

Total Economic Value of Bermuda's Coral Reefs

Valuation of Ecosystem Services

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EXECUTIVE SUMMARY

This project was initiated by Dr. Samia Sarkis in collaboration with environmental economists from the Joint Nature Conservation Committee (U.K.) and implemented by the Institute for Environmental Studies (IVM) of the Vrije University (Netherlands) and a Bermuda-based scientific team. It was funded by the Overseas Territories Environmental Programme (OTEP, U.K.), XL Foundation in Bermuda, and contributed to by the Bermuda government for initial framework development. The study's progress was overseen by a Steering Committee composed of Bermuda government representatives (Department 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	4.9	0.7%
Research & education value	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). **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. Several policy recommendations were provided 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 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 \$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, Bermudians 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. The role of Marine Protected Areas (MPAs) in sustaining a healthy ecosystem has been demonstrated in other regions, acting as a refuge for marine populations and enhancing in some cases fish catch outside of MPAs. MPAs provide an effective way of sustaining the tourism, recreational and cultural benefits provided by the coral reef system.

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

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;
- Enhanced enforcement capacity on the Bermuda platform;
- Development and implementation of mitigation measures of foreseen changes – i.e. due to climate change and/or coastal development;

- Applied research in coral restoration and growth, connectivity between fish productivity and coral reef habitats;
- Oceanographic data on the platform, including wave data during storms and hurricanes, currents, providing necessary information on impacts to the coastline;
- 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 which 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 which 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, reducing coral cover due to physical damage or disease.

Operator survey

Thirteen of the existing forty reef-associated tour operators in Bermuda were interviewed, including dive operators, glass bottom and rental boat operators, and 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 at US\$190 million for the cruise ship tourism sector and US\$154million 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\$15.6million - 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.

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; however, there is a difference between cruise ship and airplane tourists. The total tourism value of Bermuda's coral reefs per visitor is US\$611 per tourist. Cruise ship tourists value the coral reefs somewhat less at US\$591 per visit and airplane tourists value the reefs somewhat more at US\$635 per visit. The differences between cruise ship tourists and airplane tourists are mainly based on the difference in on-island expenditures. Despite the twofold producer surplus spent by air visitors, the higher volume of cruise ship visitors results in an equivalent tourism value per year; where the reef-associated tourism value for cruise ship tourism is US\$197 million and for air tourism is US\$209 million. Cruise ship tourists appreciate the reefs at almost the same level as airplane tourists; this is reflected in their **Willingness to Pay** for conservation (US\$9.7million for cruise ship and US\$5.9 million for air visitors). Nonetheless, based on on-island expenditures, the added value to Bermuda is lower for cruise ship tourists, where cruise ship tourists add US\$20 million per year to the island's reef related economy, less than half that added by airplane tourists (US\$43 million). 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 therefore 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 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 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 of US\$1.6 million to US\$2.5 million; 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 amounted to 40 - 80 % of the gross value of the total catch; due to the small sample size (based on six fishermen), this should be considered as a very rough 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

This study provided 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 below. 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 the results, the motivation for this activity by Bermudians 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 was recorded as being only 4% of the recreational total catch. Lobsters and mussels were reported to be least targeted by the fishermen interviewed, and made 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 leads to a total reef-associated finfish catch of 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). The same market prices were used as for commercial value. The recreational reef-associated value is estimated to be US\$ 3.5 million for finfish (excludes 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, and 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 were responsible for 53% of the total catch in weight. Recreational lobster diving accounted for 9% of the total lobster catch.

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

Because people generally prefer living close to reefs, it is expected that the closer one lives to the coral reef the higher the price of a house will be. This hypothesis was tested through the valuation method of hedonic pricing. 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 home owner. 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, given the coralline nature of Bermuda beaches.

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, due to the nature of Bermuda's coastline.

The amenity value was based on the estimated non-linear relationship between house prices and beach distance. Note that beaches in Bermuda would not exist without coral reefs. The

analysis revealed a quadratic relationship where house prices first increased when further away from the beach, which was unexpected, and from about 1.1km house prices decreased when further away, as expected.

The total amenity value is calculated as the difference between: 1) The total price of the houses sold in the dataset (\$ 890million) and 2) The extrapolated calculation of the house prices in a “deterioration” scenario- or should beaches disappear (US\$ 728million). This yields an amenity value for all houses in Bermuda of US\$ 5.6 billion, or US\$ 221,000 per house. 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 Bermudians implicitly enjoy the ecosystem services derived from coral reefs but because of its invisibility they do not explicitly consider such amenities when buying a house. 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 Bermudian 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, a representative sample of Bermuda’s population.

The questionnaire includes seven sections on: 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 of Bermudian residents who fish recreationally; (2) *Snorkelers and scuba divers*, comprising of Bermudian 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.

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 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 would allow for the implementation of conservation and management measures.

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. This awareness about the vital role of the rim and boiler reefs in protecting Bermuda's shoreline is also revealed in earlier coastal vulnerability assessment studies. The economic value of this ecosystem service, however, had not yet been estimated. In this study, the "avoided damages" approach was used to value this service. This involved 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, and 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 was based on reports for Hurricane Fabian, a Category 3 (bordering 4) storm, hitting Bermuda directly in 2003. This yields an average damage share of 27.5%, implying that with 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 was determined at **US\$266 million** per year.

Research and Educational Value

The research and educational 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 were 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. 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.