD increase in environmental levy. Note that the exact interpretation of the coefficients depends on the definition of attribute levels used in the choice experiment and on the way that data are coded. For example, an increase in coral reef quality from "poor" to "moderate" (as described in the choice cards – see Appendix IV.7) increases utility by 0.384, whereas a reduction in swimming restrictions from 4 to 0 days increases utility by 0.501.

TABLE 5.10. MAIN EFFECTS LOGIT REGRESSION RESULTS

	Coeff.	Std.Err.	P-value
Coral reef quality	0.384	0.031	0.000
Swimming restrictions	0.501	0.030	0.000
Fish catch	0.132	0.022	0.000
Visibility	0.326	0.029	0.000
Tax	-0.012	0.002	0.000
Derived standard deviations of parameter distributions			
Coral reef quality	0.192	0.016	0.000
Swimming restrictions	0.251	0.015	0.000
Fish catch	0.066	0.011	0.000
Visibility	0.163	0.015	0.000
N	1915		
R^2 adjusted	0.293		
Log Likelihood	-1484.898		

As stated previously, one of the primary motivations for using the choice experiment is to provide a method for valuing non-market benefits associated with Bermuda's coral reefs. The trade-offs made by respondents between the environmental levy attribute and the other non-monetary attributes in the choice experiment, indicate the compensation required for changes in the level of provision of each attribute. The marginal 'Willingness to Pay' for a change in each attribute *i* can be calculated using the formula

$$\beta_i / \beta_{levy} \, .$$

Where β_i is the part-worth utility for attribute *i* and β_{levy} is the part-worth utility for the levy attribute.

Using this method, economic values are derived for each of the four non-monetary attributes in the choice experiment (see Table 5.11). Results indicate that on average households are willing to pay 32 USD per month to improve coral reef quality from a poor to moderate condition. Multiplying this WTP value by the total number of households in Bermuda (26,900) gives a total WTP of 870,000 USD per month. The respondents state strong preferences for reducing the number of days on which there are swimming restrictions. Average monthly household WTP to reduce swimming restrictions from 4 days per year to zero days per year is 42 USD. This gives a total WTP of 1,134,000 USD per month. To improve water clarity from poor to moderate levels, respondents are willing to pay on average 27 USD per month, resulting in approximately 738,000 USD per month when considering all of Bermuda households.

TABLE 5.11. AVERAGE MONTHLY HOUSEHOLD 'WILLINGNESS TO PAY' (WTP) FOR ENVIRONMENTAL CHANGES

Attribute	Change in good/service	Average monthly household WTP (USD)	Total monthly WTP (USD)
Coral reef quality	From poor to moderate	32.33	869,644
Swimming restrictions	From 4 to 0 days	42.17	1,134,360
Fish catch	From current to 20% higher	11.13	299,444
Visibility	From poor to moderate	27.42	737,699

In terms of WTP for improving fish catch from current levels to 20% higher, average household WTP is 11 USD per month. This translates into a total WTP of approximately 300,000 USD per month across all households on Bermuda. That WTP for improvements in fish catch is lower than for the other marine attributes, may partly be explained by the fact that only 30% of the respondent households are actively engaged in fishing. It may also be attributed to the fact that the highest motivation for recreational fishing is strengthening bonds and enjoyment, rather than catching for food or for sharing. Hence, the amount of fish caught does not seem to be relevant to the recreational experience of going out fishing. If the latter is indeed true, the result of the choice experiment is likely to provide an underestimate of the value of recreational fishing. However, it will result in a good estimate of the value of fish abundance to recreational fishing (i.e. the value of having a healthy marine environment). In comparison, over 90% of respondents go swimming at least once a year, indicating a high "use" of the marine environment, explaining the substantial WTP to avoid swimming restrictions (42 USD per month).

The estimated WTP amounts for each separate attribute can be summed to obtain an aggregate measure of WTP for recreational and cultural values associated with Bermudan coral reefs. For example, the total value of an improvement in coral reef quality from poor to medium, a reduction in swimming restrictions from four to zero days per year, a 20% increase in recreational fish catch, and an improvement in visibility from poor to moderate would be around 3 million USD per month.

In order to assess the validity of these results, a number of additional questions are included in the questionnaire to gauge respondents' attitudes to paying for improvements in the marine environment and the process by which they made their choices. The choice model exercise was preceded by the following question: "Are you in principle willing to pay an environmental levy, which would be managed by a Non-Governmental Organization, contributing to improving the Bermuda environment?" The purpose of this question is to measure whether Bermudans accept the payment vehicle. Less than half of the respondents indicate to be willing to pay an environmental levy. This share is unusually high, compared to similar studies (van Beukering, 2007). Part of the explanation may be due to the lack of income tax in Bermuda, making respondents reluctant to commit to these types of economic instruments. Other possible explanations may be that respondents do not believe that paying an environmental levy will result in an improved marine environment (i.e. that it will it not be used for marine management or will not improve reef quality).

However, this apparent negative attitude towards environmental levies is not, reflected in the choices that respondents made in the choice experiment. Only a small proportion (6%) of respondents refused to make a choice or opted for the zero levy option (expected future scenario). The most common reason for opting out was that options presented were not perceived as realistic (24%). Other reasons included: a) the fact that respondents did not feel responsible for the reef degradation (18%), b) many were sceptical about whether environmental levies would be used for the intended purpose (18%), and c) others were fundamentally against increasing taxes (18%). So despite a high proportion of respondents claiming to be unwilling to pay an environmental levy in principle, the results of the choice experiment suggest that most Bermudans are actually willing to make clear trade-offs between levies and the non-monetary attributes.

In addition to the above-described question, a follow-up question was asked to reveal the selection approach that the respondents followed. The most common approach followed was to consider only a limited number of attributes (37%). One third (33%) of the respondents considered all attributes simultaneously. A small group considered one attribute only (9%), or made a purely intuitive choice (9%). Only 6% of the respondents claimed to have followed a random selection process, while 5% of the respondents have no idea how final choices were made. For the choice model results to be meaningful, it is important that respondents make choices based on their preferences for the attributes used in the choice sets. If some respondents are genuinely indifferent to some of the attributes, it is valid that they base their choices on only a limited number of attributes. If respondents make choices randomly, this introduces unexplained variance or “noise” in the choice data.

5.5 Total recreational and cultural value

The use of a choice model valuation study in Bermuda produced useful and significant results in quantifying recreational and cultural values related to coral reefs. Employing this valuation approach did, however, face some challenges. An important practical challenge relates to the difficulties associated with conducting face-to-face interviews on Bermuda arising from various cultural and social factors. These include high value of privacy to resident Bermudans, the mistrust of government institutions and thus of surveys that may seem to elicit information for government institutions, and factors related to inter-race relations. In addition, the implementation of the survey was constrained by the lack of available interviewers. When this became apparent an alternative means of survey implementation was sought. A web-based questionnaire was considered, although face-to-face surveying remained the preferred method given that the choice questions require detailed explanation and that some sections of the population might not have internet access. Ultimately, a professional research company, Research.bm, was contracted who had experience conducting face-to-face surveys in Bermuda and who employed a group of professional interviewers for face-to-face interviewing.

The results of the choice model valuation study show that Bermudan residents hold significant positive recreational and cultural values related to Bermuda's coral reefs and to the marine environment. Marine management policies that result in improvements across all four environmental attributes would generate substantial benefits to the Bermudan population. For example, improvement in coral reef quality (poor to medium), reduction in swimming restrictions (from 4 to 0 days), increase in fish catch (from current to 20% higher), and improvement in visibility (from poor to moderate) would result in a welfare improvement equivalent to an increase in average monthly household income of around 113 BMD (equivalent to 113 USD). In aggregate terms, these improvements would be worth over 3 million USD per month to the population of Bermuda, or 36 million USD per year.

6. Coastal protection value

Sebastiaan Hess, Pieter van Beukering & Samia Sarkis

6.1 Introduction

Coastal erosion, inundation, and flood risk depend on the physical properties of a given coastline (i.e. elevation, rock and soil-type, and location) as well as on biological properties (i.e. existence of buffering habitats, such as coral reefs and mangroves). Because coral reefs absorb much of the incoming wave energy, they function as natural breakwaters and help to protect the shoreline from erosion and property damage. For example, measurements show that up to 77% of the force of waves in Nicaragua is eliminated by discontinuous coral reefs (UN Atlas of the Oceans, 2002). In other words, without the wave buffering and sand production roles of coral reefs, rates of coastal erosion and beach loss (and associated economic damage) would be significantly higher (Mullane and Sukzuki, 1997).

Bermuda is almost entirely made up of aeolonite rocks, essentially wind-blown sand dunes cemented into limestone rock; because of the relatively low degree of hardening and cementation of these rocks, the island is susceptible to erosion from wave action. A recent study assessing coastal erosion vulnerability has brought to light the vital role played by the rim and boiler reefs in the protection of Bermuda's shoreline (SWI, 2004a).

The coral reefs of Bermuda dominate the coastal zone, and are one of the healthiest ecosystems in the Caribbean. It has been shown that Bermuda's coral reefs contribute markedly to the reduction in daily wave action, and the dissipation of wave energy (SWI, 2004b). Despite the presence of coral reefs, storm-induced waves are the most significant source of erosion in Bermuda, greatly affecting the shoreline. Without the reefs, wave energy reaching the shoreline would be greater, from daily and storm-induced action, markedly affecting the stability of the islands (SWI, 2004b). In order to sustain optimal coastal protection, the maintenance of the health and structure of coral reefs in Bermuda becomes primordial (SWI, 2004a).

Coral reefs are also the source of sandy beaches in Bermuda, a vital resource for both international tourism and local recreation (see Chapters 2 and 5). Beaches exist in a dynamic equilibrium - a balance between the erosive forces of storm winds and waves, the restorative powers of tides and currents, and the accretion from broken coral and sea shells. It is anticipated that loss of coral reefs will negatively affect the stability of beaches, in turn leading to even higher damage from storms and erosion.

The construction of man-made coastal defense structures is not only an expensive alternative to natural protection, but may incur further damages. More specifically, man-made defense structures are likely to have negative effects on geo-morphological processes, potentially leading to increased rates of beach erosion. Such an example is illustrated by preliminary examination on shoreline changes in Hawaii from 1949 to 1989; much of the beach degradation observed was in front of or adjacent to shoreline armoring, such as seawalls and revetments (Mullane and Sukzuki, 1997). In addition, inadequately built seawalls and other structures potentially contribute to hurricane damage, as debris and parts of failed structures act as projectiles; this has been reported on several occasions in Bermuda (SWI, 2004a). Finally, coastal man made defense structures reduce the natural beauty of the coastline; the latter is considered an important asset in Bermuda for both residents and tourists, and an attempt to preserve this is reflected in Bermuda's planning policy (SWI, 2004a).

The assessment of the shoreline protection services provided by Bermuda's coral reefs requires an understanding of the protection provided by both the rim and boiler reefs under different storm scenarios; information on property values in areas receiving at least some protection from the reefs is necessary to this assessment. An "avoided damage" approach is used to value this service, and involves the estimation of the likely damage (and associated economic losses) to a coastal area from a given storm event, with and without the presence of a reef.

6.2 Previous studies on the coastal protection value of coral reefs

Few examples exist on the valuation of coastal protection services provided by coral reef ecosystems. In a World Resources Institute (WRI) study on the total value of the coral reefs of Tobago and St. Lucia in the Caribbean, an estimate of the protective function of the reefs is made (Burke *et al.*, 2008). The method used involves the calculation of an index figure for each section of the coastline representing shoreline stability; several factors are considered, such as coastal geology, occurrence of storms, elevation, and presence of coral reefs. Elements of vulnerability and resistance are incorporated in the final index; such that, a high stability value for a particular coastal section may be due to either a low likelihood of storms or high waves in that area, or to high elevation, or to the presence of coral reefs. The share of the stability provided by the coral reefs is then determined. This is applied to the total land and property value of that share of the land, previously identified as vulnerable to wave induced erosion and storm damage. The resulting coastal protection value of coral reefs for a 25 year period ranges between US$ 450 and US$825 million (US$18-33 million annually) in Tobago, and between US$700 million and US$1.2 billion (US$28-50 million annually) in St. Lucia. The two islands have a similar surface area of vulnerable land (km^2), but differ in land value (higher in St. Lucia), and in the share of coastal stability provided by the reefs. It is worthwhile noting that these values are underestimated, as storm events stronger than 1 in 25 are not considered. Additionally, there are uncertainties in the estimates due to the lack of validation of storm damage, making it difficult to corroborate the share of coastal stability with the share of storm-induced damage.

Other studies have assumed a twofold increase in wave heights in the absence of coral reefs when assessing coastal protection value for Saipan and Guam (van Beukering *et al.*, 2006; van Beukering *et al.*, 2007b). These authors used elevation maps to determine the areas at risk of flooding with and without reefs. The total value of the properties in areas considered at risk is calculated based on an average property value of almost US$160,000 in Saipan, and US$135,000 in Guam. A damage share of 5% of the total value was assumed in case of flooding. Under these assumptions, the increase in damage without reefs is US$8.04 million (US$11.59 million damage without reefs deducted from $3.55 million with reefs) annually in Saipan, and US$8.4 million (US$12.7 without reefs deducted from $4.3 million with reefs) in Guam.

6.3 Methodology

The actual value of coral reefs in terms of protecting the coastal zone is not visible; it only becomes so in the event that reefs degrade resulting in more destructive waves, and increased damage to land and property. It is for this reason that this 'hidden' economic value of coastal protection can only be calculated by comparing hypothetical situations. In the following Section, the information available to estimate the coastal protection value of Bermuda's coral reefs is presented and the steps required for valuation of the coastal protection of Bermuda's reef are discussed. The sought-after estimate of the damages avoided due to the presence of coral reef ideally requires a comprehensive set of information obtained by:

1. Determining the *coastal profile* of Bermuda to assess the vulnerability of different coastal zones;
2. Assessing the *storm regime* for the area such as storm frequency, intensity, storm surge and wave height;
3. Analysing historic information on erosion and property *damage* caused by storms;
4. Identifying *vulnerable lands* based on elevation (i.e. flood zones) which are areas vulnerable to wave-induced erosion or storm damage;
5. Determining the extent of *reef protected shorelines* in Bermuda's coastline involving the identification of coastal segments provided for by reefs;
6. Establishing *stability of shoreline* and contribution from coral reefs, include geomorphology, geology, coastal exposure, vegetation and slope characteristics;
7. Assessing the *property values* for land areas considered "vulnerable" and "protected by coral reef"- provide an estimate of potential losses.

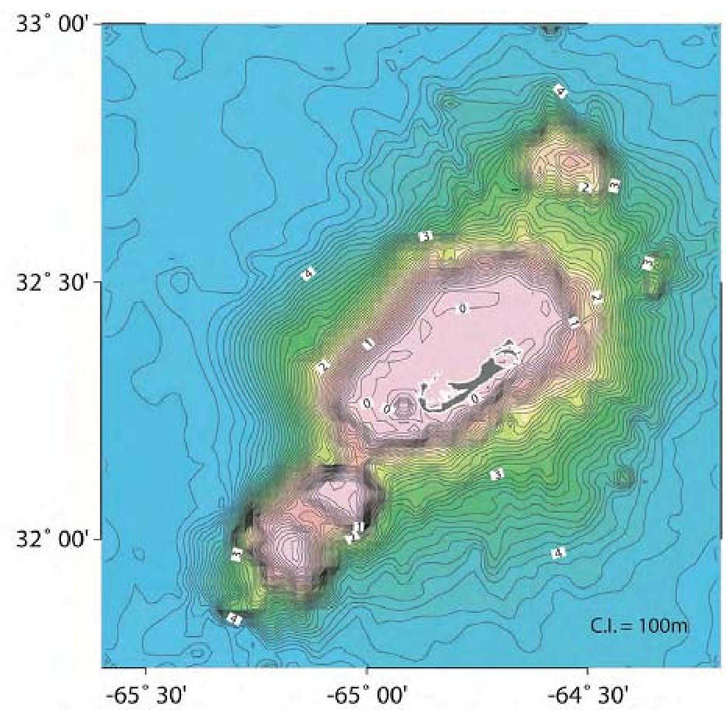
The combination of all of these enables the estimation of the value of shoreline protection provided by coral reefs through reducing erosion and mitigating wave-induced storm damage. The challenges and limitations encountered for the Bermuda case study involve the inability to obtain all of the information above due to limited data access or availability. These limitations are outlined more specifically in Section 6.4 below.

6.4 Data collection and analysis

This Section reports the data available, following the sequence proposed above.

6.4.1 Bermuda's Coastal Profile

The Bermuda islands are of volcanic origin, reaching a maximum elevation of 75m above sea level. Bermuda has two distinct types of shorelines: 1) Sandy shores/beaches and 2) Steep, rocky shore. The latter rocky shores were further categorized as flat rocky, low cliffs and high cliffs (SWI, 2004b). The Bermuda platform consists of a central lagoon averaging about 18m in depth (greatest lagoon depth is in inshore waters, 25m in Devil's Hole, Harrington Sound), surrounded by coral reefs 2-10 m deep (Vogt and Jung, 2007). Just beyond and bordering this narrow reef is a 1-3 km wide "Terrace Reef Zone", referred to as the outer reefs, approximately 20m deep. The central lagoon and outer reefs are collectively referred to as the Bermuda platform. Scattered coral patches within the lagoon rise to within a few meters of sea level (Vogt and Jung, 2007). As seen in Figure 6.1, the pattern of reefs includes a number of ring-like features with diameters of approximately 500-1500 m, commonly referred to as 'patch reefs'.



Numbers in kilometers depth

FIGURE 6.1. DETAILED BATHYMETRY AROUND BERMUDA (VOGT AND JUNG, 2007).

The North Shore of Bermuda is protected by the relatively shallow (<20 m depth average) central and flat lagoon stretching around 15 km seawards from the coast (Figure 6.2); it consists of broad reef flats, and allows for the spreading wave energy over a large surface area. The South Shore is characterized by a line of "boiler reefs", extending along the entire shoreline at approximately 1.5 km from the coast; within the reef line, bottom depth is <10 m, and wave energy tends to be concentrated on a smaller area than observed on the North Shore. Beyond the outer "terrace reef zone", the bottom slopes rapidly to oceanic depths of 3000 m and beyond. As seen in Figure 6.2, Bermuda's land mass is confined to the southern rim of the Bermuda platform, and occupies 7% of the total 665 km^2 platform (Vogt and Jung, 2007). For this reason, the South Shore of the island's coastline is much closer to oceanic depths than the North Shore, and does not benefit from a protective shelf. It follows that the near shore bathymetry along the southern coastline has a strong influence on the sections most exposed to wave action. Much of the coastline is fringed by reefs, and broken by inlets and beaches.

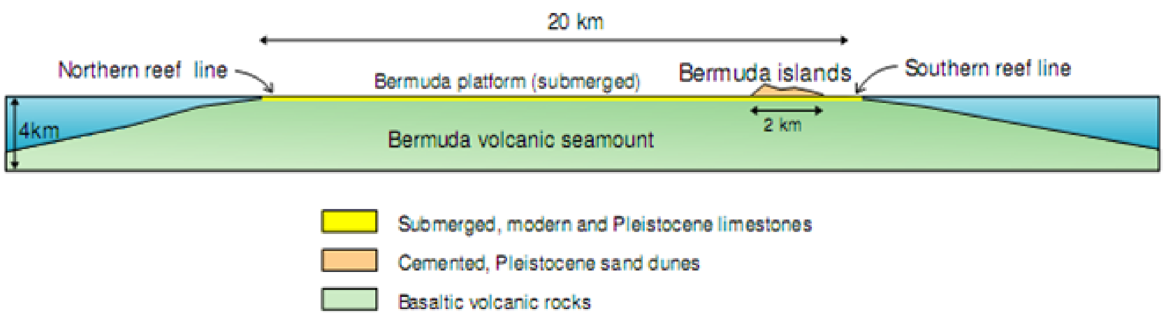


FIGURE 6.2. COASTAL PROFILE OF BERMUDA (VOGT AND JUNG, 2007).

6.4.2 History of storm occurrence in Bermuda

Bermuda is just on the outskirts of one of the hotspots most frequently hit by intense hurricanes in the North Atlantic basin. Tropical storm activity seems to be concentrated to the south and southwest of the island, exposing the island to more than the average number of high category hurricane occurrences. An overview of the number of hurricanes recorded within 150 km of Hamilton, capital of Bermuda, between 1900 and 2003 are shown in Figure 6.3. A hurricane passing within 150km of Hamilton, Bermuda is considered a direct hit by Bermuda weather forecasters (M. Guishard, *pers.comm.).* Many of the storms recorded are of Category 3 and higher, and have caused significant damage to Bermuda. The list includes unnamed storms occurring in 1899, 1917, 1922, 1926, and 1948. Since then, Edna (1953), Daisy (1962), Arlene (1963), Emily (1987), Grace (1991), Felix (1995), Karen (2001), and Fabian (2003) have been recorded. Both the 1922 and 1926 storms were category 4; Edna and Fabian were category 3 (SWI, 2004b).The current average number of storms passing Bermuda is calculated to be 11 storms every 10 years, estimated to increase to 13 storms every 10 years over the next fifty years (SWI, 2004a). It should be further noted that according to Guishard *et al.* (2006), subtropical storms occur at the same time of year as tropical storms, and wind strengths associated with these subtropical storms are in the tropical storm range. As damage from subtropical storms is not assessed in the current study due to lack of data, it should be noted that the resulting coastal protection value will be underestimated.

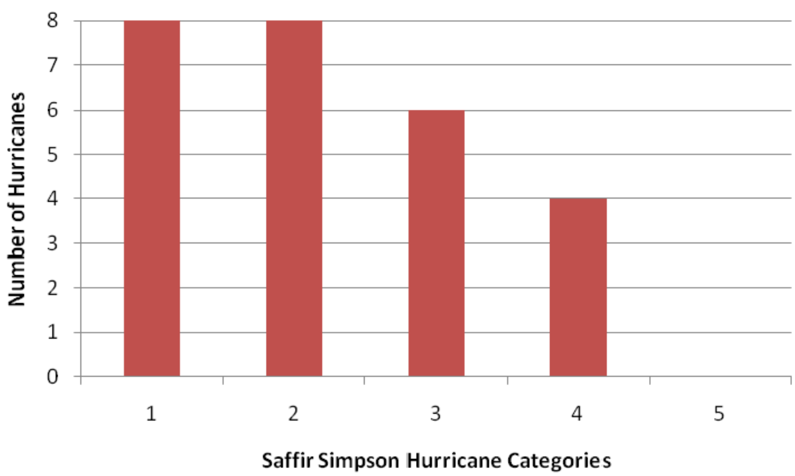


FIGURE 6.3. NUMBER OF HURRICANES PASSING WITHIN 150 KM OF HAMILTON BETWEEN 1900 AND 2003 (SWI, 2004B).

Due to the typical trajectory of tropical storms in the Atlantic basin the majority of waves from storms and hurricanes come from the southeast affecting the relatively unprotected properties on the South shore (see Figure 6.4). Maximum wave heights in deep water (i.e. >200 meter depth) is illustrated, as well as the direction of wave approach (SWI, 2004b). As can be seen in Figure 6.4, the highest waves tend to approach Bermuda from the Southeast, indicating the comparatively greater exposure to hurricane waves of the south coast to the north of the island. Note that winter storms and gales are not taken into account in this study because these weather events come for the most part from the North, having substantially less impact than the hurricanes from the Southeast. This is attributed to the lower intensity of the storms compounded with additional protection provided by the North lagoon.

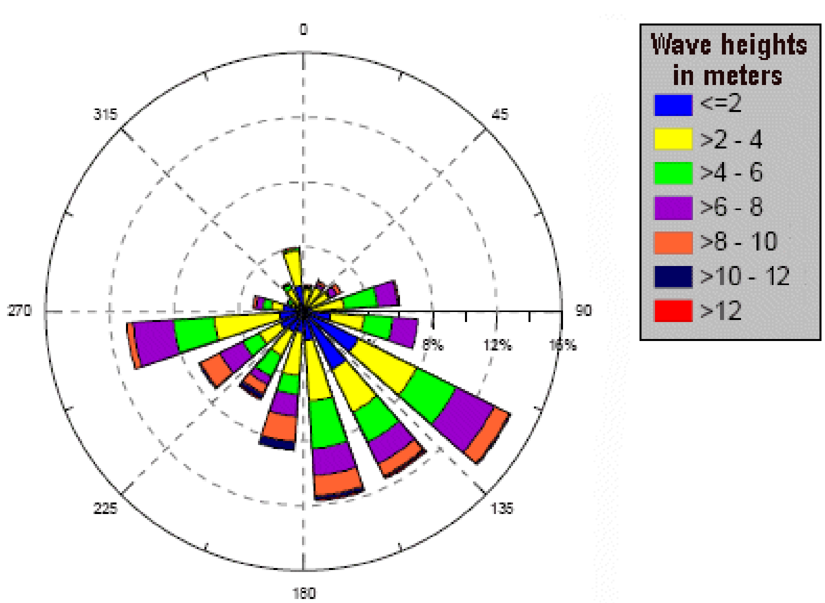
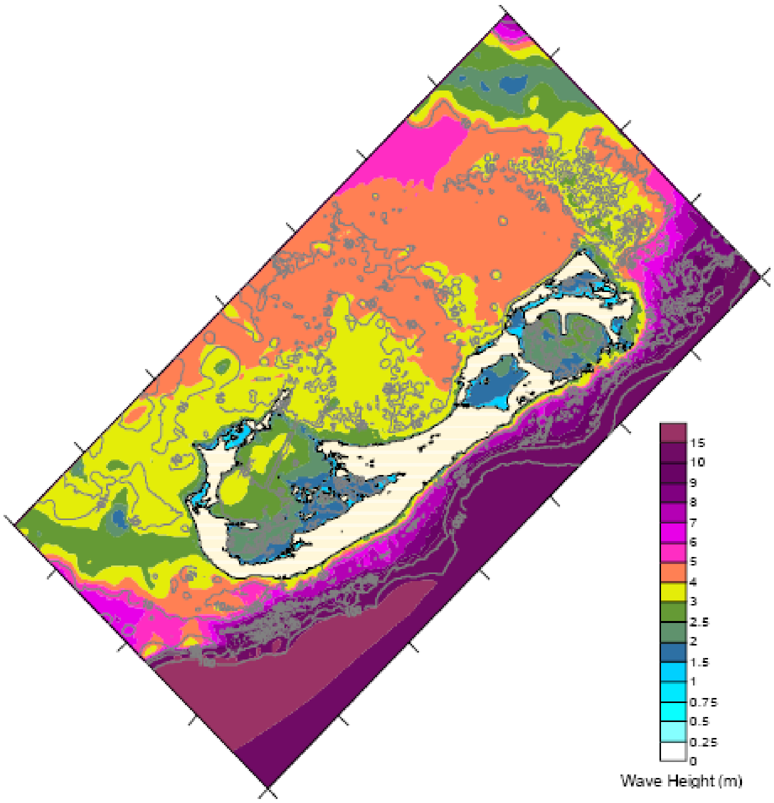


FIGURE 6.4. DIRECTIONAL DISTRIBUTION OF WAVES DURING

STORM EVENTS 1900-2003, TAKEN FROM SWI (2004B).

Information on storm occurrence in Bermuda is available, providing data on direction as well as associated data on maximum wave heights and storm surge for 1 in 50 year events and 1 in 150 year events (see Figure 6.5 for an example). In addition, deepwater wave heights and water levels are available for 1 in 10 to 1 in 200 year events. For a better analysis, additional data is recommended. It is common practice to use information for different coastal sections, with a set of maps on wave height and storm surge for 1 in 10 year events, 1 in 25 year events, 1 in 50 year events, and 1 in 100 year events, etc.[16] (Figure 6.5). Further modeling on nearshore transformation and storm surge is needed to determine the protection values at the different coastal sections of Bermuda (SWI, 2004b).

16 Compare the Atlas of probable storm effects in the Caribbean Sea, that predicts wave heights and surges for 1 in 10 year to 1-100 year events (Organization of American States (OAS), 2002).



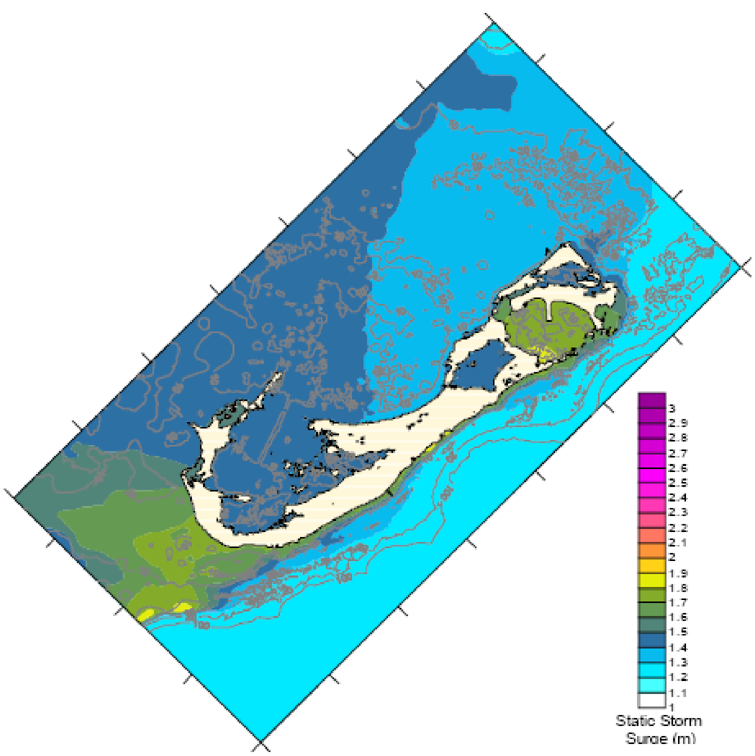


FIGURE 6.5. MAXIMUM WAVE HEIGHTS AND STORM SURGE FOR 1 IN 50 YR EVENT FROM ALL DIRECTIONS (SWI, 2004B).

6.4.3 Wave run up and risk zones

Risk zones can be separated into i) areas at risk of being hit by direct waves, and ii) areas at risk of flooding, as the damage from these occurrences will differ. This results in a set of maps indicating the location of the risk zones for each storm event.

Determining areas at risk of being hit by direct waves is based on wave height and storm surge maps, and includes data on elevation and the coastal slope at different sections of the coastline. An elevation map and a map of the coastal types[17], for Bermuda's land mass are available. In addition, wave run up or inundation levels for a 1 in 150 year event are available for the different sections of the island specified for four coastal types (SWI, 2004b) (see Table 6.1). The same inundation levels need to be calculated for the storms of other strengths.

TABLE 6.1. INUNDATION LEVELS FOR DIFFERENT COASTAL TYPES FOR A 150 YEAR EVENT (TAKEN FROM SWI, 2004B).

Location	Inundation Levels above Mean Sea Level (MSL)			
	Beach	Flat Rock	Low Cliff	High Cliff
North Shore – East	4.4-6.2	3.0-4.4	5.3-7.1	7.1-9.4
North Shore – West	4.6-6.4	3.2-4.6	5.3-7.3	7.3-9.6
West Shore	4.6-6.4	3.2-4.6	5.5-7.3	7.3-9.6
South West Shore	3.0-5.1	2.6-3.9	3.3-5.7	3.9-7.2
South Shore	5.1-9.6	3.3-6.6	6.9-11.1	9.3-14.9
North East Shore	4.6-6.4	3.2-4.6	5.5-7.3	7.3-9.6
St. Georges Harbour	2.7-4.8	2.3-3.6	3.0-5.4	3.6-6.8
Castle Harbour – North	4.8-6.6	3.4-4.8	5.7-7.5	7.5-9.6
Castle Harbour - South	3.0-5.1	2.6-3.9	3.3-5.7	3.9-7.2
Harrington Sound	2.8-4.9	2.4-3.7	3.1-5.5	3.7-6.9
Great Sound- East	2.6-4.7	2.2-3.5	2.9-5.3	3.5-6.7
Little Sound	2.7-4.8	2.3-3.6	3.0-5.4	3.6-6.8
Great Sound-West	4.5-6.3	3.1-4.5	5.4-7.2	7.2-9.5

Flood zone maps of hurricane category 1, 3, and 5 have been derived for Bermuda by the Ministry of Works & Engineering, based on a report by HR Wallingford (Cooper and Allan, 1995). The maps assume a direct hit by the respective hurricane class. Such maps can potentially be used for interpolating flood zones to hurricane category 2 and 4, as well as for indicating vulnerable areas from direct wave impact. The latter would require the incorporation of an elevation map. In addition, any damage known to occur at wave heights associated with lesser storms also needs to be taken into account.

[17] In their report, SWI (2004a; 2004b) define the coastal types as: beaches; flat rocky coastlines (elevations between mean sea level (MSL) and 1+ MSL); low cliffs (1+ to 7+ MSL); and high cliffs (> 7+ MSL).

6.4.4 Wave height for two scenarios: 'With' and 'Without' coral reefs

Wave height, and thus the wave energy hitting the coastline, is likely to increase with the disappearance of coral reefs. The wave height levels near shore 'with' coral reefs are adopted from Wallingford (1991), based on data from 10 real hurricanes passing by Bermuda and tested coming from 8 different directions. Wallingford (1991) developed a model for Category 1, 3 and 5. Information for Storm Category 2 and 4 is interpolated including only hurricanes coming from the West. Near shore wave heights resulting from the Wallingford model are in agreement with some of the real life observations made by the Bermuda weather service (M. Guishard, *pers.comm.*).

The hypothetical increase in wave height near shore 'without' the presence of coral reefs is more difficult to determine. The level of wave dissipation currently provided for the coral reefs in Bermuda is based on results obtained in other studies around the world. Sheppard *et al.* (2005) recorded a drop of 1.5 meter of "reef" surface because of a massive coral die-off in Chagos, Indian Ocean. Lugo-Fernandez *et al.* (1998) found that a 0.3 meter tidal change altered wave dissipation by 15% in St. Croix, US Virgin Islands. Using this information, it was estimated that % wave dissipation currently estimated in Bermuda to lie between 75% and 85% would decrease to 57%-66%, should corals die-off. Note that erosion would continue if reefs were not to recover, and reef surfaces would continue to drop below the 1.5m estimate- based on Sheppard *et al.* (2005)- hence gradually decreasing % wave dissipation with time. The estimates provided here are therefore reflecting the first few years of erosion following coral die-off - in Chagos the 1.5m drop was recorded within 4 years of coral die-off-. Using wave offshore data and estimated % wave dissipation without coral, wave heights near shore are calculated for this study. Results of the calculation and interpolation for Bermuda are presented in Table 6.2

TABLE 6.2. WAVE HEIGHT 'WITH' AND 'WITHOUT' CORAL REEFS IN BERMUDA

Storm intensity	With coral reefs	Without coral reefs	Factor wave increase	Average factor wave increase
Category 1	North-1.81 max	North- 3.91	2.16	1.91
	West- 2.4	West- 4.35	1.81	
	South- 2.56m	South- 4.47	1.75	
Category 2	North- 2.20max	*North - 4.75*	*2.16*	*1.91*
(Interpolated data)	West 2.01m	*West - 3.64*	*1.81*	
	South 1.92m	*South - 3.353*	*1.75*	
Category 3	North 2.72m	North-5.97	2.19	2.05
	West- 3.51	West- 6.55	1.87	
	South 2.92m	South- 6.12	2.10	
Category 4	North- 3.41m	*North -7.48*	*2.19*	*2.05*
(Interpolated data)	West- 2.94m	*West - 5.49*	*1.87*	
	South- 2.33m	*South - 4.88*	*2.10*	
Category 5	North-3.76	North-7.99	2.13	2.14
	West- 4.39m	West- 8.47	1.93	
	South 3.2m	South-7.58	2.34	

Note that values in italic are interpolated. For category 2, the category 1 “factor wave increase” has been adopted, and for category 4 the category 3 “factor wave increase” has been applied.

6.4.5 Properties at risk

The next step is to translate the increase in wave height into number of houses affected, using flood zone information and historical data on the number of houses with recorded water damage. Damage claims following Hurricane Fabian- a direct hit on Bermuda in September 2003- illustrate this (Figure 6.6). Information for a total of 40 damage claims from three of the five local insurance firms on the island was collected. These claims only pertain to flooding damage, excluding wind damage. The claims include both commercial and domestic property. As expected, most of the claims are for properties on Bermuda’s South Shore, characterized by its close proximity to the reef rim and high exposure to ocean waves. It is also worthwhile noting that Hurricane Fabian hit Bermuda from the Southeast, exposing the South coast in particular. Most of the damaged properties are situated at a relatively low elevation– 95% lie below 16 meters – and are relatively close to the coast – almost 70% lies within 50 meters of the coast[18].

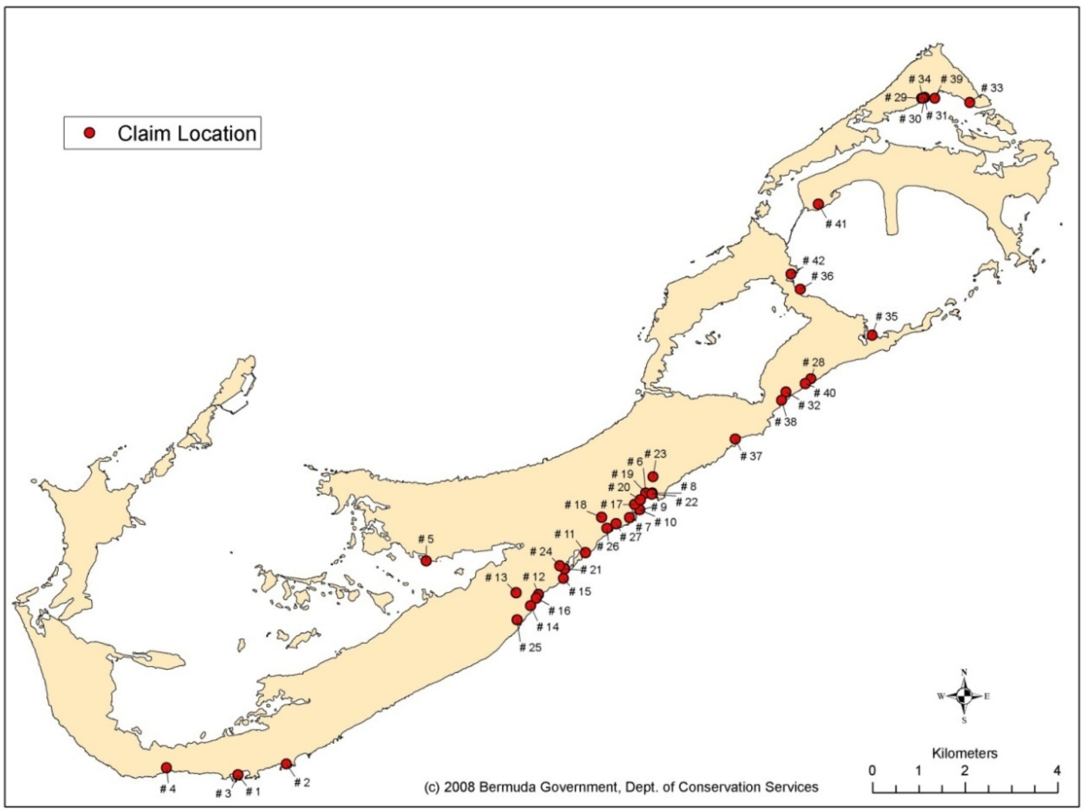


FIGURE 6.6. HURRICANE FABIAN FLOOD DAMAGE CLAIM LOCATIONS (*DATA COMPILED BY S. SARKIS*)

[18] This compares to an average elevation of 21 meters, and an average distance to the coast of 619 meters for houses in the representative sample of sold houses used in the hedonic model of this study (Chapter 5).

The number of properties affected by storm events ‘with’ and ‘without’ coral reefs in Bermuda is determined based on: 1) Flood Zones ‘with’ coral (Cooper and Allan, 1995), 2) Number of houses present in the flood zones ‘with’ coral as calculated by the Department of Conservation Services, using GIS software. Results are in accordance with earlier estimates by the Bermuda Ministry of Works & Engineering. Increasing coastal development has resulted in an increased number of buildings in the three flood zone areas over the past years, total number of buildings on Bermuda approximates 28,690 (GOB, 2009) and 3) Number of houses in the flood zones ‘without’ coral based on percentage wave dissipation and resulting wave heights.

The calculated number of properties affected by storm events ‘with’ and ‘without’ coral reefs in Bermuda is given in Table 6.3. It should be noted that the resulting near-shore wave heights for a Category 1 ‘without’ coral are very close to those of a Category 4 ‘with’ coral. Therefore, the most conservative conclusion which can be drawn is that without coral, the number of buildings at risk for a Category 1 hurricane would be equivalent to what is currently reported for a Category 4 hurricane. This conclusion is based on the following:

- It is assumed that the impact of a Category 1 event ‘without’ reefs is approximately equal to the damage done ‘with’ reefs during a Category 4 event. This is shown in the red cells of Table 6.3;
- It is also assumed that the impact for the next Category (i.e. Category 3) increases not only by the same factor Y (see green cell 2.44), but also increases due to the relatively higher waves of Category 1. This implies that an additional factor of (2.05/1.91) is applied, shown in Table 6.2. Therefore, the impact for a Category 3 equals: 2,969 houses x 2.44 x (2.05/191) = 7,751 houses, and
- In order to determine the impact for a Category 2, the average factor Y of Category 1 and Category 3 is calculated [(2.44+2.62)/2=2.53]. Similarly, factor Y for Category 4 is based on the average of Category 3 and Category 5.

TABLE 6.3. NUMBER OF HOUSES AFFECTED ‘WITH’ AND ‘WITHOUT’ CORAL REEFS.

Storm Intensity	Number of houses affected with coral reefs	Number of houses affected without coral reefs	Factor increase of number of houses affected due to absence of coral reefs = Factor Y
Category 1	1,662	4,050	2.44
Category 2	1,662	4,205	2.53
Category 3	2,969	7,751	2.62
Category 4	4,050	10,855	2.68
Category 5	4,050	11,085	2.74

6.5 Total coastal protection value

In order to determine the added protection value that coral reefs have in terms of avoiding storm damage, both the damage levels with and without reefs have been determined. Several assumptions underlie this calculation.

Because the impact of Hurricane Fabian (a Category 3 bordering 4 storm) is relatively well documented, the Category 3 to 4 storm is used as the baseline for the estimation of the damage of the other storm categories. In other words, the property damage information used in this study is based on specific information about the claims reported after Hurricane Fabian hit Bermuda (see Table 6.4 for further details). The average insured sum was equivalent to1.5 million USD per claim, and the average amount paid out by the insurance companies was 262,000 USD. Based on these claim data the average damage share is 16.6% ± 23.6 [19], implying that with a storm of Category 3 or 4 damage to property can be as high as a fifth of the property value. As a consequence of the high standard deviation, which may result from the relatively small data set and the heterogeneity of the claims, any valuation based on these data would also have large confidence intervals.

As expected, a negative relationship exists between damage share and elevation, and between damage share and distance to the coast; such that the higher the elevation, the less damage incurred by a property, and the closer to the coast, the more damage is incurred from flooding. However, these relationships are not statistically significant. Waterfront properties are not identified in the data, but properties within 20 meters from the coast do have a higher average damage share of 35%[20], than properties further away. Again, the differences are not statistically significant due to the low number of observations and a large variance of the damage shares. Because no information is available to determine a damage to infrastructure (e.g. roads), this damage category is excluded from the overall damage assessment, possibly leading to an underestimation of the coastal protection value of coral reefs.

TABLE 6.4. STATISTICS ON CLAIM DATA

Variable	Amount or level
Average sum insured (x1000)	1,581 USD
Average damage paid (x1000)	263 USD
Average elevation	8.0m (0-42)
Average distance to the coast	69m (2-457)

[19] In these calculations of the damage share, the insured and paid out amounts are assumed to reflect the market value of the property and the real damage to the property, respectively.

[20] Standard deviation=25%; no. of observations=8.

The average damage for each property during the Category 3/4 Fabian hurricane amounts to US$ 249,526, based on the insurance data; this represents 16.6% of the average house value (Table 6.5). As seen in the first column of Table 6.5, it is assumed that with each additional storm category, the damage will increase by 25% (e.g. Category 5 equals 125% relative to Category 4). Similarly, this damage factor is assumed to decline by 25% with each lower storm category. In this way, the damage per property can be calculated for all five storm category.

Next, the property damage is calculated with and without reefs in column three and four of Table 6.5 by using the number of affected properties reported in Table 6.3. Note that the damage levels reported are valid only if each storm category would occur once every year. Clearly, this is not correct, and thus the storm frequency needs to be taken into account.

TABLE 6.5. DAMAGE WITH EACH STORM INTENSITY OCCURRING EACH YEAR

Storm intensity	**Factor relative to Category 4**	**Damage per property (US$/house)**	**With reef damage (million US$/year)**	**Without reef damage (million US$/year)**
Category 1	25%	62,381	104	253
Category 2	50%	124,763	207	525
Category 3	75%	187,144	556	1,458
Category 4	100%	249,526	1,011	2,709
Category 5	125%	311,907	1,263	3,457

This study adopts the frequency of the storm occurrence reported by Wallingford (1991). Based on this, values for estimated damage are calculated and given in Table 6.6. By deducting the Damage column 'without' reefs from the Damage 'with' reefs, the avoided damage value of coral reefs is calculated (see "coastal protection" column). The total annual undiscounted coastal protection value of reefs in Bermuda averages US$ 287 million.

TABLE 6.6. DAMAGE TO PROPERTY (IN $ MILLION/YEAR) TAKING INTO ACCOUNT FREQUENCY OF STORM INTENSITY (SOURCE: WALLINGFORD, 1991).

Storm intensity	**Storm frequency**	**Damage with reefs (USD million per year)**	**Damage without reefs (USD million per year)**	**Coastal protection Value (USD million per year)**
Category 1	(1/4)	25.9	63.2	37.2
Category 2	(1/7)	29.6	74.9	45.3
Category 3	(1/11)	50.5	132.5	82.0
Category 4	(1/21)	48.1	129.0	80.9
Category 5	(1/52)	24.3	66.5	42.2
Total		**178.5**	**466.1**	**287.6**

The next step has to account for the fact that the above mentioned damages will not occur today but instead somewhere in the future. Therefore the undiscounted damages need to be discounted in order to generate present values of the damage estimates. In doing so, it is assumed that the storm event for each category will occur exactly in the median of the frequency reported by Wallingford (1991) (see second column in Table 6.6). Thus, for category 1 storm which occurs every 4 years (1/4), it is assumed that this event will occur in year 2. The discount rate adopted is 4% (Pearce and Ulph, 1995). The resulting Net Present Value of coastal protection function of coral reefs in Bermuda is $266 million per year (Table 6.7).

TABLE 6.7. DISCOUNTING ANNUAL DAMAGE VALUES

Storm category	Undiscounted coastal protection value (million USD/year)	Storm to occur in x year from now	Discounted coastal protection value (million USD/year)
Category 1	37.2	2	34.4
Category 2	45.3	4	41.9
Category 3	82.0	6	75.8
Category 4	80.9	11	74.8
Category 5	42.2	26	39.0
Total	**287.6**	**49.0**	**265.9**

To demonstrate the high sensitivity of the results with all its underlying assumptions, variations are made on one of the most uncertain parameters, i.e. storm frequency (see Table 6.8). For the lower and upper bound we assume the storm frequency to half and double, respectively. This results in a lower and upper bound estimate of respectively US$ 134 million and US$ 532 million.

TABLE 6.8. DAMAGE TAKING INTO ACCOUNT FREQUENCY OF STORM INTENSITY (US$ MILLION/YEAR)

Storm intensity	Storm frequency	Lower bound	Storm frequency	Baseline estimate	Storm frequency	Upper bound
Category 1	(1/8)	17.2	(1/4)	34.4	(1/2)	68.9
Category 2	(1/14)	21.0	(1/7)	41.9	(1/3.5)	83.8
Category 3	(1/22)	37.9	(1/11)	75.8	(1/6.5)	151.6
Category 4	(1/42)	38.3	(1/21)	74.8	(1/10.5)	149.5
Category 5	(1/104)	19.5	(1/52)	39.0	(1/26)	78.0
Total		**133.9**		**265.9**		**531.8**

The coral reefs' protective value to Bermuda's coastline and coastal property is vital to Bermuda. For this reason, providing a first estimate of this critical value is considered important. However, the above estimate is based on numerous simplifying assumptions, which can easily be criticized. For this reason, it is recommended that further modeling and data gathering be performed to improve on the preliminary calculations made within the scope of this study.

7. Total Economic Value

Pieter J.H. van Beukering

7.1 Introduction

The final step in determining the total value of the ecosystem services provided by the coral reefs of Bermuda is to sum up the individual benefits into a Total Economic Value (TEV). This TEV can be calculated for a specific area or for alternative uses of that area (e.g. preservation, tourism-based development, multiple use). As shown in Figure 7.1, the TEV of coral reef ecosystems can be subdivided into *use* and *non-use* values. Use values are benefits that arise from the actual use of the ecosystem, both directly and indirectly, such as fisheries, tourism and beach front property values. Non-use values include an existence value, which reflects the value of an ecosystem to humans, irrespective of whether it is used or not. This Chapter assesses the current TEV of Bermuda's coral reefs, and considers this value's change over time. In addition, some sensitivity analysis is conducted to investigate the robustness of the estimated TEV under different assumptions.

It is worth noting that although Bermuda's TEV is known as 'Total' Economic Value, this analysis has not included all goods and services provided by the island's coral reefs and that some aspects of coral reefs may be 'invaluable' i.e. they have intrinsic value, beyond any benefits provided to people. Hence, the TEV estimated here is likely to under-estimate the true 'total' value of Bermuda's coral reefs.

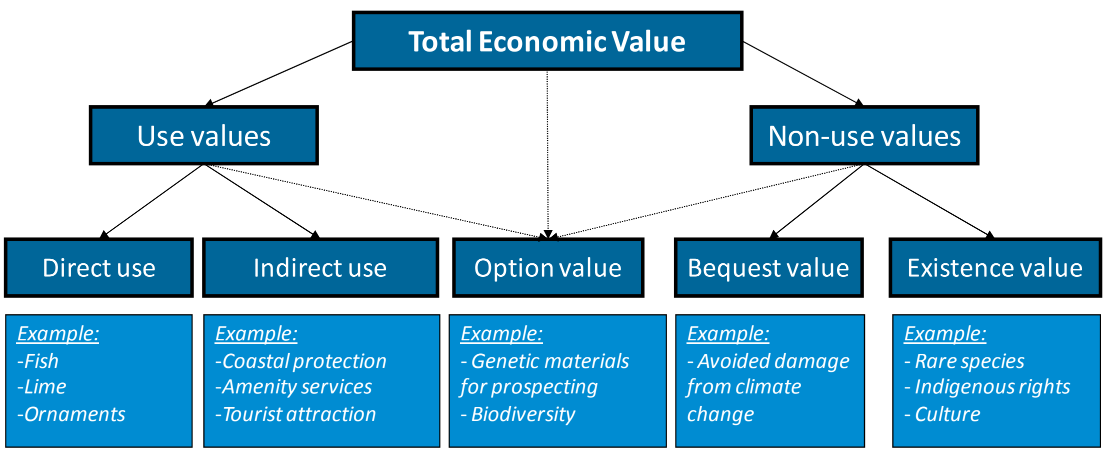


FIGURE 7.1. SUBDIVISION OF THE TOTAL ECONOMIC VALUE OF CORAL REEFS TAKEN FROM CESAR AND VAN BEUKERING (2004).

7.2 Total Economic Value (TEV) for Bermuda's Coral Reefs

Table 7.1 shows the composition of the main economic benefits of the coral reefs in Bermuda. The average annual value of the coral reef ecosystem amounts to US$722 million (based on 2007 USD). This high number certainly suggests that this ecosystem is highly valuable and worth conserving, from an ecological, social and economic perspective. Several ecosystem services contribute to this overall value:

- With an average annual benefit of **US$406 million**, the tourist value dominates the overall value. This implies that almost 56% of the value of Bermuda's coral reefs is dependent on tourism, and vice versa, that tourism is very dependent on the state of the coral reef of Bermuda.

- The second most important component is the coastal protection service with a value of **US$266 million** per year, which accounts for 37% of the TEV. With Bermuda located in a hurricane prone location, the role of coral reefs in dissipating wave energy is crucial and thus of high value.

- Another important conclusion is that despite the relatively small population of Bermuda, local recreational and cultural importance of the coral reefs is still substantial: approximating **US$37 million** per year. This also implies that local support for coral reef management is likely to be substantial.

- The same can be said for the amenity value, which is reflected in higher house prices. Although this surplus in house price is relatively small, it still amounts to a value of **US$7 million** per annum.

- The importance of the fishery in the TEV is often perceived as an important component. In actual fact, with an annual value of **US$5 million** the fishery (both commercial and recreational) is one of the lesser values derived from the coral reef ecosystem in Bermuda.

- One value that has not been described in the report is the value that research and educational organization derive from the coral reefs of Bermuda. This value is estimated based on all funds that are attributable to research and education of the reefs in Bermuda, and is explained in Appendix V. The average coral reef-related research and education budget is estimated at **US 2.3 million** per year.

Table 7.1. Undiscounted annual benefits of coral reefs in Bermuda (2007US$ million/year)

Ecosystem Service	Average (USD million per year)	Share
Tourism	405.9	56%
Coastal protection	265.9	37%
Recreation & Cultural	36.5	5%
Amenity	6.8	1%
Fishery	4.9	0.7%
Research & education value)	2.3	0.3%
Total annual economic value	**722.4**	**100%**

The estimation of the various ecosystem service values involves a large number of assumptions that simplify the underlying dynamics and complexity of coral reefs in Bermuda. Therefore, lower and upper bound estimates are determined for each ecosystem service, recognizing the uncertainty surrounding the economic analysis. The basis for this range differs for each value category. In the case of coastal protection, for example, the different storm frequencies available in the literature are used to create a range of values. In the case of the fishery value, the wide range of financial cost estimates is used to set the upper and lower bound of the value. The ranges estimated for each ecosystem service is presented in Table 7.2. With an average estimate of US$722 million per year, the lower bound estimate is determined at US$488 million per year while the upper bound is set at US$1.1 billion per year. Further study could allow for the reduction of uncertainties and thus the narrowing of the value range.

TABLE 7.2. UPPER AND LOWER BOUND ESTIMATES OF THE ANNUAL BENEFITS OF CORAL REEFS IN BERMUDA (2007US$ MILLION/YEAR)

Ecosystem Service	Lower bound	Average	Upper bound
Tourism	324.7	405.9	487.1
Coastal protection	133.9	265.9	531.8
Recreation & Cultural	17.2	36.5	66.0
Fishery	4.3	4.9	5.6
Amenity	5.5	6.8	8.2
Biodiversity research	2.1	2.3	2.5
Total annual economic value	**487.7**	**722.4**	**1,101.2**

7.3 Total economic value (TEV) over time

The TEV of coral reefs in Bermuda is changing over time for several reasons. First, as the ecological integrity of coral reefs changes over time, the level of service provision is also likely to change with it. Second, if socio-economic conditions change and lead to increasing income, Bermudans may be willing to pay more for the preservation of coral reefs or may develop habits (e.g. recreational fishing) that lead to a greater appreciation of the coral reef ecosystem, hence increasing its value. An in-depth analysis of such dynamic aspects underlying the TEV is beyond the scope of this study. However, insight into the potential dynamics of the TEV can be obtained through the simulation of scenarios; hypothetical scenarios on the change in the health of Bermuda's coral reefs and the associated changes in the economic value can be adopted. A common approach to design these scenarios is by simulating situations 'with' and 'without' coral reef management in Bermuda. An example of such a comparison is provided in Figure 7.2.

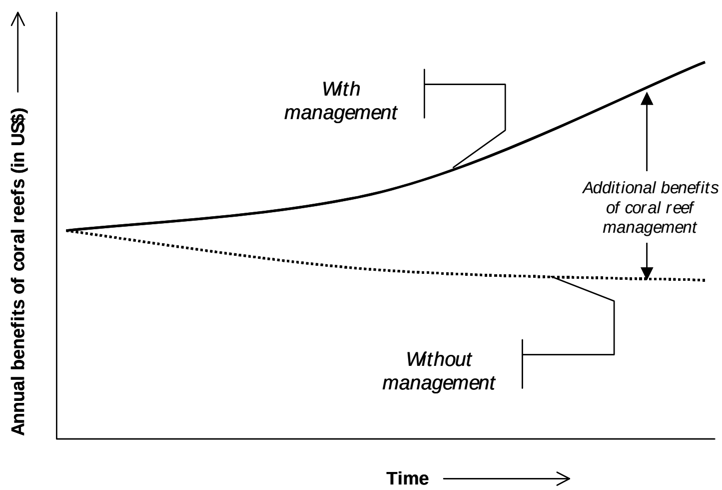


FIGURE 7.2. ANNUAL BENEFITS OF CORAL REEFS WITH AND WITHOUT MANAGEMENT

For Bermuda, three hypothetical futures are simulated for the period 2010-2035. As a baseline, it is assumed that the benefits remain constant over time. This stable situation is compared to two different degradation trajectories, which both result in a 50% decline of coral reefs. One degradation scenario follows a linear decline reaching 50% of the coral reefs remaining by 2035. The other degradation scenario reaches a similar level but follows a non-linear trajectory; the decline is less severe in the first half of the period, but declines more rapidly in the second half of the period. Note that these simulations are purely hypothetical and are only meant to demonstrate the impact of time and the discount rate on the TEV. With more time for research, scenarios could be developed that more closely align with likely internal drivers, such as reef management practices or policies, or with possible external drivers, such as climate change and population growth. Figure 7.3 shows the annual benefits over time for the three scenarios at a discount rate of 0% (i.e. undiscounted levels).

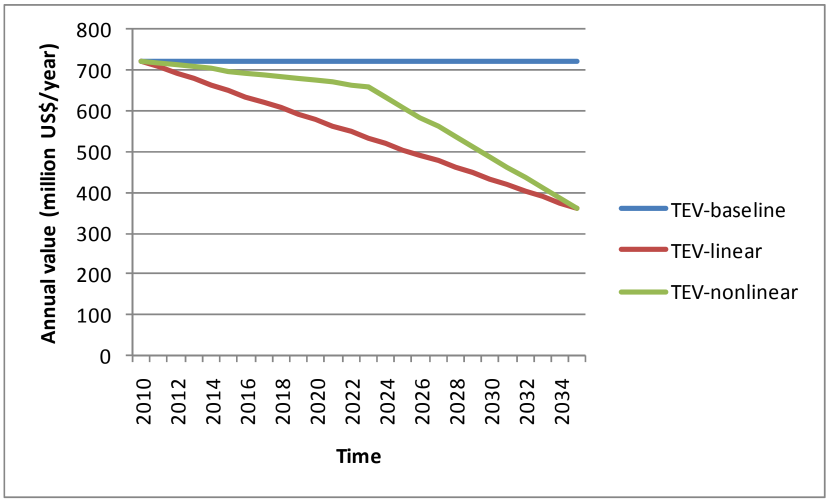


FIGURE 7.3. ANNUAL BENEFITS OF CORAL REEFS IN BERMUDA (IN MILLION US$/YEAR)

FIGURE 7.4. SENSITIVITY ANALYSIS OF THE DISCOUNT RATE ON THE PRESENT VALUE OF CORAL REEFS IN BERMUDA (26 YEARS, IN MILLION US$)

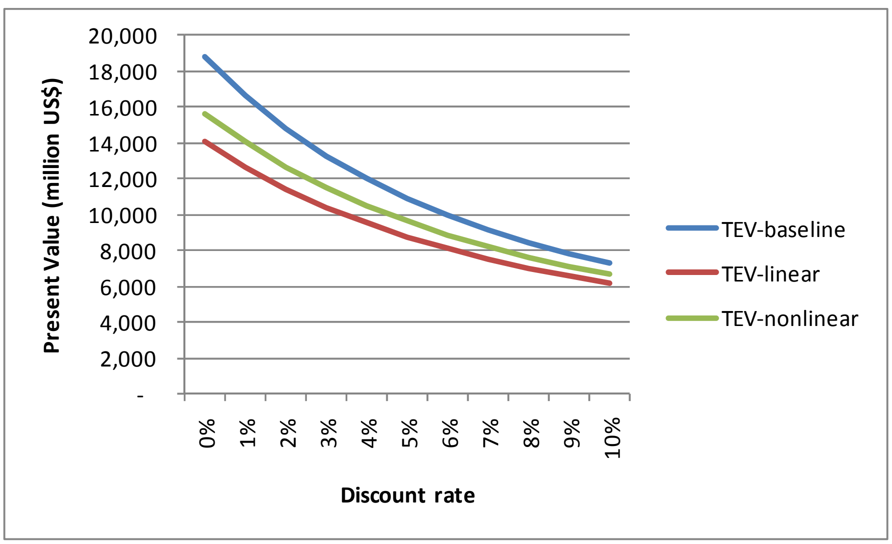


Figure 7.4 shows the sensitivity of the TEV to the discount rate. The present value is the sum of all discounted annual benefits over the full period. By definition, the present value declines with higher discount rates due to the fact that future benefits are discounted more than without discounting. Assuming a discount rate of 4% for a 25-year period, the present value of the coral reefs in Bermuda adds up to US$12 billion.[21] As expected, it can also be seen that delaying degradation of the reefs in Bermuda pays off in economic terms (TEV linear lies below TEV non-linear) (Figure 7.4).

[21] Pearce and Ulph (1995) recommend using a social discount rate between 2% to 4%. Since then, several organisations came up with similar advice, such as DEFRA (Department for Environment, Food and Rural Affairs), currently maintaining a standard social discount rate of 3.5%. In this study, 4% is adopted, and a sensitivity analysis conducted to explore the impact of the level of the discount rate.

8. The Value of Bermuda's Coral Reefs: Conclusions

Pieter van Beukering, Samia Sarkis & Emily McKenzie

8.1 Introduction

This study demonstrates that coral reefs are an important element in Bermuda's economy, greatly supporting tourism, coastal protection, recreation and culture, real estate, fisheries, academic research and environmental education. Because several of the above-mentioned goods and services are not traded on the market, measuring their economic importance is not a straightforward task.

The objective of this study is to carry out an environmental valuation, focusing on the main uses of coral reefs in Bermuda. Some of these are extractive uses, such as fisheries; others are non-extractive, such as tourism, recreational and cultural uses, and education and research. Finally, some are indirect uses, such as coastal protection and amenity values expressed in higher house prices. With a better understanding of the economic importance of coral reefs, Bermuda's decision makers can design their policies in a more efficient manner, utilizing their limited funds in the most cost-effective way, for the benefit of Bermudans. Additionally, baseline data available through this report provides insight into revenue raising mechanisms and a starting point to engage the tourist industry and the community in generating funds for long-term coral reef conservation and management.

This chapter provides an overview of the main findings of the study and translates these into policy recommendations in the Bermudan context.

8.2 Summary

The economic values are derived through analyzing six different ecosystem services provided by the coral reefs of Bermuda. Each ecosystem service is valued using a different valuation technique. Techniques are selected as appropriate to that service and based on successful use in a number of previous reef valuation studies. Besides generating monetary estimates for these ecosystem services, the analysis also provides new insights on the social and economic context in which the service is provided. The main ecosystem services covered in this study include:

- Tourism values
- Fisheries values
- Amenity values

- Recreational and cultural values
- Coastal protection values
- Research and education values

The relative contribution each ecosystem service to the TEV of Bermuda's coral reefs is given in Figure 8.1.

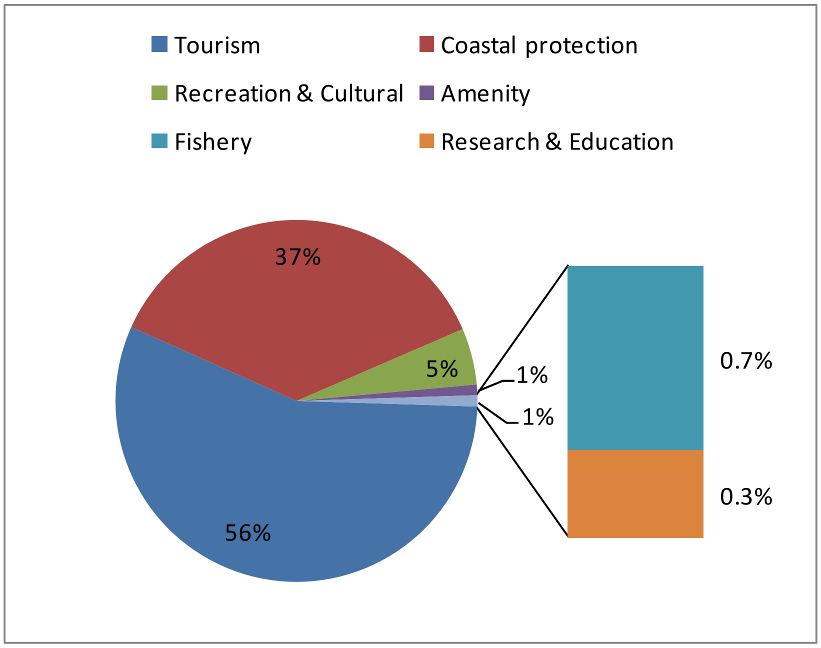


FIGURE 8.1. COMPOSITION OF ECOSYSTEM SERVICES VALUED FOR BERMUDA'S CORAL REEFS.

Tourism value: Tourists add substantial reef related value to a tropical island's economy. Based on empirical research, it may be concluded that tourists visiting Bermuda value the coral reefs at US$611 per visit (consumer surplus plus producer surplus). There is a difference between cruise ship and air tourists, where cruise ship tourists value the coral reefs slightly less at US$591 per visit compared to the US$635 per visit value calculated for air tourists. This difference in tourism value between the two sectors is mainly due to differences in on-island expenditures. The value added of on-island expenditures for cruise ship tourists is US$55 compared to US$139 for air tourists (producer surplus). The added value to Bermuda is therefore lower for cruise ship tourists, despite the fact that their appreciation of the coral reefs is relatively comparable to that of the air visitors. Per year cruise ship tourists add US$20 million and air tourists add US$43 million, more than double, to Bermuda's reef-associated economy. The total reef-related tourism value amounts to **US$406 million** per year.

Fishery value: Coral reefs are a crucial habitat for fish stock, and in this way provide important ecosystem services to the commercial and recreational fishery sector. A distinction is made between reef-associated and non reef-associated catch, in order to avoid an overestimation of the contribution of the fishery value to the coral reef value. Based on careful analyses, 42% of the total commercial finfish catch (by weight), and 68% (by weight) of the recreational finfish catch is estimated to be reef-associated. This study generates the first estimate of the total catch by recreational finfish fishermen in Bermuda. Results indicate that in 30% of the households, one or more recreational fishermen are active. This translates into almost 16,000 finfish fishermen on Bermuda in 2007. Recreational fishermen caught 40% of the total (commercial and recreational) finfish catch by weight in 2007; this group is therefore responsible for 53% of the total reef-associated for finfish and 9% of total lobster catch. The fishery ecosystem value is estimated at **US$5 million** per year.

Amenity value: It is assumed that coral reefs are a positive environmental amenity to real estate value. It is therefore expected that the closer one lives to a component of the coral reef system, the higher the house price will be. This hypothesis is tested using the hedonic pricing valuation method. The analysis generates an amenity value of coral reefs in Bermuda of around US**$6.8 million** per year. The proximity to beaches is found to best represent the relationship between the coral reef ecosystem and house price; this is justified, based on the fact that all Bermuda beaches are of coralline origin- in other words, beaches in Bermuda would not exist without coral reefs. The amenity value is based on a non-linear quadratic relationship between house prices and beach distance. This implies that houses closest to the beach are least expensive, progressively becoming more expensive until 1.1 km from the beach; beyond 1.1 km, a decrease in house prices is once again seen. These findings suggest that Bermudans implicitly enjoy the ecosystem services derived from coral reefs but because of its invisibility, these amenities are not explicitly considered when purchasing a house in proximity to coral reefs. Living close to a beach does not appear to be sought after; this may be explained by the island's long and narrow shape, rendering it a coastal habitat for virtually all Bermudans with beaches in close proximity to most residences. However, should coral reefs, and subsequently beaches, decline in quality, degrade and become scarce, the economic value in terms of a surplus on the house prices is likely to increase.

Recreational and cultural value: This study involves a large-scale resident survey aimed at getting a better understanding of what connects Bermudan households to their reefs. A special valuation technique, referred to as choice modeling, is used to quantify recreational and cultural values related to coral reefs. In total, 400 households collaborated in a face-to-face interview. The results of the choice model valuation study show that Bermudan residents hold significant positive recreational and cultural values related to Bermuda's coral reefs and marine environment. Marine management policies that result in improvements across all four environmental attributes (i.e. coral reef quality, swimming restrictions, fish catch, and ocean visibility) would generate substantial benefits to the Bermudan population. For example, improvement in coral reef quality (poor to medium), reduction in swimming restrictions (from 4 to 0 days), increase in fish catch (from current to 20% higher), and improvement in visibility (from poor to moderate) would result in a welfare improvement equivalent to an increase in average monthly household income of around 113 BMD. In aggregate terms, these improvements would be equivalent to **US$37 million** per year to the population of Bermuda.

Coastal protection: Because coral reefs absorb much of the incoming wave energy, they function as natural breakwaters and help to protect the shoreline from erosion and property damage. The vital coastal protection role of the rim and boiler reefs in Bermuda is also revealed in earlier coastal vulnerability assessment studies. This study is a first attempt to estimate the economic value of this ecosystem service in Bermuda, using the “avoided damages” approach. This involves the estimation of the potential damage (and associated economic losses) to the Bermuda coastal area from a given storm event, under current and hypothetical conditions (or ‘with reefs’ and ‘without reefs’ scenarios). Data available on Bermuda’s coastal profile, storm regime, historic information on property damage caused by storms, flood zones susceptible for high waves, coral reef locations, the role of coral reefs in shoreline stability, and property values for land areas is combined for this analysis. The economic value of the coastal protection function of coral reefs in Bermuda is determined to be **US$266 million** per year.

Research and educational value: This study also distinguishes the research and educational value of the Bermudan reefs. This value is determined in a simplistic manner. All research and education budgets assigned to coral reef ecosystems in Bermuda are included in this value category; management and enforcement funds are excluded given the difficulty in obtaining this information. Data is collected from governmental and non-governmental groups, pooling information on funds made available towards research and education of coral reef related topics (Appendix V). Information is compiled from annual budgets over a 5-year period. The sum of these activities amounts to **US$2.3 million** per year.

At the core of the economic value of coral reefs are the various ecosystem services associated with these marine systems. The sum of these ecosystem services forms the Total Economic Value (TEV), representing the entire economic importance of Bermuda’s coral reefs at a level of **US$722 million** per year. With 56%, the tourism sector is by far the greatest beneficiary of the services provided by coral reefs in Bermuda. The second most important service is coastal protection, accounting for 37% of the TEV. To place the TEV of coral reefs in the perspective of the economy of Bermuda: in 2007, the Gross National Product (GDP) of Bermuda amounted to US$5.85 billion in 2007 (GOB, 2008). Compared to the GDP, the TEV of coral reefs make up 12%. Although this is not an entirely valid comparison because some of the values measured are hidden and thus cannot be traced back to the balance sheet of Bermuda, this high percentage proves that coral reefs make an important contribution to the economy of Bermuda and the wellbeing of Bermudans, making reefs well worth protecting.

Biological diversity -the diversity of genes and species - is an attribute of coral reefs that may underpin many of the services evaluated in this study. Worm *et al.* (2006) analyzed local experiments, long-term regional time series, and global fisheries data to test how biodiversity loss affects marine ecosystem services across temporal and spatial scales. They found that rates of resource collapse increased and recovery potential, stability, and water quality decreased exponentially with declining diversity. Restoration of biodiversity, in contrast, increased productivity fourfold and decreased variability by 21%, on average. This indicates that marine biodiversity loss is related to the ocean's capacity to provide ecosystem services of food, water quality maintenance, and recovery from perturbations. Marine biodiversity may also relate to additional ecosystem services considered in this study, such as tourism, amenity, and coastal protection benefits. However, there is currently insufficient scientific evidence to be definitive about how these services relate to the biological diversity of the reef ecosystem.

8.3 Recommendations

To provide sound guidance to decision makers on the management of coral reefs, several types of information are needed:

- On *economic values*: To what extent do the various sectors benefit from the goods and services provided by coral reefs in Bermuda?
- On *threats*: What are the main threats to coral reefs in Bermuda? What are the origins of these threats and which reefs do they affect most?
- On *policy and management interventions*: Which measures should be taken to prevent further degradation of coral reefs in Bermuda, and what financial costs are involved? Are any policy or institutional changes required e.g. in how different sectors coordinate in policy development?
- On *financial mechanisms*: Which funds can be accessed to finance the management of coral reefs in Bermuda? Can novel (market-based) instruments be used to generate sustainable funds for management?

With the information above, the following actions are possible: (1) Identify both the most valuable, and most seriously threatened, reefs in Bermuda, (2) determine the type of threat jeopardizing a specific reef and select a number of potentially worthwhile interventions; (3) evaluate the economic benefits and financial costs associated with these interventions, and, (4) find sustainable sources of funding for management interventions.

The completion of all four steps above is beyond the scope of this study. However, the work presented here provides a substantial part of the required information. Step 1, and part of Step 2 are complete within the scope of this study, and background information is provided for Step 4. Step 3 remains unanswered at present; however, opportunities to integrate findings into this type of analysis, such as a Cost Benefit Analysis for the modification of shipping channels initially proposed by the Department of Marine & Ports, are present. In other words, this study provides solid information on the value of coral reefs in Bermuda, which can be used for future analysis. Based on the outcome of this study, specific policy recommendations are derived and given below:

Recommendation 1: Prioritize potential policy interventions in an economically sound manner.

A. Of immediate concern is the lack of "formal" procedure when assessing developments that have potential to impact the marine environment. Although legislation currently exists for developments originating from the coast and extending to the marine environment under the Planning Act; there is no legislation for developments in the marine environment, such as the destruction of reefs for enhanced ship passage. Strategic environmental assessments (SEA) are a good practice for policies, plans, and programmes, taking an ecosystem-based management approach. The development of a formal standard procedure for conducting SEA, supported by legislation requiring SEA for major developments in the marine environment, will enable more informed and sustainable decisions. The TEV demonstrates the urgency and importance of implementing new legislation that accounts for the full economic value of marine resources, in order to sustain valuable ecosystem services. This TEV study can:

- Help to screen whether a development requires detailed assessment (e.g. a full strategic environmental assessment), on the basis of the likely scale and location of ecosystem service impacts.
- Inform detailed assessments of the impacts of developments, although for major developments this will require additional cost-benefit analyses.
- Inform the design of programmes for ecosystem service monitoring and enforcement of legislation.

B. The efficient utilization of limited funds requires an economically sound decision support tool to facilitate prioritization and selection procedures. Prevalent options for improved marine management are: (1) improving the transparency of decisions affecting the marine environment, such as the choice of the route for incoming mega-cruise ships in Bermuda by developing an **extended cost-benefit analysis** incorporating the economic costs of damage to coral; (2) developing a standard **damage cost procedure** for marine vessel groundings and other forms of injury to the reef in Bermuda (e.g. anchoring damage), accounting for the wide range of lost benefits, which will on the one hand encourage preventative behaviour by potential violators while on the other hand guarantee sufficient funds for reef restoration and damage compensation.

> *Recommendation 2:* Make use of the cultural importance residents place on marine ecosystems to improve coral reef management.

> *Recommendation 3:* Actively involve the tourism industry in the development of sustainable coral reef management.

Recommendations 2 and 3 refer to the potential use of the information obtained in this study, as a starting point for the design of revenue raising mechanisms to generate funds for coral reef management. Currently, monies obtained through grants, donations and courses specific to coral reef ecosystems amount to US$ 2.3million (based on 2007 data); this ‘research and education value’ encompasses work conducted by NGOs and government departments, but excludes management and enforcement costs. Results of this study indicate that the engagement of the residents and tourists may potentially lead to a conservation fund of **$50 million per year**. Although the securing of funds from the resident community is a challenging issue in Bermuda, it is strongly recommended that policy-makers establish the vehicle for enabling community support for environmental conservation; it has the potential to generate $37 million per year, and **allow for the use of funds currently put into the marine environment for other socio-economic needs**. Through the comprehensive household surveys conducted during the course of this study, Bermudans have expressed their concern for the human induced impacts on their environment. Increasing awareness and education by incorporating environmental economics in the national school curriculum will ensure sustained concern and motivation for financial contribution to environmental conservation and management.

On the other hand, the Tourism sector can provide the critical mass needed to generate sustainable funding for coral reef management. The establishment of an **environmental tourist tax, and/or user fees** for divers and snorkelers is a means used by other jurisdictions of raising revenue from this group; given the small share of such contributions to the total expenses incurred by visitors, it is unlikely that such taxes and fees will discourage tourists from coming to Bermuda. An alternative mechanism for raising revenue is to engage the Tourism sector through a **Tourism/Conservation Partnership**; this has been successfully demonstrated in other jurisdictions, and entails the collaboration of the Tourism Board, tourist operators and the National Trust. Establishing such a partnership is strongly recommended and will enable the raising of a potential $15million per year through voluntary contributions of tourists to fund restoration activities on impacted reefs. Details of such activities are given below.

> *Recommendation 4:* Balance consumptive and non-consumptive uses of coral reefs by strategizing spatial management and protecting critical marine areas.

The revenues generated by the commercial fishing industry are small compared to the contribution that non-consumptive coral reef services provide to Bermuda's economy. Marine Protected Areas (MPAs) provide an effective way of sustaining the tourism, recreational and cultural benefits provided by the coral reef system. They have been shown, in other jurisdictions, to act as a refuge for marine populations and enhancing in some cases fish catch outside of MPAs. The comprehensive assessment of MPAs critical to the ecosystem is a fundamental action in the long-term sustainability of marine populations.

This study shows the importance of the reefs in sustaining fish and shellfish populations critical to sustaining local livelihood and culture. These consumptive and non-consumptive uses of the reefs can only be sustained through the protection of critical zones of the ecosystem. In this way, the high economic value of a live fish generated through diving and snorkeling activities, will remain balanced with revenues generated by the commercial fishing industry and the cultural value gained by recreational fishermen.

Prioritizing strong enforcement and protection of these zones by engaging boat and dive operators has proved successful in other jurisdictions; this has led to the establishment of self-financing MPAs through diver fees or user fees. The income generated covers the salaries and operational costs of the marine park. This may serve as a template for successful protection in Bermuda.

8.4 Coral Reef Research and Management Needs

In future work, economic analysis could be effectively used to evaluate the feasibility of the potential measures recommended above. In addition, increased funding earmarked for coral reef ecosystem sustainability would allow for the assessment of research and management needs, and their implementation. This is required to ensure the continued provision of valuable ecosystem services to Bermuda's community. Some examples are:

- Monitoring and early detection of natural/human-induced changes;
- Enhancing enforcement capacity on the Bermuda platform;
- Developing and implementing mitigation measures of foreseen changes – i.e. due to climate change and/or coastal development;
- Researching coral restoration and growth, connectivity between fish productivity and coral reef habitats;
- Predicting wave impact on Bermuda's coastline and identifying flood zones- including collecting wave information during storms and hurricanes.
- A better understanding of coastal erosion parameters required for mitigation measures of natural and human induced erosion processes.

The TEV and resulting recommendations for Bermuda's coral reefs are based on sound economic analyses. Only those ecosystem services that lent themselves to robust valuation techniques and that were feasible with existing available data were valued in this study. Although this leads to an underestimation of the TEV, it results in a sound final value that can be fully explained and justified.

This report has led to the drafting of a 16-page Ministerial brief, which was presented to the Cabinet of Bermuda in September 2010. All recommendations given above were at this time approved by the Government of Bermuda.

8.

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APPENDIX 1. TOURISM

Loes Looijenstijn-van der Putten & Pieter van Beukering

I.1 Details of Methodology used for estimating the reef-associated tourism value in Bermuda

(taken from Looijenstijn-van der Putten, 2008)

A. Travel costs method

The travel cost method is a revealed preference method used to estimate the "consumer surplus" or the value of ecosystems used for recreation by tourists. The method is based on the assumption that travel expenses incurred by tourists to visit a site represent the price of access to the site (Van Beukering *et al.,* 2007a).

There are several travel cost methods, namely the individual travel cost method and zonal travel cost method. The use of one over the other is case specific, and depends on the estimated number of trips to the site. In the Bermuda case study, the travel cost method is used to estimate the contribution of international tourism, and hence it is anticipated that the 'number of trips to the site' may be very low, as these will represent the airplane trip from their origin to Bermuda. For this reason, the zonal travel cost method is used in the Bermuda case study.

When using the zonal travel cost method, visitors to a site are divided in zones based on their region of origin. The zones have increasing distance from the visitor's point of departure to the ecosystem analysed (Van Beukering *et al.*, 2007a). The independent variable is the observed number of visitors to the site per thousand inhabitants of the zone of origin, referred to as "visitation rate" (Carr and Mendelsohn, 2003). The dependent variable is the cost of travel. Based on the travel cost information of tourists, the demand for the services provided by the site can be estimated. A demand-curve is calculated and used to estimate the average benefit of the site to the individual visitor, which can be aggregated over the total population to derive the measure of total benefits.

The demand curve, as illustrated in Figure I.1, is estimated in two steps:

(1) Regression on the visitation rate per zone and the average travel cost incurred by visitors of the zone.

The first point on the demand curve is the total number of visitors to the site at current travel costs. The other points are found by estimating the number of visitors to the site with different hypothetical additional travel costs (or access fees). The consumer surplus of the site per year – or the tourism value of the site – is the area under the demand curve (www.ecosystemvaluation.org, 2008).

A large dataset is needed for such calculations, and data is usually collected through visitor's questionnaires.

(2) The demand function is calculated, based on the regression derived in step 1.

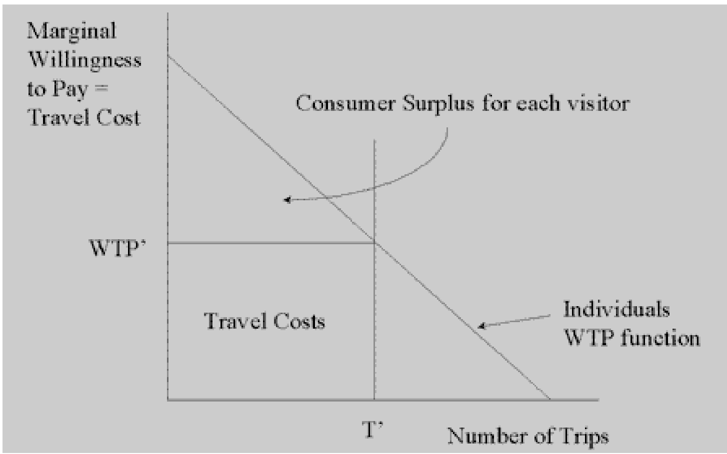


FIGURE I.1. DEMAND CURVE INDIVIDUAL TRAVEL COST METHOD

Although the travel cost method is considered to be the most appropriate method to estimate the recreational value of a natural site, there are some issues that must be addressed in implementing and estimating the method (Freeman, 1993), such as:

1. Measurement of travel costs.
2. Functional form.
3. Substitute sites.
4. Multi-destination trips.
5. Multi-purpose trips.

(1) Measurement of travel costs – issues include the identification of the components that compose the travel costs, the issue of cost of travel time and the issue of measurement of international travel by plane.

Components of travel costs- According to Van Beukering *et al. (*2007a) the travel costs include the monetary costs of travel to the site, time costs and the admittance fees. Freeman (1993) mentions the same components, but specifies the time component in time cost of travel to the site and the cost of time spent at the site. Pham and Tran (2001) also include accommodation costs and other costs (e.g. guide fees and other incidental expenses).

In the Bermuda case study, the monetary costs of travel to the site, the time costs of travel to the site and the monetary costs of staying at the site (accommodation and meals) are included.

The additional consideration in the Bermuda case study is that in order to have a comparable measure of travel costs between air and cruise ship visitors, the cost of travel and cost of accommodation and meals during travel had to be lumped. The reason for this is that it is difficult to break down the cost of a cruise ship trip between cost of travel and cost of food and accommodation.

Travel time- According to Van Beukering *et al.* (2007a) travel time needs to be included in the estimation of travel costs because time is a scarce resource and has an opportunity cost. If a person is willing to give up working time to visit a site, the wage rate is a correct measure of the cost of travel time. But, since most recreational time is spend at the expense of an alternative recreational activity, the opportunity cost of time should be measured with reference to the marginal value of other recreational activities. Based on earlier studies Van Beukering *et al.* (2007a) assume a wage rate of one-third of the actual wage rate as an appropriate measure of the cost of travel time. Pham and Tran (2001) use the same percentage. Freeman (1993) assumes that individuals are free to choose the number of hours worked at a given wage rate, and suggests that time costs should be valued at the actual wage rate. Since in most countries there are institutional constraints on the choice of hours of work (such as a standard forty-hour work week and fixed number of holidays) *this study does not adopt the Freeman approach, but the partial wage approach of one-third suggested by Van Beukering et al. (2007a).*

Measurement of international travel by plane- The travel cost method is originally designed to capture domestic travel to a site, where travel is predominantly by car. In order to apply the method to long distance destinations, like tropical islands, the method has to be extended to travel by plane. The issue with travel by plane is the fact that often the distance to the site is not well correlated with the cost of air travel. Carr and Mendelsohn (2003) mention three possible causes: (i) many tourists travel on packages in which the travel cost is not clearly defined, (ii) some tourists visit on special (very low) fares raising questions whether this is the right fare to use and (iii) some countries have no observed visitors and so there are no actual fares. The selection of using actual reported fares or consistent fares from travel agents is case specific. *In this study the actual airfares are used, since these represent the actual costs for the visitor.*

2) Functional form - According to Carr and Mendelsohn (2003) the functional form that is chosen by the researcher to fit the data on travel costs has a major effect on the demand function and thus the consumer surplus. For example a log-linear model, although an attractive functional form because it provides a non-linear demand function with few parameters, assumes that price will rise to infinity as the number of trips approach to zero, and tends to result in higher consumer surplus. *In this study a linear function is used, because of the simplicity of interpretation (and because of the very small difference between the best non-linear and linear functions).*

3) The existence of substitute sites – this may influence the demand-curve of a specific site. It is realistic that the number of visits an individual makes to a site depends not only on the price and characteristics of this site, but also on the implicit prices of any substitute site in the region (Freeman, 1993). Depending on the correlation of characteristics between the two sites, the impact of the other site on the number of visits of the site in question can be positive, neutral or negative. Since Bermuda is an

isolated island (no substitute neighbour islands) and there are an infinite number of substitutes further away from Bermuda, *a specific analysis of one specific substitute destination is not needed in this study.*

4) Multi-destination trips - a multi-destination trip is a trip in which two or more sites are visited. At least part of the travel cost would be a joint cost that cannot be properly allocated among different sites (Freeman, 1993). *In this study all airplane trips are considered as single-destination trips. For airplane tourists, travel time is functional to the destination and not part of the pleasure. For cruise ship tourists, travel time at sea is considered as 'half the pleasure' and is not related to the destination. In this study, time at sea is considered as another destination and relates to 50% of the total travel costs. Furthermore, occasionally some of the cruise ship trips to Bermuda visit three other destinations. Therefore the travel costs incurred to visit Bermuda are one fourth of total travel costs related to the destination (which is already 50% of total travel costs).*

5) Multi-purpose trip- Visitors tend to visit a location for several reasons. For this reason, only part of the travel costs can be allocated to the site valued- coral reefs in this instance. Two methods have been used in previous studies to estimate the fraction of total travel costs allocated to the specific site analysed: a) Percentage of the motivation to visit a destination (Cesar *et al.,* 2001). The advantage of this method is that it includes the perception or earlier experience of the visitor. b) Percentage of time spent at the specific site of interest (Pham and Tran, 2001). The advantage of this method is that it is based on actual behaviour. The disadvantage of both methods is that the satisfaction of the visitor is not included (Pham and Tran, 2001). *In this study the percentage of travel costs that may be allocated to the coral reefs is estimated by asking visitors to what extent certain activities contributed to their motivation to choose Bermuda as a destination.*

B. Net factor income method

The net factor income method is a direct market method used to estimate the producer surplus or the value of an ecosystem as producer of a marketed good. It estimates the value of an ecosystem service as the total surplus between the revenues and the cost price of production (Van Beukering *et al.*, 2007a). The net factor income method is very appropriate in a situation where an ecosystem provides a service which leads to an increase in producer surplus (Woodward and Wui, 2001). For example coral reefs provide services, being the beauty of the coral reefs, which can be sold and thus can lead to an increase in producer surplus of the producer or operator. In the net factor income method the physical relationship between the ecosystem and the economic activity is estimated. It is then possible to identify the increase in producer surplus that is associated with the ecosystem (Woodward and Wui, 2001).

The net factor income method is based on the actual expenditures of tourists who visit the ecosystem studied. Expenditures are categorised by type of expenditure. For example, specific expenditures related to the ecosystem itself, such as coral reef-related activities (snorkeling, diving) can be separated from other travel expenditures. The assumption is that total expenditures by tourists equal total revenues from operators or producers in the tourism sector. Consequently the expenditures that are ecosystem related equal the revenues of the ecosystem-related producers or operators.

Revenues consist of cost price, taxes and profits. Since ecosystem services –i.e. the basis of the production process of a given producer or operator – do not have a market value and hence are not represented in the cost price, the profits can be partly considered as value added by services of the ecosystem. This value represents the "producer surplus" of the tourism related value of the ecosystem.

Two issues are relevant in estimating the producer surplus of tourism-related ecosystem – or coral reefs - services. The first issue relates to the percentage of the profit of direct and indirect reef - related producers or operators which can be considered as value added (i.e. an increase in producer surplus).Due to lack of information specific to the Bermuda case study, percentages calculated for other similar studies are used. A Hawaii case study demonstrated that 25% of all indirect and direct reef related expenditures can be considered as value added or increase in producer surplus (Cesar and van Beukering, 2004). Airfares are considered to contribute for 2% as value added. Van Beukering *et al.* (2007b) estimated the value added from the coral reefs in Guam by using the same percentages. *Therefore in this study, the percentages of 25% and 2% are used to estimate the value added from the coral reefs in Bermuda. A 'new' percentage for the cost of a cruise ship trip needs to be calculated.*

The second issue relates to the indirect reef-related expenditures. As stated earlier, not all tourists visit a tropical island for one single purpose. Therefore not all expenditures can be related to the ecosystem, and an estimate of the proportion of total tourist expenditures related to the ecosystem is required. Cesar *et al.* (2001) and Van Beukering *et al.* (2007b) used the same techniques to estimate these proportions as described earlier (section A point 5- Multi-trips); this was also applied to the Bermuda case study. *The percentage of travel expenditures that may be allocated to the coral reefs of Bermuda is estimated by asking visitors what reasons contributed to their motivation to choose Bermuda as a destination.*

C. Contingent valuation method

The contingent valuation method is a stated preference method used to estimate the potential extra consumer surplus. It is based on expected human behaviour in a hypothetical situation (Van Beukering *et al.*, 2007). This is obtained through a survey, where the Willingness to Pay and/or the willingness to receive a compensation to tolerate a cost for a benefit by individuals are investigated, dependent on the case study. The personal valuations of increases or decreases in the quantity of goods in this market should be revealed. The market does not only include the good itself but also the context in which it would be provided and paid for (Pearce and Turner, 1990).

In order to evaluate whether the contingent valuation method gives an accurate value of a certain good, the possible biases connected to the method should be assessed. Sources of bias are presented in Table I.1.

There are four types of biases: Strategic, design, hypothetical and operational.

Strategic biases are associated with the free rider problem. Respondents may secure a benefit (on top of the costs they are willing to pay) by not telling the truth. Contingent valuation studies state however that strategic biases are not significant.

Design biases have three sources:

a) The starting point bias refers to the starting bid of the interviewer that may influence the respondent. Questions related to Willingness to Pay can be open ended (minimising the starting point bias) and closed ended (dichotomous or payment card). Results from contingent valuation studies vary; where some do find a correlation between starting points and respondent's bids and others do not.

TABLE I.1. SOURCES OF BIAS IN THE CONTINGENT VALUATION METHOD

Strategic	Incentive to 'free ride'?
Design	(a) Starting point bias (only for discrete choice method) (b) Vehicle bias (c) Informational bias
Hypothetical	Are bids in hypothetical markets different to actual market bids?
Operational	How are hypothetical markets consistent with markets in which actual choices are made?

Source: Pearce and Turner (1990)

b) The vehicle bias refers to the sensitivity of respondents to the payment vehicle (e.g. taxes, entrance fees, surcharges, higher prices) in relationship with prices. The same amount paid as a tax may be perceived as more costly than paid as an entrance fee.

c) Information bias is a result of the way information is presented to the respondent. The amount, quality and sequence of information may influence the respondent.

Hypothetical biases, similarly to information bias mentioned above, are considered a reliability problem rather than a bias problem.

The *operational bias* refers to the extent to which the conditions of actual operation in the hypothetical market approximate the actual market (Pearce and Turner, 1990).

In the Bermuda case study the contingent valuation method is used to estimate the Willingness to Pay (in addition to the normal travel costs) for conservation of the coral reefs around Bermuda. A payment card elicitation method is applied to minimise the design bias.

I.2 Tourist exit survey

Good morning/afternoon/evening, my name is _____. I am working for the Bermuda Department of Conservation Services. We are researching how tourists value Bermuda's coral reefs. For this we would like to ask a few questions about your motivation to visit Bermuda and your activities while in Bermuda. Would you like to participate? It will only take a few minutes. Everything you tell us will be 100% anonymous.

Only tourists of 18 years and older are included in our survey. I would first like to check whether you meet our selection criteria.

1. Are you 18 years or older?
   - Yes
   - No → THANK AND TERMINATE ♦

2. Where do you live?
   - Bermuda → THANK AND TERMINATE ♦
   - USA → specify state: _____
   - Canada → specify province/territory: _____
   - Europe → specify country: _____
   - Other → specify country: _____

3. What was the purpose of your visit?
   - Business → THANK AND TERMINATE ♦
   - Leisure
   - Both (only if you spend one day or more on leisure activities)

You meet our selection criteria. Now we start the survey.

4. How many days did you stay in Bermuda? _____ days

5. How did you travel to Bermuda?
   - By plane → TO QUESTION 7
   - By cruise ship → TO QUESTION 6
   - By (sailing) boat → TO QUESTION 6

6. What is the total number of days in your cruise/boat trip? _____ days

7. How many times have you visited Bermuda including this trip? _____ times

8. How many persons, including yourself, are in your immediate travelling company? _____ persons

9. What kind of travel arrangement did you book before departing from your own country (tick one)?

- Package → TO QUESTION 10
- Separately arranged → TO QUESTION 11

10. What was included in the package at the moment you booked (tick all that apply)?
    - Cruise ship
    - Flight
    - Accommodation (cruise ship passengers: if accommodation on land is included)
    - Meals
    - Local transportation
    - On island activities
    - Other: ______

11. How much did you pay before departing from your own country (<u>per person</u>)?

	Currency	Amount
Package (only if relevant, check question 8)		
Flight		
Accommodation		

12. In addition to what you paid in your own country, how much did you spend during your stay in Bermuda (<u>per person</u>)?

BMD

13. Of this amount, how much did you spend on average during your stay in Bermuda for (<u>per person</u>):

Accommodation (if not pre-paid)	BMD
Diving	BMD
Snorkeling	BMD
Touring the coral reef by boat	BMD
Shopping	BMD
Local transportation	BMD
Food and beverages	BMD
Other:	BMD

14. On a scale from 0 to 5 can you indicate how important the following reasons were in coming to Bermuda (1 means not important and 5 means very important)?

	Not important		< >		Very important
	1	2	3	4	5
Business					
Snorkeling					
Diving					
Touring the coral reef by boat					

Enjoying beach					
Shopping					
Sailing					
Sightseeing					
Playing golf					
Fishing					
Eating and drinking					
Other:					

IF DIVING OR SNORKELING > 3 → CONTINUE
OTHERWISE → QUESTION 17

15. Roughly how many dives and days of snorkeling have you had in your lifetime (refer to the boxes)?
    Number of dives:
    - ○ 0
    - ○ 1 – 10
    - ○ 11- 25
    - ○ 26 – 50
    - ○ 51 – 100
    - ○ > 100

    Number of days of snorkeling
    - ○ 0
    - ○ 1 – 10
    - ○ 11- 25
    - ○ 26 – 50
    - ○ 51 – 100
    - ○ > 100

16. On a scale from 1 to 5 can you indicate how important the following attractions were to your overall experience of diving or snorkeling in Bermuda (1 means not important and 5 means very important)?

	Not important		< >		Very important
	1	2	3	4	5
Coral reefs					
Fish					
Wrecks					
Sharks					
Other:					
No preference					

17. Would you still have come to Bermuda if the coral reef was dying or damaged?
    - Yes
    - No

Let's go more in depth on how you appreciate Bermuda's coral reefs. At this moment the coral reefs around Bermuda are beautiful and healthy. However there are some threats caused by human activity that can change that. One of them is the increased pressure from tourism. If these threats are not dealt with, they can damage the reefs. This would ultimately mean losing Bermuda's beaches and blue waters. To help preserve the coral reefs of Bermuda, extra funds may be needed for which tourists may be asked to pay.

18. Would you - in principle - be willing to pay any amount in addition to your current expenses, to fund activities to preserve Bermuda's coral reef?
    - Yes → TO QUESTION 20
    - No → TO QUESTION 19

19. What is the main reason you are <u>not</u> willing to pay to preserve Bermuda's coral reef (tick one)?
    - No need for management of coral reefs
    - Conservation is the responsibility of Bermuda
    - My activities have no impact on coral reefs
    - This conservation program would not be effective
    - I cannot afford
    - Other: _____
    - Don't know/refused

    → TO QUESTION 23

20. What would be the maximum you would be willing to pay <u>per visit to Bermuda</u>, in addition to your current expenses, to fund activities to preserve Bermuda's coral reef (tick one, <u>refer to the list</u>)?
    - BMD 1
    - BMD 3
    - BMD 5
    - BMD 10
    - BMD 15
    - BMD 25
    - BMD 40
    - BMD 60
    - BMD 80
    - BMD 100
    - More than BMD 100: _____ (please specify)
    - Don't know/refused

21. What is your preferred method to pay the contribution to preserve Bermuda's coral reef (tick one)?
    - Per visit to Bermuda
    - Per dive, snorkel or other water sport activity
    - Per year

- No preference
- Don't know/refused

22. Do you believe a contribution to preserve Bermuda's coral reefs should be voluntary or mandatory?
    - Voluntary
    - Mandatory
    - Don't know/refused

The remaining questions are for statistical purposes.

23. What is your sex?
    - Male
    - Female

24. What is your age? _____ years

25. What is your household size?
    - Number of adults: _____
    - Number of children living at home: _____

26. What was your annual <u>household</u> income in 2007 (<u>before taxes</u>)?
    - Less than 25,000 ____ (specify currency)
    - Between 25,000 and 50,000 _____ (specify currency)
    - Between 50,000 and 75,000 ____ (specify currency)
    - Between 75,000 and 100,000 ____ (specify currency)
    - Between 100,000 and 150,000 ____ (specify currency)
    - Between 150,000 and 200,000 ____ (specify currency)
    - Between 200,000 and 300,000 ____ (specify currency)
    - More than 300,000 _____ (specify currency)
    - Prefer not to answer

27. What is the highest level of education that you completed?
    - Did not finish high school
    - High school
    - University or college degree
    - Master or other advanced degree
    - Don't know/refused

28. Which employment category applies to you?
    - Employed → TO QUESTION 29
    - Self-employed → TO QUESTION 29
    - Unemployed/seeking work → FINISHED ♦
    - Retired/student/not in the work force → FINISHED ♦

29. How many hours per week do you work? _____ hours ♦

♦ *Thank you very much for participating in our survey!*

I.3 Tourist Exit Survey: Detailed Results

General description of tourists to Bermuda

Results below are those of the tourist exit survey designed for the purpose of the Bermuda study and administered by Total Marketing, a Bermuda-based private company. A total of 407 tourists were interviewed, with an equal proportion of air passengers (201) and cruise ship passengers (206). General data obtained within the scope of this study proved to be in accordance with that reported by the Department of Tourism during routine tourist exit surveys, and discussed in Chapter 2 of the main text. Results were statistically analysed using SPSS.

Based on the representative sample of tourists interviewed, there is an equal female: male ratio (48%:52%) of tourists visiting Bermuda, with no significant difference in this ratio between airplane tourists and cruise ship tourists (Figure I.2).

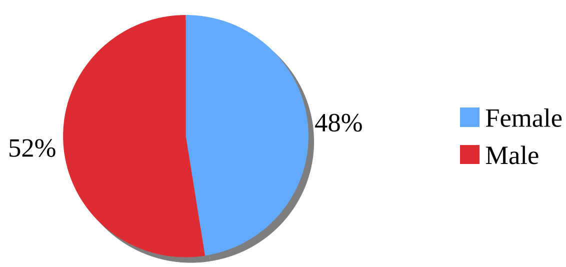


FIGURE I.2. GENDER OF TOURISTS VISITING BERMUDA

Half of all tourists visiting Bermuda have a university or college degree and 28% have a master or other advanced degree (Figure I.3). There is no significant difference between airplane tourists and cruise ship tourists.

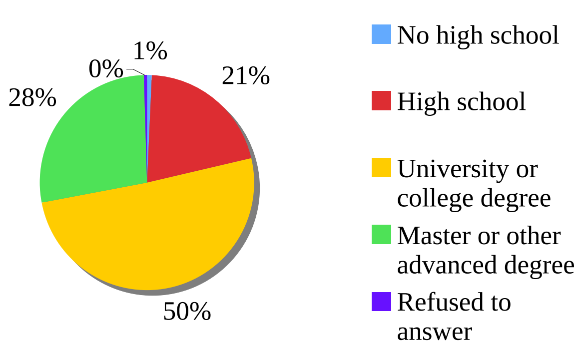


FIGURE I.3.   EDUCATION OF TOURISTS VISITING BERMUDA

Of all tourists visiting Bermuda 80% are employed of which 14% are self-employed (Figure I.4). A relative high percentage (19%) is not in the workforce (most of them retired). There is no significant difference between airplane tourists and cruise ship tourists.

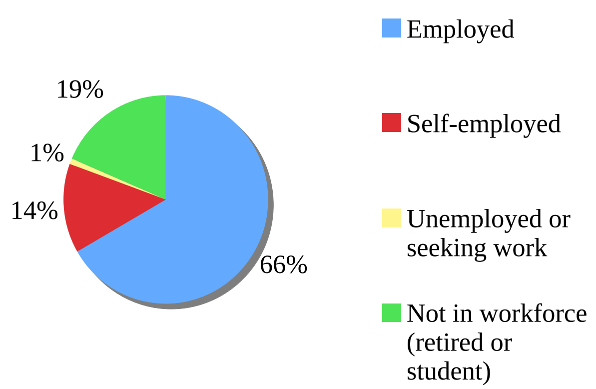


FIGURE I.4.   EMPLOYMENT TYPE OF TOURISTS VISITING BERMUDA

In Table I.2 , other general characteristics of tourists visiting Bermuda are given. Air and cruise ship tourists show similarities in most characteristics, with the only significant difference being that of the household size adults. Pooling data from both tourist sectors, results indicate that the average tourist age in Bermuda is 48 years; the average household composition is 2 adults and 0.8 children under 18 years; and the average gross income is US$120,000 and net income US$95,000.

TABLE I.2. GENERAL CHARACTERISTICS OF TOURISTS VISITING BERMUDA

	Air	*Cruise*	*Significant*
Age	47	48	No
Household size adults	1.8	2.2	Yes
Household size children	0.8	0.8	No
Gross household income	$119,496	$121,031	No
Net household income	$93,954	$96,142	No

Origin

Table I.3 indicates that the majority (95%) of cruise ship tourists live in the U.S.A. On the other hand, although 71% of air tourists also report living in the U.S.A., a noticeable proportion come from elsewhere - 23% from Europe, and 5% from Canada.

TABLE I.3. REGIONS FROM WHICH BERMUDA TOURISTS ORIGINATE, EXPRESSED AS NUMBER OF INDIVIDUALS (NO.) AND PERCENTAGE OF TOTAL.

	Air(no.)	*Air (%)*	*Cruise(no.)*	*Cruise (%)*	**Total no.**	**Total (%)**
USA	142	71%	196	95%	338	83%
Canada	11	5%	8	4%	19	5%
Europe	46	23%	2	1%	48	12%
Rest world	2	1%	0	0%	2	0%
Total	201	100%	206	100%	407	100%

Within the U.S.A. 75% of all tourists visiting Bermuda (both air and cruise ship) live on the East Coast (Table I.4). This proportion is larger when considering only the cruise ship tourists, of whom 90% are reported to live on the U.S. East Coast.

TABLE I.4. .TRAVEL ZONES FOR BERMUDA'S TOURISTS, EXPRESSED AS NUMBER OF INDIVIDUALS AND PERCENTAGE OF TOTAL.

	Air(no.)	*Air (%)*	*Cruise(no.)*	*Cruise (%)*	**Total no.**	**Total (%)**
North east coast	84	43%	163	79%	247	61%
South east coast	34	17%	23	11%	57	14%
Mid East	17	9%	18	9%	35	9%
Mid West	6	3%	0	0%	6	1%
West Coast	8	4%	0	0%	8	2%
Alaska	1	1%	0	0%	1	0%
South America	0	0%	0	0%	0	0%
Europe	45	23%	2	1%	47	12%
Africa	0	0%	0	0%	0	0%
Asia	1	1%	0	0%	1	0%
Oceania	1	1%	0	0%	1	0%
Total	197	100%	206	100%	403	100%

Trip characteristics

Only the visitors that visit Bermuda for leisure or partly for leisure were included in the survey. All cruise ship tourists visit Bermuda for leisure. On the other hand, 2% of the air tourists interviewed indicated that their trip was part leisure and part business. In the context of this study, these 2% can be interpreted as business people that have spend a minimum of one day on leisure activities (Table I.5)

TABLE I.5. THE NUMBER AND PERCENTAGE OF LEISURE AND BUSINESS TRAVELLERS COMING TO BERMUDA.

	Air(no.)	*Air (%)*	*Cruise (no.)*	*Cruise (%)*	**Total no.**	**Total (%)**
Leisure	195	98%	204	100%	399	99%
Leisure and business	5	2%	0	0%	5	1%

Total	200	100%	204	100%	404	100%

Airplane tourists spend, on average, almost 7 days in Bermuda. Cruise ship tourists spend y less time in Bermuda, slightly more than 2 days (Table I.6).

TABLE I.6. AVERAGE NUMBER OF DAYS IN BERMUDA

	Days in Bermuda	*Standard deviation*
Air	6.8	7.77
Cruise	2.3	0.95

Bermuda is visited more often by most airplane tourists than cruise ship tourists. Airplane tourists interviewed indicated they had been more than 4 times in Bermuda, including the current trip. Cruise ship tourists visited Bermuda significantly less, and for the most part, the current trip was only the second trip to Bermuda (Table I.7).

TABLE I.7. FREQUENCY OF VISITS BY ANY ONE TOURIST IN BERMUDA (INCLUDING THE CURRENT TRIP)

	Number of visits to Bermuda	*Standard deviation*
Air	4.3	9.3
Cruise	2.0	2.7

In this study, cruise ship trips are considered as a package. Therefore 100% of all cruise ship tourists' travel arrangements are packages. For airplane tourists this is significantly less, and only 33% of air visitors book their trip as a package (Table I.8).

TABLE I.8. TRAVEL ARRANGEMENTS MADE BY BERMUDA TOURISTS.

	Air(no.)	*Air (%)*	*Cruise (no.)*	*Cruise (%)*	**Total no.**	**Total (%)**
Package	66	33%	206	100%	272	67%
Individually arranged	135	67%	0	0%	135	33%
Total	201	100%	206	100%	407	100%

Most packages bought by airplane tourists include the flight to Bermuda and the accommodation. Around 24% of all packages also include meals (Table I.9).

TABLE I.9. COMPONENTS OF A TRIP PACKAGE FOR AIR TOURISTS

	Included	*Included (%)*
Accommodation	62	94%
Flight	64	97%
Meals	16	24%
Local transportation	5	8%

Other	1	2%

Travel costs

The average air tourist visiting Bermuda pays US$405 for a travel package (including in most cases the flight and accommodation only; please note that only 24% of packages include meals) (Table I.10). Air tourists coming to Bermuda and booking separately for flight and accommodation (excluding meals), pay on average $569 for flight, and $348 for accommodation (*Note: Average given here considers payments made as accommodation/flight packages, and separately; this results in a lower average than expected based on accommodation prices*). Cruise ship tourists pay, on average, US$1.089 for their cruise. The small amounts recorded for accommodation and flight refer to cruise ship tourists flying to the port of embarkation or stay in a hotel at the port of embarkation, before or after the cruise. (*Note: A very small percentage of cruise ship tourists pay for flight and accommodation to reach the port of departure; this cost is spread over all cruise ship tourism and results in a $6 charge for flight given here*).

TABLE I.10. TRAVEL COSTS INCURRED AT HOME

	Air	Cruise
Package	$405	$1,089
Flight	$569	$6
Accommodation	$348	$122

TABLE I.11. TRAVEL COSTS INCURRED IN BERMUDA

	Air	Cruise
Accommodation	$313	
Diving	$19	$5
Snorkeling	$12	$17
Touring the reef	$7	$11
Shopping	$229	$84
Local transportation	$99	$20
Meals	$383	$38
Other	$46	$29
Total	**$1,107**	**$204**

In addition to the travel costs made at home, airplane tourists spend on average US$1.107 on the island. Cruise ship tourists spend one fifth of this amount, US$204 (Table I.11). All subcategories of costs are significantly different between airplane tourists and cruise ship tourists, except the costs of snorkeling and “other” costs. Other costs are in all cases on-island activities, like motorcycle rentals, boat rentals, bus tours, fishing and golf.

Out of 407 tourists (air and cruise), 41 tourists went diving and 89 snorkeling. In Table I.12 the break-down between air tourists and cruise ship tourists is presented. More air visitors go diving and if they go diving, they spend almost double the amount that cruise ship visitors do. The total overlap –i.e. tourists who go diving and snorkeling – is 26. The overlap is larger for air than cruise ship visitors (19 and 7 respectively).

TABLE I.12. NUMBER OF TOURISTS DIVING AND SNORKELING WITH ASSOCIATED COSTS.

	Air(no.)	*Cost to air visitor*	*Cruise (no.)*	*Cost to cruise visitor*
Diving	28	$134	13	$76
Snorkeling	41	$59	48	$72

Motivation to visit Bermuda

For both air and cruise ship tourists visiting the beach, dining (eating /drinking), sightseeing and shopping are the main reasons to visit Bermuda. In Table I.13 responses to all motivations identified are given for air visitors, cruise ship visitors, and both combined. There are significant differences between the motivation of air and cruise visitors for approximately half of the activities identified. The following motivations are considered reef-related: snorkeling, diving, touring the reef and visiting the beach; the latter is justified as all beaches in Bermuda are of coralline origin. Air tourists interviewed report that 37% of their motivation to visit Bermuda is related to the coral reefs; this is slightly higher for cruise ship tourists, for whom 40% of their motivation to visit the island is coral reef-associated.

TABLE I.13. MOTIVATION TO VISIT BERMUDA FOR BOTH AIR AND CRUISE TOURISTS, EXPRESSED AS A PERCENTAGE OF TOTAL INTERVIEWED. SIGNIFICANT DIFFERENCE BETWEEN THE TWO TYPES OF TOURISTS IS SHOWN.

	Air	*Cruise*	*Significant different*	**Total**
Business	4.5%	4.3%	No	4.4%
Snorkeling	7.3%	9.6%	Yes	8.6%
Diving	5.9%	5.5%	No	5.7%
Touring the reef	7.4%	9.1%	Yes	8.3%
Visiting the beach	16.1%	15.4%	No	15.8%
Shopping	11.1%	11.3%	No	11.2%
Sailing	6.2%	6.6%	No	6.4%
Sightseeing	13.7%	15.3%	Yes	14.5%
Playing golf	5.5%	5.4%	No	5.4%
Fishing	4.6%	5.2%	Yes	4.9%
Eating and drinking	16.0%	11.5%	Yes	13.7%
Other	1.5%	0.7%	Yes	1.1%

Total	100%	100%	100%
Total reef related	36.8%	39.7%	38.3%

Active users of the reef

The definition of active users for the current case study was selected using the following reasoning. There are three definitions which may be used in the context of this survey (Table I.14): These are:

1. Travel costs: tourists who spend money on diving or snorkeling while in Bermuda. Since actual spending may be limited because of different factors, among which inclement weather conditions, this is not a usable definition.
2. Motivation: tourists who are motivated to visit Bermuda because of diving or snorkeling opportunities (demonstrated by checking # 4 or #5 in the survey). Since motivation may also be limited due to different factors, such as age or physical condition, this is not a usable definition.
3. Number of dive or snorkel experiences: tourists who have been diving or snorkeling previously, answered by #15 in the questionnaire. This defines a group of people who have enjoyed at least once, a practical experience relating to the beauty of coral reefs.

Definition number 3, identifying the groups of people who have previously demonstrated a practical enjoyment of coral reefs by diving or snorkeling will be used in further analyses in this study

TABLE I.14. DIFFERENT DEFINITIONS OF ACTIVE USERS

	Air	*Cruise*	*Total*	**%**
Travel costs in Bermuda on diving or snorkeling	49	54	103	25%
Motivation to visit Bermuda is diving or snorkeling	49	75	124	30%
Number of dives or snorkel experiences in life	71	95	166	41%

Of the tourists interviewed, almost half (41%) can be classified as active users of the reefs (Table I.15). Cruise ship tourists demonstrate a higher number of active users than air visitors (95 and 71 respectively). Nonetheless, those air tourists reported as active users demonstrate more activity than cruise ship tourists, as seen in Table I.15. This group reports an average of 20 dives and 34snorkel (54 in total) experiences in their lives, as compared to cruise ship tourists who report an average of 14 and 26 (40 in total). (Table I.15).

TABLE I.15. NUMBER OF DIVES AND SNORKEL EXPERIENCES OF ACTIVE USERS BASED ON EXPERIENCE

	Air	*Cruise*	**Combined ***
Number of dives	20	14	17
Number of snorkellers	34	26	30

Total	**54**	**40**

**refers to an estimate for all tourists (air and cruise ship passengers)*

Importance of coral reefs

The coral reefs themselves are considered the most attractive attribute, compared to sighting fish or other, while diving or snorkeling in Bermuda by all visitors; there is no significant difference in the response of air and cruise ship tourists to this question (Table I.16).

TABLE I.16. PREFERRED SIGHTINGS DURING AN UNDERWATER REEF EXPERIENCE FOR BOTH AIR AND CRUISE SHIP TOURISTS

	Air	*Cruise*	**Total**
Coral reef	35%	34%	34%
Fish	30%	31%	31%
Wrecks	21%	20%	20%
Sharks	12%	10%	11%
Other	2%	5%	4%
Total	100%	100%	100%

Results based on n (air) = 69 and n (cruise) = 82, where n is the number of individuals responding. Please note that two data points are missing for air visitors attributed to poor quality interviewing.

Additionally, users and non-users of the reef do not significantly differ in their opinion of the importance of the coral reefs in relation to other aspects (Table I.17).

TABLE I.17. IMPORTANCE REEFS FOR USERS AND NON-USERS

	User	*Non-user*	**Total**
Coral reef	35%	33%	34%
Fish	31%	29%	31%
Wrecks	20%	21%	20%
Sharks	11%	9%	11%
Other	3%	8%	4%
Total	100%	100%	100%

Results based on n (user) =139 and n (non-user) = 12. This question was not answered by all non-users.

Importance of Coral reef ecosystem quality and health

Of all tourists visiting Bermuda 14% would not have come to Bermuda if the coral reef was dying or damaged. With over 660,000 visitors in 2007, this means a decrease of tourists of more than 90,000 (Table I.18). The response by the cruise ship tourists (18%) was stronger.

TABLE I.18. RESPONSE OF AIR AND CRUISE SHIP TOURISTS TO HYPOTHETICAL REEF QUALITY DECLINE

	Air(no.)	*Air (%)*	*Cruise (no.)*	*Cruise (%)*	**Total (no.)**	**Total (%)**
No	18	10%	26	18%	44	14%
Yes	157	90%	120	82%	277	86%
Total	175	100%	146	100%	321	100%

Note: There are 86 missing values attributed to poor quality interviewing/data recording

As expected, active users indicated a greater interest in coral reef quality than non-users, where 19% reported they would not come back should coral reefs be damaged or seen to be dying in Bermuda (Table I.19).

TABLE I.19. RESPONSE OF USERS AND NON-USERS TO HYPOTHETICAL REEF QUALITY DECLINE

	User(no.)	*User (%)*	*Non-user(no.)*	*Non-user (%)*	**Total (no.)**	**Total (%)**
No	30	19%	14	8%	44	14%
Yes	126	81%	151	92%	277	86%
Total	156	100%	165	100%	321	100%

Note:"No" indicates that the respondent would not come back should coral reefs be seen as damaged or dying. There are 86 unreported answers of the 407 questionnaires administered due to poor interviewing.

I.4 Reef-related Tour Operator Survey

We are working with the Bermuda Department of Conservation Services on an economic valuation of the coral reefs. We need your help to learn more about how water sports (mainly diving and snorkeling) industry works and how important Bermuda's coral reefs are to tourists. Everything you tell us will be 100% anonymous.

1. How long have you run your operation in Bermuda? ___________ years

2. If your operation owns or charters boats, please fill in the following:

a. Number of boats	
b. Type of boats	
c. Average passenger load per boat	

3. What activities does your operation offer, how many customers went on tours sold by your operation in 2007[22] (roughly) and what was the price they paid for it:

	Number customers	Price
a. Dive courses		
b. Dives (per dive)		
c. Snorkeling tours		
d. Glass bottom boat tours		
e. Helmet diving tours		
f. Non-reef related boat tours, including: ○ ○ ○ ○ ○		

4. How important are the following aspects to your customers (1 = not important at all and 5 = very important)?

	1	2	3	4	5
a. Simply getting out on the ocean					
b. See fish					
c. See turtles					
d. See wrecks					

[22] If 2007 information is not available, please indicate what other (fiscal) year is used

e. See healthy coral reefs					
f. Good visibility					
g. Go to secluded beaches					
h. Entertainment and food you provide					
i. Learning to snorkel or dive					
j. Information, education you provide about marine life					
k. Other:					

5. What percentage of your snorkel or glass bottom boat trips are[23]:

Wreck dives	%
Reef dives	%
TOTAL	%

6. What is your operation's TOP 5 most visited reefs and TOP 5 most visited wrecks?

REEFS	WRECKS
○ Aquarium	○ Airplane
○ Bad Caves	○ Aristo
○ Bad Lands	○ Beaumaris Castle
○ Barracuda	○ Blanche King
○ Basilica	○ Caraquet
○ Ben's Bender	○ Constellation
○ Blue Hole	○ Cristobal Colon
○ Castle Harbour	○ Darlington
○ Commissioner's Point	○ Hermes
○ Hangover Hole	○ Kate
○ Hog Breaker	○ Kevin's Wreck
○ In-Betweens	○ King George
○ Kevin's Wreck	○ L'Herminie
○ Killa Puffa	○ Lartington
○ Mill's Breaker	○ Madiana
○ Nonsuch	○ Marie Celeste
○ North East Breaker	○ Minnie Breslauer
○ North Rock	○ Montana
○ Parrot's Mission	○ North Carolina
○ Sandy Hole	○ Pelinaion
○ Sandy Hole West	○ Pollockshields
○ Shell City	○ Rita Zorvetta
○ Sic-O-Big-C	○ Taunton

[23] Is this a meaningful difference considering the value of coral reefs?

○ Smugglers Notch	○ The Dry Dock
○ Snake Pit	○ The King
○ South West Breaker	○ Virginia Merchant
○ Table Top	○ Vixen
○ Tarpon Hole	○ Xing Da
○ The Cathedral	
○ Three Sisters	
○ Virginia Merchant	
○ Watch Hill Park	

7. Of all your customers in 2007, what percentage came from (roughly):

	TOTAL	Reef related tours	Other tours
Bermuda	%	%	%
USA	%	%	%
Canada	%	%	%
Europe	%	%	%
Other areas	%	%	%
TOTAL	100%	%	%

8. Of all your non-Bermudan customers in last year, what percentage came to Bermuda by (roughly):

Airplane	TOTAL	Reef related tours	Other tours
Cruise ship	%	%	%
Yachties	%	%	%
TOTAL	100%	%	%

9. In your experience, how has quality of marine life (coral, fish) in Bermuda changed in the last five years:
   - ○ Improved
   - ○ Worsened
   - ○ No change

10. If quality of marine life <u>stays about the same</u> for the next five years, how will your business be affected?
    - ○ Improve a lot (over 10% more annually)
    - ○ Improve some
    - ○ No change
    - ○ Get worse
    - ○ Get a lot worse (over 10% less annually)

11. If quality of marine life <u>improves</u> because of better management, how will your business be affected in the next five years?
   - Improve a lot (over 10% more annually)
   - Improve some
   - No change
   - Get worse
   - Get a lot worse (over 10% less annually)

12. If quality of marine life <u>worsens</u> how will your business be affected in the next five years?
   - Improve a lot (over 10% more annually)
   - Improve some
   - No change
   - Get worse
   - Get a lot worse (over 10% less annually)

13. What do you think are (future) threats to the quality of marine life in Bermuda (1 = no threat at all and 5 = very serious threat)?

	1	2	3	4	5
a. Over-fishing (recreational)					
b. Over-fishing (commercial)					
c. Diving and snorkeling					
d. Coastal development					
e. Boating and anchoring by residents					
f. Sewage pumping and leaking					
g. Cruise ships					
h. Scientist or researchers					
i. Everyone					

14. In your experience, how did your business develop in the last five years or so?

Number of customers	% growth
Revenues	% growth
Type of customers (airplane/cruise ship/yachties)	From to

15. What share of total costs make up the following categories?

Fuel	%
Boat maintenance	%
Diving and snorkeling equipment	%
Personnel	%

Housing	%
Licenses and insurances	
Other: ______	%
TOTAL	%

16. What percentage of 2007 revenues came from:

Reef related tours	%
Other tours	%
TOTAL	100%

17. Please give an indication of 2007 revenues and profit margin:

Revenues	$
Profit margin	%
Total boat rental market	$

18. How do cruise ship tourists come to your operation?
   - Directly (via advertising, brochures, travel guides and word of mouth)
   - Via on board agents (please mention fee paid): ______
   - Via on shore agents (please mention fee paid): ______
   - Other (please specify):

19. How do other tourists come to your operation?
   - Directly (via advertising, brochures, travel guides and word of mouth)
   - Via hotel (please mention fee paid): ______
   - Via on shore agents (please mention fee paid): ______
   - Other (please specify):

20. To what extend do your customers appear environmentally sensitive (e.g., worried about preserving fish and corals, careful about trash) (1 = not sensitive at all and 5 = very sensitive):

	1	2	3	4	5
a. Air plane tourists					
b. Cruise ship tourists					
c. Yachties					

21. What needs to be done to protect, maintain, or enhance the coral reefs in Bermuda?

____

____

____

22. Do you think it is a good idea to ask water sport tourists (that enjoy Bermuda's coral reefs) to pay a fee that is used to protect the reefs?

- Yes (→ to question 23)
- No (→ to question 24)

23. Who is responsible for collecting the fees (and the management of the reefs)?

- Government
- Specific body (to be formed)
- Water sports operators together
- Other: ____

24. What is the main reason you are not in favour of this fee:

- No need for management of the reefs
- Conservation is the responsibility of the government
- Water sport tourists have no impact on the reef, so why letting them pay
- To much an administrative burden
- In the end, the fees will not be used to protect the reef
- Other: _____

We will share a summary of our research after we finish our survey with all operators. Would you like a copy? Individual information will not be published, only a summary (with aggregated information).

- No
- Yes

Name and e-mail

____

____

I.5 Tour Operator Survey: Detailed Results

General description

In this study a reef-related operator is defined as an operator who offers tourists the possibility to enjoy Bermuda's coral reefs. Reef- related operators are classified as follows for the purpose of this study:

1. Diving (including renting of snorkeling gear) and helmet diving operators- these offer an underwater reef experience. There are 5 such operators in Bermuda. This type of operation is considered 100% reef-related.

2. Glass bottom boat operators - these offer coral reef enjoyment from a boat. There are 5 such operators in Bermuda. This type of operation is considered 100% reef-related.

3. Small boat rental operators (including rent of snorkeling gear) - these offer rental services for small motor boats, kayaks, paddle boats, small sail boats and jet-ski with the possibility to enjoy the reef from the boat with rented snorkeling gear. There are 5 such operators in Bermuda at the time of this study. This type of operation is considered 50% reef-related, based on the fact that 50% of the customers use snorkeling gear (according to the operators).

4. Boat charter operators (including rent of snorkeling gear)- these offer boat cruises with the possibility to enjoy the reef from the boat with rented snorkeling gear. There are approximately 25 such operators in Bermuda. This type of operation is considered 50% reef related, on the same basis as point 3 above.

At the time of data collection, a total of 40 reef-related operators were listed in Bermuda (based on information from operators and available documentation). For the purpose of this study, 13 of these were interviewed (Table I.20), covering a range of activities associated with coral reefs.

TABLE I.20. TYPES OF REEF RELATED OPERATORS

	Percentage reef related	*Total in Bermuda*	*Interviewed*
Diving and helmet diving	100%	5	5
Glass bottom boat	100%	5	3
Small boat rentals	50%	5	3
Boat charters	50%	25	2

Reef-associated activities

Bermuda is known for its large number of wrecks accessible by SCUBA divers mostly, as they are too deep for snorkellers and/or glass bottom boat sightseeing. Dive operators often combine a wreck dive with a reef dive. The most visited reefs and wrecks are presented in Table I.21.

TABLE I.21. MOST VISITED WRECKS AND REEFS

Most visited reefs	*Most visited wrecks*
Blue Hole	Constellation
Castle Harbour	Montana
The Cathedral	Vixen
Eastern Blue Cut	Darlington
Kevin's Wreck	Hermes
Nonsuch	Lartington
South West Breaker	Marie Celeste
	Minnie Breslauer
	Virginia Merchant

The sighting of healthy coral reefs and of fish is considered the two most important attributes during a SCUBA dive or snorkel to the customers of reef- related operators (Figure I.5).

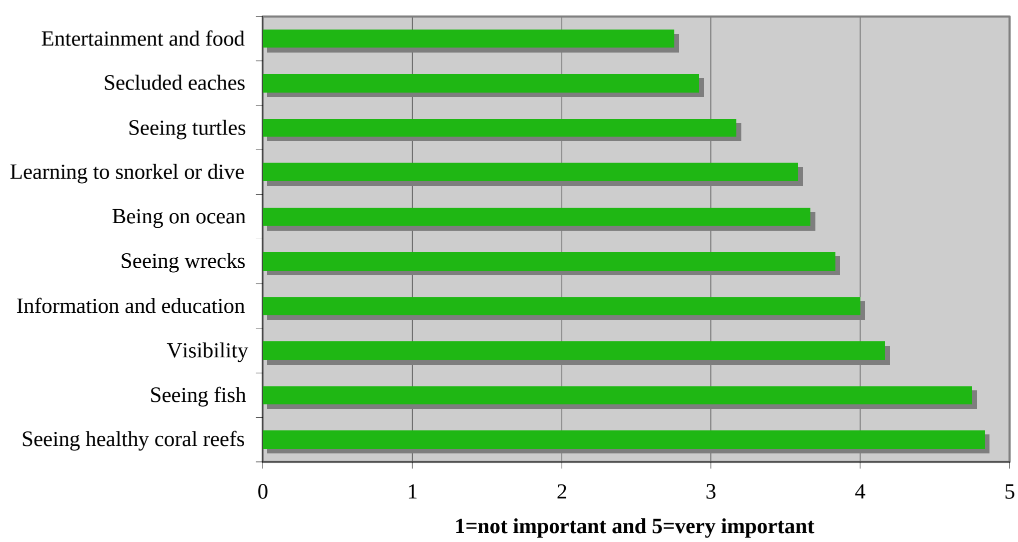


FIGURE I.5. RELATIVE IMPORTANCE OF ASPECTS OF ALL REEF-RELATED ACTIVITIES

Customer profile of reef-associated operators

The majority of the customers of reef related operators are from the U.S.A., with the second largest portion being of local origin. Visitors from Canada and Europe are a small proportion of this group (6% and 4% respectively) (Figure I.6).

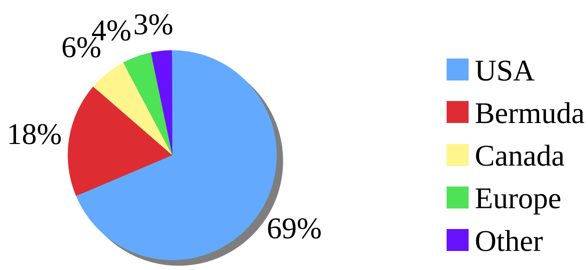


FIGURE I.6. ORIGIN OF CUSTOMERS OF REEF-RELATED TOURIST OPERATORS

A little more than half of all foreign customers arrive in Bermuda by air, the others by cruise ship and a very small fraction by yacht (Figure I.7). Most operators (58%) indicate that this did not change during the last 5 years, 33% indicate that they have more cruise ship tourists now (during survey period- 2007) and 8% indicate that they have more air tourists than 5 years ago.

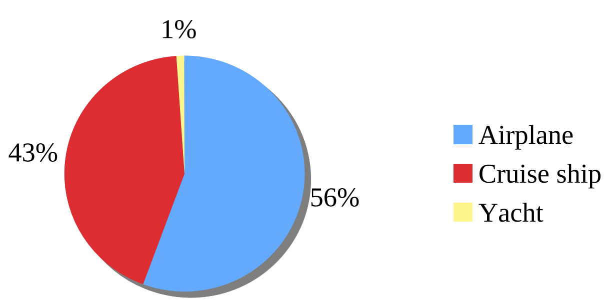


FIGURE I.7. MEANS OF TRANSPORTATION TO BERMUDA

Tourist operators attract their customers as follows: 83% of the acquisition of cruise ship tourists is direct-i.e. cruise ship visitors come individually and directly to operator-; 33% is acquired via on-shore agents -i.e. Meyer's Shipping- and 17% via on-board agents. The profit margin – as a percentage of the price a customers pays - of on-shore agents is estimated at 5% and the margin of on-board agents is 35% (according to some operators).

Environmental Sensitivity

Customers arriving by air appear more environmentally sensitive (-i.e. demonstrating concern of fish conservation and responsible behaviour towards littering) than cruise ship customers and yachties (Figure I.8).

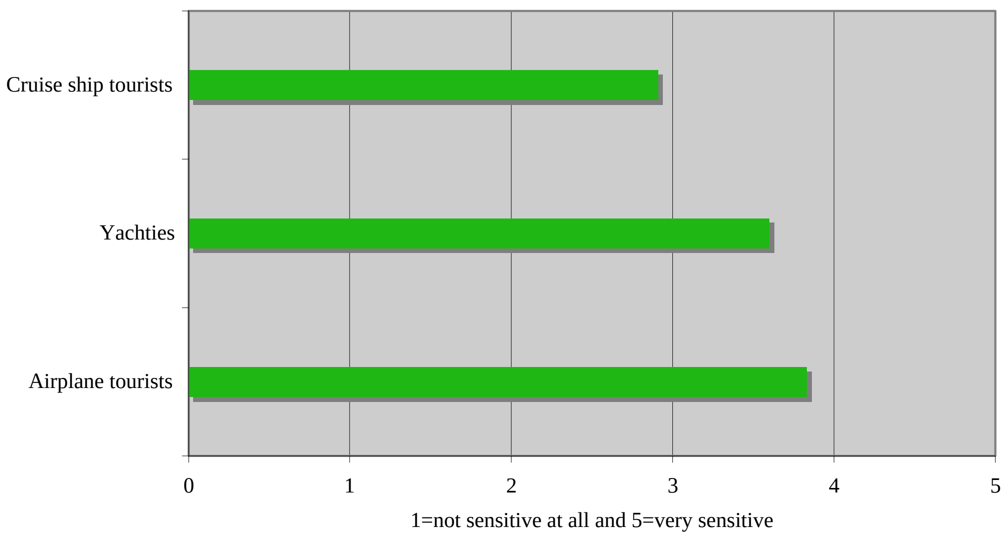


FIGURE I.8. ENVIRONMENTAL SENSITIVITY OF CUSTOMERS, BASED ON TOURIST OPERATOR SURVEY

Quality of coral reefs

Tourist operators feel that the quality of coral reefs has a high impact on their business. Responses indicated the following: a) should coral reefs remain stable in quality and health, improvement in business will be small. b) should the quality of the reefs improve, a substantial increase in business is predicted. c) should the quality of the reefs worsens, a decline in business is expected.

Most of the operators (58%) feel that the quality of Bermuda's coral reefs has improved during the last 5 years, 25% experienced no change and 17% report a decline of quality. Most operators admit that coral reefs are threatened in the (near) future. Figure I.9 gives an overview of what they perceive as being the most important threats. Over-fishing – both recreational and commercial – is considered the most important serious threat, and potential impacts by cruise ships a minor threat.

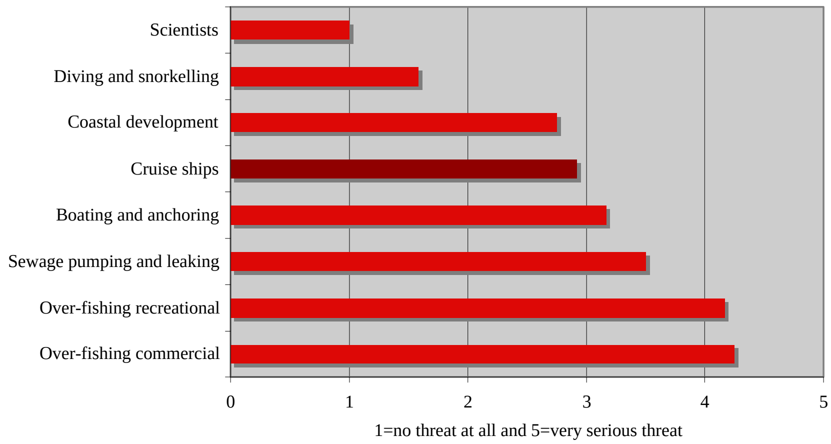


FIGURE I.9. THREATS TO BERMUDA'S CORAL REEFS, AS PERCEIVED BY REEF-ASSOCIATED TOURIST OPERATORS

The reef related operators were asked what should be done to protect the reefs. Three categories of improvements were suggested:

1. Improved publicity and education to both locals and visitors about the quality and the threats of coral reefs. It is suggested that education should start at school. The Bermuda Institute of Ocean Sciences (BIOS) and the Bermuda Aquarium are parties that were named to raise public awareness and educate the community on this subject.
2. Improved enforcement of the laws protecting the quality of the coral reefs. For example stricter penalties for over-fishing.
3. Improved laws to protect the quality of the coral reefs, or more incentives to promote protection. For example, the use of mooring buoys instead of anchoring, incentives for island clean up initiative, prohibit or limit use of jet ski through site and speed restrictions, identification and enforcement of marine protected areas (marine parks).

Only one third (33%) of all operators interviewed agree with the statement that visitors should pay a fee for protection of the reefs. Two third do not agree to a fee for a number of reasons shown in Table I.22. Those who agree feel that a non-governmental organisation specifically formed for this purpose, or a collective group of water sport operators should be responsible for the collection and managements of such funds.

TABLE I.22. REASONS WHY TOURISTS SHOULD NOT PAY A FEE

Reason	*Percentage of operators that agrees*
Water sports has no impact on reef	25%
Operators will pay in the end	25%
Too much administrative burden	13%
Bermuda is already expensive	13%
Tourist may enjoy what God has given them for free	13%
It is no money issue but a government issue	13%

Reef-associated Direct Revenue

The total reef-related revenue, extrapolated from data given by 13 reef related operators, is in the order of US$7.4 million (Table I.23). The profit margin is estimated to be 28%. The market growth, in terms of customers and revenues, during the last 5 years is estimated at 13%.

TABLE I.23. TOTAL REEF RELATED REVENUES IN BERMUDA (2007)

	Total in Bermuda	*Total revenues (US$)*
Diving and helmet diving operators	5	2.7 million
Glass bottom boat operators	5	2.4 million
Small boat rental operators	5	1.0 million
Boat charter operators	25	1.3 million
Total		7.4 million

Survey results obtained here were cross referenced with data from the Ministry of the Environment (GOB 2005). In this paper two survey results are presented on revenues of commercial marine operations. This government document reports that revenues of all commercial marine operations (including non-reef related activities) were estimated to be US$ 11 million in 1989 and US$ 7.5 million in 1998. This is comparable to the current study, as reef-related and non-reef related activities are estimated to bring a total revenue of US$ 10 million.

The revenues of reef related operators are dependent, on reef quality, but also on a number of costs outlined in Table I.24. Personnel costs are the most important item, contributing 41% to total costs. Boat maintenance contributes 20% to total costs, and fuel 17%.

TABLE I.24. COST ITEMS AS PERCENTAGE OF TOTAL COSTS OF REEF RELATED OPERATORS (N=13)

Cost item	*Percentage of total costs*
Personnel	41%
Boat maintenance	20%
Fuel	17%
Licenses and insurances	9%
Equipment	6%
Housing	5%
Other	2%

APPENDIX II. Fishery value

Sebastiaan Hess

II.1 Catch data and lobster length distribution

TABLE II.1. TOTAL CATCH SPECIFIED PER SPECIES GROUP FROM BOTH THE BANKS AND THE PLATFORM (IN POUNDS), BERMUDA.

Species	2000	2001	2002	2003	2004	2005	2006	2007
Groupers	86,870	101,037	114,129	72,682	82,367	109,097	119,733	133,907
Jacks	96,063	91,598	116,812	91,181	109,768	103,238	117,150	112,533
Snappers	76,923	71,064	76,932	68,078	47,295	78,153	74,034	66,307
Miscellaneous	57,423	56,654	49,128	36,016	32,498	37,482	37,037	39,873
Tuna, Mackerel, etc.	454,419	283,890	393,491	377,585	459,332	429,308	363,587	463,148
Sharks	22,568	18,165	16,093	25,217	20,274	24,444	22,051	23,364
Bait	90,344	47,798	92,206	87,435	82,060	89,188	86,035	85,949
Total	**884,610**	**670,205**	**858,789**	**758,193**	**833,593**	**870,911**	**819,626**	**925,080**

TABLE II.2. LENGTH DISTRIBUTION OF SPINY LOBSTER SAMPLES TAKEN BY THE MARINE RESOURCES SECTION, IN BERMUDA.

Carapace length	2000	2001	2002	2003	2004	2005	2006	2007*
92-102	28.1	33.9	16.0	18.1	17.6	18.3	12.5	21%
102-112	26.5	24.3	26.8	23.2	23.0	13.6	21.1	23%
112-122	21.7	23.1	25.8	25.6	26.6	15.0	26.4	23%
122-132	15.0	13.4	18.2	20.1	21.0	17.2	23.8	18%
132-142	6.2	4.0	8.0	9.2	8.6	11.6	10.4	8%
142-152	1.6	1.0	3.3	3.1	2.3	10.8	4.4	4%
152-162	0.4	0.2	1.2	0.6	0.8	9.3	1.1	2%
162-172	0.2	0.1	0.6	0.1	0.1	3.5	0.2	1%
172-182	0.1	0.0	0.1	0.0	0.0	0.7	0.1	0%
182-192	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0%
192-202	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0%
202-212	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0%
No. of observations	852	1145	1790	3334	1712	3340	1585	Na

* No sample was available for 2007. The average distribution of the years 2000-2006 was used

II.2 Species composition of commercial catch

The excluded pelagic species are marked in grey. This list of reef-dependent species was composed by experts from the Marine Resources Section. The abbreviations SRF, DRF, and DSF stand for Shallow Reef Fish, Deep Reef Fish, and Deep Sea Fish, and are explained in Table II.3.

TABLE II.2. COMPONENTS OF EACH SPECIES GROUP AS CLASSIFIED BY THE MARINE RESOURCES SECTION, DEPARTMENT OF ENVIRONMENTAL PROTECTION, BERMUDA.

Rockfish, Groupers		**Miscellaneous (Cont'd)**	**SRF**
RockFish (Black)	SRF	Bream/Pin Fish	
RockFish Monkey, Flag	SRF	Squirrelfish	
Red Hind	SRF	Moray	
Coney	SRF	Mullet	
Barber	SRF	Parrot Fish	
Misty Grouper (John Paw)	DRF	Doctorfish	
Wreck Fish	DRF	Other miscellaneous	
Graysby	SRF		
Hamlet (Nassau Grouper)		**Tuna, Mackerel, Etc.**	**DSF**
RockFish Gag or Tiger		Yellowfin (Allison)	
RockFish Red, or Princess		Blackfin	
Other - Rockfish, Groupers		Albacore	
		Mackerel	
Jacks	**SRF**	Dolphin	
Amberjack		Oceanic Bonito	
Bonito (Almacojack)		Barracuda	
Gwelly		Wahoo	
Blue Runner		Blue Marlin	
Rainbow Runner		White Marlin	
Goggle Eye		Sword Fish	
Robins		Other - Tuna, Mack, Etc	
Steelhead			
Other - Jacks			
		Sharks	**DSF**
Snappers		Tiger Shark	
Grey Snapper	SRF	Dusky Shark	
Silk Snapper	SRF	Blue Shark	
Yellowtail	SRF	Mako Shark	
Red Snapper	DRF	Gummy Shark	
Wenchman Snapper	DRF	Other Shark	
Queen Snapper	DRF		
Other - Snapper		**Bait**	
		Fry	

Miscellaneous	**SRF**	Anchovy
Porgy		Herrings
Chub		Pilchards
Hogfish		Flying Fish
Grunts		Ballyhoo (Gar Fish)
Turbot		Other - Bait

II.3 Estimating the recreational fishery value: Conversion from catch numbers to weight

For each fisherman reporting his catch in numbers, the share of catch categories Shallow Reef Fish (SRF), Deep Reef Fish (DRF), Deep Sea Fish (DSF), and Bait Fish were multiplied by the total number of fish caught. This gives the number of fish caught per category. This was then subsequently multiplied by the average weight for each category. Table II.4 below shows the weight categories used in the conversion from fish numbers to weight. For the shallow reef fish category, 3 pounds is used for fishermen who both go out in boats and fish from shore. We have reduced the weight to 2 pounds for fishermen who fish almost exclusively (>90%) from shore, and increased it to 4 pounds for those who do almost all their fishing from boats, to reflect size differences in fish that dwell close to shore and those that live in more open water.

The weights have been based on statistics from the Marine Resources Section catch data for commercial fishermen. Because there are species of different average weight within each category – Table II.3 (Appendix II) shows which species are included in the different categories. *Please note:* These weights are only approximations of the real numbers, and as noted by the Marine Resources Section, average weight statistics are not completely trustworthy.

TABLE II.3. ESTIMATED AVERAGE WEIGHT (POUNDS) FOR EACH FISH CATCH CATEGORY (TAKEN FROM: MARINE RESOURCES SECTION, GOVERNMENT OF BERMUDA).

Fish category	Average weight
Shallow reef fish	2-4 Lbs
Deep reef fish	5 Lbs
Deep sea fish	15 Lbs
Bait	0.5 Lbs

Following the mathematical conversion, described above, it can be seen that the average catch of fishermen who reported in numbers is only a little more than half of the average catch of those recreational fishermen who reported directly in pounds: 68 (SD 85) and 119 (SD 164) pounds, respectively. This may seem an unrealistically large difference, and raises questions on the conversion used. However, given that:

1) the “numbers” group, on average, goes out fishing 12 times a year, while the “pounds” group goes out 17 times;

2) the share of deep sea fish, which tend to be larger, is smaller for the ‘numbers” group (7%) than for the “pounds” group (20%); and

3) the typical gear used by the two groups would also make us suspect smaller catches for the “numbers” group: the hand line is used far more often by this group – 81%

compared to 58 % – and rod and reel fishing, and trawling is done less often – 55% compared to 67 % for rod and reel, and 4% compared to 8 % for trawling.

It is therefore concluded that the conversion method used is suitable and results can be relied upon.

APPENDIX III. Amenity value

(taken from Roelfsema, 2008)

III.1 Literature review

Hedonic pricing is often applied in an urban and environmental context, and used for estimating the effect of air and noise pollution measures, as well as the amenity of lakes, parks and beaches.

Characteristics used in previous hedonic pricing studies include structural variables - such as land size, house quality and size-, and accessibility variables - such as ease of access to work and recreation (Abelson, 1979). Major determinants to house prices are found to be house quality and size, land size and inflation. Other studies have indicated the proximity to an airport as a positive and negative effect, dependent on the residents' occupation (Nelson, 2004); where for those working at the airport or requiring much travel, proximity as a positive factor, and for others, it as a negative due to the associated noise pollution.

Environmental characteristics such as proximity to a lake yield different results among studies. In some cases, proximity to a lake results in a positive effect, and house price increases with distance from the city (closer to the lake) (Feather, 1992). Note that a lake provides a number of services, as a water source, and as a source of aesthetic and recreational enjoyment. Not all studies value all services. Another environmental characteristic which has been studied is the proximity to beaches. This amenity has been investigated through distance factors- i.e. distance from house to the nearest beach-, ocean view, beach frontage, value of surrounding lots. The distance factor has demonstrated a positive effect of beaches on house prices (Wertheim, 1992), and has been used to estimate the recreational value of beaches (Edwards and Gable, 1991). The width of beaches has been considered a factor for increased recreational pleasure and protection of oceanfront property by Pompe and Rinehart (1995); their study shows a positive relationship between beach width and property value.

In a review of the coral reef valuation studies (Brander *et al.,* 2007), there is little reference to the use of hedonic pricing in valuing the amenity of coral reefs. A first attempt was made in the economic valuation research project for the Guam coral reef (Van Beukering *et al*., 2007b). Results indicate a negative relationship between house prices and the distance to the coast in Guam. The marginal price per kilometre was found to be $17,000, yielding a surplus amenity value of $321 million, and an annual value of $15.4 million (discount rate of 5%). This value represents the total value of all marine-related amenities and therefore is an upper bound.

Table III.1 summarises the literature review. Based on this summary, the following was taken into account for the Bermuda case study:

- Hedonic pricing can be used to estimate the amenity value of environmental characteristics.
- The expected relationship between beach distance and house price is negative.
- Based on Nelson (2004), GIS models are important in capturing the characteristics that people take into account when buying a house.
- Proximity to location can have both negative and positive effects at the same time. Not considering this, will result in an upward or downward bias.

TABLE III.1. A SUMMARY OF HEDONIC PRICING STUDIES

Reference	**Country**	**Environmental subject**	**Main conclusions**
Abelson, 1979	Australia (Sydney)	Disamenities: aircraft noise, road traffic, planned road widening, railway noise Amenities: view, non-environmental	Disamenities show negative relationship with house prices, major determinants are house quality, size, land size and inflation
Nelson, 2004	Canada, United States	Airport noise	It is important to distinguish between amenities and disamenities when considering airport proximity
Feather, 1992	USA (Florida)	Land value near lakes	Lake resources positively influence house prices.
Edwards, Gable, 1991	USA (South Kingstown, Rhode Island)	Recreational value of public beaches	Distance to nearest beach and house prices are negatively related
Wertheim, 1992	USA (North Carolina)	Residential beach lot property	Market value of beach lot property and distance to beach show a negative relationship. Other significant variables are ocean view, average value of surrounding lots, shape of lot and the amount of beach

			frontage
Pompe, Rinehart, 1995	USA (South Carolina)	Beach quality	Positive relationship between beach width and house values. Negative relationship between distance to beach, given the beach width
Van Beukering, *et al.*, 2007b	Guam	Coral reef amenity	Negative relationship between distance to coast and house prices

III.2 Theoretical background

The underlying assumption to the hedonic pricing method is that for two houses equal in all attributes except for their proximity to the coral reef, the house closer to the coral reef has a higher price. In other words, it is assumed that people prefer to live close to ecosystems such as coral reefs.

The hedonic pricing method is an indirect valuation method, based on the price of houses sold in competitive markets. Houses are seen as a bundle of attributes such as number of rooms, distance to commercial centre and air pollution. Some attributes are market-induced and others, such as air pollution, are not. The variation in price of an attribute is used to estimate the Willingness to Pay for that attribute; hence, the Willingness to Pay for proximity to the coral reef can be deducted from the price of a house in Bermuda.

The hedonic pricing technique is a revealed preference technique, where a house is assumed to be built up of several characteristics, with each an implicit value. The hedonic pricing equation shows the relationship between the house price and the characteristics and thus reveals the implicit price house owners have paid at the time of purchase. In the Bermuda case study, the relationship between house prices and the coral reef is investigated. Given that beaches are considered a coral reef attribute in Bermuda- all beaches are of coralline origin- care must be taken to avoid double counting. Beaches do not only represent an amenity value, but also a recreational or tourist value, as they are used by all (residents and tourists for leisure). The tourist associated value is investigated within the tourism chapter of this report, and the recreational value to residents in the recreational and cultural chapter. Within the amenity chapter, only the surplus value to real estate provided by beaches is considered.

The hedonic pricing function describes the relationship between the price of a house and its characteristics. In the housing market utility maximizing consumers and profit maximizing sellers determine the equilibrium price of the house that is build up from several characteristics, which can be written as follows:

$$p = h(z), z = \{z_1, \ldots, z_n\} \quad (1)$$

In general this function is unknown and in implementing this method the functional form is a choice to the researcher. The hedonic price function can be used to implicitly value the change in one of the attributes. The budget constraint can now be rewritten by adding the house price function and the maximum utility can be derived using this new formulation:

$$\max U(x, q)$$
$$C(x, p) + h(z) \leq y \quad (2)$$

The Willingness to Pay for a change in environmental quality can be assessed using the hedonic price function, if this change affects one of the house attributes. For a very small change, the Willingness to Pay is determined using the Lagrange function. The relationship between the utility function and the housing price function for a change in one of the attributes is determined as follows: The utility change divided by the marginal utility of income, equal to the marginal Willingness to Pay, results in the marginal change in the hedonic price function,

$$\frac{\frac{\partial U(x, q, y)}{\partial z_i}}{\lambda} = \frac{\partial h(z)}{\partial z_i} \quad (3)$$

A larger quality change can mean two things

1. The change is still small enough to let the demand and hedonic price function remain the same
2. The change also changes the demand and hedonic price function

In the case of point 1), the Willingness to Pay given the same level of utility is estimated:

$$U(x, q, y - h(z) - WTP, z^*) = U(x, q, y - h(z), z) \quad (4)$$

This requires using the compensated demand function and estimation of the utility function and its parameters. The hedonic price function is not equal to the demand function. Only if all consumers have similar utility functions, would this be true (Freeman, 1973). In the market equilibrium the marginal price is equal to the marginal demand (is marginal Willingness to Pay). The problem is that each individual chooses one point along the hedonic price function (Kolstad, 2000) (see Figure III.1).

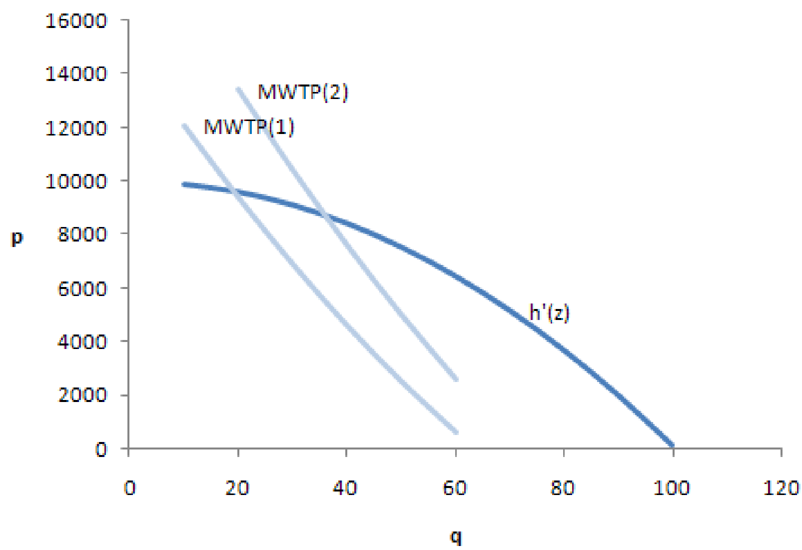


Figure III.1. MARGINAL WILLINGNESS TO PAY

Freeman proposes a two-step approach to estimate the demand curve (1974). The first step is to determine the hedonic price function using regression analysis. In the second step the compensated demand curve is estimated. Freeman assumes that all consumers respond similarly to any given set of property values. The different individuals are assumed to be the same person but with different income and characteristics (Kolstad, 2000). The demand function than can be estimated using data that determine the demand, such as income and age:

$$h'(z) = f(Y, \text{"age}, \ldots\text{)"} \qquad (5)$$

The marginal price h'(z) can be retrieved from the hedonic price function and data for age and income must be gathered. Often it is only possible to use census data.

Most researchers have abandoned attempts to recover these preferences (Haab and McConnell, 2002). The only option is to assume that all consumers have the same utility function. The hedonic price function now is equal to the Marshallian demand function. The Willingness to Pay is equal to the difference in house price given the change in environmental quality.

$$WTP = h(z^*) - h(z) \qquad (6)$$

The Willingness to Pay for a change of one unit can now be estimated using the derivative of the hedonic pricing function to the attribute that is influenced by the change in environmental quality.

$$\Delta WTP = \frac{\Delta h(z)}{\Delta z_i} \qquad (7)$$

The hedonic pricing function is thereafter estimated through regression analysis. Based on the data, a functional relationship is estimated, using a parametric linear regression analysis. The hedonic pricing function is a function of all the house attributes.

$$h(z) = a_i + \sum_{i=1}^{n} b_i z_i + \varepsilon_i \qquad (8)$$

Because a linear relationship between house price and its attributes is not representative, a transformation is necessary to represent an applicable functional form. This encompasses three steps

1. Define the functional form of the hedonic price function
2. Determine what attributes to include
3. Estimate the parameters for the hedonic price function

Having determined the marginal Willingness to Pay function based on the hedonic pricing function, it is possible to determine the total amenity value. Under the assumption that the marginal benefit functions are identical for all households, the marginal demand curve is equal to the marginal price curve which is the derivative of the hedonic pricing function to the environmental variable (Freeman, 1974).

The aggregated benefits for an increase in the environmental variable from Z to Z* when n houses are taken into account are:

$$\sum_{i=1}^{n} \int_{Z}^{Z^*} h'(z)dz = \sum_{i=1}^{n} \left(h(Z^*) - h(Z)\right) \qquad (9)$$

This means that the hedonic price function must be calculated for the current situation Z and the new situation Z*.

<u>Functional form</u>

The hedonic pricing function describes the relationship between the price of a house and its attributes. Theoretically, if all the attributes could be unbundled and bought and sold individually at the market, the price of the house would be equal to the sum of the attributes. The hedonic price function would be a linear function of its attributes. But most attributes like rooms, accessibility, air pollution etc. cannot be unbundled and increasing the number of an attribute does not necessarily increase the house price with the same amount for each concurrent increase. According to (Halvorsen and Pollakowski, 1981) the choice of functional forms is often chosen arbitrarily, but because it can have a major effect on the outcomes, it is preferable to base the choice on relevant statistical procedures.

The linear regression function seen above needs to be changed by using a transformation. Only attributes that have positive values and are not dummy variables can be transformed. A very general functional form is given by the Box-Cox transformation.

$$p(\lambda) = \sum_{i=1}^{n} a_i z_i(\theta) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_i z_i(\mu) z_j(\mu) + \varepsilon$$

$$f(\varphi) = \begin{cases} \dfrac{f^{\varphi} - 1}{\varphi}, & \varphi \neq 0 \\ \ln(f), & \varphi = 0 \end{cases} \qquad (10)$$

The most commonly used settings are the linear (λ =1, θ =1, μ =1), logarithmic (λ =0, θ =0, μ =0) or semi-log (λ =1, θ =0, μ =0). The parameters must be chosen in a way to maximize the explained variation in the regression results. In this way, all the commonly used settings are also part of the optimisation process. Consideration must be given to the fact that increasing the explained variation often increases the collinearity between the variables. A trade-off between these two criteria needs to be achieved. The appropriate functional form cannot be specified on theoretical grounds, therefore a statistical procedure where the log-likelihood is optimized would be able to aid in the choice of parameters (Halvorsen and Pollakowski, 1981). The maximum likelihood (if μ=0) is (Halvorsen and Pollakowski, 1981):

$$\sigma(\lambda, \theta) + (\lambda - 1)\sum_{i=1}^{n} \ln(p_i) \qquad (11)$$

The maximum log-likelihood can be calculated by choosing a range of values for λ and θ and calculate the maximum log-likelihood. For a pre-specified range of parameters the likelihood is calculated and the maximum is determined. A confidence region consists of all points (λ *, μ*) that satisfy the following condition (Halvorsen and Pollakowski, 1981):

$$L_{\max(\widehat{\lambda,\theta})} - L_{\max(\lambda^*\theta^*)} < \frac{1}{2}X_2^2(\alpha) \qquad (12)$$

where α is the confidence level and X chi-distribution.

Although the Box-Cox procedure is theoretically appealing, best practice in hedonic modelling is to choose a simple form (Haab and McConnel, 2002). These are often the linear and logarithmic forms. The question is whether to transform the dependent and/or the independent variables and whether to include the quadratic variables, and what variables to exclude. Therefore, it is advised to both estimate the simple forms and estimate the optimal parameters by optimizing the log-likelihood of the regression function. The dependent variable is analyzed separately because it can take on different values for its transformation parameters. The environmental variable will be also analyzed separately from the other independent variables because of its importance.

Two options are investigated; in the first, the quadratic terms are omitted and in the second, these terms are considered. This procedure could also show the stable parameters that do not change much under the different settings.

Data definition and collection

Initial work on hedonic pricing used census data to determine the hedonic price function, but the use of individual house data is now preferred (Abelson, 1979; Haab and McConnel, 2002). The literature on environmental economics provides guidelines about what data are important for inclusion. In this study, the classification mentioned in Perman *et al.* (2003) is used.

Information for this study was collected on structural characteristics such as number of rooms, lot size, accessibility and environmental characteristics. The variables related to coral reefs amenity are especially important in this context. Most of the accessibility variables are determined using a geographical information system (GIS). Location is the most important parameter for real estate valuation and can only be taken into account using the descriptive framework of GIS (Kong *et al.,* 2007).

The constructed dataset contains a number of cases and per case several data fields, referred to as variables. The relevant data used in this project was extracted from a database that was maintained in the real estate agency Rego Realtors®.

Because incorrect data entry can result in missing or incorrect data, a process for handling missing values was adopted. Allison (2002) gives several solutions to the missing value problem. Both the number of missing values and the reason for missing data are critical. The number of missing values determines if the cases containing missing values can be deleted, this is called list-wise deletion. The disadvantage is that possibly a large fraction of the dataset may be excluded. Besides this, the reason of missing data can determine the right solution. If the data is missing randomly and the number of missing cases is small enough, list-wise deletion is the best option although it increases the standard errors. If the data are not missing randomly, the relationship between these missing values and other values should be analysed.

Imputation is one solution for missing data- this involves the substituting of missing values either by the mean or some value determined by regressing this variable to other independent variables. This method underestimates standard errors and overestimates test statistics. Maximum likelihood (ML) is a novel approach to handling data that can overcome the problems mentioned above. The Expectation-

Maximization (EM) method is a general method for obtaining ML estimates. It is an iterative process and consists of two steps. In the first expectation step, the missing data are replaced by imputation values using regression on independent variables not containing missing values. In the second maximization step, the new means and co-variances are calculated using the imputed data. The steps are repeated until the values converge.

Designing and implementing the model

In order to determine the linear regression model, data collected is first analysed, and used to design the model. This provides the relevant characteristics that house owners take into account when buying a house in the Bermuda case study. The assumptions made are also analysed to verify their validity.

Data analysis

Mean, variance and percentiles of the data are calculated and histograms drawn for each characteristic. The correlation between two variables is calculated and the missing values in the dataset determined.

Design of the linear regression model

A linear regression model tries to define the dependent variable in terms of several independent variables. The dependent variable is the house selling price, the independent variables are the characteristics people consider important in the decision which house to buy. Linear regression can be used to predict some variable of interest or can be used to approximate a variable which cannot be measured explicitly. *Y* refers to the dependent variable and *X* for independent variables. Linear regression between the two can be described as follows, where n is the number of cases in the dataset:

$$\hat{Y} = f(X_1, X_2, \ldots, X_n)$$

The relationship between house prices and coral related characteristics is estimated in this way, and all relevant house characteristics are considered. The process of selecting relevant characteristics from the total dataset is described below in four steps.

1. *Full model (sold price and log sold price)*: A model using all variables was run for both the untransformed dependent variables and the log-transformed dependent variable. This resulted in both a set of relevant variables used in the next step and a choice of the functional form of the dependent variable.
2. *Hierarchical linear regression (some transformations):* This involves a sequential analysis where groups of variables are introduced to the model in phases. The variables selected in the first step were first analysed, and the coral related variables introduced thereafter. Lastly, other variables of

interest are tested. The result of the second step is a relationship between house prices and each of the coral related variables.

3. *Transformation using Box Cox:* Data is analysed using transformations for both the dependent and independent variables, and the best fit model evaluated.

4. *Integrating coral related equations:* This involves the integration of the different models determined per coral related variable. Interaction variables are used to control for the correlation between these variables.

In the process described above, the relevance of variables becoming part of the value function is assessed. The statistical signifcance of a parameter or a group of parameters shows the probability that the resulting coefficients are not equal to zero. This does not say anything about either the uncertainty of this coefficient nor of the strength of the relationship, called effect size (ES). Confidence intervals are calculated to indicate the strength, especially for coral related variables. The effect size can be specified using the explained variance or multiple correlation coefficient (R^2). If a variable or group of variables is signficant, the R^2 increases and the confidence interval is acceptable, then the regression model is accepted. In all cases, the assumptions made underlying the linear regression model are made. The criteria for accepting (a group of) variables in the current study are: (1) R^2 increases; (2) Significance per variable is maximum 0.05 (α=0.05); (3) Confidence interval is acceptable; and (4) assumptions are met.

Analysts should carefully look at both the original data and the linear regression residuals (Cohen et al, 2003). If assumptions are violated, the estimates of regression coefficients and their standard errors may be incorrect. In turn, this may raise questions about the correctness of confidence intervals and significant tests. To detect violations of the underlying assumptions it is possible to use graphical analysis and statistical tests. Graphical analysis is an effective method to check data characteristics, inconsistencies and assumptions. Histograms show the empirical distribution of each variable considered; scatter plots illustrate the bivariate relationship between two variables.

Calculating the total amenity value

Mathematically, the total amenity value is the surface under the demand function that represents the consumer's marginal Willingness to Pay for amenity. The demand function is derived from the hedonic price. This demand function ideally is the compensated (Hicksian) demand function. However, this is complex. For this reason, the Marshallian demand function is calculated within the context of this study, where the amenity value becomes based on the preferences of local house owners. The amenity value of the coral reefs is calculated using the collected dataset, and total value extrapolated to encompass all of Bermuda. The amenity value obtained is the difference between the current house value and that in a hypothetical deterioration scenario; the latter is explained in the main text of the document.

III.3 Assumptions underlying the regression analysis

Homoscedasticity

The residuals' variances are assumed to be constant. The data is said to be homoscedastic. If the variance is not constant the data shows heteroscedasticity. In case of heteroscedasticity, the estimates of the coefficients are unbiased, but the standard errors will be incorrect. Scatter plots between the predicted values for *Y* and the residuals or between the independent variables *X* and the residuals can be used to determine if the variances are constant. The residual plots for heteroscedasticity are checked graphically.

Normality of residuals

Non-normality often points at problems in the regression model such as misspecification of the functional form. Normality is assumed in doing the t- and F-tests. This does not mean that the individual variables need to be normally distributed. These tests are based on the standard error which is built up of the sum of the residuals and the standard deviation of the *X* variable. It is possible to use two graphical methods to check the residual normality assumption: using a histogram of the residuals and a normal q-q plot.The first method compares the normal distribution with the histogram, where both have the same mean and variance, but it is less accurate. The normal q-q plot plots the residual percentiles against the normal distribution percentiles. If the graph shows a straight line, the residuals are normally distributed. The same concept applies to p-p plots where the probabilities are plotted instead of the percentiles. A statistical test for checking the normality assumption is the Kolmogorov-Smirnov test. This test compares the sample distribution to the hypothesized distribution and calculates the test statistic:

$$\max_{x}\left(N(\hat{\mu},\hat{\sigma}) - F(x)\right)$$

Non-normality of the residuals can often be solved by finding an appropriate transformation of the variables.

Functional form

Earlier on in the report, the reasoning for transforming data from an economic theoretical point of view is discussed. An important assumption from a statistical standpoint is that the form has been properly defined. If this is not the case, both the regression coefficients and the standard errors may be biased. Proper choice of the functional form can address problems of nonlinearity, heteroscedasticity and non-normal residuals simultaneously. It is possible to both transform the dependent variable and the independent variables. The form of the relationship between the dependent variable *Y* and an independent variable *X* can be detected by plotting the *Y* data against the *X* data or the residuals against the *X* data. It then is possible to compare the lowess fit line against the 0-line. The lowess fit procedure smoothes the data to make a continuous smooth looking graph.

What kind of transformation is appropriate? The first thing to consider is if there is a transformation that can be determined on theoretical grounds or on best practice. House prices are often transformed using the log function. If only the dependent variable is log-transformed this is called the semi-log transformation. The regression coefficients can be interpreted as the percentage increase in the house price if the independent variable increases one unit. A double-log transformation consists of log-transforming both the dependent and independent variables. The regression coefficients can now be considered as the elasticity: the percentage increase in house price if the independent variable increases one percent. Cropper *et al.* (1988) find in a simulation study that the linear and linear-quadratic transformations give the smallest mean square error of the true marginal price of the attribute. It is common to use simple transformations when estimating functional forms (Haab and McConnel, 2002). The quadratic transformation should be considered with care, because if the data is sparse at the low or high values of *X* then it is possible that there is insufficient information to make a judgment. The Box-Cox procedure can be used to determine the theoretical best choice of transformation and its uncertainty.

In this project, the transformations are analysed in two ways:

1. The best practice parameters for the dependent and coral related variables (step 2).
2. The Box-Cox transformation for all dependent and independent variables, excluding the interaction variables (μ=0 equation) (step 3).

Note the difference between the two approaches above can be mathematically written as:

$$\hat{Y} = \beta_1 f(CV) + \beta_2 X_2 + \cdots + \beta_n X_n \quad (1)$$

$$f_1(\hat{Y}) = \beta_1 f_2(CV) + \beta_2 f_2(X_2) + \cdots + \beta_n f_2(X_n)(2) \qquad (1)$$

where

CV = coral related variable

f(*x*) = functional form

The occurrence of outliers and collinearity may influence the results of these analyses.

Collinearity

Collinearity appears when two or more independent variables are highly correlated. It makes parameter estimates imprecise and makes it difficult to separate the effect of different variables (Haab and McConnel, 2002). If two or more variables are perfectly correlated, an estimation of the coefficients is not possible. Ocean related variables such as view, proximity to the beach and coral reef have potentially high correlation. Therefore it is necessary to investigate the relationship between these variables.

Based on available literature, should collinearity appear in the data, one of the correlated variables is removed. However, this is not always straightforward, and care must be taken that the remaining model is meaningful, useful and includes the variables under investigation (Gunst and Vaart, 1994).

The following criteria are followed to define collinearity in the Bermuda case study:

- Correlation higher than 0.6 indicates possible collinearity
- A variance inflation factor of 10 indicates suspicion of collinearity
- A condition number higher than 30 gives rise to collinearity remedies

Note that a correlation between two parameters, higher than 0.6, indicates bivariate collinearity and not collinearity between more than two variables.

The variance inflation factor is calculated for each variable and represents the increase in variance because of possible correlation with other variables. A maximum of 10 is used as a rule-of-thumb.

In order to calculate the condition number, eigenvalues are determined and indicate if the linear relationship is solvable. An eigenvalue close to zero gives rise to suspicion. The condition number equates the square root of the largest eigenvalue divided by the lowest eigenvalue:

$$K = \sqrt{\frac{\lambda_{max}}{\lambda_{min}}} \qquad (2)$$

A large condition number shows a relatively high difference between the contributions of two variables in the variance of the set of independent variables. Traditionally, a rule-of-thumb is to use 30 to indicate a high degree of collinearity.

Outliers

Outliers are atypical data points and may represent contaminated data or represent rare cases. Often the impact of the outliers on the estimation results is high. Scatter plots can be used to determine a-typical data points. It is not said that points far away from the other points are outliers. The influence on the results must be analysed.

To determine the influence one must check (1) the leverage; (2) the discrepancy; and (3) the total influence of the atypical points. The first two criteria give rise to suspecting a data point to be an outlier. The third criterion will determine the final verdict: the outlier will be deleted. Based on the above theory, the criteria used in the Bermuda case study, to determine if a data point was an outlier are:

- A case having a leverage value of 0.5 or higher
- Studentised residual higher than 5
- A Cook's distance higher than 1

The leverage statistic checks how unusual the case is by comparing the value to the mean value per variable. It is a potential outlier if the value is close to one. A boundary of 0.5 is used in this study based on Vocht (2008).

The discrepancy can be checked by removing an outlier and check the difference in the prediction. The outlier might influence the relationship estimated coefficients and therefore, will not show a high residual. Removing the data point shows the difference in total outcome. The studentised residual is calculated by dividing the distance between the two predicted Y values by the distance's standard error. The cut-off point 5.0 is used in this study to determine a potential outlier.

A measure of influence combines the leverage and discrepancy value. The Cook's distance provides information about how case *i* affects overall characteristics of the regression equation. It calculates the difference between the predicted value with and without case *i*. This is then divided by variance of the residuals. Cases having a Cook's distance of 1 or higher have a too large influence on the results (Vocht, 2008).

III.4 Checking assumptions

The regression results shown above are only valid if the assumptions underlying the model are satisfied. Normality assumptions, heteroskedasticity and outliers are checked. Collinearity and the functional form in the hierarchical linear regression are also analysed. It is assumed that the results for the three models with different coral related variables are the same, and only the results for the model containing the 'distance to coral reef' variable is given.

To check if the residuals are normally distributed Figure III.2 shows the (normal) probability plot of the residuals and the histogram of the standardized residuals. It shows that the residuals are not normally distributed: the distribution has smaller tails and has a higher kurtosis ("peakedness"). The residual plots for the log-transformed price are shown in Figure III.3. Although the log-transformation does not fully solve the tail and kurtosis problem, it does improve it significantly. From hereon, the model with the log-transformed dependent variable is used as the base model.

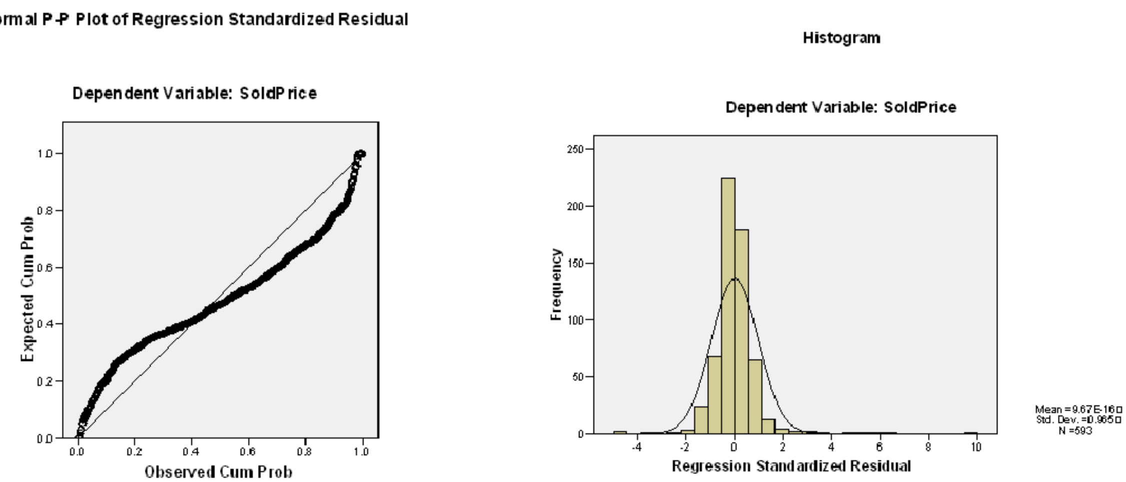


FIGURE III.2. CHECKING NORMALITY ASSUMPTION (BASE)

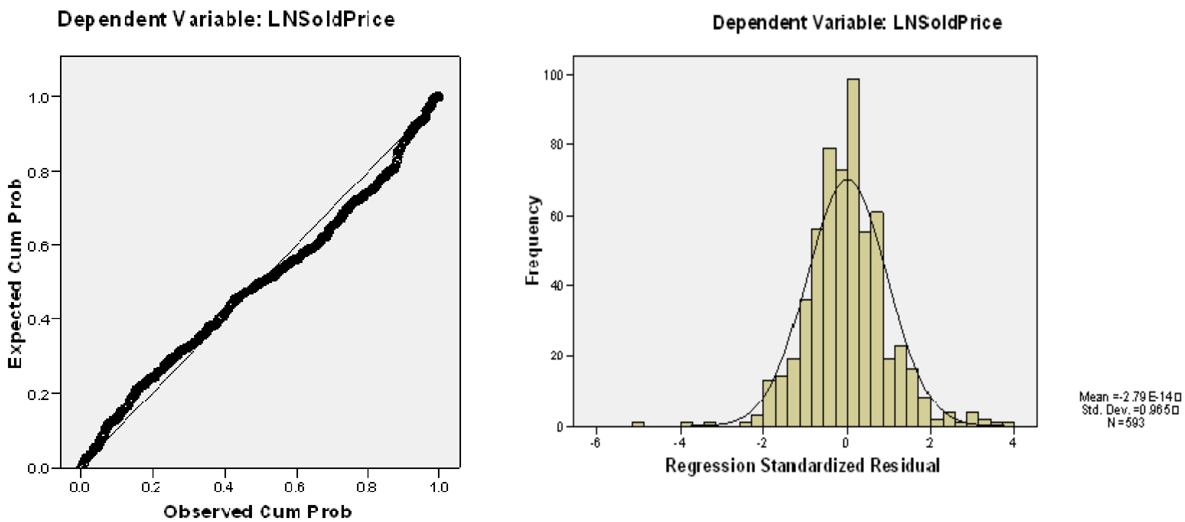


FIGURE III.3. CHECKING NORMALITY ASSUMPTION (LOG PRICE)

Heteroscedasticity is checked by plotting the residuals against the predicted value (see Figure III.4). Although, there is a slight trend in the residuals it is not enough to give rise to suspicion. Heteroscedasticity is checked once again in the hierarchical model.

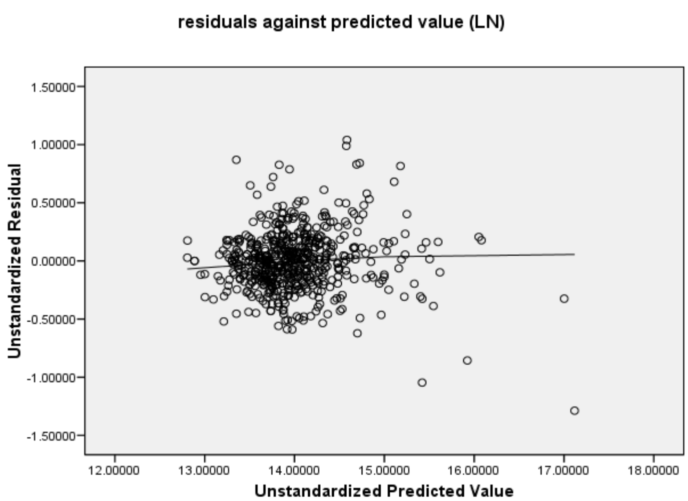


FIGURE III.4. CHECKING HETEROSCEDASTICITY

Lastly, the existence of possible outliers is investigated. The uncentered leverage value, studentised residuals and the cook's distance are drawn for every point. These are shown in Figure III.5. This was analysed for the variant containing the distance to the reefs as its coral related variable. It is assumed that the effect for the other two variants is the same. Based on the rules-of-thumb reported earlier, none of the data points can be earmarked as outlier.

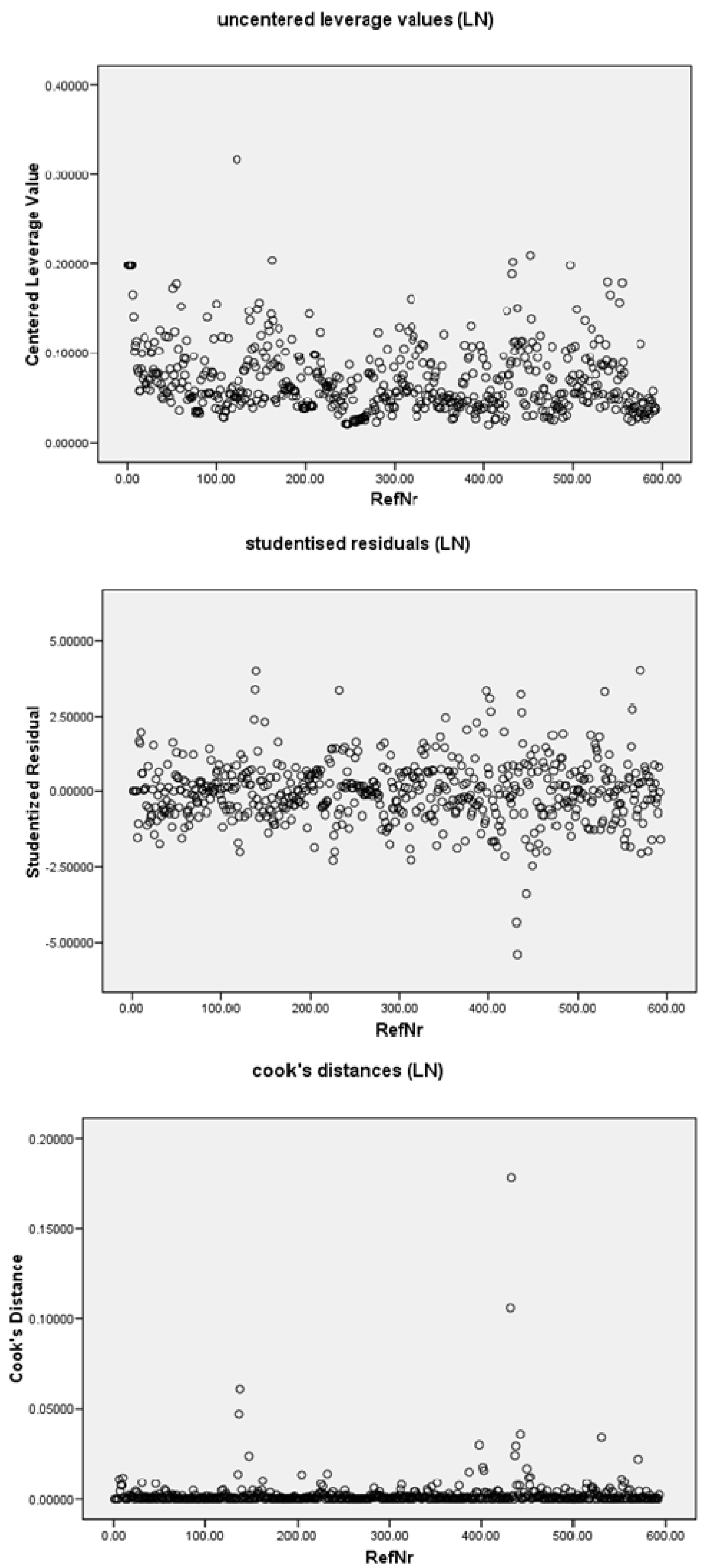


Figure III.5. Outlier analysis (log Price)

III.5 Checking normality assumption of residuals of beach variant

The residuals of the beach variant for normality and the dataset for collinearity and heteroscedasticity are analysed to determine which of the two transformations is a best fit. The assumptions for the beach model are first checked. The normality assumption of the residuals are checked for the following three variants: (1) Base variant; (2) Log transformation; and (3) Quadratic transformation.

The first normality check is done by checking the histogram of the (standardized) residuals and plotting the observed probability against the expected probability (if the data were normally distributed). The quadratic transformation shows a slightly better fit than the normal distribution. The base and log transformation distributions show higher peaks. The second normality check is based on the Kolmogorov-Smirnov test (see Table III.2).

TABLE III.2. KOLMOGOROV-SMIRNOV TEST

(K-S test)	Base	LN	L+Q
Kolmogorov-Smirnov Z	1.591	1.616	1.640
Asymp. Sig. (2-tailed)	0.013	0.011	0.009

Based on the K-S tests, all variants can be regarded as originating from a normal distribution. The linear-quadratic test has the lowest p-value and is therefore the most significant.

Determining if homoscedasticity is fulfilled is conducted by visually inspecting the residuals. The residual graphics for the two significant transformations (log and added quadratic) are shown in Figure III.6. Both graphs confirm the homoscedasticity assumption.

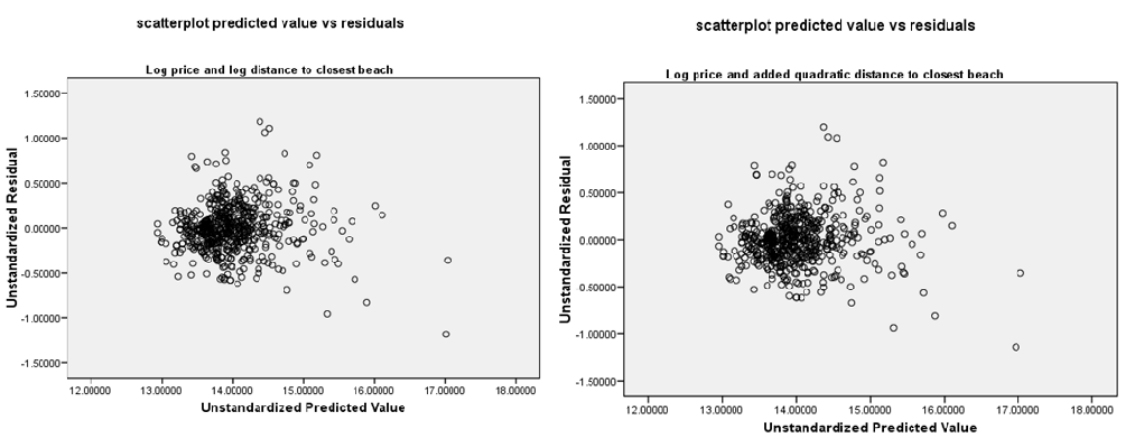


FIGURE III.6. PREDICTED VALUE AGAINST RESIDUALS

The confidence intervals for the 'distance to beach' coefficients for the base and two significant transformations are given in Table III.3. The linear-quadratic interval is smaller, indicating a more certain estimate.

TABLE III.3. CONFIDENCE INTERVAL

Variable		Confidence interval			%-interval	
(price)	(distance to beach)	left	beta	right	left	right
log	linear	-0.000032	0.000013	0.000057	-355%	355%
log	ln	0.014707	0.037987	0.061266	-61%	61%
log	linear	0.000150	0.000276	0.000402	-46%	46%
	quadratic	-0.00000018	-0.00000012	-0.00000007	45%	-45%

The tolerance, variance inflation factor (VIF) and the condition index are checked. The VIF for the linear/quadratic model is slightly higher than 10, but because the condition index is much lower than the boundary value of 30, removal of variables is not warranted**.**

The collinearity analysis indicates a high correlation between number of bedrooms and number of bathrooms. The latter variable (no. of bathrooms) is therefore excluded, and the linear regression model recalculated. Removing the 'number of bath' variable does not affect the signs or magnitude of the coefficients. The R^2 changes from 0.79 to 0.75 when removing the bath variable. For this reason, both the 'number of beds' and 'number of bath' variables in the model.

TABLE III.4. CHECKING COLLINEARITY

Collinearity Statistics	LN		Linear/quadratic	
Variables	Tolerance	VIF	Tolerance	VIF
NoOfBeds	0.45	2.23	0.45	2.23
NoOfBath	0.41	2.45	0.41	2.45
DistancetoCityofHamiltonm	0.71	1.41	0.69	1.46
Distancetoclosestschoolm	0.65	1.54	0.63	1.60
Distancetoclosestsupermarketm	0.75	1.33	0.74	1.35
Distancetoclosestgolfcoursem	0.93	1.08	0.84	1.19
PropertyType	0.45	2.21	0.45	2.22
AvailInterPurchaser	0.73	1.36	0.73	1.37
Pool	0.72	1.39	0.71	1.40
Waterfront	0.69	1.45	0.67	1.49
Parking	0.55	1.83	0.55	1.83
Garage	0.79	1.26	0.79	1.27
Mooring	0.78	1.28	0.77	1.31
PriceAdjusted	0.92	1.09	0.92	1.09
Distancetoclosestbeachm	0.72	1.38	0.09	11.46
LNDistancetoclosestbeachm			0.09	11.19

Based on the analysis above, it is concluded that the linear-quadratic model is a best fit based on:

- The increase in R^2 for the linear-quadratic model is higher;
- Although both the log-transformed and the linear/quadratic variables are significant, the F-significance for the linear and quadratic variables is higher;
- The K-S test shows a higher significance;
- The confidence interval for distance to beach is smaller in the linear-quadratic variant.

Fit of the various models and variants

The R^2's for non-transformed house prices and log-transformed house prices are shown in Table III.5. The R^2's for all models are satisfactory, and explain between 70% and 80% in the model.

TABLE III.5. EXPLAINED VARIANCE

Model	R	R Square	Adjusted R Square
reef	.850	0.723	0.702
beach	.850	0.723	0.702
coast-reef	.851	0.724	0.702
reef (log)	.896	0.803	0.788
beach (log)	.850	0.803	0.788
coast-reef (log)	.851	0.803	0.788

APPENDIX IV. Recreational and cultural values

Luke Brander & Tadzio Bervoets

IV.1 Choice model valuation method

Choice modeling is a stated preference methodology that has increasingly been employed to analyse public preferences towards environmental goods and to estimate their economic value. Choice models are a generalised version of the dichotomous choice Contingent Valuation Method (CVM) (Biénabe and Hearne, 2006). In a CVM study, the survey environment is used to create a hypothetical market for a non-market good or service (e.g. local recreation or important species) usually by giving a detailed description of the non-market benefit. In the simplest case, respondents are asked how much they would be willing to pay for a change from the current situation to a hypothetical future situation (Mitchell & Carson, 1989). However, many researchers have raised concerns about the ability of CVM studies to derive valid estimates of economic value (see Kahneman and Knetsch,1992) for a discussion of some of the limitations of CVM).

Choice modeling or 'discrete choice experiment' (DCE) is also a hypothetical method in that it asks people to make choices based on a hypothetical scenario. The choice modeling valuation method, however, addresses a number of the difficulties traditionally associated with contingent valuation methods. Rather than simply asking respondents how much they are willing to pay for a single improvement in a given non-market good, a choice model requires respondents to repeatedly choose between complex, multi-attribute profiles that describe various changes in non-market benefits at a given cost (e.g. a change in tax paid). As such, the choice modeling approach is useful as a tool for exploring proposed or hypothetical policy options. The value estimates from a choice model study can then be used in a decision support tool, such as cost-benefit analysis, to assess the desirability of alternative policies.

Choice modeling is generally an efficient means of collecting information, since choice tasks require respondents to simultaneous evaluate multi-attribute profiles. In addition, economic values are not elicited directly but are inferred by the trade-offs respondents make between monetary and non-monetary attributes. As a result, it is less likely that WTP information will be biased by strategic response behaviour. A further advantage of the choice experiment is that research is not limited by pre-existing market conditions, since the levels used in a choice experiment can be set to any reasonable range of values. Finally, and perhaps most importantly in the context of non-market valuation, choice experiments allow individuals to respond to non-market benefits that are described in an intuitive and meaningful way, but without asking respondents to complete the potentially objectionable task of directly assigning dollar figures to important services such as species conservation.

In a typical DCE study, respondents are presented with a series of choice sets composed of two or more multi-attribute alternatives (one alternative is often the current situation or business-as-usual scenario). For each choice set, a respondent evaluates the alternatives and chooses a preferred option. The alternative options in each choice set are described by a common set of attributes, which summarise the important aspects of the alternatives. In economic valuation studies, one of the attributes is a monetary indicator (e.g. tax), which makes it possible to calculate Willingness to Pay for different levels of the other attributes. Each attribute is defined by at least two distinct levels, which are varied systematically between the choice sets according to an underlying statistical experimental design plan. Values are inferred from the hypothetical choices or trade-offs that people make between the different combinations of attributes.

In the analysis of choice experiment responses, the objective is to derive a utility function that explains the value of the different attributes in the choice experiment. The importance of the non-monetary attributes relative to the monetary attribute gives the part-worth utilities of the attributes. The utility function can be used to calculate the welfare changes resulting from different policy scenarios that are described in terms of the attributes used in the choice experiment.

The theoretical basis for stated choice research lies in random utility theory in which a person's utility from a particular site or experience is described by the following utility function (sometimes referred to as a conditional indirect utility function):

$$U_{in} = V_{in} + \varepsilon_{in}. \qquad (1)$$

The utility gained by person *n* from alternative *i* is made up of an objective or deterministic and observable component (*V*) and a random, unobservable component (ε) (Adamowicz *et al.*, 1994, 1998).

The observable component of utility (*V*) can be expanded as follows:

$$V_{in} = \mathrm{ASC}_i + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k. \qquad (2)$$

ASC_i is an alternative-specific constant which represents the "mean effect of the unobserved factors in the error terms for each alternative" (Blamey *et al.*, 1999, p. 341). The X_k values are associated with each attribute level used in the choice experiment, while the β_k coefficients are included to capture the corresponding part-worth utility associated with each attribute level for all *k* attributes.

An individual will choose alternative *i* over alternative *j* if and only if the total utility associated with alternative *i* is greater than alternative *j* or $U_{in} > U_{jn}$. The probability that person *n* will choose alternative *i* over alternative *j* is given by the equation:

$$\mathrm{Prob}(i|C) = \mathrm{Prob}\{V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}; \forall j \in C\}, \qquad (3)$$

where *C* is the complete set of all possible options from which the individual can choose.

The unobservable component ε, often referred to as a random error component, is commonly assumed to be type I or Gumbel distributed and to be independently and identically distributed (McFadden, 1974).

If the ε term is assumed to be Gumbel-distributed, the probability of choosing alternative *i* can be calculated by the equation (McFadden, 1974):

$$\text{Prob}(i) = \frac{\exp^{\mu v_i}}{\sum_{j \in C} \exp^{\mu v_j}}, \qquad (4)$$

which represents the standard form of the multinomial logit model (MNL).

Although the MNL is the most common form applied to the analysis of discrete choice data due to its robustness and simplicity associated with calculating the probabilities (Louviere and Woodworth, 1983), other models are also regularly used in stated choice research (e.g. the probit model). An important outcome of the logit model is that choices are assumed to be independent of irrelevant alternatives (IIA), meaning that "the ratio of choice probability for any two alternatives is unaffected by addition or deletion of alternatives". In other words, the alternatives are assumed to be independent.

The β_k coefficients (or part-worth utilities) are derived by fitting the choice model to the observed data on the stated choice probabilities (aggregated over all respondents) and the experimental design used to define the attribute levels seen by respondents for each choice set. Choice models are usually estimated using maximum likelihood analysis.

To calculate efficient part worth utilities, the choice experiments are normally designed to ensure orthogonality[24] of attribute levels both within and between alternatives. A full factorial design where all main effects and interactions are orthogonal represents one extreme. However, full factorial design plans require individuals to evaluate an unrealistic number of choice sets (e.g. every possible combination of attribute levels), even in cases where the total number of attributes is small. Therefore, researchers typically make trade-offs between the ability of a design plan to estimate all possible interactions and the necessity to limit evaluation to a reasonable number of choice sets by employing a fractional factorial design plan. Fractional factorial designs typically permit the orthogonal estimation of all main effects and at least some interactions between the attributes.

[24] In an orthogonal design, the attribute levels are uncorrelated with any other attributes, thus ensuring that the part worth utilities measure only the intended attribute and are not confounded with other attributes.

IV.2 Attribute selection

During the consultations held with the recreational fishers and the snorkeling/diving focus group, preliminary suggestions were made as to what attributes would be included based on the preliminary attributes mentioned above. The following is a synopsis of what was arrived at based on the recommendations from the focus group and experts.

- *Payment vehicle*: Due to a recent increase in the property tax it was decided not to include this as the payment vehicle. Introducing a new environmental levy was considered a better choice. The general consensus was that there is a great concern amongst the general public about how the funds from such a levy would be administered. Many residents felt that the money would disappear into the general coffers and would not be used for environmental protection and management. The distrust of the current government is quite high, especially with regards to financial matters and environmental issues. It was suggested that perhaps the money could be administered through an NGO. It was also recommended that a monthly general levy be set. It was also mentioned that in the attribute explanation, the levy should be explained or tied into what Bermudans already pay with regards to taxes and fees, e.g. if there would be an environmental levy tied to the monthly electricity bill etc. The levy levels were set at 5 BMD, 10 BMD, 20 BMD, and 50 BMD per month.

- *Quality of the Coral Reef*: significant discussions were held during the focus group consultations regarding whether or not coral health and reef fish abundance should be separated or combined into one attribute. It was suggested that perhaps the attribute be labelled reef health and diversity or reef biodiversity. It was also suggested that somehow coral cover should be included in the attribute, though discussion regarding the levels, specifically the Business as Usual (BAU), were complex. It was suggested that a level of 10-20% loss of coral cover be included as the BAU, and because it may not appear to be particularly high to the average Bermudan, it was also suggested that a comparison be included. This loss of coral coverage can be related to the size of Bermuda, e.g. 10% loss being the size of Bermuda, 20% being twice the size of Bermuda etc, though this was later changed to reef quality or reef health and the levels were set at poor, moderate, and high. Reef quality included both coral diversity and abundance and the amount of reef creatures.

- *Fish catch per trip*: Most of the discussion related to fish catch centered on either fish size or number of fish, but number was seen as more important. It was recommended that an increase/decrease from the present catch in percentage be included. This would allow for the creation of a linear variable. The levels were set at 20% higher catch, no change in catch, and 20% lower catch.

- *Water Clarity*: Average visibility was seen as a good attribute by most focus group participants and experts. Examples for the levels were decided at: 0-10 ft; 10-30ft; 30-50ft; 50-80ft (or more). Another option that was discussed for the units was the chance of having a good day of visibility, but this was less preferred. After further focus group consultation, it was suggested that the visibility numbers included in the choice sets were quite low. Though the visibility depends on the season, it is usually quite good around Bermuda. Recommendations were made that the visibility be changed to 0-20ft., 20-50ft., 50-100ft., and 100-150ft. respectively.

- *Coastal Development*: Three possible options for describing the level of coastal development are: natural coastline; filling of holes, overhangs and crevasses with concrete (to prevent erosion); and seawalls. The levels for this attribute were difficult to define in that all three features already exist, and will not disappear, so giving them as levels will not make much sense. It was decided to delete this attribute.

- *Swimming Restrictions*: the visual beauty of Bermuda was of great importance, particularly with regards to the quality of the island's turquoise waters. The number of beach closures was suggested as an indicator for water quality. Although the current number of beach closures is limited, it has occurred in the past and is quite a sensitive issue on Bermuda. It was suggested that the levels regarding this be the number of closures during the swimming season (the summer months when the waters are warmest) or the percentage of swimming sites closured during the swimming season (this should not be limited to beaches as many Bermudans like to swim off of rocks or piers).

IV.3 Questionnaire

I. Name Interviewer:		*V Interview No.:*
II. Date of interview:		
III. Parish and street location of interview:	***Parish:***	
	Street:	
IV. Start time/end time of interview	***Start time:***	***End time:***

Hello my name is.......... I am affiliated with the Department of Conservation Services. We are conducting a survey with local residents on the importance of Bermuda's coral reefs. We would like to know your personal opinions about the values of coral reefs for local people. Everything that you tell us will be kept strictly confidential.

The interview will take about twenty minutes. Would you be willing to participate?

I. General Questions

1. Are you Bermudan?

a. Yes	☐ (GO TO Q.5)
b. No	☐

2. If not, where were you born? (*Tick only one*)

1. The United Kingdom	☐
2. The United States	☐
3. The Caribbean	☐
4. Canada	☐
5. Portugal/ Azores	☐
6. Elsewhere, specify …	☐
7. Refused	☐

3. If non-Bermudan, when did you arrive in Bermuda?

1. Please fill year of arrival in Bermuda	………

4. How much longer do you expect to stay in Bermuda? (*Tick only one*)

1. Forever /All my life	☐	4. 5 to 10 years	☐

2. 15 to 25 years	☐	5. 1 to 5 years	☐
3. 10 to 15 years	☐	6. Don't Know/Refused	☐

II. Recreation

5. Please indicate who in your immediate family can swim? (*Tick all options that apply*)

a. Respondent	b. Spouse	c. All children	d. Some children
☐	☐	☐	☐

6. How often do you or anyone else in your household participate in each of the following activities?

	a. More than 12 times a year	c. 6-12 times a year	d. 2-5 times a year	e. Once a year	g. Never
1. Beach picnic/ BBQ/ waterside camping	☐	☐	☐	☐	☐
2. Swimming	☐	☐	☐	☐	☐
3. Water sports	☐	☐	☐	☐	☐
4. Snorkeling/ Scuba diving	☐	☐	☐	☐	☐
5. Other, specify ____________________	☐	☐	☐	☐	☐

III. Environmental awareness

7. How important do you consider the following environmental issues facing Bermuda? (*1 being not important and 5 being very important*)

	not important				very important
1. Increased development/ lack of open space	1	2	3	4	5
2. Overfishing	1	2	3	4	5
3. Noise pollution	1	2	3	4	5
4. Degradation of coral reefs	1	2	3	4	5

6. Increased container and cruise ship traffic	1	2	3	4	5
7. Trash/littering/ illegal dumping on **land**	1	2	3	4	5
8. **Marine** pollution (e.g. sewage/dumping/trash)	1	2	3	4	5
9. Other, specify …	1	2	3	4	5

8. Have you donated any money or time towards an environmental cause in the last 12 months, and if yes, how much time/money did you donate?

a. Yes	☐	_______BMD	________Days
b. No	☐		

9. Are you in principle willing to pay an environmental levy, which would be managed by a Non-Governmental Organization, contributing to improving the Bermuda environment?

a. Yes	☐
b. No	☐

IV Choice experiment

REFER TO THE INTERVIEW PROTOCOL

IMPORTANT: INDICATE VERSION NUMBER____

10. Record the respondent's answers to each choice question in the table below. *(Check only one box in each row).*

Choice set	Option A	Option B	Expected Future Scenario	Refused the Question
Choice Set 1	☐	☐	☐	☐
Choice Set 2	☐	☐	☐	☐
Choice Set 3	☐	☐	☐	☐
Choice Set 4	☐	☐	☐	☐
Choice Set 5	☐	☐	☐	☐

[ONLY ASK THE FOLLOWING QUESTION IF THE RESPONDENT HAS CHOSEN SCENARIO "EXPECTED FUTURE WITHOUT EXTRA MANAGEMENT" EACH TIME OR REFUSED TO MAKE A CHOICE, OTHERWISE SKIP TO NEXT QUESTION]

11. You have chosen the 'Expected Future Scenario' in each card or refused to make a choice. Can you explain why?

1. I am not responsible for the damage to the reef	☐	7. Don't need another tax no matter what it is used for	☐
2. I am not confident that the money will be used as specified	☐	8. Other activities are more damaging to the reefs than the ones described in the questions	☐
3. I do not believe there are serious threats to the reef	☐	9. I couldn't understand the questions...too hard to make the choices	☐
4. I was not convinced that the options were realistic	☐	10. The choices weren't relevant to me. Didn't describe what matters to me	☐
5. The issues are more complex than these questions suggest	☐	11. Other, specify…	☐
6. The costs were too high	☐	12. Don't know/refused	☐

12. How did you make your choices? Did you:

1. Consider all items simultaneously	☐	4. Use your intuition	☐
2. Consider a few items	☐	5. Make a random choice	☐
3. Only consider one item	☐	6. Don't know	☐

13. In making your choices, how important were the following items to you? *(1 being not important and 5 being very important)*

	not important				very important
1. Quality of the reef	1	2	3	4	5
2. Fish Catch Per Trip	1	2	3	4	5
3. Safe swimming	1	2	3	4	5
4. Clarity near-shore	1	2	3	4	5
5. Environmental Levy	1	2	3	4	5

V. Demographics

The following questions are for statistical purposes only

14. What is your ethnic background? I consider myself

1. Black	☐
2.White	☐
3. Mixed	☐
4. Other, specify…	☐

15. What is the highest level of education you have completed?

	☐
ry	☐
e school	☐
4. Senior School	☐
ical/ Vocational/ Pre-university	☐
6. University degree	☐
7. Don't know/refused	☐

16. In which sector are you employed? (*Check only one*)

1. Management, professional etc.	☐	7. Banking/Financial sector	☐
2. Service & tourism	☐	8. Student/education	☐
3. Sales and office	☐	9. I am unemployed	☐
4. Fishing or Agriculture	☐	10. Manufacturing	☐
5. Construction, transport &	☐	11. I am retired	☐
6. Re-insurance industry	☐	12. Other, specify	☐
7. Public Administration	☐	13. Don't Know/Refused	☐

17. Please tell me about your total household income, in BMD$, last year.

1. $10,000 to $36,000	☐	5. $90,000 to $118,000	☐	9. $250,000 to $300,000	☐
2. $36,000 to $54,000	☐	6. $118,000 to $144,000	☐	10. $300,000 to $400,000	☐
3. $54,000 to $72,000	☐	7. $144,000 to $200,000	☐	11. More than $400,000	☐
4. $72,000 to $90,000	☐	8. $200,000 to $250,000	☐	Prefer not to answer	☐

18. If you have any other comments, please leave them in the box below.

VI. Fishing

19. How many people currently fish in your household? Number: _______ (IF 0 GO TO Q.25) (Important Note – fishing can include any method of harvesting marine food from the sea; hook and line, spearing, netting, gathering lobster, etc).

IF ANYONE FISHES IN THE HOUSEHOLD, ASK IF THE PERSON IN THE HOUSEHOLD WHO MOST ACTIVELY FISHES CAN HELP ANSWER THIS SECTION.

How many times do you fish per year and how much do you usually catch, **__either__ in pounds or number of fish?**

Month	On average, how many times do you fish in these months?	How much do you usually catch per trip	
		Pounds	Fish
Jan			
Feb			
Mar			
Apr			
May			
Jun			
Jul			
Aug			
Sep			
Oct			
Nov			
Dec			

20. Can you indicate how important the following reasons are for you to go fishing? (*1 being not important and 5 being very important*)

(You may also check less than 4 boxes)	not important				very important
1. I enjoy fishing	1	2	3	4	5
2. I catch for food	1	2	3	4	5
3. To give catch to family and friends	1	2	3	4	5
4. For tradition: my family has always fished. Fishing is my life!	1	2	3	4	5
5. Fishing strengthens the bond with my friends and family	1	2	3	4	5
6. Other, specify …	1	2	3	4	5
7. Don’t know	1	2	3	4	5

21. Can you indicate how much of your actual fishing time (not including travel time) you spend in the locations listed below (***Table should add to 100%***)?

Shore fishing	**%**
South Shore	
East End	
North Shore/Lagoon	
West End	
Inshore (St. George, Castle & Hamilton Harbor, Harrington & Great Sound)	
Boat fishing	
South Shore	
East End	
North Shore/Lagoon	
West End	
Inshore (St. George, Castle & Hamilton Harbor, Harrington & Great Sound)	
Banks	

22. What percentage of your total catch is made up of each of the following types of fish? (***Distribute catch across the different types of fish, total table should add to 100%***)

Type of catch	*Share (must add up to 100%)*
1. Shallow reef fish (less than 80 ft)	
2. Deep reef fish (more than 80 ft)	
3. Deep Sea fish (tunas, Wahoo etc.)	
4. lobster	
5. Bait fish	
6.Mussels	

23. Please indicate which fishing technique(s) you usually use? (*Tick all options that apply*)

1. Hand line	☐
2. Rod and reel	☐
3. Trawling	☐
4. Diving for lobster	☐
5. Spear fishing	☐
6. Bait netting	☐
7. Other techniques? Specify…	☐

VI. Scuba Diving and Snorkeling

24. How many people currently scuba dive/snorkel in your household? Number: _______ (IF 0 SKIP TO END)

IF ANYONE IN THE HOUSEHOLD SCUBA DIVES OF SNORKELS, ASK IF THE PERSON IN THE HOUSEHOLD WHO MOST ACTIVELY SCUBA DIVES/SNORKELS CAN HELP ANSWER THIS SECTION.

25. In which of the following activities do you participate in Bermuda? *(You may check more than one)* (IF ONLY SNORKEL GO TO Q.32)

1. Scuba diving	☐	2. Snorkeling	☐

26. Can you indicate how important the following items are when you go diving or snorkeling? (*1 being not important and 5 being very important*)

	not important				very important
1. Fish	1	2	3	4	5
2. Rare species	1	2	3	4	5
3. Coral	1	2	3	4	5
4. Wrecks	1	2	3	4	5
5. Other ________	1	2	3	4	5

27. Roughly how many times have you gone snorkeling in your lifetime?

Snorkeling	
☐ a 0-20	☐ d 100-300
☐ b 20-50	☐ e 300-500
☐ c 50-10	☐ f > 500

28. Roughly what share of this did you snorkel in Bermuda? _______%

29. Where do you usually go snorkeling in Bermuda? ______________

____

____

IF RESPONDENT ONLY GOES SNORKELING, THIS SECTION IS FINISHED.

30. (NOTE: THIS QUESTION FOR DIVERS ONLY) Roughly how many dives have you made in your lifetime?

Diving	
☐ a 0-20	☐ d 100-300
☐ b 20-50	☐ e 300-500
☐ c 50-10	☐ f > 500

31. (NOTE: THIS QUESTION FOR DIVERS ONLY) Roughly what share of this did you dive in Bermuda?
_______%

32. How often did you visit the following dive sites in the last year?

Sites	# dives	Sites	# dives
1. North East Breaker		8. Snake Pit	
2. Mills Breaker		9. North Rock	
3. Tarpon Hole		10. Northern Wrecks	
4. The Cathedral		11. Southern Wrecks	
5. Commissioners Point		12. Eastern Wrecks	
6. Hog Breaker		13. Western Wrecks	
7. Eastern Blue Cut		14. Other________________	

33. (NOTE: THIS QUESTION FOR DIVERS ONLY) What is the highest level of dive training you have (if not PADI certified, please use equivalent certification)?

1. No training at all	☐
2. Discover Scuba	☐
3. Open Water Diver	☐
4. Advanced Open water diver	☐
5. Rescue Diver/Dive Master or higher	☐

IF RESPONDENT WANTS TO LEAVE HIS OR HER PERSONAL INFORMATION IN ORDER TO RECEIVE INFORMATION OF THE REPORT, ASK HIM OR HER TO DO SO NOW AND NOTE.

Name (optional): ______________________

Phone (optional): ______________________

E-mail (optional) ______________________

THANK THE RESPONDENT FOR HIS/HER TIME AND PATIENCE

IV.4 Instructions for interviewers

What to bring for a day of surveying:

1. These instructions
2. A supply of blank questionnaires
    a. The general questionnaire
    b. The separate fishing and diving/snorkeling sections and envelopes
3. The set of laminated choice sets
4. The ‘read along’ version of the general questionnaire
5. The interview protocol
6. Notebook
7. Pens (more than one!)
8. Folder for completed surveys

How the survey works:

The Bermuda coral reef valuation survey consists of two key parts.

1. The general questionnaire (including the fishing and diving/snorkeling sections)
2. The choice experiment

Overview of the questionnaire:

Sections I-III – General, Recreation, Environmental Awareness

Section IV – Choice Experiment

Section V – Demographics

Section VI – Fishing section (only if household has a fisherman)

Section VII – Diving/snorkeling section (only if household has a diver or snorkeler).

A special note on the choice experiment:

There are six versions of the choice experiment. You have all of these six versions in your set of laminated cards. Each of the six versions again consists of six choice cards. The cards are numbered on top. The first choice card is the same in all versions and should be used as the example when explaining the choice experiment to the respondent.

For each interview that you do, you will use a different version of the choice cards. To avoid bias in the sample, we want you to cycle through these versions as you complete interviews with different households, so that you will have the same number of filled out questionnaires for each version. If you finish one day with version 4, start the next day with version 5, etc.

CRITICAL - IT IS ABSOLUTELY ESSENTIAL THAT YOU RECORD THE CORRECT VERSION OF THE CHOICE CARDS THAT YOU ARE USING IN THE MAIN QUESTIONNAIRE. IF THE INCORRECT VERSION IS RECORDED, WE WILL NOT BE ABLE TO ANALYSE THE RESULTS AT ALL!!! DOUBLE CHECK THAT VERSION OF THE CHOICE CARDS YOU SELECT MATCHES THE VERSION NUMBER THAT YOU RECORDED

How to conduct an interview:

1. Select a household to approach (see sampling strategy, next section)
2. CRITICAL - Complete the header information (e.g. date, time, ID number)
3. Greeting and introduction – use text box at the top of the questionnaire
4. Start the interview – see interview protocol
5. Choice experiment – select the version you will use (see previous section). **Record the version number in the main questionnaire.** Refer to the interview protocol for instructions on how to work through the choice experiment with the respondent. After each respondent answer to the choices, record the response in the main questionnaire. After all choices ask the remaining questions in the choice experiment section.
6. Ask section V, demographics
7. Fishing section – when you get to the fishing section of the questionnaire, ask the first question in the questionnaire about the number of fishermen in the household. Then there are four options:
    a. There are no fishermen in the household – skip the fishing section and continue with the diver and snorkeler section.
    b. There are fishermen in the house and you are already talking to the main fisherman – complete the fishing section with the fisherman.
    c. There are fishermen in the house and the main fisherman is at home, but you are talking to someone else – Ask if the main fisherman wouldn't mind completing the fishing section.

   d. There are fishermen in the house but the main fisherman is not home, or does not have time – Ask the respondent if you can leave the fishing section for the fisherman to fill out when he gets home or has time. Ask them to send the section back to Conservation Services in the accompanying envelope. CRITICAL – When you leave a section at someone's house, you must always record (in the appropriate boxes) your name, the date and the questionnaire ID number. COPY THIS INFORMATION FROM THE FRONT PAGE OF THE GENERAL QUESTIONNAIRE SO THAT THEY MATCH. We need this information so we know to which general questionnaire the fishing section belongs.

   e. Right after you leave a house, write down the in your notebook that you left behind a fishing section together with the questionnaire ID number and the address. We will use the address to send a reminder if they do not return the section to Conservation Services. We will not use the address for anything else.

8. Scuba diver and snorkeler section – do the same as with the fishing section (remember to copy the questionnaire ID number to the section you leave behind, and write the address in your notebook together with the ID number).

9. Finish and thank the respondent for their time.

Sampling strategy:

You can start by sampling every third house in a given street. If you are not able to get a response from a given house, try the one right next door, but otherwise stick with the systematic selection of every third house.

- **Questionnaire ID number (what is it and how to record it):** Here is an example questionnaire ID: TB-0506-1. The questionnaire ID number is composed of three pieces of information…
- **Surveyor ID:** your initials (e.g. TB)
- **Four digit date ID:** the month and then the day. So 0506 is May 6th.
- **Questionnaire number:** The nth questionnaire that you have completed in a given day. For example, the first questionnaire of the day would be 1. The tenth questionnaire of the day would be 10.

In summary, the questionnaire ID, TB-0506-1, means that Tadzio Bervoets administered this questionnaire on May 6th and it was his first questionnaire completed that day.

IV.5 Interview protocol

Introduction:

[This explanation of the questionnaire and choice model is meant to help you understand what we want with our questions, and help ensure that all interviewers understand this the same way to provide consistent interviewing.

You will have a laminated read-along questionnaire with you to give to the respondent. He does not have to fill out anything himself on there, but he might find it easier to read along.

At the top of your questionnaire is a grey box with information for you to fill out. Please do this right before and after each interview to make sure you do not forget (of course the (end-)time can only be filled out at the end of the interview, but the rest of the information should be filled out beforehand). See the interviewer instructions on how to fill out the questionnaire ID number.

There are different sections in the questionnaire. We start with a few general questions, questions about recreation and environmental awareness (Questions 1-9). Sometimes you will find skip codes after some answers (like in Question 1, if people say yes). These skip codes and other instructions to you, the interviewer, are always in CAPITAL CASE, and should not be read to the respondent.

After these first questions follows the section with the choice experiment. For this you have a laminated explanation card, and 6 versions of 6 choice cards (also laminated). The first card is an example card to explain the choice experiment to the respondent. You can write down their choices on your questionnaire. Also, DON'T FORGET TO WRITE DOWN THE VERSION (1-6) OF THE CHOICE CARDS. THIS IS VITAL! Please use the 6 versions sequentially, so that you will have the same number of filled out questionnaires per version. The text below will help you explain the choice experiment to the respondent. Try to stick to this text, but you can use your own words, if you feel some sentences don't flow well for you.]

Choice model:

Now we come to a new section of the interview. As you know, “Bermuda is another World”…and the reefs and water around Bermuda are a big part of it. At this moment the coral reefs and the marine environment around Bermuda are pristine, beautiful and healthy. However, in the next few years there are certain threats that can change this. These threats include:

- Increased coastal development to accommodate residents and tourists
- Widening of shipping channels and dock construction
- Over-fishing

- The runoff of pesticides and fertilizer

`

If these threats are not dealt with they can lead to loss of the reef system in the long term. Losing the reefs means:

- Accelerating natural erosion (Loosing our beaches)
- Losing habitat for fish
- Losing the overall beauty of Bermuda.

In the next 6 questions I will ask you to make a choice between possible future scenarios for Bermuda's marine environment. [Use the card with attribute descriptions to explain how the future scenarios are built up].

1. In each question you can choose between 3 scenarios [show the 3 scenarios on the example card. The example card is the first card (no. 0) in all versions of the choice sets, and is the same in all versions]. In order to make your choice between these three scenarios, I will explain how they differ.

To make the choice between the 3 scenarios you have to look at the values of all the items. In the third scenario, the "Expected future without extra management" scenario, there is no environmental levy, but because the threats to the reef are not dealt with all items of the reefs have deteriorated from today. This scenario does not change in the 5 choices. In scenarios 1 and 2 the marine environment is in better shape than in scenario 3, but there is a monthly environmental levy. The scenarios 1 and 2 are different in each question.

Try to imagine in which situation you would like to be most (taking into account the environmental levy, which would reduce the amount of money you could spend on other things) and then choose that scenario.[show on the example choice card that the items for one scenario belong together and indicate he should choose one of the three scenarios]

Please remember that maybe none of these scenarios will be perfect from your point of view and that some choices may be difficult. There is no right or wrong answer; it is simply your opinion that matters.

[Then ask if the respondent understands or would like to ask you something more about it. If you think he understands show him the first real choice card. If necessary you could help him a little with the first card by showing the differences between the scenarios. For the second choice card explain to the respondent that this is a new choice; it has nothing to do with the previous choice; he should just choose the best scenario from the new card. For the second choice card try not to help the respondent too much, unless he really doesn't understand. Just briefly point out the differences between the options if necessary but try to give a balanced presentation. Do not let your values and preferences influence the respondent's choice!! After all choices are made, ask the respondent the follow up questions.]

[What to do if a respondent refuses to choose any of the options: there will most likely be two reasons for respondents to do this.

1. They don't really understand the question or what you are asking them to do

2. They fully understand what you are asking, but they don't agree with the concept or how the choices are being portrayed

Note how the respondent approached the question. Did they read it or try to compare the options at first? Or did they quickly glance at the sheet and hand it back to you?

Gently probe the reasons for the response.

If you get a clear reason that sounds like one of the responses to follow-up question, continue asking the remaining choice questions (if any) but try to point out some key differences in the options to make sure that the respondent knows what the choices are. If they refuse, it should at least be an informed refusal. Don't just skip the rest of the questions!

If you get an unclear reason or a reason that sounds something like "I don't know about these things" or "I don't understand" (they may look a little embarrassed) then bring out the last choice set again and go over how the options are composed and what the key trade–offs are. Remind them that they just have to choose what they think is the best option. Stress that it is their opinion and that there is no right or wrong answer.]

IV.6 Questionnaire pre-test

The questionnaire was pre-tested in order to identify any difficulties with implementing the survey. The benefits of pre-testing are threefold; (i) it allows for the testing of the survey on the respondent and gauges the difficulty the respondent has regarding the questions, (ii) it determines if the attributes and attribute levels are clear, and (iii) it determines if there are any attribute level combinations included in the choice model that are confusing or do not make sense to the respondents.

While pre-testing, specific attention was paid to a number of considerations. These items for consideration were:

1. Did people accept the general scenario? If not, what were the problems? Did problems relate to the threats, the measures, or the payment?

2. Were the attribute descriptions, pictograms, and levels clear to the respondents? If not, what were the problems?

3. Were there any combinations of levels (high-low) that were protested against?

4. How long did respondents take to answer the choice questions? Did they take enough time to consider all details of each option in every choice?

5. Was one attribute (item) consistently more important to respondents in making choices between the options?

6. Did respondents take the amount of the environmental levy into account in making their choices?

7. Was the range of payment amounts for the environmental levy acceptable?

8. Were five choice questions manageable? Did respondents become bored, impatient, or answer without considering the options? Would six choice questions have been more acceptable?

The pre-test was conducted in the field and was administered to ten to twelve persons. The conclusions of the pre-test resulted in a number of changes. First, the major issue regarding the questionnaire was the difficulty of certain questions for the respondent, particularly questions that asked for the ranking of importance of a list of items. These questions resulted in respondents taking considerable time responding to the questions. The format of these questions was changed using the Likert scale. Second, the recreational fisheries questions added considerable length to the questionnaire. Some lengthy recreational fishing questions had been added on behalf of the Department of Conservation Services and the Fisheries Department. It was decided to place the recreational fishing section towards the end questionnaire so that respondents were not fatigued at the point that they answered the choice questions, which is considered to the most complex part of the questionnaire. Third, similarly the diving/snorkeling portion of the survey was also moved to the end of the questionnaire.

It was found during the pre-testing phase that there were no complaints regarding contradictory attribute level combinations appearing in an alternative. Therefore no design restrictions were included.

The focus groups and expert consultations resulted in several rounds of alterations to the questionnaire. After the recommendations and considerations were taken into account, and after final pre-testing, the questionnaire length was approximately 30 to 40 minutes, depending on whether or not the respondent or anyone in the household engaged in recreational fishing and/or scuba diving or snorkeling. The fishing and scuba diving/snorkeling sections added each about five minutes to the length of the questionnaire.

APPENDIX V. Research and education value

This study also distinguishes the biodiversity value that is relevant for the Bermudan reefs. This includes the research value. The research value is determined in a rather straightforward manner. All research budgets that are assigned to coral reef ecosystems in Bermuda is included in this value category. To determine this value a brief survey was held. All potential research candidates were asked to provide us with their annual budget for the former five year. The sum of these activities amounts to US$2.3 million in 2007. For confidential reasons, the breakdown of funds given to each source approached cannot be published here.

The list of NGOs based in Bermuda and governmental departments involved wholly or partly in reef-related research and/or education and who contributed to assessing the coral reef-related research and education value is as follows:

Government of Bermuda

- Department of Conservation Services
    - Biodiversity
    - Seagrass
    - Environmental Moorings
    - Conservation Care Hatchery Facility
- Department of Environmental Protection
    - Black grouper acoustical tagging study
    - Age and growth study
    - Spawning Aggregations (blue-striped grunt)
    -
- Bermuda Zoological Society
    - Coral related research
- BIOS- Bermuda Institute for Ocean Sciences
    - College and Grad levels courses
    - Educational groups
    - Elderhostel
    - Research Marine Program

APPENDIX VI. Mapping Bermuda's Coral Reefs

Mandy Shailer

Coral reef surveys conducted by Murdoch (2007) and BIOS (2004-2007), formed the basis of the interpolated coral cover map provided in Chapter 1. For a better insight into Bermuda's coral cover, three maps are given here (Figures VI.1, VI.2, and VI.3). The first is an image of the Bermuda Platform, outlining the 20m and 200m depth contours, the lagoonal patch reefs and the fore reefs (Figure IV.1); the second indicates the survey sites assessing hard coral cover (excluding soft corals) on top of reefs (and excluding any coral species on the side of reefs) (Figure IV.2), mapped as circles proportional to the resulting percent coral cover and overlaid onto the platform map; finally, the third map, forming the final overlay, is an interpolation of the coral cover determined at specific sites (Figure IV.3).

An attempt is made here at explaining the approach taken to interpolation, as care must be taken in interpreting such a map. Interpolation creates continuous (or prediction) surfaces from sampled point values. The values at sampled points are used to predict values at all unsampled locations within the output raster (image).

There are several different interpolation models to choose from. For this project, the Spline with barrier model was chosen. This is a deterministic model which assigns values to locations based on the surrounding measured values and on specified mathematical formulas. This minimum curvature technique results in a smooth surface that passes exactly through the input points. The barrier used was the entire coastline of Bermuda, to prevent the small rocky islands from being included in the interpolated surface.

The resulting interpolated surface was manually reclassified into intervals of 10% coral cover. The next step was to convert the reclassified surface into polygons. Finally, those polygons were overlaid onto the existing reef polygons to classify the reefs based on the interpolated percentage coral cover.

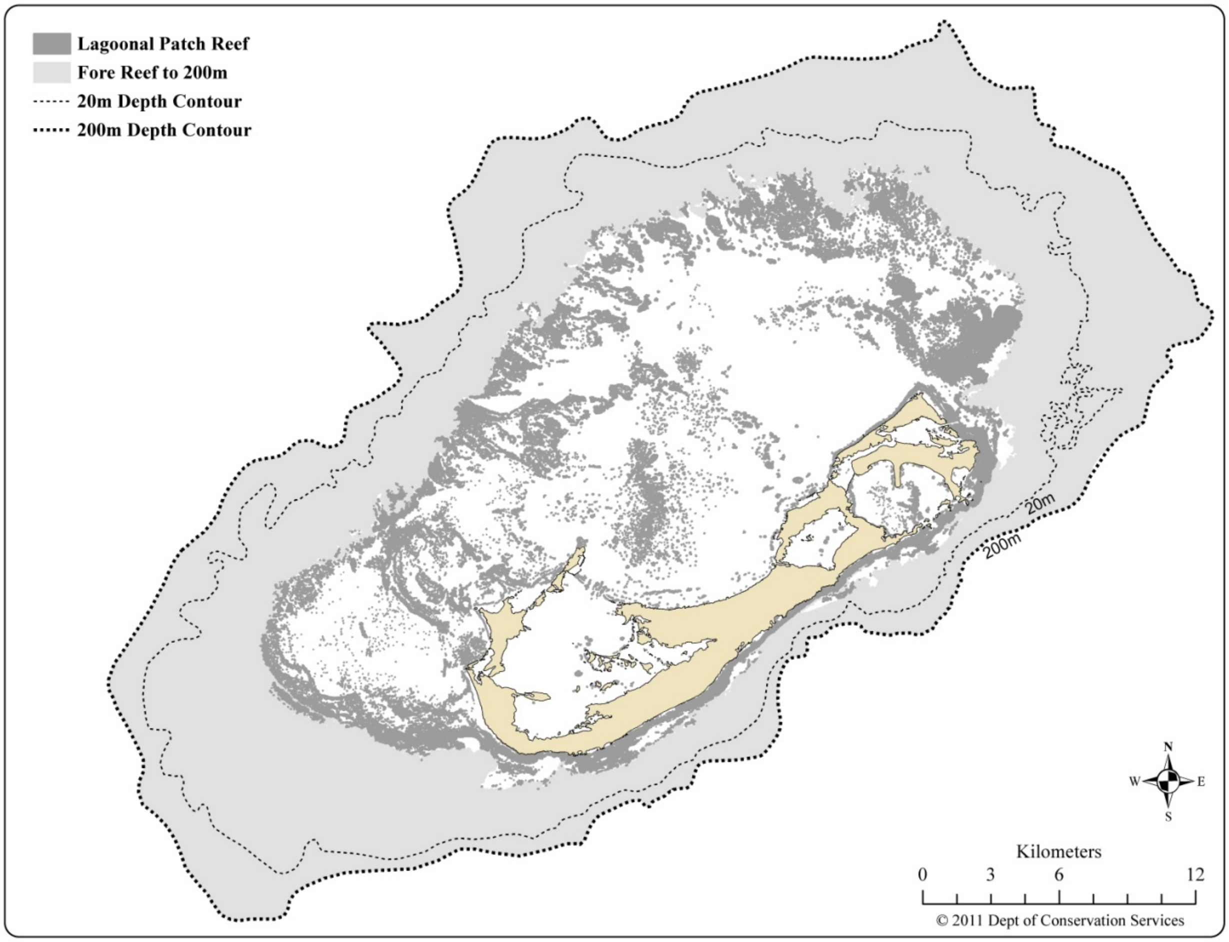
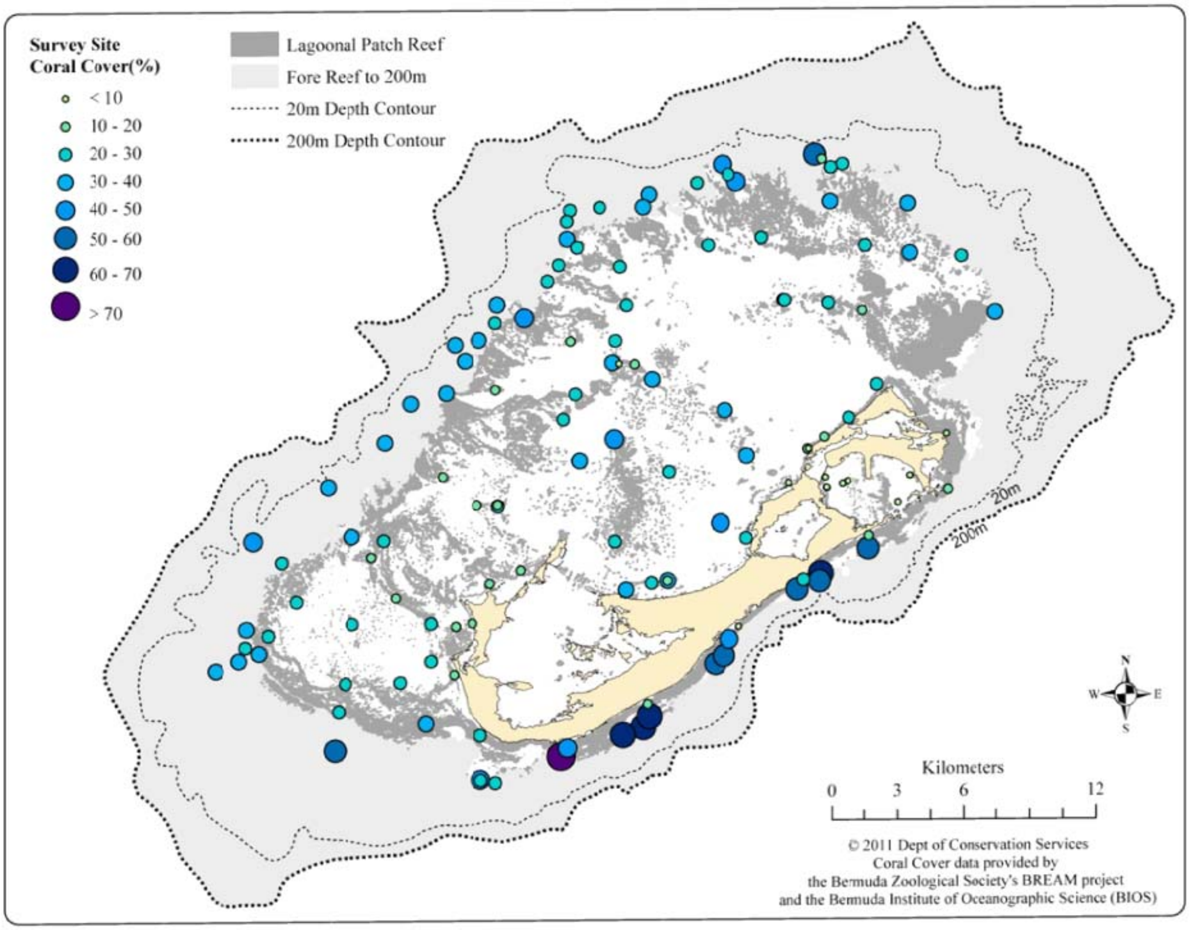


FIGURE VI.1. BERMUDA'S CORAL REEF PLATFORM



F

IGURE IV.2. PERCENTAGE CORAL COVER AT SPECIFIC SITES AROUND BERMUDA (MURDOCH, 2007; BIOS 2004-2007).

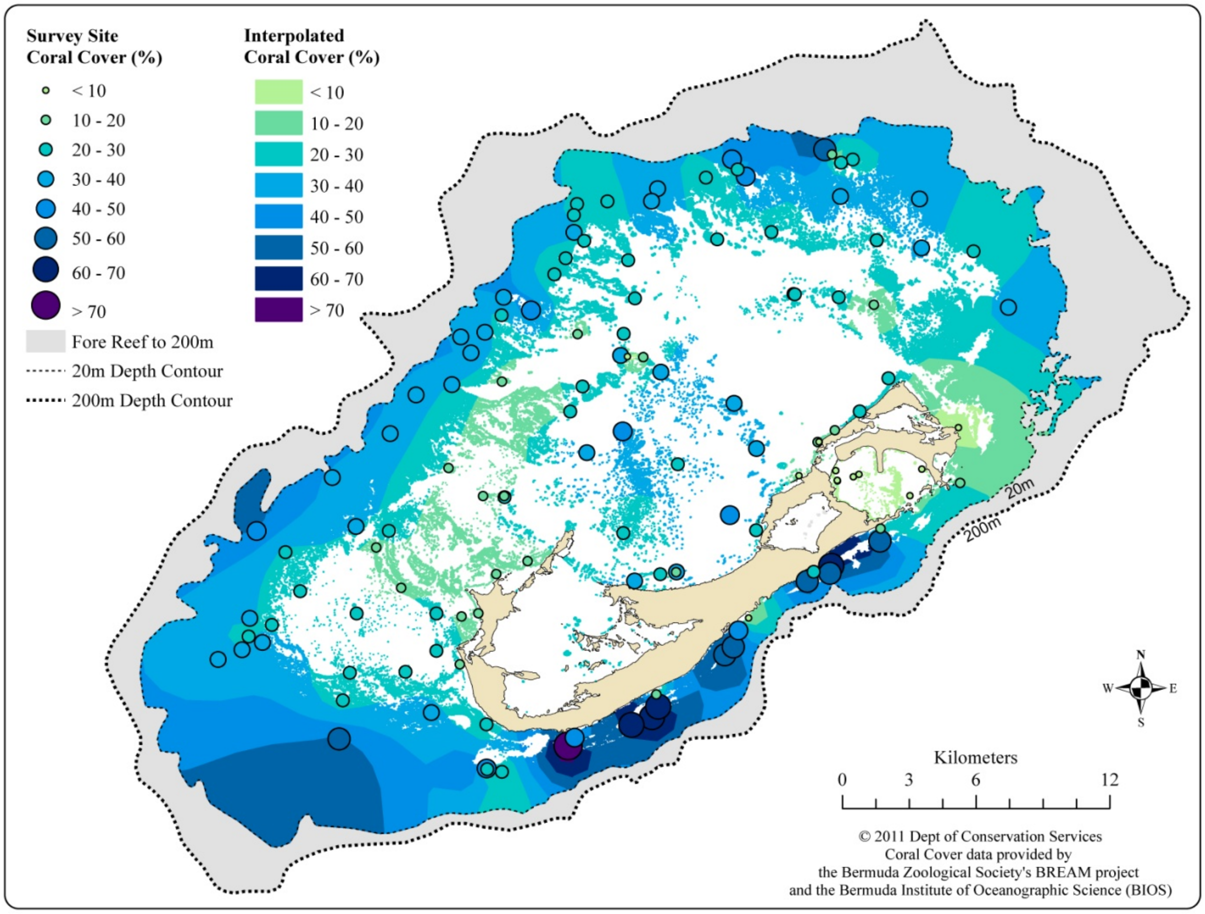


FIGURE IV.3. INTERPOLATED CORAL REEF COVER (AS A PERCENTAGE) AROUND BERMUDA. (DEPARTMENT OF CONSERVATION SERVICES, BERMUDA).