Coastal Capital –
Economic Valuation of Coral Reefs in Tobago and St. Lucia

by Lauretta Burke, Suzie Greenhalgh, Daniel Prager and Emily Cooper

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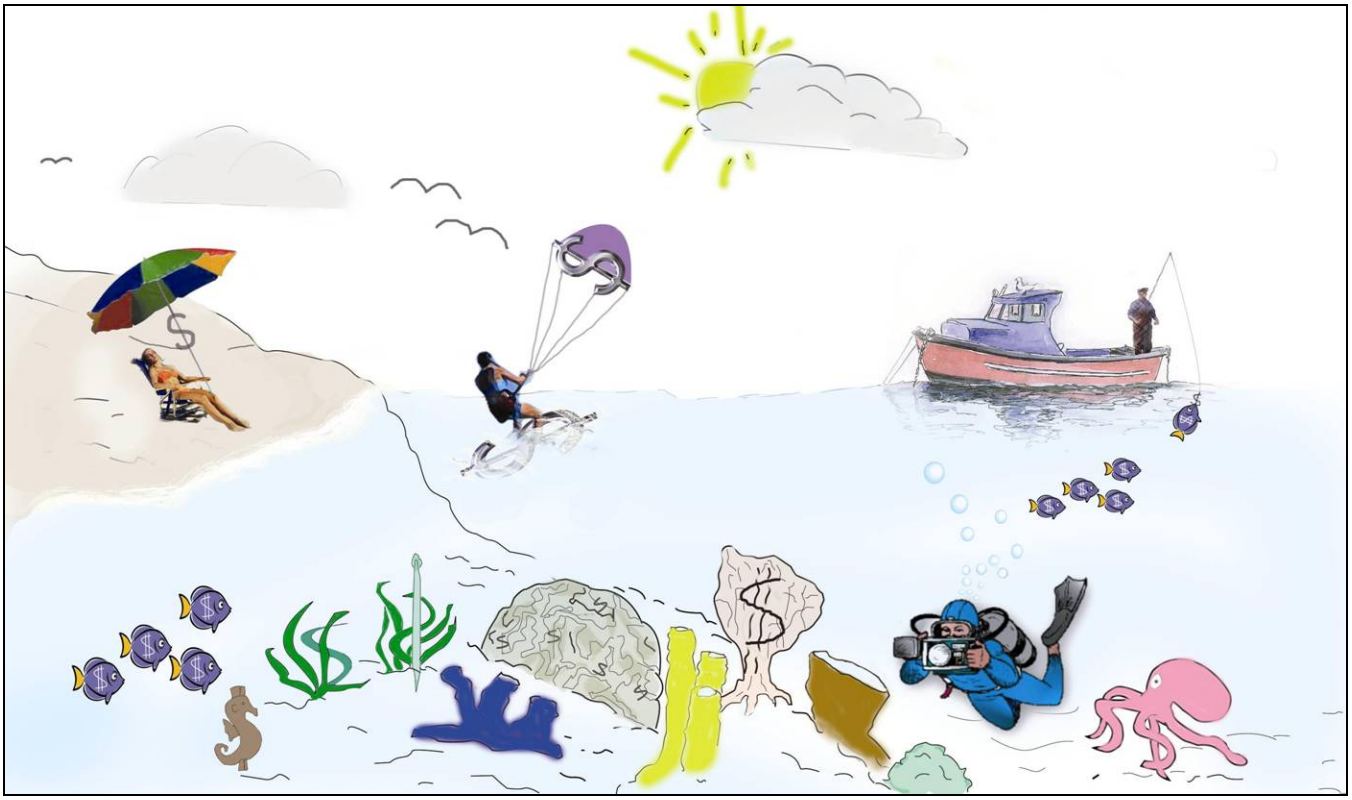

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Saint Lucia

The *Economic Valuation of Coral Reefs in the Caribbean* project was led by the World Resources Institute, and was implemented in close collaboration with:

Institute of Marine Affairs (IMA),

Buccoo Reef Trust (BRT),

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Executive Summary

The economic benefits derived from coral reefs are vital to the economies of small island states in the Caribbean. Economic valuation of these benefits helps to guide the wise, sustainable use of these resources.

Coral reefs provide many benefits, sometimes called ecosystem goods and services, which are of high value and critical importance to local and national economies in the Caribbean. These values are frequently overlooked or underappreciated in coastal investment, development and policy decisions, resulting in short-sighted decisions that do not maximize the long-term economic potential of coastal areas. This project focuses on development of a valuation methodology that will be broadly applicable in countries across the Caribbean, supporting wise, long-term coastal policy and management. This report provides a comprehensive summary of the valuation methodology as well as valuation results from implementation in two pilot sites in the Eastern Caribbean (St. Lucia and Tobago). Shorter, island-specific summaries of results, along with an Excel-based Valuation Tool for implementing the methodology are available from www.wri.org/project/valuation-caribbean-reefs.

Estimating the economic benefits of coral reefs to local economies is neither easy nor straightforward, due to the range of approaches available and frequent limitations of underlying data. Many valuation methods exist, and results are rarely comparable. A priority for this project has been the development of a simple, broadly applicable methodology to value coral reef goods and services, based predominantly on commonly available data. Use of a consistent approach should lead to more comparable estimates of value for different places and time periods. An easily replicable methodology can also be applied while varying key assumptions in order to assess the impacts of different development and management options. This methodology does not assess Total Economic Value (TEV), but rather focuses on three key goods and services: coral reef-associated tourism, fisheries, and shoreline protection services. These goods and services were chosen because of their importance to local economies and because data are available to support estimation of these values. The method was developed based on literature review, feedback from local partners and examination of coral reef use and data availability in two pilot locations (St. Lucia and Tobago).

The results from the economic valuation of coral reefs in St. Lucia and Tobago—sites with very different coastal management and data richness situations—are presented below. Even assessing only a subset of goods and services demonstrates that the benefits provided by coral reefs are economically significant, particularly with respect to island GDP. These estimates should be viewed as lower bound (partial) estimates of the economic contribution of coral reefs to the economy of these two islands.

The economic impact of coral reef-associated tourism and recreation and fisheries is evaluated using a financial analysis method—tracking the financial flows generated by these two industries, and their wider impact on the economy. Shoreline protection services are evaluated using a modified avoided damages approach, where the value of a reduction in wave-induced erosion and property damage due to coral reefs is estimated. The methodology, as well as the Valuation Tool, uses a tiered approach, allowing results to be calculated at different levels of detail depending upon the data available.

Results

Tourism and Recreation. Coral reef-associated tourism contributes significantly to the economies of both pilot sites. The valuation focuses on tourists visiting at least in part due to coral reefs—estimated at 40% of visitors to Tobago and 25% in St. Lucia. Direct economic impacts from visitor spending on accommodation, reef recreation, and miscellaneous expenditures in 2006 are estimated at US$ 43.5

million for Tobago and US$ 91.6 million for St. Lucia. This comprises 15% and 11% of GDP, respectively, in Tobago and St. Lucia. Additional indirect economic impacts, driven by the need for goods to support tourism (such as boats, towels and beverages) contribute another US$ 58–86 million to the national economy in Trinidad and Tobago and US$ 68–102 million in St. Lucia. The resulting combined direct and indirect impacts from coral reef associated tourism equal an estimated US$ 101–130 million for Tobago and US$ 160–194 million for St. Lucia in 2006.

The study also produced rough estimates of two values not currently captured within the economy. These include the annual value of local residents' use of the reefs and coralline beaches—estimated at US$ 13–44 million in Tobago and US$ 52–109 million in St. Lucia—as well as consumer surplus from reef recreation (i.e. the additional satisfaction derived by participants above what they paid for dive and snorkel trips). Consumer surplus was estimated at US$ 2.3 million for St. Lucia and $1 million for Tobago.

Fisheries. Coral reef-associated fisheries have a much smaller economic impact, but provide other important values including jobs, cultural value, and a social safety net. The annual direct economic impact of coral reef associated fisheries is estimated at US$ 0.7 – 1.1 million for Tobago and US$ 0.4 – 0.7 million for St. Lucia. Additional indirect impacts from the need for boats, fuel, nets, etc. is estimated at about US$ 0.1 – 0.2 million for both islands, resulting in a total economic impact of about US$ 0.8 – 1.1 million per year in Tobago and US$ 0.5 – 0.8 million per year in St. Lucia.

Shoreline Protection. Coral reefs play a vital role protecting the shorelines of both St. Lucia and Tobago. This project developed an innovative method for evaluating the role of coral reefs in protecting the shoreline. Coral reefs contribute to the protection of over 40 percent of the shoreline of both islands (about 44 percent for St. Lucia and nearly 50 percent for Tobago). Although both islands have steep topography, extensive cliffed coastlines, and relatively little coastal lowland area, there is still significant land area that is vulnerable to wave-induced erosion and storm damage—about six percent of land in Tobago and four percent of land in St. Lucia. Of this vulnerable area, approximately 10 sq km is protected by coral reefs for both islands—about three percent of Tobago's total land area and 1.5 percent of land in St. Lucia.

In both islands, the relative share of protection provided by coral reefs varies greatly with coastal context—the elevation and slope of the shore, the geologic origin of the area (and resistance to erosion), and the wave energy along the coast. In all areas where corals are present, they are estimated to provide at least 20 percent of the shoreline stability. In some areas, this share is over 40 percent. The annual value of shoreline protection services provided by coral reefs (in potentially avoided damages) is estimated to be between US$ 18 and 33 million for Tobago and US$ 28 to 50 million for St. Lucia in 2007. The importance of coral reefs in protecting the shoreline will increase with rising sea level and increased storm intensity associated with warming seas.

Limitations

The valuation methodology focuses on valuing a subset of ecosystem goods and services related to coral reefs in the Caribbean. It is designed to provide consistent and replicable results, allowing comparisons over time and among areas. The methodology does not attempt to provide the total economic value of coral reefs. Some of the values that are not captured include poverty reduction and the nutritional benefits of subsistence fishing; social, spiritual, religious or inspirational values of coral reefs; pharmaceutical or bioprospecting values; existence values; and the value of coral and sand as building materials. Overall, the values from this valuation methodology should be considered a lower bound estimate of the "true" value of these reefs.

Some of the main challenges for implementing the valuation methodology are:

a) Distinguishing reef-related visitors from non-reef-related visitors in support of determining which expenditures should be attributed to the presence of coral reefs;
b) Estimating the use of coralline beaches and reefs for informal recreation and fishing by local residents;
c) Estimating the catch of coral reef-associated fish species, as data are often limited or unreliable. In addition, the methodology focuses on current economic benefits, but does not take into account whether fishing is occurring at sustainable levels.
d) Validating the shoreline protection model, as data on wave-induced storm damage are limited; and
e) Evaluating visitor responses to marginal changes in reef quality, as data are rarely available. This is a potentially important factor for assessing future scenarios of reef use.

An additional limitation of the methodology is the focus on current financial value and economic impact, rather than on underlying economic value and future "potential value." This is most important in evaluating tourism value, which emphasizes current expenditures by tourists, giving credit (value) only to areas where tourism is developed. This focus on financial analysis and economic impact consequently undervalues those coral reefs that may have significant non-use values but limited financial or economic impact.

Summary of Coral Reef Valuation Results

	Tobago	**St Lucia**
Island GDP (for reference)	US$286 million (2006)	US$825 million (2005)
Coral Reef-associated Tourism and Recreation	($US million)	($US million)
Percent of visitors classified as visiting at least in part due to the coral reef	*40%*	*25%*
Total Direct Impact	**43.5**	**91.6**
Indirect economic impact	58 – 86 [a]	68 – 102
Total Impact (Direct and Indirect)	**$101 – 130**	**$160 – 194**
Other Values		
Consumer Surplus	1.0	2.3
Local Use	13 – 44	52 – 109
Coral Reef-associated Fisheries		
Total Direct Impact	**.7 – 1.1**	**.4 – .7**
Indirect economic impact	.1 –.2	.1 –.2
Total Impact (Direct and Indirect)	**US$.8 – 1.3 million**	**US$.5 –.8 million**
Local Use Value	Estimate not reliable; probably small.	.2 – .8
Shoreline Protection by Coral Reefs		
Land Area (sq km)	300 km^2	610 km^2
Vulnerable Land Area (sq km)	6%	4%
Vulnerable Area Protected by reefs (sq km)	3%	1.50%
Potentially Avoided Damages (annual value - 2007)	**US $18 – 33 million**	**US $28 – 50 million**

[a] Indirect economic impacts are a benefit to both Trinidad and Tobago.

Conclusions

The importance of coral reefs to local economies is frequently underappreciated by government officials, coastal developers, and the wider population A clear presentation of the magnitude of these impacts (the economic values derived from coral reefs) can provide support for appropriate policy, investment, and development decisions. Decisions on land use, including the removal of mangroves and other wetlands, development along the coast, construction of roads, and management of agriculture can all have significant negative effects on coastal water quality and coral reef health. Managing the pressures from fisheries and tourism is also a delicate process with important consequences for reef condition.

In many areas, coastal and marine management policies and regulations exist to limit pressure on coastal ecosystems, including coral reefs. But these regulations are often not enforced—even in Marine Protected Areas—often due to a lack of resources for enforcement (staff, boats, fuel, etc.). At the heart of many of these management concerns is the problem of assessing trade-offs. Investing in better enforcement, capping tourist numbers, or limiting coastal development, for example, all have economic consequences for individuals and for the economy. However, longer-term revenue streams and societal benefits from the goods and services provided by healthier reefs are often not included in the equation. Adding these factors to the decision-making process is an important step toward better resource management.

This study includes a policy application focused on the Buccoo Reef Marine Park in southwest Tobago, which explores three management options for reducing pollutant discharge and one focused on reducing overfishing in and around the Bon Accord Lagoon. The study compares the long-term economic benefits of a healthy reef with the approximate costs of these interventions, finding that there is a strong economic argument for investment in improved water quality in the lagoon and more active management of the Buccoo Reef.

In St. Lucia, valuation results will be useful for guiding future development planning, including evaluating potential impacts on coral reef goods and services from proposed Marina developments along the central west and east coasts of the island, and resort developments elsewhere along the coast. Economic valuation can also be used to help weigh the benefits of investing in reef health through improved sewage treatment, enhanced management of Soufriere Marine Management Area (SMMA), and other management options.

On both islands, valuation results can help decision-makers to get a sense of the magnitude of some of the important services provided by the reef, and to do a better job of weighing these services against the benefits of alternative policy options. In all cases, additional considerations—including distributional effects (who will benefit) and the importance of cultural, bequest, and other values not counted here—need to be acknowledged in order to make well-informed decisions on coastal and marine management.

Introduction: Coral reefs are precious, but threatened

Coral reefs provide a wide range of commercial and non-commercial benefits to human society. Many of these benefits, or "ecosystem goods and services," are of high value and critical importance to local and national economies in the Caribbean. Coral reefs provide habitat for commercially valuable fish, are a magnet for coastal recreation, and reduce the impact of waves on the shore, slowing erosion and beach loss, and lessening damages from storms. In addition, coral reefs harbor vast biodiversity with unknown potential uses, and spark the imagination of millions of people who have no regular contact with them at all. Despite these varied and high value benefits, the extent and health of Caribbean coral reefs have declined dramatically in recent decades, and continue to be threatened by human activities.

Coral Reef Benefits

Coral reefs provide important habitat for fisheries, which are critical for nutrition and food security within the Caribbean region. An estimated 200,000 people in the region work as full- or part-time fishers, and an additional 100,000 are employed in fish processing and marketing (CARSEA Assessment 2007:23). Coral reefs, teeming with a diversity of colorful species, are a magnet for millions of visitors to the region each year. Tourism is the single largest economic sector for the region, accounting for more than 15% of total employment and 13% of GDP (CARSEA Assessment 2007:30).

Coral reefs also perform important physical functions. Limestone from dead coral builds the beautiful white sand beaches that draw many tourists to the region. Reefs also act as a barrier, reducing wave energy, and protecting the shoreline from erosion and storm damage. In total, coral reefs provide protection for an estimated 20 percent of the region's coastline (Burke and Maidens 2004:58). This protection creates calm waters and lagoons along many stretches of shoreline, allowing highly productive sea grass and mangrove habitat to form. Mangroves and sea grass, in turn, provide important nursery habitat for many species and filter nutrients entering coastal waters, thereby maintaining the low-nutrient water conditions required by corals. These are highly interdependent and valuable habitats.

In addition to these goods and services, coral reefs provide benefits that are more difficult to quantify; they are of cultural significance to many coastal societies, have pharmaceutical potential, and—many would argue—are valuable in their own right as beautiful ecosystems independent of human use.

Threats to Coral Reefs

Despite their importance and the many benefits they provide, most Caribbean coral reefs are threatened. An estimated 70% are threatened by human activities including overfishing, coastal development and runoff from land (Burke and Maidens 2004). Water quality changes threaten many reefs, due to removal of mangrove and sea grass habitat, siltation from construction or dredging, runoff from roads and agriculture, and sewage discharge. Fertilizer- and pesticide-laden runoff from many large rivers in the region is transported great distances, contributing to the increased incidence of coral decline across the region. Widespread overfishing of reefs has removed many of the herbivorous fish that keep algae in check, creating conditions which favor algae over coral. Finally, climate change is beginning to pose an overarching threat to coral reefs. Gradually warming seas contributed to widespread coral bleaching across the region in 1998-99 and 2005.[1] Many corals have recovered from these bleaching events, while others have not. Although battering and damage from storms are an important part of regeneration for many coral reefs, increasingly intense storms in recent years, coupled with bleaching and other pressures

[1] Coral bleaching refers to the loss of the colorful, symbiotic algae as a result of stress, such as thermal stress. Without the algae, the coral limestone skeleton appears white. These algae provide an important part of coral nutrition through photosynthesis. If coral are not able to regain or "recolonize" the symbiotic algae, they will die.

have damaged many reefs, hindering their recovery from other threats. Ocean acidification caused by rising atmospheric carbon dioxide levels may hinder coral growth and regeneration going forward (Orr et al. 2005). These compound threats have resulted in widespread degradation of coral reefs, and an estimated decline in live coral cover of over fifty percent between 1982 and 2002.[2]

Economic and Social Value of Coral Reefs

In addition to the ecological consequences of coral reef loss, the decline of these ecosystems directly affects the people who depend upon them. As a result, measuring the economic and social impacts of ecosystem decline is gaining popularity as a relevant tool for decision-makers. The Millennium Ecosystem Assessment (MA) made an effort to define and assess the global status of the ecosystem goods and services upon which humans rely. The MA framework identifies four categories of services provided by ecosystems: provisioning services, regulating services, cultural services and supporting services (see Figure 1).

Figure 1 – Goods and Services provided by coral reefs

Provisioning Services *-products obtained from ecosystems-* food – fish and shellfish genetic resources natural medicines and pharmaceuticals ornamental resources building materials	**Regulating Services** *-Benefits obtained from regulation of ecosystem processes-* erosion control storm protection	**Cultural Services** *-Nonmaterial benefits obtained from ecosystems-* spiritual and religious values knowledge systems / educational values inspiration aesthetic values social traditions sense of place recreation and ecotourism
Supporting Services *- Natural processes that maintain the other services* - sand formation - primary production		

Source: adapted from MA 2003

Identifying the goods and services provided by ecosystems is important as a first step in good ecosystem management. Equally important is determining how to quantify ecosystem services in a way that is meaningful for decision-makers. One way of putting these benefits into a policy context is to translate them into monetary units; "dollar" values are easily understood and readily comparable. This approach, known as "economic valuation," is discussed in greater detail in the following sections. A key goal of this paper is the development of a simple and consistent valuation methodology, the application of which would result in more comparable estimates of value for different places and different time periods.

[2] Gardner *et al*. 2003 suggest that average live coral cover has declined from between 25 and 30 percent of area to about 10 percent.

Application of the methodology can also help to guide management decisions through assessments of potential changes in value under different scenarios of coastal management.

Section 1 provides some background on economic valuation of ecosystems and lays out the context for this study. Section 2 presents the coral reef valuation method developed and applied under this study. Sections 3-6 present the results of the economic valuation for Tobago and St. Lucia—for tourism and recreation, fisheries, shoreline protection, and finally, a summary of the three. Section 7 explores the subject of policy applications of economic valuation of coral reefs. Section 8 offers some conclusions and a description of our plans for extension of the methodology.

1. Valuing Ecosystems

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. For example, in deciding whether to allow land clearing for agricultural development, decision-makers rarely take into account a resulting increase in sedimentation on coral reefs, which can lead to biodiversity loss and impact the livelihoods of coastal communities. When policy-makers and environmental agencies underappreciate the benefits coral reefs provide or underestimate the importance of these ecosystems to the economy of Caribbean islands, coastal monitoring and the enforcement of pollution laws are often neglected.

The economic valuation of ecosystem goods and services is an approach that has gained popularity because it offers a useful means of inserting the concept of ecosystem value into policy discussions and decision-making. By quantifying—even imperfectly—the value of an array of 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 many rapidly developing coastal areas around the Caribbean.

Economic valuation has a wide range of policy applications. Some examples related to coral reefs include:

- estimating the economic value coral reefs contribute to an island’s economy (this can support arguments for increased investment in maintaining coastal water quality or managing coastal development, for example);
- estimating the economic value of coral reef goods and services under different development scenarios, such as with different residential and tourist developments, different types of sewage treatment, or different sediment control methods;
- 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 (many MPAs do not enforce restrictions on fisheries, for example, even though this might make long-term economic sense.);
- identifying sources of financial support and setting user fees for MPAs and other coastal areas (user fees can influence visitation rates, making this an effective management tool);
- estimating coral reef value to underpin fines or other forms of compensation for coral reef damage from boat 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).

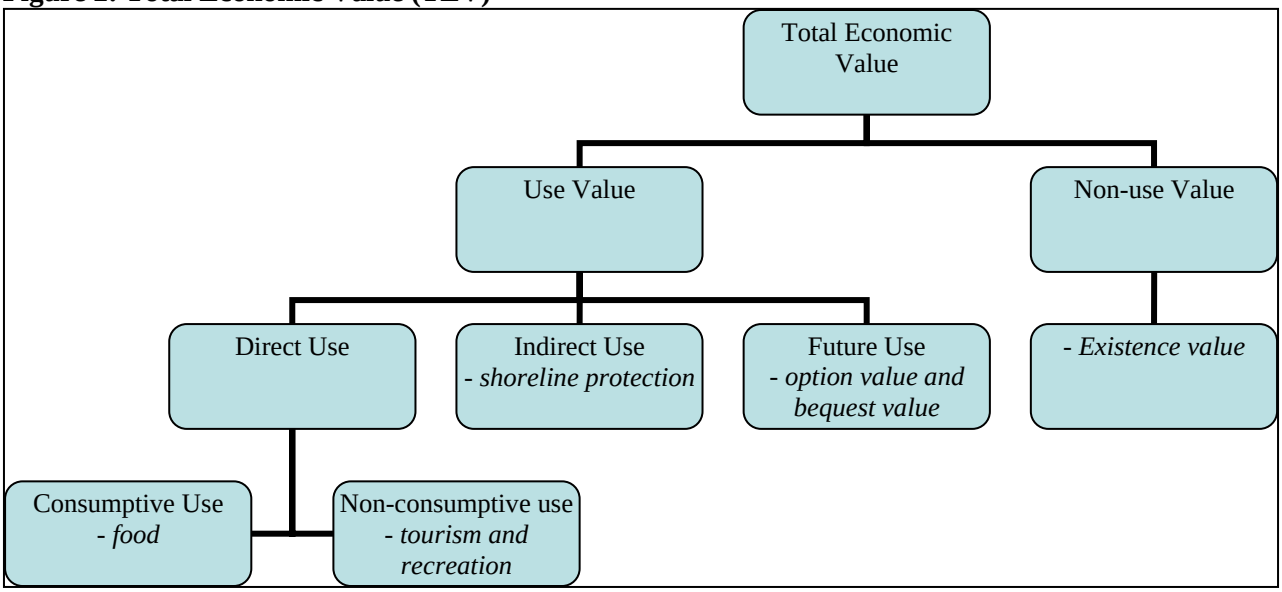
One example where economic valuation has been successfully applied to a coral reef policy decision is in Bonaire, Netherlands Antilles. The willingness to pay (WTP) expressed by scuba divers in Bonaire was used to support a fee of US$10 per diver in the Bonaire Marine Park (Dixon et al. 1993). This fee was later increased to US$25 per diver and US$10 per visitor for other users. The fee 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.

Diversity and Complexity of Economic Valuation Methods

Economic valuation assesses a resource in terms of its value to humans. The commonly used Total Economic Value (TEV) framework (see Figure 2) 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 timber and food—and non-consumptive uses, such as tourism and recreation. *Indirect use* values include ecosystem services such as water filtration and shoreline protection. *Option values* estimate the value of preserving the use of ecosystem goods and services for the future, including "bequest value," where the value is for future generations. *Non-use values* typically refer to *existence* value; i.e., the value humans place on the knowledge that a resource exists, even if they never visit or use it. Non-use and option values are frequently the most controversial elements of TEV; they are the most difficult to quantitatively measure, and have the greatest uncertainty attached to them.

Economic valuation studies may attempt to quantify all or some of the use and non-use values of a resource. Although valuation is a useful and potentially powerful decision-making tool, users should always bear in mind the high degree of uncertainty in most economic valuation studies, and should pay attention to the methods used, assumptions made and the caveats attached to their results.

Figure 2: Total Economic Value (TEV)



Adapted from Pagiola et al, 2005.

As ecosystem goods and services are often not traded in conventional markets, a variety of approaches have been developed to estimate their value. Box 1 summarizes some of the economic valuation methods that have been used to quantify the benefits of ecosystem services.

Box 1. Economic Valuation Methods

Methods based directly on the observed behavior of humans

The **effect on productivity** method uses the change in a provided good or service that results from a change in the environmental resource, such as assessing whether fish productivity will decrease after damage to or destruction of a coral reef. One challenge with this method is determining and modeling the relationship between the damage to an environmental resource and its corresponding impact on the production of the specified good or service.

Financial analysis uses observed market prices to analyze the economic activity generated by use of an ecosystem good or service. This method focuses on current financial activities, revenues, costs and financial flows in the economy from market-based uses of the reef (such as diving and snorkeling).

Methods based indirectly on the observed behavior of humans (Revealed Preference)

The hedonic pricing method is used to estimate economic values for ecosystem or environmental services that directly affect market prices. It is most commonly used to examine variations in housing prices that reflect the value of local environmental attributes. Environmental attributes can be included in an analysis to assess their impact on the market price of the specified commodity in that area. For example, hedonic pricing has been used to assess the influence of an ocean view on land and housing prices. One challenge of this approach is to ensure that all relevant attributes are included in the analysis; it often has substantial data requirements;

The **travel cost** method uses data about visitation to a site or set of sites to construct a demand curve for an environmental resource, e.g., a beach. This method is primarily used to ascertain the recreational use value of a resource based on its specific characteristics.

Replacement cost methods value an environmental service by determining the cost of manmade infrastructure required to replace the service provided by the ecosystem in its current state. It has been frequently used to assess values such as nutrient filtering by wetlands and shoreline protection by coral reefs. This method relies on the assumption that society would actually pay to replace the good or service that is damaged or destroyed and requires accurate estimates of the engineered solution for the location in question.

Avoided damages methods look at the costs that are avoided because a given ecosystem good or service is present. It is often used to estimate the damages avoided by having protection against natural disasters such as hurricanes and floods. One challenge with this method is determining the value of threatened areas as well as estimating the damages under different storm scenarios and different levels of protection.

Methods based on the hypothetical behavior of humans (Stated Preference)

The **contingent valuation** (CV) method attempts to place a value on ecosystem goods or services by

directly asking people to state their willingness-to-pay (WTP) or willingness-to-accept (WTA) for a specific set of ecosystem goods and services or for changes in those goods and services. This method is useful for assessing non-use values such as the value of simply knowing that a coral reef exists. This method is vulnerable to many sources of bias and requires careful survey design. CV studies can be expensive to carry out, and require personnel with survey and analytical training. They vary widely in quality and design, and can be difficult to compare or replicate. Appropriately designed CV studies, however, can be useful in providing a defensible estimate of the value of natural resources when faced with development or damage assessment decisions.

Other

Benefits transfer methods involve applying results obtained in existing studies to different areas (e.g., estimating the value of one beach using the value calculated for a different beach of a similar size and type in a different area). Some benefits transfer approaches may use an economic model developed in one location to estimate the value of a resource in another, new location; characteristics of the new location can then be inserted in the previously developed model, providing a potential advantage over simply transferring the value estimates between locations. Because of the difficulty of accurately assessing the many factors affecting the values of an ecosystem good or service that may vary between sites, this method should be used with caution.

(Adapted from Emerton and Bos, 2004; Pagiola et al., 2005; MA 2003; updated at WRI, 2008.)

Valuing Coral Reefs in the Caribbean

Economic valuation studies have been conducted for a number of coral reefs in the Caribbean. Some studies include:

- Pennekamp Coral Reef State Park in Florida—the tourism and recreation value of the park was valued at between $285 to $425 per person per day using the travel cost method (Leeworthy, 1991).
- Negril Marine Park, Jamaica—the recreational use value of the park was estimated at US$5.3 million per year using a financial analysis and contingent valuation (Cesar et al. 2003).
- Virgin Islands Marine Park—the direct contribution of the park to GDP through tourism and recreation was estimated at $45 million per year, with an additional $25 million in indirect impacts to the economy (Israel, 2004).

These and other studies use a variety of methods and assess a range of ecosystem goods and services, making the results difficult to compare. In addition, extrapolating these results to other parts of the Caribbean is difficult because of the lack of consistency between studies' methods. This highlights the need for a consistent and replicable valuation approach that can be applied on a wider regional basis. A consistent method allows for more comparable estimates for different places and different times; it also enables researchers or decision-makers to run scenarios to assess the impact of different policy and management options on the future value of the reef.

Developing a Coral Reef Economic Valuation Methodology

As part of the *Reefs at Risk* series, the World Resources Institute (WRI) used spatial analysis in a geographic information system (GIS) to identify the location and severity of critical threats to coral reefs. For the Caribbean region, WRI supplemented its mapping work with a preliminary attempt to estimate the economic losses that could result from continuing degradation of Caribbean reefs. The *Reefs at Risk in the*

Caribbean report estimated that the region's coral reefs provide ecosystem goods and services with an annual net economic value between US$3.1 billion and US$4.6 billion in 2000. This total includes the values attributed to fisheries, dive tourism, and shoreline protection services (Burke and Maidens 2004:58). These figures should be regarded as a lower-bound (conservative) estimate of the value of coral reefs, as this is only a subset of coral reef-associated goods and services and does not reflect a total economic valuation (TEV). Table 1 illustrates the estimates of potential future decline in these values from the continued degradation of coral reefs.

Table 1 - Economic Losses from Coral Reef Degradation in the Wider Caribbean

Ecosystem Good or Service	**Estimated Annual Benefit (2000)**	**Estimated Future Annual Losses**
Fisheries	US$ 312 million	Fisheries productivity could decline an estimated 30-45 percent by 2015 with associated loss of net annual benefits valued at US$ 100-140 million (in constant-dollar terms, standardized to 2000).
Dive Tourism	US$ 2.1 billion	Growth of Caribbean dive tourism will continue, but the growth rate by 2015 could be 2-5 percent lower as a result of coral reef degradation. Region-wide losses of net annual benefits are valued at an estimated US$ 100-300 million (in constant-dollar terms, standardized to 2000).
Shoreline Protection	US$ 0.7 – 2.2 billion	Over 15,000 km of shoreline could experience a 10-20 percent reduction in shoreline protection by 2050 as a result of coral reef degradation. The estimated loss in net annual benefits is estimated at US$ 140-420 million (in constant-dollar terms, standardized to 2000).
Total	**US$ 3.1 – 4.6 billion**	**US$ 350 – 870 million**

(Burke and Maidens 2004:58)

These regional results have been useful for informing discussions around the decline of reefs in the Caribbean, but were not of sufficient resolution to inform decision-making at a national level. In 2005, WRI initiated a project to develop and implement a national scale economic valuation methodology. The premise was that the method would be simple to use, replicable, and could be applied using existing available data, rather than relying on expensive and often subjective survey techniques. The methodology was designed and piloted in two locations—St. Lucia and Tobago in the Eastern Caribbean (see Box 2). It is being further tested in other sites to assess its appropriateness for other areas in the Caribbean. It is also anticipated that the valuation will be repeated at routine intervals in some of these locations to assess changes in reef values over time, and using different assumptions in order to explore different policy scenarios and development options.

Box 2. Choice of Pilot Study Locations

St. Lucia and Tobago were the two locations chosen for the pilot economic valuation studies. They were selected because the inherent differences between two sites would be useful in developing a robust valuation methodology. The nature of the landforms and coral reefs differ substantially between the two countries—St. Lucia is volcanic in origin and has many fringing reefs close to the shore, while Tobago is more varied. Tobago's geography includes a volcanic range, a lowland which is coralline in origin, and an extensive reef and lagoon system at the Buccoo Reef.

The economies of both countries depend heavily on tourism; in 2005, tourism contributed about 47 percent of GDP in St. Lucia, and about 46 percent of GDP in Tobago (WTTC 2007; WTTC 2005).

Both countries have a wide variety of tourists, with Tobago having a higher percentage of visitors focused on ecotourism and coral reef recreation. The management of marine protected areas differs substantially between the two sites. The Soufriere Marine Management Area (SMMA) in St. Lucia is an actively managed MPA. It has a good data collection system, and is self-financed by user fees. The Buccoo Reef Marine Park (BRMP) in Tobago, by contrast, is more of a "paper park" with little enforcement of regulations; it collects no user fees, and has a management committee that lacks an operating budget.

There are also significant differences in data availability for the physical environment, fisheries, and tourism. These differences helped develop an economic valuation methodology that was flexible and applicable beyond these two pilot locations.

Map 1 – Pilot Study Locations

To complement the economic valuation methodology, a Valuation Tool was developed to guide the implementation of the methodology and to aid the evaluation of different policy and development scenarios. Broad partnerships were developed in both countries to help develop and review the methodology, to implement the coral reef valuations, and to assess the policy applications (see acknowledgment section for further details).

Estimating the economic value of coral reefs to local economies is neither easy nor straightforward. Rather than attempting to assess the Total Economic Value (TEV) of coral reefs, this project focuses on assessing the key direct and indirect uses that could be most reliably valued. By omitting non-use values, this approach undervalues these resources. However, it also avoids the use of complex and expensive surveys that might make replication difficult and are often subject to high levels of uncertainty and skepticism.

The methodology focuses on three key ecosystem goods and services: coral reef-associated fisheries (a provisioning service), reef-associated tourism and recreation (a cultural service), and the shoreline protection provided by coral reefs (a regulating service). The valuation examines the economy-wide contributions of coral reefs by looking at the direct and indirect financial flows that result from the use of these goods and services. Among the use and non-use values that are not included are research and option values (such as pharmaceutical potential), religious and spiritual values, bequest values (knowing that coral reefs will be available to future generations), and existence values (the satisfaction derived from knowing that coral reefs exist). The methodology does include the option of appending the "consumer surplus" (satisfaction gained above and beyond the price paid for the experience) of recreational reef use to the results. Consumer surplus captures some of the non-use values listed above, but is not included in the final estimate of direct and indirect economic impact because it is not a current financial flow within the economy.

2. Caribbean Coral Reef Valuation Methodology

The Caribbean coral reef valuation methodology provides a simple, consistent and replicable method for estimating the economic value of three coral reef ecosystem goods and services. The methodology focuses on coral reef-related tourism and recreation, coral reef-associated fisheries, and shoreline protection services. It uses a tiered approach, allowing results to be calculated at different levels of detail depending upon the data available.

This section outlines the general approach used to estimate the value of the three target goods and services. More detail on the specific application of the valuation methodology and the relevant data sources can be found in Section 3 and Appendices 1 and 2.

A. Coral Reef-Related Tourism and Recreation

The value of coral reef-associated tourism is assessed using a financial analysis method. This method involves calculating the gross revenue of tourism and recreation, and subtracting operating costs to arrive at net revenue. Labor costs, service charges, and taxes are subtracted where applicable, but are later added back when estimating direct economic impact, as these expenses are likely to remain in the local economy.[3] Hence, the direct economic impact is equivalent to gross revenue – non-labor operating costs. A multiplier is used to estimate the wider economic impacts of visitor expenditure. Where appropriate, the value of individual tourism activities is prorated by the number of visitors coming to the area because of the coral reefs ("reef visitation") in order to derive the reef-related tourism and recreation value.[4]

This study also attempts a rough estimate of some of the value that local residents derive from using coralline beaches and reefs. This "local use" value is not a part of the formal economy, but is important in many coastal areas.

The reef-related tourism and recreation activities are:

1. Accommodation
Identifying the "reef-related" share of accommodation expenditures requires compiling standard information on hotel room rates, occupancy rates, operating costs, taxes and service charges, as well as determining whether a guest's choice of destination is, in part, due to the area's coral reefs. Depending upon data availability, information can be compiled by individual hotel, by accommodation type (hotel, guest house, etc.), or based on average values for the country, region, or study area. For each, an estimate of the "percent of visitors using the reef" is specified, which is used to prorate accommodation credited to the reef. In addition, foreign versus domestic ownership of hotels can be used to estimate the amount of net revenue that is likely to remain in the country.

[3] This study considers wages, taxes and services charges to be benefits to the economy, as these primarily stay in the local economy and result in additional expenditures. These expenses are deducted from the gross revenue of reef-related businesses, but add them back into our total as "pass throughs" to the economy. Non-labor operating costs are also deducted from gross revenue. It was assumed that many of these non-labor purchases would come from outside of the country. Non-labor costs are not counted as benefits to the local economy, resulting in a conservative estimate of economic impact.

[4] In each island, local information is used to estimate the percentage of visitors coming to the destination at least in part due to coral reefs. For example, using an exit survey and expert opinion, the study estimates that 40 percent of visitors to Tobago spend part of their time visiting the reef. All of the spending by these tourists during their visit is counted in the valuation—much of it as 'miscellaneous expenditures'—with the judgment that many of these tourists would not have come to Tobago if the reef and coralline beaches were not present. More refined estimates of reef use were not available, but the 40 percent figure is likely a conservative estimate of reef and beach visitation overall.

2. Reef Recreation
Reef recreation includes international and domestic visitor use of coral reefs for snorkeling, diving and sport fishing. The value of reef-related activities is estimated by totaling gross revenues and subtracting the costs. This can be estimated based on company-level information, or based on the price of specific activities (dive or snorkel trips, etc.) coupled with the number or percent of visitors who engage in these activities. An additional value, consumer surplus—a measure of the additional satisfaction derived by visitors beyond the price they paid for the experience—can be derived for reef recreation activities using estimates from field surveys or using benefits transfer.

3. Marine Protected Areas
MPAs are an important draw for tourists as well as an important tool for managing coastal resources and protecting coral reefs. MPAs are worth considerably more than the direct income they earn from tourist fees and visitation. If well managed, MPAs should help increase fish stocks, reduce stress on reefs, and improve the country's reputation as a dive and snorkel destination. In places where MPAs have good reef visitation data, these can be used as a starting point for estimating reef use for the country. This study does not attempt to isolate the value of MPAs, but captures some of these values in the analysis of economic benefits of reefs for each island. Revenue from visitor fees and other relevant fees (mooring, diving, etc.) are counted as benefits, and the non-labor costs of operating the parks are subtracted from the total. The fee revenues do not in any way represent the value of the parks, but are important to include as part of the overall income from reef-based tourism.

4. Additional Miscellaneous Expenditures
In addition to accommodation and recreational activities, visitors also spend money on restaurants, local transportation, shopping, etc. as part of their visit. These expenditures have been estimated using general tourism industry data on visitor expenditure. This expenditure is prorated by reef visitation.

5. Economy-wide Effects
The values described above are considered direct economic impacts of reef-related tourism and recreation. Expenditures by tourists have additional economic benefits beyond these direct effects. For example, food purchased by visitors may be sourced from local farmers; fuel used for transportation is purchased from local fuel distributors, etc. These additional "indirect" or "secondary" economic impacts are estimated using a tourism multiplier. The multiplier attempts to capture the overall impact of direct tourist expenditure on the economy. The size of the multiplier is influenced by the portion of goods and services required by tourism operators that is produced domestically, such as linen, beverages, produce, dive equipment, construction materials, etc.[5] A larger proportion of imported goods, all other things being equal, will generally lead to a smaller tourism multiplier. Because of the difficulty in finding appropriate multipliers to transfer between locations and the high level of uncertainty inherent to estimating economy-wide effects, the results of direct and indirect economic impacts are presented separately in this study.

6. Local Use
Use of coralline beaches and reef recreation activities, such as snorkeling, by the local population are important values that may not be captured in the "formal economy." This value can be estimated based on the typical number and duration of visits by locals to coralline beaches or reefs, coupled with average local wage rates (as a proxy for the value of leisure time). This value can be estimated through either formal or informal surveys. This is one of two parts of the valuation methodology where surveys may be required to obtain the necessary information. There is little information in the literature or that is routinely collected that reflects the local use of coral reefs.

[5] A tourism multiplier will always be greater than 1.0, as the first 1.0 represents the direct expenditures themselves. Hence, a multiplier of 1.6 represents 60 cents of additional impact for every $1 in direct tourist expenditure.

Challenges and Limitations

A key challenge for valuing reef-related tourism and recreation is distinguishing those expenditures that can be attributed to the presence of coral reefs. In estimating accommodation value, for example, the study only counts visitors who come at least in part because of the presence of the coral reefs, including coralline beaches (i.e., these tourists would have selected other travel destinations if not for the extent and quality of the coral reefs and coralline beaches present). Some approaches that can be used to estimate reef visitation are:

- MPA visitation rates
- Tourist profiles ("sun and sand," "eco-tourists" and "dive tourists")
- Visitor exit surveys

In calculating economic impact, the methodology deducts non-labor operating costs from the total revenues of reef-related industries. These costs can be difficult to estimate, as this data is rarely publicly available, and businesses may be reluctant to release it. Costs can be estimated using expert opinion, regional norms, or industry-wide statistical data.

B. Coral Reef Associated Fisheries

The value of coral reef-associated fisheries is estimated using a financial analysis approach. This method involves calculating the gross revenue of commercial fishing and processing activities, and subtracting operating costs to arrive at net revenue. Labor costs and taxes are subtracted where applicable, but are later added back when estimating economic impact, as these expenses are likely to remain in the local economy. In economic impact assessments, a multiplier is used to estimate the wider economic benefits associated with the fishing industry (the ripple effects on the economy of purchases made on fishery products). The value of local (non-commercial) fishing for consumption or for pleasure is also assessed.

The valuation focuses on fisheries that depend directly on a coral reef for at least a portion of their life-cycle, including snappers (Lutjanidae), groupers (Serranidae), parrotfish (Scaridae), squirrelfish (Holocentridae), lobsters (*Panularius argus*), and sea urchins (Echinoidea). Positive or negative changes in coral reef health will impact fisheries productivity and total fisheries revenue as a result.

The activities included in the total reef-associated fisheries value are:

1. Commercial Fisheries
The revenue from commercial fisheries is based on reef-associated fish catch and sale price, by species. Annual catch can be estimated from data by landing site, based on a sample of fishermen, or using estimates of fisheries productivity per unit of reef area. Local expert opinion is used to estimate both labor and non-labor costs as a percent of gross revenue.

2. Fish Processing Industries
The value added from formal fish processing is estimated using the sale price minus purchase price of fish and the quantity purchased by fish processers. Operating costs are then subtracted to arrive at a net value. Informal on-site cleaning is estimated based on earnings associated with cleaning at landing sites. Specific data on processing volumes and revenue are often not available, so this value may have to be approximated based on available information and expert knowledge.

3. Local Fishing
The values from local fishing for consumption and pleasure are calculated separately using estimates of the percent of the population engaging in these activities, the time spent fishing, and the market prices of

reef fish. The value of leisure time, based on average local wages, is used to estimate the enjoyment value from local fishing. This is the second part of the valuation methodology where surveys may be necessary to obtain the necessary information. There is little information in the literature or that is routinely collected that reflects local informal fishing activities.

Challenges and Limitations

The valuation methodology attempts to capture the direct and indirect economic benefits that result from coral-reef associated fisheries. It does not fully capture the social and cultural values associated with fishing (including social relations, tradition, and employment), nor the food security benefits that coral reefs provide. Valuing these social benefits would require surveys which are not in keeping with the objective of this project, which is to develop a methodology that is easily implemented from existing data.

The methodology focuses on current economic benefits, but does not take into account whether fishing is occurring at sustainable levels. If reefs are being overfished, the value of reef-associated fisheries is likely to decline in the future. This situation can be examined through scenarios of future conditions, looking at changes in the fish productivity level of the reef and the resulting impacts on revenues.

The availability and reliability of data on commercial reef-associated fisheries will vary by country. In the absence of data on landings, commercial fisheries value will need to be approximated based on fishing effort or estimated productivity of the reef. Few countries will have data on local (non-commercial) fisheries. Formal or informal surveys are needed to assess the value of this sector.

C. Shoreline Protection Services

Evaluation of the shoreline protection services provided by coral reefs requires an understanding of the protection afforded by different types of coral reefs in different coastal settings, under different storm scenarios, coupled with information on property values in areas receiving at least some protection from coral reefs. A modified “avoided damages” approach is used to estimate the value of this service along coastal segments protected by coral reefs. This involves estimating the likely damage (and associated economic losses) to a coastal area from a given storm event, both with and without the reef present. The difference is the “avoided damages.” The approach developed by WRI and IMA has a GIS analytical modeling component as well as an economic component. This method was selected because reliable estimates of the cost of replacement by manmade structures are limited, making estimation of value difficult. The avoided damages approach has the additional benefit of producing analytical results which support informed coastal planning and development.

Essential elements of understanding the damages avoided due to the presence of coral reefs include:

1. understanding the storm regime for an area (expected storm frequency, intensity, and associated storm surge and wave height), as well as the historic damage caused by these storms (particularly due to wave damage);
2. identifying the land areas considered “vulnerable” to wave-induced erosion or storm damage (based on elevation and coastal proximity);
3. identifying coastal segments which are protected by coral reefs;
4. evaluating the overall stability of the shoreline as well as the share of coastal protection provided by coral reefs;
5. estimating the property values (land and structures) of land areas identified as both vulnerable and protected by coral reefs (the estimate should also consider the revenues generated by businesses in these areas);

6. combining these individual elements to estimate the reduction in potential damage attributable to the coral reefs.

1. Storm Regime

Information on tropical storms and hurricanes is the most relevant aspect of the storm regime, as these are typically the most damaging storm events. The typical wave heights associated with storms is important for predicting likely damage, and determining which lands are most vulnerable to wave-induced erosion or storm damage. Historic information on erosion and property damage from particular storms is also useful for validating the predictions of future losses and should be collected where possible. This valuation focuses on storms likely to occur within a 25 year period for a given area (i.e., a 1 in 25 year event as well as lesser storms).

2. Vulnerable Lands

The elevation and slope of coastal land influences how vulnerable an area might be to damage from wave action. Higher elevation and greater distance from the shore both lessen the potential damage from waves and storm surges. The definition of vulnerable lands is based on the sum of the average storm surge and wave heights associated with a 25 year storm event along a given coastline.[6] For the development of this methodology for St. Lucia and Tobago, "vulnerable lands" were defined as any areas that are 5m or less in elevation within 1 km of the coast, and all areas immediately adjacent to the coast (within 25 m resolution coastal grid cells).

3. Reef Protected Shorelines

Coral reef occurrence, type and distance from shore depend on biological and physical characteristics of the area. Much less than half of the Caribbean coastline is protected by coral reefs (Burke and Maidens 2004:57). For this valuation, the shoreline segments "protected" by coral reefs were defined as those within 100m of a fringing reef, or enclosed by a barrier reef or a lagoon-forming fringing reef, such as the Buccoo Reef (see Map 5.)

4. Coastal Protection and Coral Reefs

a) Shoreline Stability (Relative Total Coastal Protection). A coastal protection index that integrated ten physical characteristics to estimate the relative resistance of each coastal segment to wave-induced erosion and damage from storms was developed by the Institute of Marine Affairs (IMA) in Trinidad. The index could also be used to evaluate the role coral reefs (or mangroves) play in reducing vulnerability to erosion and storm damage. The physical characteristics included in the coastal protection index were coastal geomorphology (limestone cliff, beach, etc.); coastal geology (igneous, metamorphic, etc.); coastal exposure (protected by headland, seawall, or riprap, or exposed); wave energy (typical maximum wave height); storm frequency (frequency of tropical storms and hurricanes); coral reef characteristics (reef type, continuity, and distance from shore); coastal vegetation (mangroves, wetlands, etc.); coastal elevation (m); coastal slope (percent); and the presence of erosive anthropogenic activities, such as sand mining.[7] These physical characteristics were converted to a value between 0 and 4 (see Table 2) and then averaged aggregated to produce a single index value for each shoreline segment.

The relative total coastal protection (RTCP) for a particular coastal segment is the average value for the ten factors combined. This integration of individual factors is done in a geographic information system

[6] Predicted wave and storm surge data are available from: Organization of American States (OAS). 2002. *Atlas of Probable Storm Effects in the Caribbean Sea.* Online at: http://www.oas.org/CDMP/document/reglstrm/index.htm.

[7] Technical note: The classification scheme has been modified slightly to allow application in the two pilot areas - St. Lucia and Tobago. The full scheme involves integration of 10 factors, but can be adjusted if data for all factors are not available. A minimum of five factors—including elevation and coral reef locations—is recommended for results to be meaningful. If data are incomplete for a factor, an average or most likely value can be substituted.

(GIS). The calculation can be repeated with the coral reef variable set to "no reef" to examine the change in RTCP due to the reef.

b) The Role of Coral Reefs (Relative Reef Contribution). Several studies suggest that the wave attenuation (reduction in force) from coral reefs is 75 – 95% of wave energy (Brander et al. 2004; Roberts et al. 1992). Coral reefs play a more significant role in mitigating small to moderate waves than they do for the large waves and storm surges associated with Category 3 and higher hurricanes. Mangroves play an important role in coastal defense for these larger storm events.

There are a number of considerations in estimating the contribution of reefs to shoreline protection. If one simply calculates the percentage of RTCP provided by coral reefs (by taking the Coral Reef Index [described in the fifth line of Table 2] and dividing by the sum of Coastal Protection Factors), the resulting percent will be very low compared with measured wave attenuation.[8] In addition, this approach is very sensitive to the number of Coastal Protection Factors used in the analysis (which can be between 6 and 10).

To address these issues, IMA has developed an indicator called the "Relative Reef Contribution" (RRC), which is the scaled percentage of the reefs' contribution to protecting the shoreline, relative to all other factors. RRC is calculated by taking the square root of the ratio of the Reef Index over the Sum of all Coastal Protection Factors Divided by the RTCP for each coastal segment. This approach serves to increase the apparent relative contribution of reefs (making it closer to observed values)[9] and reduces the effect of potential changes in the number of factors considered (due to data not being available for some).

$$RRCx = \sqrt{\frac{Coral\_\mathrm{Re}ef\_Index / \sum_{1}^{N} Coastal\_\mathrm{Pr}otection\_Factors}{RTCP}}$$

5. Property Values

Property values for land areas identified as both "vulnerable" and "protected by a coral reef" are required to estimate potential losses due to erosion and storm damage. Land value (to capture losses due to erosion) and value of built structures (to capture property damage) are required. Specific values are desirable, but average property values can be used. In addition, the revenues from businesses in vulnerable areas are used to capture potential losses due to loss of land or property use, based upon duration of expected loss of use.

6. Damages Avoided Attributed to Coral Reefs

The factors described above are integrated to estimate the value of shoreline protection provided by coral reefs through reducing erosion and mitigating wave-induced storm damage. The value of property on "vulnerable lands" "protected by a coral reef" is multiplied by the relative reef contribution to coastal protection (RRC) to arrive at an approximation of the value of this service.

[8] A high degree of wave energy (on the order of 75-95%) is typically mitigated by coral reefs (Brander et al. 2004). Evaluation of the simple percent of protection coming from the Reef Index will typically result in a value between 13% and 30%, which is low compared to measured attenuation.

[9] Relative Reef Contribution (RRC) values will typically range from 25 to 40%, so are somewhat closer to measured attenuation due to reefs.

Table 2 - Coastal Protection Factors
Source: developed by the Institute of Marine Affairs (IMA)

Factor	***Level Of Coastal Protection***				
	Very High 4	**High 3**	**Medium 2**	**Low 1**	**None 0**
Coastal Geomorphology	Rocky, Cliffed Coastline	Soft (Limestone) Cliffs or Low Bluffs	Mangroves	Beaches	N/A
Coastal Geology	Igneous and/or Volcanic	Metamorphic	Sedimentary	Unconsolidated Sediments	N/A
Coastal Protection Structures	Protected by 2 prominent headlands and breakwater	Protected by 2 prominent headlands	Seawalls, Riprap or Breakwaters	Protected by one or two small headlands	No protection by headlands
Wave Energy (~ Max. Wave Height [cm])	< 20	20 – 40	40 – 60	>60	N/A
Coral Reef Index *(sum of 3 factors / 10 *4)* **Reef Type** **Reef Distribution** **Reef Distance (m)**	 Barrier Not applicable (N/A) < 250	 Patch N/A 250 - 500	 Fringe Continuous 500 - 1000	 Apron Discontinuous > 1000	 No reef present No reef present No reef present
Storm/Hurricane Events	Affected by 1-5 Tropical Storms every 10 years	Affected by at least 5 Trop. Storms every 10 years	Affected by at least a Category 1 every 25 years	Affected by at least a Category 3 every 25 years	N/A
Coastal Elevation (m)	> 12	5 – 12	1 – 5	0 – 1	< 0 (N/A) **
Coastal Slope (%)	6.2 – 9.7	2.6 – 6.2	1.1 – 2.6	0.4 – 1.1	N/A
Coastal Vegetation Index *(average of 2 factors)* **Type** **Distribution**	 Mangroves > 75 % length of coastline	 Coastal Woodlands 50% - 75 % of length	 Thicket 25% - 50 % of length	 Runners < 25% length of coastline	 None No Vegetation
Coastal Anthropogenic Activities	No sand mining, coastal development, etc.	Misc. Other Activities	Either sand mining or coastal development	Sand mining and coastal development	N/A

Challenges and Limitations

This innovative methodology provides a useful means for evaluating potential avoided damages afforded by coral reefs, as well as providing an aid to coastal planning by identifying coastal areas which are vulnerable to storm damage. This method can also support planning for adaptation to climate change by considering future scenarios of sea level rise, storm regime changes, and associated changes in storm surge and wave heights. These scenarios can be introduced by adjusting the elevation used to define "vulnerable lands."

Implementation of the shoreline protection valuation requires detailed data on coral reef locations and coastal elevation (these are the most important), a variety of data sets on coastal characteristics, as well as expertise in GIS.

There are inevitably uncertainties associated with a multi-stage modeling approach designed to emulate complex physical processes. In addition, few data are available specifically on wave-induced storm damage making the calibration of the model difficult. To address some of the uncertainties in the modeling and data sources, the analysis can be implemented using ranges. For instance, a range of values can be used to reflect estimates of property values. In addition, the relative reef contribution (RRC) values along coastal segments can be varied (by + and – 20%, for example) to develop an uncertainty range, rather than a single value. Results should be evaluated using available information on historic wave-induced storm damage in the study area or a similar area, if available.

Limitations of the Caribbean Coral Reef Valuation Methodology

The valuation methodology focuses on valuing a subset of ecosystem goods and services related to coral reefs in the Caribbean. The methodology does not attempt to provide the total economic value of coral reefs. Some of the values that are not captured include poverty reduction and the nutritional benefits of subsistence fishing; social, spiritual, religious or inspirational values of coral reefs; pharmaceutical or bioprospecting values; existence values; and the value of coral and sand as building materials. Furthermore, coastal systems are made up of highly interconnected habitats, of which coral reefs are one important component. This methodology also strives to isolate the benefits (goods and services) provided by coral reefs, but it should be noted that many of these goods and services benefit from proximity to sea grass and mangroves. Overall, the values from this valuation methodology should be considered a lower bound estimate of the "true" value of these reefs.

Limitations specific to the individual goods and services were detailed in the previous sections. In summary, some of the main challenges for implementing the valuation methodology are:

a) Distinguishing reef-related visitors from non-reef related visitors;
b) Estimating the use of coralline beaches and coral reefs for informal recreation and fishing by local residents;
c) Estimating the catch of coral reef-associated fish species. Data are often limited or unreliable;
d) Validating the shoreline protection model. Data on wave-induced storm damage are limited; and
e) Evaluating visitor responses to marginal changes in reef quality, a potentially important factor for assessing future scenarios of reef use. Data are rarely available.

An additional limitation of the valuation is the focus on current financial value and economic impact, rather than on underlying economic value and future "potential value." This is most important in evaluating tourism value, which emphasizes current expenditures by tourists, giving credit (value) only to areas where tourism is developed. This focus on financial analysis and economic impact consequently undervalues those coral reefs

that may have significant non-use values but limited financial or economic impact. Many coral reefs have additional, potential tourism value, in undeveloped or less developed areas. The maximum potential value is limited, however, by the sustainable tourism level. An attempt to estimate potential financial value can be incorporated into the valuation if sufficient information on tourism potential and carrying capacity is available, along with the costs of developing tourism in those areas.

Implementing the Caribbean Coral Reef Valuation Methodology in Tobago and St. Lucia

Pilot applications of the methodology were undertaken in two sites in the Eastern Caribbean—Tobago and St. Lucia. The following sections present details of the valuation of coral reef-associated tourism and recreation, fisheries, and shoreline protection services for both study sites. The results should be regarded as lower bound estimates of coral reef value, as this study has examined a limited number of goods and services, and within each of these, used a conservative approach to estimating value. Despite implementing a partial and conservative estimate of the contribution of coral reefs to the economies of Tobago and St. Lucia, these valuations show coral reefs to be important to the economies of both islands.

The following sections outline the key values derived from the valuation methodology. Further details on data sources and the actual implementation of the methodology are outlined in Appendix 1 for Tobago and Appendix 2 for St. Lucia.

3. Valuation of Coral Reef-Related Tourism and Recreation

The economic activity generated by the overall tourism sector is critical to the economies of both Tobago and St. Lucia, comprising about 46 percent and 47 percent of their respective GDPs in 2005 (WTTC 2005, 2007). Not all visitors come to these lovely islands because of coral reefs, but for many, it is an important component of the islands' attraction. Marine tourism in St. Lucia and Tobago relies heavily on healthy coral reefs—as the focus of dive and snorkel tours, and as a source and protection for beautiful white sand beaches. The high value of coral-reef related tourism and recreation in Tobago and St. Lucia suggests that investment in maintaining the health of coral reefs is, in the long term, of interest to both islands.

Tobago

Tobago's tourism profile[10]

Tourism is an important and growing economic sector in Tobago, contributing approximately 46 percent of the island's GDP in 2005 (WTTC 2005). Between 2002 and 2004, there was an average of 69,900 international visitor arrivals and 290,400 domestic arrivals (this included both foreign visitors arriving via Trinidad and Trinidadians and Tobagonians coming to Tobago). These numbers do not take into consideration those visitors arriving by ferry in Tobago. A majority of the visitors come to Tobago for vacation—in 2003, approximately 88 percent of the visitors to Tobago were vacationers and another 4 percent came for a wedding or honeymoon. Most of the visitors (77 percent) were first-time visitors and spent between 8 and 14 days in Tobago. Hotels were the predominant source of accommodation,

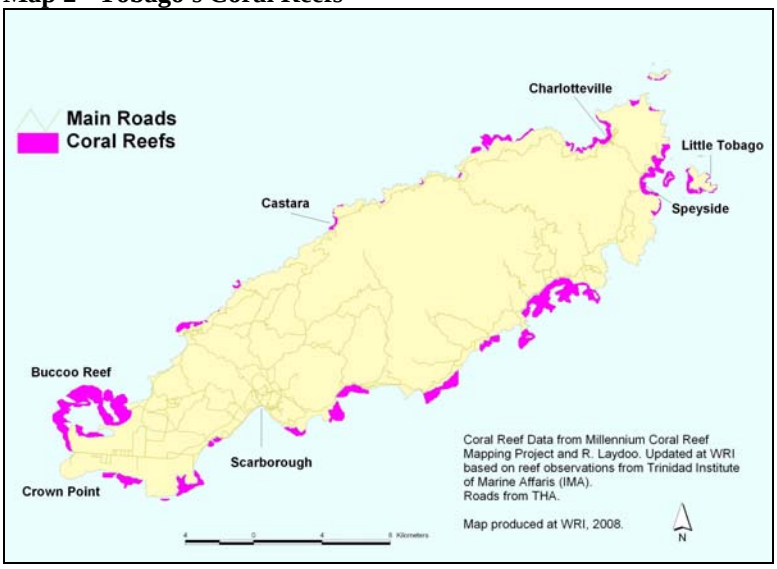
[10] Tobago's tourism profile is based on 'Tobago Visitor's Exit Survey Report, 2003' compiled by The Policy and Development Institute (PRDI) and Department of Tourism, Tobago House of Assembly (THA).

accounting for about 76 percent of visitors. Great Britain and Germany were the largest sources of visitors in 2003.

The most significant factors influencing a tourist's decision to visit Tobago were the tropical climate and the cost of the trip—89 percent of the visitors in the 2003 exit survey said the tropical climate was important, while 57 percent indicated that the cost of the trip was important. Of the visitors surveyed, 40 percent found eco-tourism important. The most visited tourist attractions on the island were the beaches at Pigeon Point and Store Bay, the Buccoo Reef, Fort King George and Argyle Waterfall. Approximately 60 percent of tourists visit the Buccoo Reef (THA/ PRDI, 2003).

Two areas in Tobago are renowned for their coral reefs. The first, Buccoo Reef, is a fringing reef, enclosing the Bon Accord Lagoon. The second is in Speyside and hosts the world's largest brain coral. Other smaller and lesser known reef areas fringe about half of Tobago's shoreline.

Map 2 - Tobago's Coral Reefs



Reef Visitation

Using the percent of tourists who identify eco-tourism as an import aspect of visiting Tobago (40 percent), and the percent taking glass bottom boat and snorkel trips to the Buccoo Reef (60 percent), this study conservatively estimates that approximately 40 percent of visitors come to Tobago at least in part because of its coral reefs. This percentage is used in this study to prorate the accommodation value and the additional miscellaneous expenditures of visitors to the island. Tourist expenditures on reef recreation—diving, snorkeling and glass bottom boat tours—are directly related to the coral reefs and are not prorated.

Valuation Results

The following section outlines total economic impact of reef-related tourism and recreation in Tobago, and breaks down the individual components of the analysis. More detailed information on the assumptions and data (e.g. wage and tax rates, dive and snorkel prices, etc.) used in the valuation are found in Appendix 1. All values have been converted to 2006 US dollars.

Total Economic Impact. The total economic impact from reef-related tourism and recreation in Tobago is estimated to be between US$101 and $130 million in 2006.[11] This value includes both direct and indirect impacts, as described below (see table 3).

Direct Economic Impacts. The total direct economic impact of coral reef-related tourism and recreation in Tobago is estimated at around US$43.5 million per year in 2006, or approximately 15% of Tobago's GDP. This value comprises net revenues[12] and transfers to the economy[13] from accommodation (US$24.7 million), miscellaneous expenditures (US$16 million), glass bottom boat/snorkeling trips (US$1.5 million) and diving (US$1.3 million) (See Table 3). Approximately 27 percent of this direct economic impact is due to wages and service charges. An additional 10 percent comes from transfers to the government via value added taxes (VAT).[14]

Indirect Economic Impacts. An additional US$58 to $86 million of indirect economic impacts result from coral reef-related tourist expenditure.[15]

Other Values. In addition to the economic impacts, two values not currently captured by the economy have been estimated:

- US$1 million for consumer surplus associated with diving and snorkeling activities
- US$13 to 44 million from local use activities.[16]

Table 3 - Coral Reef-Associated Tourism Impact for Tobago (2006)

Expenditure Categories	**($US million)**
Accommodation	$24.7
Reef Recreation – Diving	$1.3
Reef Recreation – Snorkeling and glass-bottom boats	$1.5
Marine Park Revenues	n.a.
Miscellaneous Visitor Expenses	$16.0
Total Direct Impact	**$43.5**
Indirect economic impact[a] (from multiplier)	$58 – 86
Total Direct and Indirect Impact	**$101 – 130**
Other Values	
Consumer Surplus	$1.1
Local Use	$13 – 44

a. Indirect economic impacts include benefits to both Trinidad and Tobago.

[11] This estimate includes the secondary impacts to Trinidad and Tobago, so is not directly comparable to estimates from WTTC of economic impacts to Tobago alone.

[12] Net revenue is gross revenue minus costs.

[13] Transfers to the economy include wages, services charges and taxes.

[14] Transfers to the government as taxes includes VAT only, and does not include income or corporate taxes.

[15] The indirect economic impacts associated with tourist expenditure in Tobago are counted as benefits to the national economy of Trinidad and Tobago as it was not possible to isolate the effects for Tobago alone.

[16] This value was derived from: UWI/SEDU 2007. "Local Use Values of Beaches and Reefs in the Caribbean – Case Studies of Saint Lucia and Tobago," a report to the World Resources Institute submitted by the Sustainable Economics Development Unit (SEDU), University of the West Indies (UWI), St. Augustine, Trinidad. Oct 10, 2007. (Available from the WRI web site)

A. Accommodation

The total accommodation value for Tobago was derived from information compiled on 461 hotels, guesthouses, villas and other rental properties in Tobago. Rate information (by season) was obtained for 325 of these providers, and occupancy rates are based on the estimates of tourism experts in Tobago. The total value was then prorated by the percent of visitors coming to Tobago for the reefs.

Total reef-related accommodation value (including transfers) is estimated at US$24.7 million.[17] Gross reef-related accommodation revenue in Tobago is approximately US$41 million. Total operating costs are approximately US$30.3 million. Costs include US$16.5 million in other non-labor operating costs, and several costs treated as transfers to the economy – US$6.7 million in wages, US$3.7 million in service charges, and US$3.4 million in hotel VAT taxes.

B. Reef Recreation

Diving

An estimated 9,900 people went diving in Tobago in 2006, with most divers (80%) doing more than two dives.[18] Dive prices are based on published rates from 12 of the 17 dive operators in Tobago.

The diving value in Tobago was estimated at US$1.3 million[19] derived from approximately US$2.0 million gross revenue and US$1.5 million total operating costs, of which US$0.7 million is non-labor costs and US$0.9 million is transfers to the economy via wages and taxes.

Snorkeling

Most snorkeling in Tobago is done from glass bottom boats in the Buccoo and Speyside areas. Glass bottom boat / snorkel tours are the predominant form of reef recreation in Tobago, with approximately 19 glass bottom boats in operation. These activities have relatively high profit margins and generate more economic activity than diving. An estimated 174,000 people engaged in this activity in 2006.[20]

The snorkeling value in Tobago is estimated at US$1.5 million, derived from approximately US$2.7 million gross revenue and US$1.7 million in other total operating costs, of which US$1.2 million is non-labor operating costs and US$0.5 million in transfers to the economy via wages. This estimate does not capture the value of snorkeling from the beach, which is important for enjoyment value, but does not generate much economic activity beyond accommodation and transportation revenues, which are captured in other components. No VAT is charged on glass bottom boat / snorkel tours.

C. Additional Miscellaneous Expenditures

The additional miscellaneous expenditures are estimated at just over US$16 million. This includes departure taxes (~US$0.7 million) as well as tourist spending on entertainment, land transport, shopping

[17] Accommodation value is calculated as: (gross revenue) – (total operating costs) + (transfers within the economy (wages, services charges and taxes)). All components are pro-rated for the 40% of visitors estimated to be reef-associated.
[18] Dive estimates on based on interviews with dive operators and other tourism professionals in Tobago.
[19] Diving value is calculated as: (gross revenue) – (total operating costs) + (transfers). Numbers may not sum due to rounding.
[20] Snorkel estimates based on interviews with Tobago Reef Operators Association, coupled with results of 2003 exit survey.

and other expenses (~US$15.4 million). These expenditure estimates are based on a 2002 visitor survey conducted by Tourism Intelligence International (see Appendix 1). This study estimates 40% non-labor operating costs, and subtract these from total revenues to arrive at net revenue from miscellaneous expenditures. As with accommodation, this value is prorated by reef visitation.

D. Indirect Economic Impacts

As mentioned in the methods section, direct expenditures on tourism result in indirect expenditures such as the purchase of sheets for hotels, fruit for breakfast, and fuel for dive boats. Because Trinidad and Tobago has significant agriculture, oil and gas, and manufacturing sectors, a large portion of the supplies for the tourism industry are sourced domestically. As a result, the tourism multiplier for Trinidad and Tobago is relatively high compared to other Caribbean islands. However, because the majority of these industries are based in Trinidad, much of this additional economic activity is captured by that island. It was not possible to isolate the indirect economic impacts on Tobago alone with the available data. Singh (2003 in Boxill et al. 2004) estimates a tourism multiplier of 2.0 for Trinidad and Tobago. To arrive at indirect economic impact, this multiplier is applied to total reef-related visitor expenditure, estimated at US$72 million for Trinidad and Tobago. Total visitor expenditure includes gross revenues from accommodation and reef recreation, as well as entertainment, transport, shopping and other miscellaneous expenses. To reflect some of the uncertainty involved in estimating indirect impacts, the tourism multiplier is varied by 20 percent (from 1.8 to 2.2). [21] This produces a range of US$58 million to US$86 million in indirect economic impacts.

E. Consumer Surplus

Consumer surplus from reef recreation—the additional satisfaction derived by visitors beyond the price they paid for dive and snorkel trips—is an important benefit of coral reefs that is not captured in the economy. Total consumer surplus for the dive industry in Tobago is estimated at approximately US$0.4 million.[22] Consumer surplus from snorkeling and boating is estimated to be approximately US$0.7 million.[23] This consumer surplus is not part of the direct economic benefit from coral reefs, but can be an important value in setting recreation or visitation fees.

F. Local Use of Beaches

The value of local residents' use of coralline beaches is estimated to be between US$13 and 44 million (UWI/SEDU, 2007). The local use value of beaches is based on the average number of visits Tobago residents make to the beach each year, the average duration of the visits, and the average hourly wage in Tobago (see Appendix 1 for more details). The value is reported as a range because of the uncertainty attached to the parameters used to ascertain the local use value. It should be used with caution as the sample size in the local use survey was too small to enable us to say with certainty that the true value was captured. Rather, this value should be treated as suggestive of the likely magnitude of the local use value.

[21] Multipliers of 1.8 and 2.2 mean that the indirect economic impact is between 80% (for 1.8) and 120% (for 2.2) of the gross direct tourist expenditure. This indirect economic impact is a benefit to both Trinidad and Tobago.

[22] Consumer surplus is estimated to be 19% on top of the average purchase price of a dive trip, based on estimates by Cesar et. al. 2002

[23] Consumer surplus is estimated to be 27% on top of the average purchase price of a snorkel trip, based on estimates by Cesar et. al. 2002

G. Sensitivity of Results

Several of the assumptions or parameters used in the valuation have high levels of uncertainty. Two of the most important are the estimate of the percent of tourists who are visiting due to the reef (discussed below) and the choice of a tourism multiplier (discussed in section D above.)

Reef Visitation. Reef visitation affects this study's estimates of both accommodation value and additional miscellaneous expenditure value, which together make up much of the direct economic impact of the reefs. In order to explore the sensitivity of the results to this assumption, reef visitation is varied by +/- 20 percent (see Table 4). With 32 percent reef visitation, the accommodation value drops to approximately US$19.8 million. At 48 percent it increases to US$29.6 million.

The estimate of additional miscellaneous expenditures (US$16 million) is also sensitive to the estimated percent of visitors using the reef. When varying reef visitation by +/- 20 percent (from 32% to 48%), the miscellaneous expenditures value ranges from US$12.8 million to US$19.3 million, resulting in estimated total direct expenditures ranging from US$35.4 million to US$51.6 million, with a central estimate of $43.5.

Non-Labor Operating Costs. Assumptions about non-labor operating costs (set at 40% of gross revenue in this study) also affect the results. If these costs are varied +/- 20 percent, total accommodation value ranges between approximately US$21 million and US$28 million, respectively, from the base value of US$24.7 million.

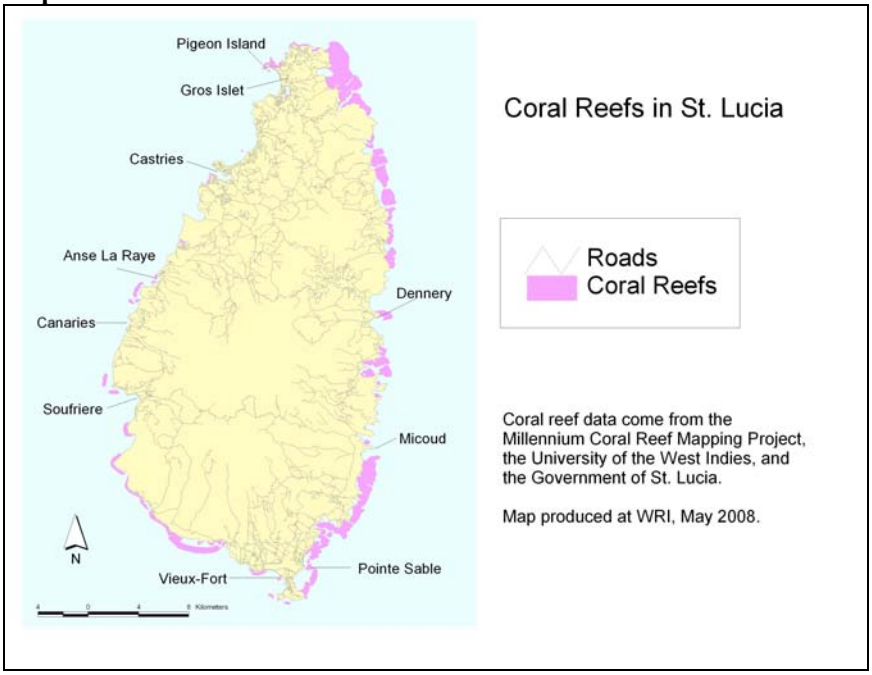
Table 4 - Reef-Related Tourism and Recreation Sensitivity Analysis for Tobago

Total Value in $US millions			
	- 20 percent	**Base**	**+20 percent**
Tourists Visiting the Reef	(32 %)	(40%)	(48%)
Accommodation	19.8	24.7	29.6
Additional Miscellaneous Expenditure	12.8	16.0	19.2
Reef Recreation (dive and snorkel)[a]	2.8	2.8	2.8
Total Direct Impact	**35.4**	**43.5**	**51.6**

a. Reef recreation does not vary with the visitation assumption, as it is measured directly.

Saint Lucia

Map 3 - Saint Lucia's Coral Reefs



St. Lucia's tourism profile

The travel and tourism economy's contribution to overall GDP in St. Lucia was approximately 47% in 2005, making it the country's most important economic sector (WTTC 2007).[24] In 2006, there were over 302,000 international overnight visitors to St. Lucia. Of these, US visitors dominate the market at 36.5 percent; visitors from the UK and the Caribbean each make up an additional 27 percent of the total. Overnight visitors stay an average of 9 – 10 days and most stay in all-inclusive hotels (St. Lucia Tourism Board, 2005, 2006).

Cruise visitors are also an important part of the tourism industry in St. Lucia. In 2004, there were 679,000 cruise visitors (nearly 70% of all visitors.) Although cruise visitors compose a large proportion of visitors, the economic impact of the stayover visitors is more significant because of their longer average stay and higher average expenditure. The cruise industry has grown rapidly since the 1990s, but has leveled off in the last seven years. The beneficiaries of the cruise industry include small scale tourism operators, taxis, and businesses in the informal sector such as local craft sellers, which are frequently not accounted for in national GDP calculations. Significant investment has been made in port expansion and upgrades to cater for the expanding cruise industry. In this study, the only cruise visitor expenditures captured are expenditures on marine recreation. Further research on the costs and benefits of cruise visitors is needed. Many local experts believe that the expenses to the island from hosting cruise ships are in fact higher than the income derived from cruise passengers.[25]

[24] WTTC (2005) defines the tourism economy as the "economy wide impact (direct and indirect) of travel and tourism.
[25] Anecdotal reports from a stakeholder workshop conducted in March 2006.

Along St. Lucia's Caribbean coast are two important marine parks—the Soufriere Marine Management Area (SMMA) and the Canaries Marine Management Area (CAMMA), which borders the SMMA. In addition, there are smaller reef areas around Laborie and Vieux Fort in the south and Pigeon Point in the North. The Atlantic coast also has some reefs but less is known about their locations and extent.

Reef Visitation

Visitors come to St Lucia for its sun, sea and sand attractions. There is no detailed information collected on visitor activities. However, an informal survey by Clauzel (2001) indicated that beaches, parks and nature reserves, and water sports were among the most popular activities undertaken by visitors. Diving, while popular, was less popular than terrestrial activities. In addition, a formal survey of tourists at coastal hotels suggested that 44% of those visitors came to St. Lucia because of the SMMA, but this survey did not cover all tourists (Barker and Roberts 2004). This valuation conservatively estimates that approximately 25% of visitors come to St. Lucia at least in part due to coral reefs.[26] This percentage is used to prorate accommodation and additional miscellaneous expenditure values.

Valuation Results

The following section outlines the total reef-related tourism and recreation impact and other values in St. Lucia. More specific information on the assumptions and data (e.g., wage and tax rates, dive and snorkel prices, etc.) used in the valuation can be found in Appendix 2. All values have been converted to 2006 US dollars.

Total Economic Impact. The total reef-related tourism and recreational economic impact for St. Lucia is estimated to be between US$160 and $194 million. This value is a combination of direct and indirect economic impacts of spending by reef-associated visitors (see Table 5).

Direct Economic Impacts. The total annual direct economic impact of coral reef-related tourism in St. Lucia is estimated at roughly US$91.6 million in 2006 (or approximately 11% of GDP). This value comprises the net revenues and transfers to the economy from accommodation (US$64.7 million), miscellaneous expenditures by tourists (US$21.2 million), glass bottom boat/snorkeling trips (US$0.8), diving (US$4.9 million) and user fees at MPAs (US$0.05 million) (See Table 5). Approximately 30 percent of the direct economic impact was from transfers to the economy via wages and service charges, with an additional 10 percent being from transfers to the government via taxes.[27]

Indirect Economic Impacts. An additional US$68 to $102 in indirect (secondary) economic impacts results from the direct coral reef-related tourist expenditures.

Other Values: In addition to the economic impacts, two values not currently captured by the economy have been estimated:

- ~US$2.2 to 2.4 million consumer surplus associated with diving and snorkeling activities
- ~US$52 to 109 million from local use activities.[28]

[26] This estimate is based on the expert opinion of project partners on the number of visitors to St. Lucia that engage in diving or snorkeling, coupled with the informal survey results described above.
[27] Taxes include room taxes, but not corporate taxes.
[28] This estimate is based on survey results from UWI/SEDU. 2007. "Local Use Values of Beaches and Reefs in the Caribbean – Case Studies of Saint Lucia and Tobago," a report to WRI by the Sustainable Economics Development Unit (SEDU), University of the West Indies (UWI), St. Augustine, Trinidad. Oct 10, 2007. Ranges were developed to reflect the uncertainty associated with the small sample size (See later section on local use values).

Table 5 - Coral Reef-Associated Tourism Impact for St. Lucia

Expenditure Categories	**($US million)**
Accommodation	$64.7
Reef Recreation – Diving	$4.9
Reef Recreation – Snorkeling and glass-bottom boats	$0.8
Marine Park Revenues	$0.05
Miscellaneous Visitor Expenses	$21.2
Total Direct Impact	**$91.6**
Indirect economic impact (from multiplier)	$68 – 102
Total Direct and Indirect Impact	**$160 – 194**
Other Values	
Consumer Surplus	$2.2 – 2.4
Local Use	$52 to 109

A. Accommodation

Information on the accommodation sector was obtained from the St. Lucia Hotel Association and from internet research. A total of 226 accommodation providers were identified.[29] Average occupancy rates of 62 percent for hotels and 67 percent for all-inclusive resorts were used.[30]

The total reef-related accommodation value is estimated at US$64.7 million.[31] Gross reef-related accommodation revenue in St. Lucia is approximately US$108 million. Total operating costs are approximately US$73 million[32] Costs include US$43 million in non-labor operating costs and several costs treated as transfers to the economy - US$13 million in wages, US$9 million in service charges, and US$7 million in government hotel taxes. Nearly 28 percent (US$30 million) of the gross revenue is passed through the economy via employee wages and service charges or to the government via taxes. These transfers are included in the total accommodation value in order to capture some of their impact on the economy.

B. Reef Recreation

The numbers below reflect diving and snorkeling revenues from visitors to St. Lucia, including day visitors from cruise ships. However, much of the diving and snorkeling on the island is done from all-

[29] Information on accommodation was compiled prior to the 2007 Cricket World Cup, so the number of accommodation providers in St Lucia is likely to have increased.
[30] Occupancy rates are based on surveys undertaken by the St. Lucia Tourist Board (2006)
[31] Accommodation value is calculated as: (gross revenue) – (total operating costs) + (transfers). All components are pro-rated for the 40% of visitors estimated to be reef-associated.
[32] May not add up to total costs because of rounding errors

inclusive resorts. The revenues counted here exclude all trips occurring through these resorts, since the financial flows from these activities is captured in the accommodation component.

Diving
Diving is an important aspect of tourism in St. Lucia, with the SMMA serving as an important draw for divers. Much diving goes on both inside and outside of the MPA; in 2005 5,659 dive permits were issued in the SMMA. An estimated 45,000 total dives occurred in St. Lucia in 2006.[33]

The diving value in St Lucia is estimated at US$4.9 million,[34,] derived from US$8.7 million gross revenue and US$6.1 million total operating costs, which includes Us$3.8 million in non-labor operating costs and transfers to the economy and government of US$1.6 million in wages and US$0.7 million in taxes.

Snorkeling
Most snorkeling in St. Lucia is done from beaches in front of hotels or in the SMMA. During 2005 and 2006, an estimated average of 95,000 visitors participated in snorkeling. This estimate is based on the number of SMMA snorkel permits sold (25,850 in 2005) and an estimate of the number of people snorkeling off the beach (69,000 in 2006).[35] Snorkeling from the beach does not generate much revenue directly, but is an important aspect of hotel desirability and accommodation "value-for-money." Snorkeling from the beach was included in consumer surplus estimates.

The snorkeling value in St Lucia is estimated at US$0.8 million, derived from approximately US$1.2 million gross revenue, US$0.4 million non-labor operating costs and US$0.3 million in transfers to the economy via wages, service charges and taxes.

C. Marine Protected Areas

The SMMA is an actively managed area, which is financed through the collection of visitor fees. In 2005, 25,850 snorkel permits, 3,286 daily dive permits, and 2,373 annual permits were sold. Snorkel permits are sold for EC$3/day (about US$1.14), while the diving permits are US$5 for a daily permit or US$15 for an annual permit.

The gross revenue generated by fees from yacht moorings and dive and snorkel permits was approximately US$190,000. After expenditures of US$141,300, the MPA value was US$48,700.

D. Additional Miscellaneous Expenditures

Additional miscellaneous expenditures include spending by visitors on departure taxes, wedding licenses, meals and drinks, local transportation, entertainment, and shopping (including handicrafts and duty free shopping). Visitor expenditure patterns differ between those staying at all-inclusive hotels versus those at other hotels. In 1998, payments to all-inclusive hotels in St. Lucia made up about 81% of expenditures by those visitors. Visitors to other hotels only spent about 63% of their total expenditures on

[33] The estimated number of dives is based on the number of divers diving in the SMMA, coupled with the professional opinion of Kai Wolf (manager, SMMA) on the number of divers operators typically take out each day. This information was validated against an informal survey conducted for this project by Laverne Walker of the Sustainable Development Unit, within the Government of St. Lucia.
[34] Diving value is calculated as: (gross revenue) – (total operating costs) + (transfers). Numbers may not sum correctly because of rounding errors.
[35] Based on feedback during our project workshop in March 2006, it is assumed that most visitors to beach-front hotels have access to snorkel equipment and participate in snorkeling at least once during a visit.

accommodation. Estimates on tourist spending categories were based on a CTO (2000) study (see Appendix 2). All miscellaneous expenditures are prorated by reef visitation to give the amount that can be attributed to coral reefs.

Total net miscellaneous expenditures are estimated at just over US$21 million.[36] This includes approximately US$1.6 million in departure taxes and US$19.6 million on all other spending.

E. Indirect Economic Impacts

To arrive at indirect economic impact, a tourism multiplier is applied to total reef-related visitor expenditure in St. Lucia. Total visitor expenditure includes gross revenues from accommodation and reef recreation, as well as entertainment, transport, shopping and other miscellaneous expenses. To reflect the uncertainty involved in estimating indirect impacts, a multiplier range of 1.45 to 1.67 was used.[37] The estimated indirect economic impacts are between US$68 million and US$102 million per year.

F. Consumer Surplus

The price of recreation excursions does not always capture the full value (or satisfaction) derived by participants. This consumer surplus is not part of the direct economic impact due to coral reefs, but can be an important value for managers, in setting recreation or visitation fees. Total consumer surplus for the dive industry in St. Lucia is estimated at approximately US$1.7 million.[38] Consumer surplus from snorkeling and boating is estimated to be approximately US$0.54 to US$0.68 million.[39]

G. Local Use of Beaches

The value of local residents' use of coralline beaches is estimated to be between US$52 and $109 million. This estimate is based on data collected during the "local use" survey implemented under this project by UWI/SEDU[40] (for more detail see Appendix 2). The local use value of beaches is based on the average number of visits residents make to the beach each year, the average duration of the visits, and average hourly wage within the surveyed communities. The estimate is derived from an average annual per person value for beach visitation between US$194 and $497 per person for those living close to a reef or coralline beach and US$362 to $754 per person for those who did not live close to a reef or coralline beach. The higher values associated with the second group is mostly due to their higher average wages.

This value should be used with caution as the sample size in the "local use" survey was too small to enable us to say with certainty that the true value was captured. Rather this value should be used as a suggestive value for the likely magnitude of the local use value.

[36] Values may not add correctly because of rounding.

[37] The tourism multiplier range is based on a multiplier of 1.56 for St. Lucia from Boxill et. al., 2004. This study implements the multiplier as a range of 1.45 – 1.67 to reflect the uncertainty of the estimate. A multiplier of 1.45 means that the indirect economic impact is 45% of the gross direct tourist expenditure.

[38] Consumer surplus is estimated to be 19% on top of the average purchase price of a dive trip, based on estimates by Cesar et. al., 2002.

[39] Consumer surplus is estimated to be 27% on top of the average purchase price of a snorkel trip, based on estimates by Cesar et. al. 2002. For snorkeling from the beach, a consumer surplus range of US$3-$5 was used.

[40] The local use values do not come directly from the local use survey, but were derived based on data collected during the survey, which were adjusted to account for errors in the survey design. (See Appendix 2 for details.)

H. Sensitivity of Results

Reef Visitation. The estimate of coral reef-associated tourism value is very sensitive to the assumption about the percentage of tourists coming to St. Lucia at least in part to visit the coral reefs. Therefore, the sensitivity of the "Total Direct Impact" estimate is tested by varying the base assumption (25% of tourists come at least in part due to the reefs) by +/- 20% (resulting in a range of 20 – 30% of visitors being reef associated). This results in a potential range of Direct Impacts of US$ 74.4 to $108.8 million (as compared with US$91.6 million (see Table 6). At 30 percent reef visitation, the accommodation value increased from the base value of US$64.7 million to US$77.6 million. At 20 percent reef visitation it value decreased to US$51.7 million. The additional miscellaneous expenditures estimate is sensitive to the estimated percent of visitors using the reef. Varying reef visitation by +/- 20 percent (from 20% to 30%), the corresponding range in miscellaneous spending is US$16.9 to US$25.4 million.

Table 6 - Reef-Related Tourism and Recreation Sensitivity Analysis in St. Lucia

Total Value in $US millions			
	- 20 percent	**Base**	**+20 percent**
Tourists visiting the reef	20%	25%	30%
Accommodation	51.7	64.7	77.6
Additional Miscellaneous Expenditure	16.9	21.2	25.4
Reef Recreation (dive and snorkel)	5.7	5.7	5.7
Total Direct Impact	**74.4**	**91.6**	**108.8**

Comparing the Study Sites

Table 7 - Coral Reef-Associated Tourism and Recreation Economic Impact Summary

	Tobago	St Lucia
Resident Population (in year)	54,084 (2000)	170,649 (2007)
International Air Arrivals (in year)	69,858 (2002-4 avg)	302,510 (2006)
Arrivals from Trinidad (domestic air)	290,384 (2002-4 avg)	n.a.
Cruise Visitors (in year)	24,952 (2004)	679,000 (2004)
Island GDP (in year)	US$285.7 million (2006)	US$825 million (2005)
Percent of Visitors classified as visiting at least in part due to the coral reef	**40%**	**25%**
Coral Reef-associated Tourism Impacts	**($US million)**	**($US million)**
Accommodation	$24.7	$64.7
Reef Recreation – Diving	$1.3	$4.9
Reef Recreation – Snorkeling and glass-bottom boats	$1.5	$0.8
Marine Park Revenues	n.a.	$0.1
Miscellaneous Visitor Expenses	$16.0	$21.2
Total Direct Impact	**$43.5**	**$91.6**
Indirect economic impact	$58 – 86 [a]	$68 – 102
Total Direct and Indirect Impact	**$101 – 130**	**$160 – 194**
Consumer Surplus	$1.0	$2.2 – 2.4
Local Use	$13 – 44	$52 – 109

a. Indirect economic impacts are a benefit to both Trinidad and Tobago.

Direct Impacts. The two study sites have a few key differences that influence the relative importance of coral reef-related tourism and recreation to each island. St. Lucia is a bigger and more expensive tourism market; it has 62 percent more rooms than Tobago, and room rates are significantly higher there than in Tobago ($156/night versus $89/night). Despite these differences in overall size, a smaller percentage of St. Lucia's tourists come to visit the coral reefs. Only 25 percent of its visitors were counted as "reef-related" in the valuation, as opposed to 40 percent of visitors to Tobago. As a result, the direct impacts of reef-related tourism in St. Lucia are roughly twice the size of direct impacts in Tobago (US$91.6 million to US$43.5 million), despite a much larger difference in the overall size of their respective tourism industries. The direct impacts of tourism comprise about 11 percent of annual GDP for St. Lucia and 15 percent for Tobago.

For both islands, reef recreation contributes about six percent of the total direct economic impact of coral reef-associated tourism and recreation. Snorkeling trips play a much more significant role in Tobago than in St. Lucia, where the majority of snorkeling is done off the beach at coastal hotels. The economic

benefits from these "beach snorkelers" as well as from a portion of other reef activities are captured by the accommodation sector in St. Lucia, a consequence of the large number of all-inclusive resorts in that country. As a result, the value of the reef recreation component in St. Lucia (US$5.7 million) understates the actual economic importance of this sector. All-inclusive resorts are less of a factor in Tobago, but because snorkeling trips (which are relatively inexpensive at about US$15 per person) dominate reef recreation here, the direct effects are also relatively small (US$2.8 million) compared to the revenue that these same tourists bring to the accommodation sector.

Indirect Impacts. The indirect economic impacts of reef-related tourism are important to the economies of both study sites. In St. Lucia, a higher percentage of goods used in the tourism sector are imported, so the tourism multiplier is lower. Reef-related tourism in St. Lucia still produces an estimated US$68 to US$102 million/year in indirect economic impact (using a multiplier of 1.45 to 1.67). In Tobago, a considerably higher multiplier range was used (1.8 to 2.2), due to the larger percentage of secondary goods and services that are produced domestically. Indirect impacts from reef-related tourism in Tobago are estimated at US$58 to US$86 million a year, a very large sum relative to the size of the economy. However, these results are somewhat misleading as indirect impacts accrue to Trinidad and Tobago as a whole. The indirect economic activity generated on Tobago alone was likely significantly smaller.

Total Economic Impact. Total estimated economic impact (direct and indirect) related to coral reefs in Tobago is approximately US$101 to $130 million. In St. Lucia, it is approximately US$160 to $194 million. The higher value in St Lucia—despite a lower percentage of reef-related visitors and lower tourism multiplier—is a result of the larger overall number of visitors and substantially higher accommodation rates there.

Challenges in Implementing the Valuation Methodology for Tourism and Recreation

There are a number of challenges in implementing the valuation methodology for reef-related tourism and recreation. These include:

- **Defining reef-associated visitation**. Information on coral reef-associated recreation and visitation of coralline beaches does not seem to be routinely collected by government or other groups and may have to be inferred from visitor activity surveys. Valuation results are very sensitive to this assumption.
- **Identifying relevant, up-to-date, and comprehensive data sets.** Data will most likely be an issue for many aspects of the reef-related recreation value. Good data on accommodation room rates and occupancy rates are not uniformly available, and diving and snorkeling statistics are rarely compiled at a centralized source. Operating costs for all enterprises or tourism sectors will most likely have to be estimated from regional averages or expert opinion, because of a lack of publicly available information.
- **Estimating indirect economic impacts.** The most common way to estimate the flow-on effects through the economy of tourism expenditure is to use multipliers. These multipliers are not readily available for Caribbean countries. As a result, it is currently difficult in many countries to a) locate an appropriate multiplier and b) compare indirect economic impacts between countries if the multipliers come from different sources. In some cases, it will not be possible to estimate the indirect impacts.
- **Accounting for local use values.** Local use of reef-related resources is poorly documented. Surveys may be required to obtain reliable information on local residents' use of reef resources.

4. Valuation of Coral Reef-Related Fisheries

Our valuation of coral reef-associated fisheries indicates that these are an important element of the local economy in both St. Lucia and Tobago, providing important sources of employment and revenue generation. They also provide a basis for long-established cultural activities in both countries. While the other components of the fisheries sector, such as flying fish and other pelagic species, generate more foreign exchange, reef-associated species are heavily fished because of cultural traditions and the habitat's proximity to the coast. These estimates focus on species which are directly dependent on coral reefs for at least some part of their lives, including various grouper, snapper, conch, parrotfish, squirrelfish, and lobster in both islands, as well as sea urchin in St. Lucia. While many fishermen generate more income from pelagic species, the seasonal nature of fisheries leads most fishermen to fish on reefs for at least part of the year.

The reef-related fisheries sector varies in St. Lucia and Tobago. St. Lucia has slightly more coral reef area than Tobago[41] and better data collection efforts and regulation exist. A lack of consistent data between the two countries, however, makes direct comparison difficult. Though St. Lucia has exported reef-associated fish in the past, it currently does not; Tobago does export snapper, grouper and some other species, though exact data are not collected by any government or industry source and cannot be observed based on extant information. The range of valuation estimates presented below shows that in each country, aspects of the reef fishery provide notable economic value.

The current estimate captures the direct economic impact of fisheries, but does not fully encompass either the social safety net implications or the cultural value. More extensive socioeconomic studies would be required to estimate this value. In the Eastern Caribbean, fishing is an important cultural activity. Historically, many cities are located near good fishing locales and cultural events centered on fishing remain popular. In St. Lucia, hundreds attend fish fries on many Friday nights, and many attend barbeques on the beaches in Tobago.

In both Tobago and St. Lucia, commercial fishing provides the largest portion of direct economic impact from reef-related fisheries, although local (non-commercial) fishing for enjoyment and consumption are also important components of value. This study also attempted to measure the value of local fishing in both islands, but issues of survey design have limited the degree to which reliable estimates can be developed. This issue is discussed below.

Tobago

Fisheries Profile for Tobago

The reef fishery in Tobago is predominantly artisanal (small-scale and traditional) and operates seasonally (FAO 2006). Pot fishing is the primary fishing method, though seine fishing is also practiced. The most commonly used boat is the pirogue, usually about 7–9 meters in length. In 2005, there were over 1,000 registered fishermen and almost 700 registered boats, but this overstates levels, as many of these are no

[41] Estimates of reef are from different sources vary. Maps compiled under this project from the Millennium Coral Reef Mapping Project (http://imars.usf.edu/MC/index.html) and national data sources suggest that reef area is about 30 sq km for Tobago and 33 sq km for St. Lucia.

longer active or full-time fishermen. Much of the fish catch and exports from Tobago are not reef-associated; however, grouper, snapper and lobster are exported.

Valuation of coral reef-associated fisheries in Tobago was hampered by a lack of reliable data on commercial fish landings. The Marine Resources and Fisheries Unit of the Tobago House of Assembly (THA) Division of Agriculture, Marine Affairs and the Environment conducts periodic sampling of catch at landing sites, which provided some information on composition of catch. Unfortunately, it is not possible to scale this sample up to a landings estimate, because the samples are not recorded within the context of overall fishing effort in Tobago. In addition, there are only limited data on fish processing sales and exports.

Many individuals provided both qualitative and quantitative information to guide the development of estimates of the value of coral reef-associated commercial fisheries in Tobago. They include staff from the Fisheries Division, the Buccoo Reef Trust, the head of the Tobago Fisherfolk Association, several fishermen, and Tobago Live (a fish exporter). Information from these consultations suggests that many coral reefs in Tobago are overfished, and that fish size and overall productivity of the coral reef fishery is declining.

Overview of Coral Reef-Associated Fisheries Values

Direct Impacts. The total direct economic impact of coral reef-associated fisheries in Tobago is estimated to be between US$640,000 and $913,000 per year. This value includes the estimated net revenues from commercial fisheries (approx. US$552,000 – $736,000) as well as estimated net revenues from fish cleaning and processing (US$88,000 – $177,000) in 2006. Net revenues are calculated from gross revenues minus non-labor operating costs.[42] (See table 8.)

Indirect Impacts. The additional indirect impact from coral reef-associated fisheries is estimated to be between US$118,000 and $235,000. This economic value includes the additional economic activity generated by the need for fishing equipment, such as boats and pots. Details on these estimates are provided in the following sections.

Total direct and indirect economic impact from coral reef associated fisheries is estimated to be between US$758,000 and $1.1 million.

Table 8 - Coral Reef-Associated Fisheries Impact for Tobago

Coral Reef-Associated:	**($US thousand)**
Commercial Fisheries – Gross Revenue	$736 – 981
Operating Costs (25%)	$184 – 245
Commercial Fisheries – Net Revenue	$552 – 736
Fish cleaning and processing	$88 – 177
Total Direct Impact	**$640 – 913**
Indirect economic impact (multiplier)	$118 – 235

[42] Fishermen are often paid in catch, rather than in currency. Labor costs, either paid in fish or in money, are considered a benefit to the economy. Only non-labor operating costs are deducted because these often consist of fuel, gear, and other items that need to be imported.

Total Economic Impact (Direct + Indirect)	**$758 – 1,148**
Local (non-commercial) fishing	Estimate not reliable; probably small.

A. Tobago – Commercial Fisheries

To support a reliable approximation, coral reef-associated commercial fish landings in Tobago were estimated using two approaches—first, based on estimates of reef fish productivity per unit area of coral reefs and then based on estimated pot fishing effort.

a) Estimate based on fish productivity of coral reefs
Fish productivity rates are the change in fish biomass per unit of reef area per year. Typical fish productivity rates in the Caribbean can range from less than 1 MT / km^2 / yr to over 5 MT / km^2 / yr (Burke and Maidens 2004; Munro 1974; Mahon 1993; Sarv et al. 2003; McAllister 1988). Fish productivity rates for Tobago are thought to be reasonably high due to upwelling and proximity to open ocean, but may now be declining due to overfishing. Fish productivity rates for Tobago of 2 to 5 MT / km^2 / yr were used for this estimate of potential sustainable harvest.

Using a coral reef area estimate of 30 sq. km[43] and fish productivity rates of 2 – 5 MT / km^2/ yr, the annual potential sustainable harvest is 20 – 150 MT / yr or 130,000 – 330,000 lb of reef fish per year.

b) Estimates of reef fish landings based on number of boats and pot fishing effort.
The catch of coral reef-associated fish was also estimated based on the number of boats engaged in pot fishing and level of effort during the pot fishing season (July through November). The estimate is based on the following assumptions, which were developed during a series of consultations with fisheries experts in Tobago. Sixteen boats are engaged in pot fishing[44] and these each make an average of 105 trips per year.[45] The boats land an average of 200 lbs per trip.[46] This level of pot fishing effort leads to an estimated 336,000 lbs of fish caught, which is very similar to the upper bound of the reef fish productivity estimate of 330,000 lb of reef fish per year. Reef fish are typically sold as collective "pot-fish" which include a mix of desirable species as well as bycatch (unintended catch).

c) Commercial Fisheries Valuation
This valuation used an average catch range (to reflect some uncertainty) of 150 – 200 pounds per pot fishing trip[47], which leads to annual landings of 252,000 to 336,000 lbs. Using an average price for pot fish of TT$15 ($2.50 US), the estimated gross value of the pot fish catch is US$630,000 – $840,000. In

[43] Several data sets reflecting coral reef locations were integrated under this project Data from the Institute for Marine Remote Sensing (IMaRS) Millennium Coral Reef Mapping Project, Institute of Marine Affairs (IMA), Buccoo Reef Trust and Richard Laydoo were combined and edited.) The resulting data set has an area of approximately 30km2 of coral reefs.
[44] The Tobago Development plan of June 2005 suggests there are 1,039 registered fishermen and 694 registered fishing boats in Tobago. Consultations with fisheries experts suggest that this might be a significant overestimate, due to people remaining registered, even when no longer active. Many boats are engaged in other types of fishing activities. Experts suggest that sixteen boats focus on pot fishing during the pot fishing season - 8 at Pigeon Point, 3 at Scarborough, 2 at Studly Park, 2 at Speyside.
[45] Boats engaged in pot fishing are assumed to make about 5 trips per week for 21 weeks during the July to November pot fishing season.
[46] 200 lb of pot fish per trip estimate based on average of 10 pots per boat and 20 lb catch per pot.
[47] A lower bound estimate of 150 lbs catch per pot boat trip was used to account both for the potential unsellable bycatch as well as to address the situation that current fishing levels might be above the sustainable limit.

addition to the pot fish, the study assumes 15,000 – 20,000 lbs of lobster are caught[48] and sold for an average of US$7 per lb, for an additional gross revenue of US$106,000 – $141,000. Total gross revenue from coral reef associated commercial fisheries is estimated at approximately US$735,000 – $981,000 per year. Non-labor operating costs were assumed to be 25% of gross revenue (US$184,000 – $245,000), resulting in a estimated net revenue from commercial coral reef associated fisheries of between US$552,000 and $736,000.

B. Fish Processing and Cleaning

Only limited information was available on fish processing, cleaning and export for Tobago. This information was integrated, and used to develop a conservative estimate of the additional (added) value that results from cleaning and processing the fish—between US$177,000 and $353,000, which is the equivalent of between one-eighth and one-sixth of gross revenue from commercial fishing. This estimate captures the value added in hotels and restaurants, which prepare and sell fish and lobster at higher prices, as well as exports from operations such as Tobago Live.

C. Economy-Wide Benefits (Indirect Impacts)

Commercial fishing for coral reef-associated species generates additional indirect economic impact both through the production of goods needed to fish (boats, pots, traps, line) and through the additional revenues that are generated as the money spent by fishermen spreads through the economy. A fisheries economy multiplier of 1.16 – 1.24 was applied to the gross value of commercial fish catch to capture these secondary effects. A relatively low multiplier was chosen in order to produce a conservative estimate. The estimated indirect economic impacts from this multiplier range from US$118,000 to US$236,000.

D. Local Use (Non-Commercial) Fishing of Coral Reefs

Very limited data are available on non-commercial fishing of the reef by Tobagonians. A “local use” survey was implemented under this project by UWI/SEDU. Three hundred people were surveyed in six communities in Tobago. The survey design, however, resulted in only a very small number of responses to questions regarding fishing on the reef. The limited survey results, coupled with feedback from experts, suggests that non-commercial fishing of the reef is a relatively small scale and low value activity. No estimate has been attempted under this valuation.

In addition to conventional local fishing, Tobago also has a six-month season (October through February) during which it is legal to capture sea turtles, and this practice is common. Capture is only permitted of males and is never legal on land, though some poaching on land occurs. The value of the harvest of meat, however, is likely to be less than the value that can be obtained from live sea turtles through tourism (Troëng and Drews 2004). A compilation of studies on consumptive and non-consumptive use of sea turtles suggests that revenues from tourism are usually much higher than revenue for consumption and the benefits have a wide distribution (See Box 3, Note 7.) Tourism benefits both from tourists willing to pay US$20-40 or more to view turtles nesting on beaches, as well as through the increased value of dive and snorkel trips where sea turtles are encountered (turtles bring delight to many). Values related to

[48] Lobster catch is based on previous seasons where lobster weight was typically 6% of reef fish weight. (THA fish catch data from 1996 – 2004.)

consumptive use of sea turtles were not included in this estimate. Text Box 3 provides an overview of current knowledge of status, trends and use of sea turtles in Tobago.

Box 3. Consumptive and non-Consumptive use of Sea Turtles in Tobago

Sea Turtles are ancient creatures, and are widely distributed throughout the Caribbean. Five species of sea turtle have been reported in Tobago—leatherback, hawksbill, green, olive ridley and loggerhead. Leatherback turtles are the most common species seen nesting on Tobago's beaches. Hawksbill turtles are associated with coral reefs while Green turtles forage among sea grass beds and are the target of turtle harvests. Loggerhead and olive ridley turtles are the least abundant of the five species.

All five species of sea turtle found in Tobago are listed as endangered by IUCN, with leatherback and hawksbill listed as critically endangered. In Tobago, monitoring of sea turtle populations is of insufficient duration to clearly identify population size and trends, and longer monitoring is needed to be conclusive.[1] However, for all species, anecdotal observations by elders suggest that the population is much smaller than thirty years ago.

In Tobago, sea turtles are the object of both consumptive (hunting) and non-consumptive (viewing) human use. Each type of use generates revenue in the local economy, but the two types have differing implications for future turtle populations, and therefore future use.

Consumptive Use: Turtle Hunting. Hunting of sea turtles for their meat is a long-standing tradition in Tobago. The meat is prized both for home consumption (especially at holidays) and is sold in some markets, where it commands a high price—between US$3–10 per pound. A single turtle provides a large amount of meat: the green turtle, for example, grows to a maximum size of about 4 feet and a weight of 440 pounds.[2]

Turtle hunting is legal in Trinidad and Tobago from October through February under the Fisheries Act of 1975.[3] Turtles may not be captured on land, and females may not be captured within 1000 yards from the high water mark or anywhere on the reef. However, these restrictions cannot be imposed due to insufficient enforcement capacity, and the difficulty of identifying the sex of immature turtles.

Non-Consumptive Use: Turtle Viewing. Two types of turtle viewing—on the beach during nesting season, and during diving and snorkeling trips—are economically important in Tobago.

Tours to view the large, charismatic leatherback turtles are common during the peak of the nesting season (May-June). Tourists visit the beach at night to watch an 800-pound female haul herself up the beach, dig a large nest, lay over 100 eggs, and finally find the energy to cover the nest and return to sea. Tourists—as many as 100 per night—typically pay US$ 20-40 per tour, although the price can be much higher.[4] The tours operate at low cost, so most of the revenue is profit. This income is important to the guides, as it comes during a relatively slow season.

Although tourists do not pay specifically to view sea turtles during diving and snorkeling trips, seeing the turtles surely adds value in the form of consumer surplus. Current research at the University of the West Indies (UWI) is focused on divers' willingness to pay to see sea turtles, and seeks to infer the added value from seeing one or more turtles during a dive or snorkel trip.[5] If turtle viewing is common and is advertised, trip fees could be increased to capture this added value—which, with an estimated 10,000 divers and over 170,000 snorkel trips in Tobago (in 2006), could prove to be significant.

Economics of Use. Currently, there is limited information on the revenue generated from consumptive and non-consumptive use of sea turtles in Tobago. UWI research, however, seeks to develop reliable estimates of the number of people capturing turtles for meat, the number of turtles caught and the

associated revenue, as well as the economic value of turtle viewing.[6] Until these results become available, we must rely on economic estimates from other locations. A compilation of studies on consumptive and non-consumptive use of sea turtles in developing countries suggests that revenues from tourism are usually much higher than revenue for consumption, and that the benefits have a wider distribution.[7]

Conclusion. Although the harvest of sea turtles for consumption has been a tradition in Tobago, the practice puts additional pressure on endangered species population. More monitoring is required to confirm the (likely declining) population trends in Tobago, to establish the individual population trends, and to establish whether current harvest practice undermines future use (both consumptive and non-consumptive). Non-governmental groups like Save Our Sea Turtles (SOS), Environment Tobago, and UWI are working to collect better information on both harvest of turtles and on tourist views and revenue, while the Institute of Marine Affairs (IMA) has studied turtle bycatch (unintentional capture) in gillnet fishing operations in Trinidad. This information is vital to support well-informed management of sea turtles in Tobago.

Although current harvest is not in violation of national law, better enforcement of the law is needed to curb the poaching of turtles outside of season and any harvest of nesting females. Furthermore, given the significant economic benefits for non-consumptive use, and the likely declining sea turtle population, perhaps it is in the best interest of the local economy for Trinidad and Tobago to reconsider its legal harvest season for these internationally endangered species.

1. Personal communication with Tanya Clovis and Giancarlo Lalsingh (Save Our Sea Turtles).
2. http://www.fws.gov/northflorida/SeaTurtles/turtle-facts-index.htm
3. Prior to 1975, hunting of sea turtles was implicitly prohibited by the Conservation of Wild Life Act (1958), which did not include turtle hunting in the hunting schedule, and therefore implied year-round protection of turtles. The Fisheries Act makes explicit the season and the restrictions on sea turtle capture. However, Trinidad and Tobago is a party to the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) of the Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, which entered into force in 2000. Article 11 (1) (b) of SPAW prohibits "the taking, possession or killing…or commercial trade in [endangered] species, their eggs, parts or products." Article 14 does provide an exemption "to meet traditional subsistence and cultural needs of its local populations...[without causing] the extinction of, or a substantial risk to, or substantial reduction in the number of…threatened, endangered or endemic species." It would thus appear that the Fisheries Act relies on Article 14 to avoid violation of SPAW. (http://untreaty.un.org/unts/144078_158780/18/7/8839.pdf)
4. Troëng, S. and C. Drews. 2004. Money Talks: Economic Aspects of Marine Turtle Use and Conservation, WWF-International, Gland, Switzerland, cites personal communication with W. Herron.
5. Results of research by Michelle Cazabon of UWI are expected later in 2008.
6. Personal communication with Michelle Cazabon (UWI).
7. Troëng, S. and C. Drews (2004) use nine case studies to estimate that gross revenue from consumptive use ranges from US$158 to US$1,701,328 per year per site with an average of US$581,815 per year. Gross revenue where non-consumptive use of marine turtles, such as tourism, is a major revenue generator ranges from US$41,147 to US$6,714,483 per year per site with an average of US$1,659,250 per year.

Saint Lucia

Fisheries Profile for Saint Lucia

In St. Lucia, total maritime area is greater than land area and fisheries are important both culturally and historically. While coral reef-associated fisheries are not the most significant fisheries in St. Lucia in terms of contribution to fish landings, they play an important role in St. Lucian society.

Most of St. Lucia's reef-related fishery can be considered artisanal. The majority of fishermen use small fiberglass boats powered by motors or wooden canoes. Approximately 70% of the island's catch is comprised of migratory pelagic species. However, many reef-associated fish are caught, including

groupers, parrotfish, wrasses, snappers, grunts, and squirrelfish. Many demersal reef species, such as groupers and red snappers, are regarded as overexploited. Lobster is the most commercially important species caught in St. Lucia, accounting for nearly 40% of total value of fish caught during the time period examined.

Studies conducted in the Soufriere Marine Management Area (SMMA) in the last few years show that the creation of no-take areas has resulted in an increase in the number of reef fish both within the marine reserve and in other coral reef areas (ICEM 2003). This "spill-over effect" has resulted in increased landings of reef fish in Soufriere. The SMMA can also be described as one of Saint Lucia's most successful co-management initiatives where the fishers play an important role ensuring compliance with the Area's law.

Overview of Coral Reef-Associated Fisheries Values

Direct Economic Impacts. The total direct impact of coral reef-associated fisheries in St. Lucia is calculated to be between US$437,000 and $656,000 per year. This value includes the estimated net revenues from commercial fisheries (approx. US$386,000 – 579,000) as well as estimated net revenues from fish cleaning and processing (US$51,000 – 77,000). Net revenues are calculated from gross revenues minus non-labor operating costs (See Table 9).

Indirect Economic Impacts. The additional indirect impact from coral reef-associated fisheries is estimated to be between US$82,000 and $185,000. Combined, the total economic effects are estimated to be between US$520,000 and US$841,000.

Local Use Value. There is significant additional value derived from non-commercial fishing on coral reefs in St. Lucia. This includes fishing for consumption, some trade in the informal economy, and fishing for pleasure. Due to the small number of valid survey respondents, there is considerable uncertainty in the local use estimate. This uncertainty is reflected in the wide range of the estimate. Local use is valued at between US$155,000 and $790,000. The size of even the lower end of this estimate relative to commercial reef-associated fishing revenues reflects the relative importance of this component.

Details on these estimates and their derivations are provided in the following sections.

Table 9 - Coral Reef-Associated Fisheries Impact for St. Lucia

Coral Reef-Associated:	**($US thousand)**
Commercial Fisheries – Gross Revenue	$515 – 772
Operating Costs (25%)	$129 –193
Commercial Fisheries – Net Revenue	$386 – 579
Fish cleaning and processing	$51 – 77
Total Direct Impact	**$437 – 656**
Indirect economic impact (multiplier)	$82 –185
Total Economic Impact (Direct + Indirect)	**$520 – 841**
Local (non-commercial) fishing	**$155 – 790**

A. Commercial Reef Fisheries in Saint Lucia

a) Estimate based on landings data

Commercial sale by fishermen is the biggest element of the reef-associated fisheries sector in St. Lucia. There are nine main landing sites in St. Lucia. The fisheries department in St. Lucia is active and collects data on a regular basis; therefore the data on fisheries catch can be considered reliable. Data on commercial fisheries catch was compiled in 2006 and spans 2002 to 2004. During these years, an average of 76,000 pounds of reef fish (snapper, grouper, parrotfish, and squirrelfish) per year were caught, along with 29,000 pounds of lobster. Sea urchin catch was also significant (see Table 10). Total revenue from reef fish constituted US$693,000, which includes some revenue (about US$47,000) from fish processing. An estimated range for gross revenue from coral reef-associated commercial fishing is obtained by excluding the fish processing revenue (as it is addressed later) and by using an error range (of +/- 20%) around the central estimate, to reflect both uncertainty and variability in fisheries. The resulting estimate for gross revenue is US$516,000 to $772,000. Costs for commercial fisheries are difficult to estimate and can vary with fuel and maintenance costs. In St. Lucia, the study assumed non-labor operating costs to be 25% of revenue, resulting in costs between US$129,000 and $193,000, and net revenue between US$386,000 and $579,000.

b) Comparison to fish productivity of coral reefs

Another way to estimate potential coral reef-associated fish catch is to examine potential productivity based on estimates of reef area and the amount of biomass produced per unit area of reef. Typical fish productivity rates in the Caribbean can range from less than 1 MT / km^2 / yr to over 5 MT / km^2 / yr (Burke and Maidens 2004). Using a reef area estimate of 33 sq. km of coral reef[49], these productivity rates yield production (and potential annual catch) of 33 to 165 MT (73,000 to 363,000 lbs.) of fish or shellfish. The upper range of potential annual catch predicted using reef productivity is significantly higher than recorded catch in St. Lucia, possibly suggesting that reef harvest may be occurring at a sustainable level.

Table 10 - Landings and Value of Reef-Associated Fish, Lobster and Sea Urchin, Average 2002-2004

	Pounds	Value ($US)	Percent of Value	Landing Sites
Squirrelfish	13,459	$50,788	7.3%	7
Snapper	44,995	$169,795	24.5%	7
Grouper	8,244	$31,108	4.5%	7
Parrotfish	9,930	$35,445	5.1%	7
Total for finfish	**76,628**	**$287,137**	**41.4%**	
Lobster	29,000	$273,585	39.5%	9
Sea Urchin	7,251	$132,538	19.1%	1
Grand Total	**112,879**	**$693,260***	**100.0%**	

*The estimates of gross revenue include some US$47,000 for fish processing. Source: St. Lucia Fisheries Department, 2006.

B. Fish Processing and Cleaning

[49] Coral reef map and area estimates developed under this project are based on GIS data from *Millennium Coral Reef Mapping Projec*t (http://imars.usf.edu/MC/index.html) and Government of St. Lucia.

While the majority of fish processed in St. Lucia are not associated with reefs, several thousand pounds of reef-associated fish and lobster are processed each year. In 2005, the St. Lucia fish processing facility processed 10,800 pounds of lobster and 5,500 pounds of reef fish. (Reef fish are sold as "pot fish" rather than by individual species.) This generated US$47,000 of net profit based on US$123,800 of revenue. Fish processing facilities offer a lower unit price for fish than can be found by selling directly to restaurants, hotels, or consumers, but will guarantee purchase. As reef fish can be sold directly, relatively small amounts are sold to the processing facilities. In addition, roughly 60% of those reef fish landed are cleaned on-site for EC$1 (US$0.38) per pound. This generates approximately US$17,000 in revenue based on 76,000 pounds of finfish landed in various sites in St. Lucia. Combined, the total net revenue from fish processing and cleaning is estimated at US$64,000. This central estimate is again varied by +/- 20% to arrive at a range of US$51,000 – $77,000, reflecting both the variability in the fisheries sector and some uncertainty in the data.

C. Economy-Wide Impacts

The fisheries sector provides additional economic benefits to the areas in which they are located. These effects can be quantified using an economic multiplier. There was no source for a multiplier for fisheries in St. Lucia, but in order to capture at least some of this value, a conservative multiplier of 1.16 to 1.24 was used to reflect uncertainty and avoid overstating indirect impacts. The fishermen who are employed in the fisheries sector spend the money they earn on boat purchase/repairs, on food for their families, and on other expenses. These expenses, taken together, create other economic activity by enabling boat repairmen, etc. to become employed. The economy-wide multiplier of 1.16 – 1.24 results in an indirect economic value of US$82,000 – $185,000.

D. Local Use (Non-Commercial) Fishing of Coral Reefs

In 2007, a local use survey was undertaken by UWI/SEDU to evaluate the amount of non-commercial fishing that takes place in St. Lucia. 300 people were surveyed in 6 locations—three communities close to reefs (Soufriere, Laborie or Vieux Fort, and Anse La Raye) and three non-reef communities (Castries, Dennery / Micoud and Gros Islet). While reliable estimates for the total value of local fishing cannot be garnered from the survey results due to survey design, 17% of respondents indicated that they fish for reef fish in St. Lucia. The primary reason was for home consumption (38%). The other major reasons for fishing were enjoyment (34%) and income (26%). Those with incomes under EC$2,000/month (US$755/month) are significantly more likely to fish for commercial purposes (92%) and for their own consumption (88%).

The survey results may be used to derive a rough estimate of the potential value of non-commercial (local use) fishing on reefs. This estimate is intended to be conservative and is low compared to the original survey results.[50]

- **Fishing for enjoyment** assumes between 250 and 500 people in coastal communities fish an average of 2–4 hours per week (less than the survey suggested), and used an average hourly wage of US$2.07 – $3.55. Using these assumptions, fishing for enjoyment is valued between US$55,000 and $380,000 per year.

[50] This study used the survey results conservatively by a) focusing only on the estimated 15,500 people in communities close to coral reefs (excluding 90% of the population); b) using a lower range for percent of population who fish (although 17% of survey respondents in both coral reef and non-reef communities say they fish, it was assumed that only 5-10% of people in coral communities fish). In keeping with the survey results, it was assumed that about one-third of these non-commercial fishers fish for enjoyment, while two-thirds fish for consumption or for trade in an informal economy.

- **Fishing for consumption or informal sale** assumes that between 500 and 1000 people in coastal communities fish for this purpose, and each catch between 50 and 100 pounds of fish per year, which has an average value of $US3.80 per pound. Using these assumptions, fishing for consumption or informal sale is valued between US$100,000 and $410,000 per year.

Combined, local fishing value is estimated to be between US$155,000 and US$790,000 per year. This wide range reflects a high degree of uncertainty regarding local (non-commercial) fishing on reefs, but is indicative of this very important and likely significant value.

Fisheries – Discussion of Results for Tobago and St. Lucia

Isolating the value of fisheries specifically associated with coral reefs is difficult because the fisheries tend to be small scale and artisanal, many landings are not recorded, and many statistics do not differentiate by species (or by species group). Recorded landings data were available for St. Lucia, but not Tobago. As a result, different estimation methods were used, and the results are not directly comparable.

The total economic impacts of coral reef-associated fisheries in Tobago is estimated to be between US$846,000 and US$1.3 million. This estimate is dominated by the direct economic impacts of commercial fishing (with net benefits of approx. US$552,000 – US$736,000 per year) and fish cleaning and processing (valued between approximately US$177,000 and $353,000 per year). While the monetary contribution of coral reef-associated fisheries to Tobago is less than one-half of one percent of GDP, the reef fisheries contribute to society in several ways not fully captured in this report. Reef fisheries play a pivotal role in the Tobagonian culture; families congregate on beaches, as they have for many decades. Fisheries also provide an important safety net to families with uneven income—they can be harvested for food or used as a way to generate capital. In addition, the reef fisheries provide a nursing ground for pelagic fish.

In St. Lucia, the total economic impacts of coral reef-associated fisheries are estimated to be between US$520,000 and $841,000, which is very small relative to GDP. However, as with the case of Tobago, there are many additional benefits of coral reef-associated fisheries which have not been valued—the societal benefits of employment, social cohesion, nutrition, and the social safety net value of fishing. The valuation of coral reefs for enjoyment and consumption found this to be a significant value, estimated to be between US$155,000 and $790,000. The wide range of this estimate reflects the degree of uncertainty about numbers of people and level of effort in this area, but the overall magnitude reflects the importance of coral reefs to the local population.

Table 11 - Coral Reef-associated Fisheries Impacts – Comparison for Tobago and St. Lucia

	Tobago	**St. Lucia**
Coral Reef-associated:	**($US thousand)**	**($US thousand)**
Commercial Fisheries – Gross Revenue	$736 – 981	$515 – 772
Operating Costs (25%)	$184 – 245	$129 – 193
Commercial Fisheries – Net Revenue	$552 – 736	$386 – 579
Fish cleaning and processing	$88 – 177	$51 – 77
Total Direct Impact	**$640 – 913**	**$437 – 656**
Indirect economic impact (multiplier)	$118 – 235	$82 – 185

Total Economic Impact (Direct + Indirect)	**$758 – 1,148**	**$520 – 841**
Local (non-commercial) fishing	Estimate not reliable; probably small.	**$155 – 790**

5. Valuation of Shoreline Protection Services provided by Coral Reefs

The shoreline protection services provided by coral reefs are valued at between US$18 and 33 million for Tobago and US$28 to 50 million for St. Lucia in 2007. In Tobago, about half of the coastline is protected by coral reefs, while about 44% is protected in St. Lucia. This study estimates that where reefs are present, they provide from about 20 to over 40 percent of the natural stability of the coast.

Coral reefs are the source of white sand beaches on both St. Lucia and Tobago, which are a vital resource for both local recreation and international tourism. Beaches exist in 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. Loss of some of the protection along these beaches (such as from loss of coral reefs) will result in increased storm energy and increased erosion. Beach replenishment and construction of coastal defense structures are expensive alternatives to natural coastal protection, and have potentially negative side effects. Construction of sea walls lessens the aesthetic appeal of an area, and only replaces some functions of coral reefs. Sand mining for beach replenishment can have negative impacts through inappropriate sourcing of sand—promoting erosion in other areas. In addition, beach replenishment is a stop-gap measure which will continue to be required if the loss of the natural defense provided by a reef has resulted in a new equilibrium for the beach.

This analysis of shoreline protection services provided by coral reefs progresses through the six steps outlined in the methods section, but is presented here in four sections:

a) Identifying vulnerable lands based on storm surge and wave heights associated with a 25-year storm event (steps 1 and 2 from the method);
b) Identifying coastal segments which are protected by coral reefs (step 3 in the method);
c) Evaluating the overall stability of the shoreline as well as the share of coastal protection provided by coral reefs (step 4 in the method);
d) Determining the property values (land and structures) in areas identified as both vulnerable and protected by coral reefs, and combining this with the share of protection provided by coral reefs to estimate the reduction in potential damage attributable to the coral reefs (steps 5 and 6 in the method).

Tobago

Coastal Profile for Tobago

The island of Tobago is of volcanic origin, and has a land area of approximately 300 sq km. Tobago is the summit of a single mountain mass that rises from the sea floor and reaches an elevation of approximately 550 m (1,800 ft) above sea level. The island is oriented in a northeast / southwest direction, and is about 40km in length and about 10 km at its widest. The leeward (Caribbean) coast faces northwest, while the

windward (Atlantic) coast faces southeast, and is more exposed. The northeast two-thirds of the island is steep, rocky, rugged and irregular, resulting in a highly indented coastline. The southwestern part of the island, however, is flat or rolling and formed of coral. Much of the coastline is fringed by coral reefs. The coastline is broken by inlets and sheltered beaches. The beaches of Tobago are generally of biogenic origin (derived from broken coral and shells) and some of them are leatherback turtle nesting sites (Institute of Marine Affairs, 2004).

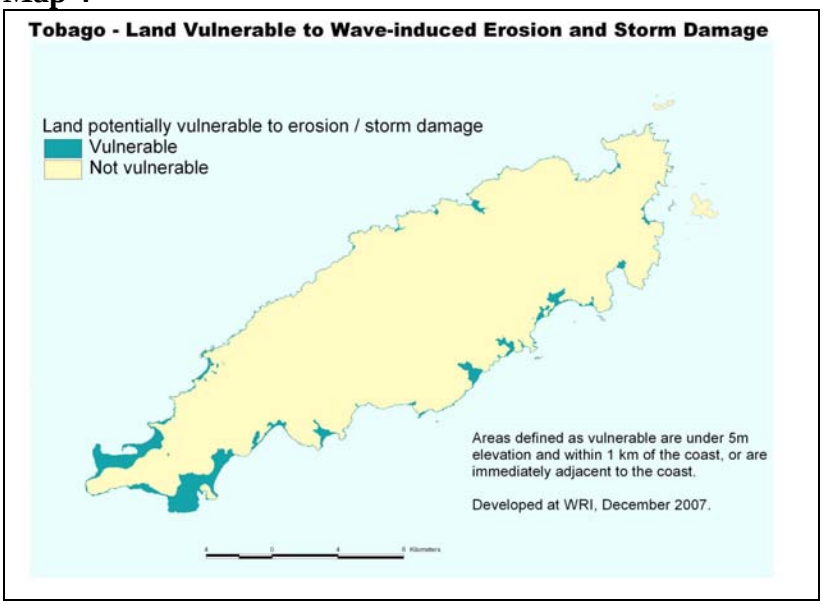
Analysis Results

A. Vulnerable Lands in Tobago

The definition of "land vulnerable to wave-induced erosion and storm damage" is based on expected wave heights and storm surge associated with a 25-year storm event, adjusted to be precautionary in light of anticipated sea level rise and increased storm intensity associated with warming seas.[51] Vulnerable lands are defined as any land area of 5m or less elevation, within one km of the coast, as well as all land immediately adjacent to the coast (as defined by the 25m grid cell adjacent to the sea). This analysis focuses on a 25-year period, including the typical 25-year storm event as well as lesser storms.

Just over 6% of Tobago's land area was classified as vulnerable to wave-induced erosion and storm damage (about 19 sq km). The majority (16 sq km) was included due to elevation and about 3 sq km was included due to immediate adjacency to the coast (See Map 4).

Map 4

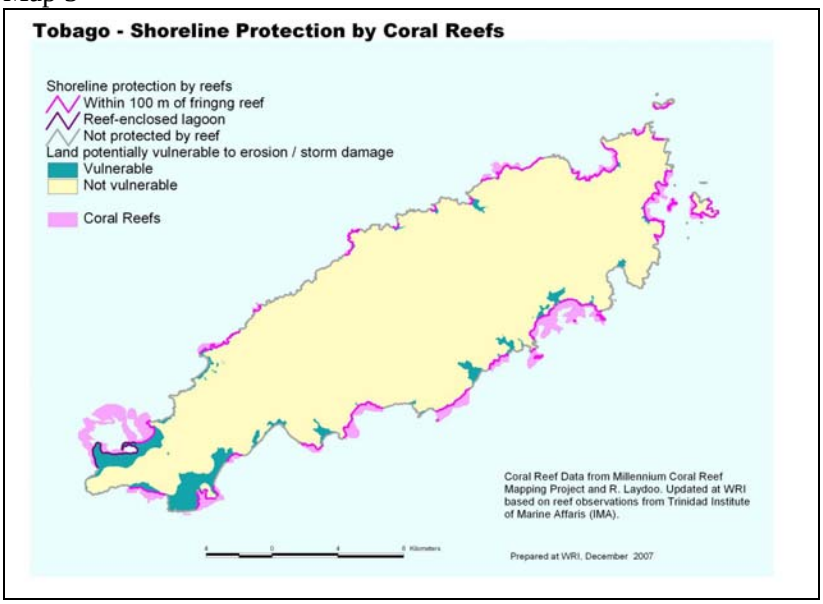


B. Coastline Protection by Coral Reefs

[51] OAS 2002 projects maximum wave heights for the 25 year storm event of 3m for Tobago and 4.5 m for St. Lucia, and storm surge of less than 0.5 m for both islands. The 5 m threshold was selected to approximate the combined maximum storm surge and wave height, while accommodating modest some increase in sea level and storm intensity.

Much of Tobago's coastline is bordered by near shore, fringing reefs. Southwest Tobago is characterized by a lagoonal system enclosed by the Buccoo Reef. Shoreline segments protected by coral reefs were defined as those within 100 m of a fringing reef, or enclosed by a lagoon-forming reef. Using this definition, nearly 90 km (just under half) of Tobago's coastline was classified as protected by a coral reef. See Map 5.

Map 5



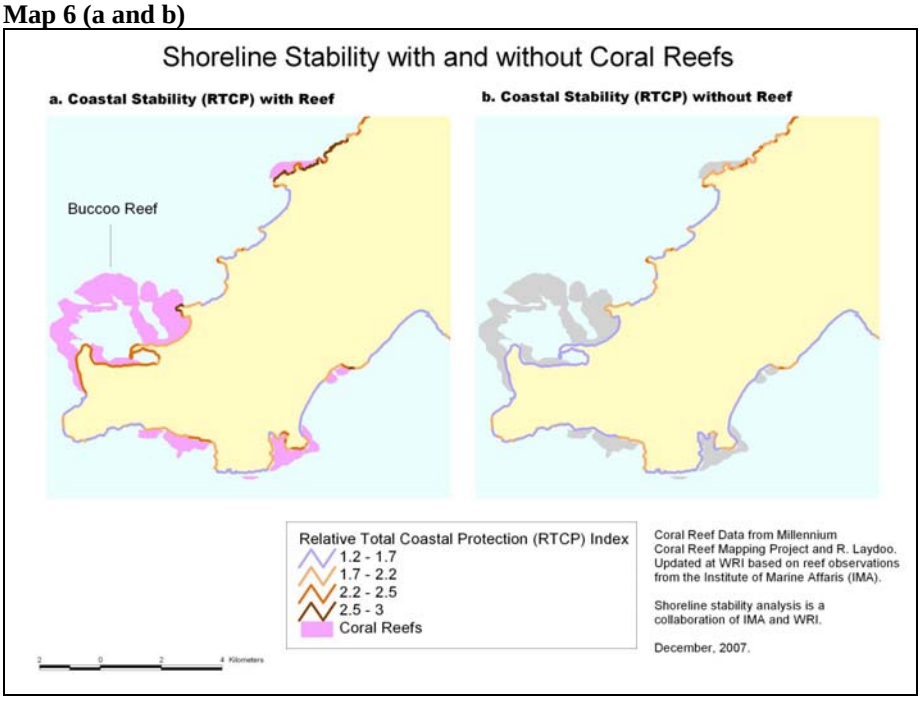
The information from these two steps was then used to identify the segments of the coast that are both vulnerable to wave-induced storm damage and protected by the presence of a reef. Slightly over half of the 19 km sq of land classified as "vulnerable" was identified as having shoreline protected by coral reef. This "vulnerable yet protected" area is just over 10 sq km.

C. Stability of the Shoreline and the Role of Coral Reefs

a) Relative Total Coastal Protection (RTCP). The relative stability of Tobago's shoreline was evaluated using the coastal protection framework developed by IMA (see Table 2, page 24.) The framework was implemented using only six of the ten potential input variables because of lack of data for the other four. Data on coastal geomorphology, geology, wave height, storm events, and elevation, as well as coral reef type, continuity, and distance offshore were integrated to evaluate the stability of the shoreline or Relative Total Coastal Protection (RTCP) for all of Tobago.[52] Areas with steeply cliffed coastlines as well as areas protected by coral reefs have some of the highest stability values. Maps 6a and b reflect the RTCP for southwest Tobago both with reefs present (current situation) and without the reefs. The low-lying areas behind the Buccoo Reef have very low shoreline stability without the reef present, while the rocky, cliffed coastline in the upper right of the map still has reasonable shoreline stability, even without the reef. This highlights the fact that the importance of the coral reef varies along different segment of the shoreline.

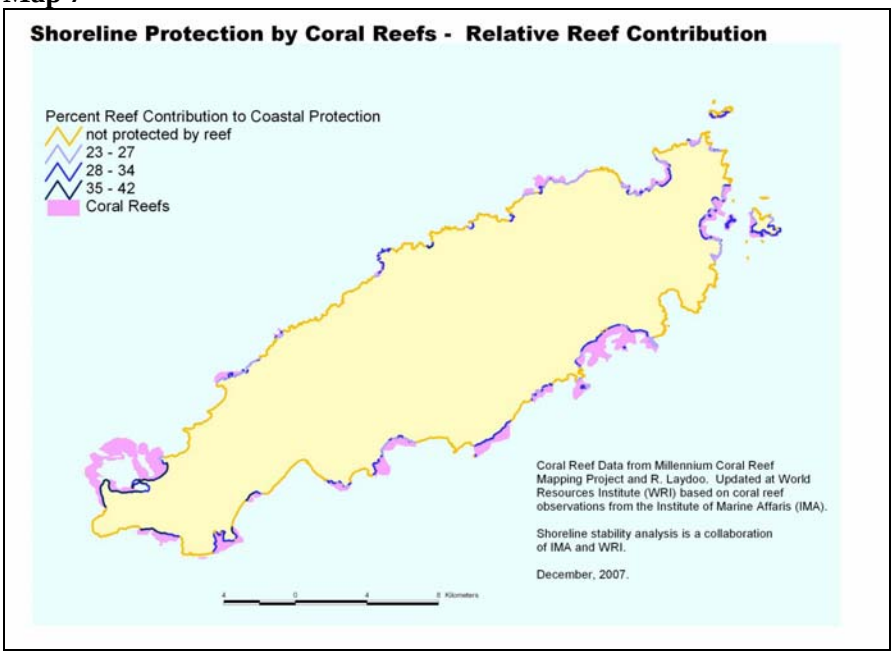
[52] Six factors were used to evaluate RTCP for Tobago. The framework is considered valid with a minimum of five variables. Omitted due to lack of data were presence of coastal protection structures (headlands, breakwaters, etc.), coastal slope, coastal vegetation, and anthropogenic activities (sand mining, etc.)

Map 6 (a and b)



b) The role of coral reefs in protecting the shoreline. The IMA framework was also used to evaluate the contribution of coral reefs to shoreline stability, which is shown in Map 4. The relative reef contribution is zero in areas not protected by a coral reef, and ranges from 27 percent where the shoreline has relatively good protection due to other factors, to 42 percent where the shoreline would be most vulnerable without the reef. The relative share of protection provided by coral reefs is particularly high behind the Buccoo Reef in southwest Tobago and in Roxborough Bay, as well as along several other portions of the windward coast. (See Map 7.)

Map 7



Data sources and notes on the implementation of the shoreline protection framework for Tobago are included in Appendix 1.

D. Property Values and Potentially Avoided Damages Due to Coral Reef

Information on property values for both developed and undeveloped land was collected in Tobago and through internet searches. A range of US$18–22 per sq ft was used to reflect current average property values in coastal areas in Tobago.

Property values in vulnerable areas protected by coral reefs (an area of about 10 sq km) are combined with the Relative Reef Contribution[53] to coastal protection (RRC), to arrive at the value of "potentially avoided damages" over a 25-year period due to the presence of coral reefs around Tobago. This value is estimated to be between US$450 and $825 million over a 25-year time period. The annual value for 2007 is between US$18 and 33 million.[54] Table 12 provides a summary of this estimate for Tobago.

Table 12 - Shoreline Protection Valuation Summary for Tobago

	Tobago	
Land Area (sq km)	300 km^2	
Vulnerable Land Area (sq km)	19 km^2	6%
Vulnerable Area Protected by reefs (sq km)	10 km^2	3%
Average Property Value (US$ per sq ft)	US $18 - $22	
Potentially Avoided Damages (over 25 years)	**US $450 – 825 million**	
Potentially Avoided Damages (annual value for 2007)	**US $18 – 33 million**	

Estimate for Buccoo Reef. About 30% of this shoreline protection service in Tobago is provided by the Buccoo Reef, because of the extent of low-lying, vulnerable land behind the reef. The potential damages avoided due to the presence of the Buccoo Reef are estimated to be between US$140 and 250 million over 25 years. The annual value for 2007 is between $5 and 10 million.

Saint Lucia

Coastal Profile for Saint Lucia[55]

Like most of the islands in the Lesser Antilles, Saint Lucia is volcanic in origin. The 610 sq km island is dominated by high peaks, narrow valleys and rain forest in the interior. A north-south trending range, with Mount Gimie as the highest point (over 950m), also includes the striking twin peaks of Gros Piton and Petit Piton. On both the eastern and western side of the range are heavily forested ridges which

[53] Note: the RRC was varied by + / - 20% to reflect some of the uncertainty surrounding this estimate.
[54] The value of shoreline protection for 2007 was estimated using property values for 2007 and a 1 in 25 probability (4% chance) of the occurrence of the a 25-year storm event. The damage estimate for the 25-year time period uses a 3% discount rate and assumes an average real increase in property values of about 3%.
[55] Based on information from the University of the West Indies, Seismic Research Unit.

descend steeply to the coast. The northern part of the island is older and has smaller, more rounded hills and gentler valleys. The only coastal plain is in the southeast corner of the island. Much of the coast is cut by steep river valleys, and dotted with beautiful sandy beaches. Mangroves are not widespread, but are present along some sheltered coastal stretches, particularly on the windward coast.

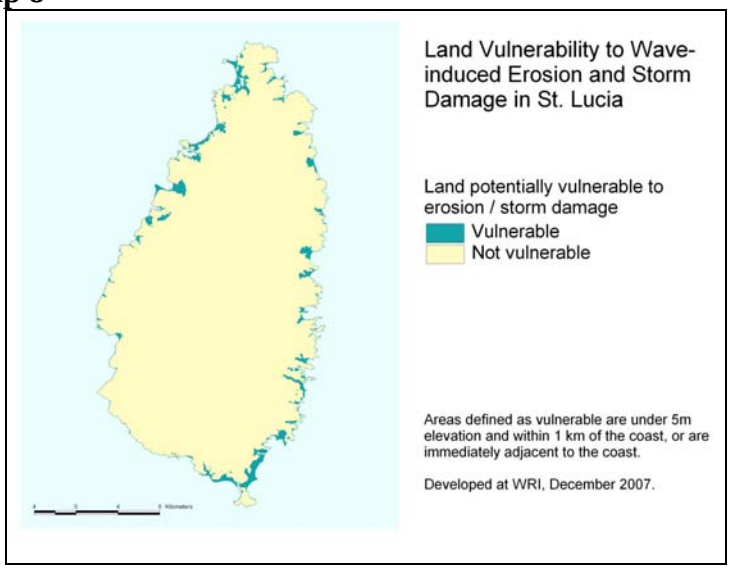
Analysis Results

A. Vulnerable Lands in St. Lucia

Vulnerable lands were defined as any land area of 5m or less elevation, which is within one km of the coast, as well as all land within 25 m of the coast (as defined by the 25m grid cell adjacent to the sea).[56] This analysis focuses on a 25-year period, including the typical 25-year storm event as well as lesser storms.

Just over 4 percent of land in St. Lucia was classified as vulnerable to wave-induced erosion and storm damage (about 24.5 sq km). The vast majority was included due to low elevation, while only about 1.5 sq km was included solely due to immediate adjacency to the coast. (See Map 8.)

Map 8

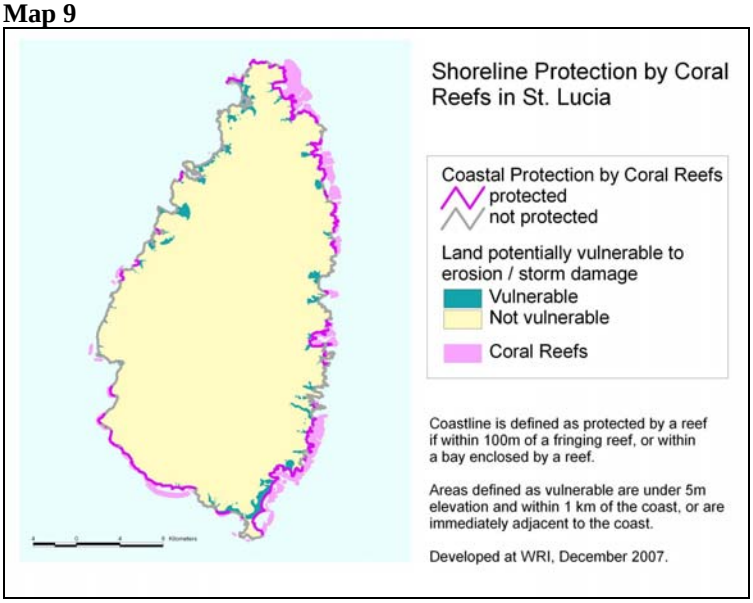


B. Coastline Protection by Coral Reefs

Much of St. Lucia's coastline is bordered by near shore, fringing reefs. Shoreline segments protected by coral reefs were defined as those within 100 m of a fringing reef, or in bays protected by a reef. Using this definition, about 44 percent of St. Lucia's shoreline was classified as protected by a coral reef (see Map 9).

[56] The *Atlas of Probable Storm Effects in the Caribbean Sea* - http://www.oas.org/CDMP/document/reglstrm/index.htm projects maximum wave heights for the 25 year storm event of 4.5 m for St. Lucia, with a storm surge of less than 0.5 m.

Map 9



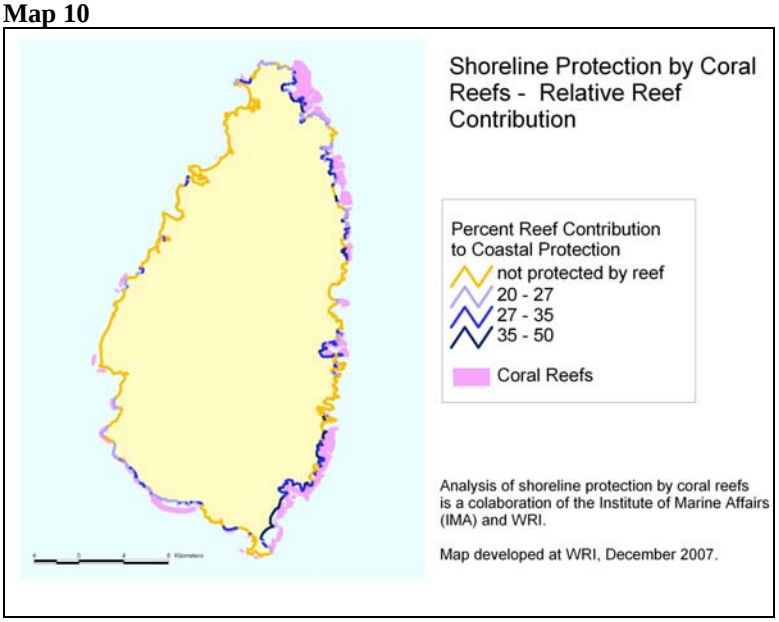
The information from these two steps was then used to identify the segments of the coast that are both vulnerable and protected by the presence of a reef. Just over one third (35%) of the "vulnerable land" in St. Lucia was identified as having shoreline protected by coral reef. This "vulnerable yet protected" land is an area of about 10 sq km (about 1.5 percent of the total land area of St. Lucia).

C. Stability of the Shoreline and the Role of Coral Reefs

The relative stability of St. Lucia's shoreline was evaluated using the coastal protection framework developed by IMA (see Table 2 in method section.) The framework was implemented using eight of the ten potential input variables.[57] Data on coastal geomorphology, geology, vegetation, wave height, storm events, elevation, and slope, were integrated with coral reef type, continuity, and distance offshore to evaluate the stability of the shoreline or "Relative Total Coastal Protection (RTCP)" for all of St. Lucia. As one would expect, shoreline stability is, in general, higher on the leeward coast, and higher is areas of steep terrain. Wide bays in the southeast and northwest have the lowest shoreline stability. The contribution of coral reefs to RTCP was also evaluated (see Map 10). The reef contribution ranges from 20 percent to nearly 50 percent in some areas. Areas along Point Sable in the southeast, some bays along the southeast coast, and bays in the northeast have the highest proportion of shoreline stability provided by coral reefs.

[57] Data were not available for anthropogenic activities (such as sand mining), or coastal protection structures (such as breakwaters and sea walls.)

Map 10



D. Property values and Potentially Avoided Damages due to coral reef presence

Information on property values (land and built structures) was collected during 2007 through internet searches to arrive at a range of US$25 – 30 per sq. ft. to reflect average property values in vulnerable coastal areas in St. Lucia. Property values in vulnerable areas protected by coral reefs (an area of about 10 sq km) are combined with the Relative Reef Contribution[58] (RRC) to coastal protection for the nearest coastal segment, to arrive at the "potentially avoided damages" over a 25-year period due to the presence of coral reefs around St. Lucia. This value is estimated to be between US$700 million and $1.2 billion over a 25-year time period. The annual value for 2007 is between US$28 and 50 million.[59] Table 13 provides a summary of this estimate for St. Lucia.

Table 13 - Shoreline Protection Valuation Summary for St. Lucia

	Saint Lucia	
Land Area (sq km)	610 km2	
Vulnerable Land Area (sq km)	24.5 km2	4%
Vulnerable Area Protected by reefs (sq km)	10 km2	1.5%
Average Property Value (US$ per sq ft)	US $25 – 30	
Potentially Avoided Damages (over 25 years)	**US $0.7 – 1.2 billion**	
Potentially Avoided Damages (annual value for 2007)	**US $28 – 50 million**	

[58] Note: the RRC was varied by + / - 20% to reflect some of the uncertainty surrounding this estimate.
[59] The value of shoreline protection for 2007 was estimated using property values for 2007 and a 1 in 25 probability (4% chance) of the occurrence of the a 25-year storm event. The damage estimate for the 25-year time period uses a 3% discount rate and assumes an average real increase in property values of about 3%.

Comparison and Discussion of Results

Coral reefs play a vital role protecting the shorelines of both St. Lucia and Tobago. Coral reefs contribute to the protection of over 40 percent of the shoreline of both islands (about 44 percent for St. Lucia and nearly 50 percent for Tobago). St. Lucia is about twice the area of Tobago, at about 610 and 300 sq. km., respectively. Although both islands have steep topography, extensive cliffed coastlines, and relatively little coastal lowland area, there is still significant land area which is potentially vulnerable to wave-induced erosion and storm damage—about 6 percent of land in Tobago and 4 percent of land in St. Lucia. Focusing on the subset of vulnerable land with shoreline protected by coral reefs, the two islands have about the same land area in this category—approximately 10 sq. km, which is about 3 percent of Tobago's area and 1.5 percent of St. Lucia.

In both islands, the relative share of protection provided by coral reefs varies greatly with coastal context—the elevation and slope of the shore, the geologic origin of the area (and resistance to erosion), and the wave energy along the coast. In all areas where corals are present, they are estimated to provide at least 20 percent of the shoreline stability. In some areas, this share is over 40 percent.

Table 14 - Summary of Shoreline Protection Valuation Results for Tobago and St. Lucia

Comparison	Tobago		Saint Lucia	
Land Area (sq km)	300 km^2		610 km^2	
Vulnerable Land Area (sq km)	19 km^2	6.0%	24.5 km^2	4.0%
Shoreline length protected by coral reefs	about 50%		about 44%	
Vulnerable Area Protected by reefs (sq km)	10 km^2	3.0%	10 km^2	1.5%
Average Property Values (US$ per sq ft)	US $18 – $22		US $25 – 30	
Potentially Avoided Damages (over 25 years) [a]	**US $450 – 825 million**		**US $0.7 – 1.2 billion**	
Potentially Avoided Damages (annual value for 2007)	**US $18 – 33 million**		**US $28 – 50 million**	

a. Damage estimates for years beyond 2007 use a 3% discount rate. Property values are based on values in 2007 and assume a 3% real growth rate.

This analysis is intended to prompt further thinking on and analysis of shoreline protection by coral reefs. The methodology allows exploration of both physical and economic aspects of this ecosystem service. The innovative multi-stage approach involves compound assumptions, so there is inevitably uncertainty around the valuation estimates. It does, however, provide useful indicators of the relative stability of the coast to wave-induced erosion, and the relative role coral reefs play in protecting the shore. Coastal planning could benefit greatly from information on which lands are vulnerable to waves and storm damage, as well as the share of protection provided by coral reefs. This information is useful for both current coastal planning and for planning adaptation to future climate scenarios. The role of coral reefs and mangroves in protecting the shoreline will increase as the sea warms due to climate change, prompting rising sea level and increased storm intensity.

6. Summary of Coral Reef Valuation Results

The previous sections provided details on the implementation of the valuation of coral reef-associated tourism and recreation, fisheries and shoreline protection services for Tobago and St. Lucia. Table 14 provides a summary of these values.

In both islands, coral reef-associated tourism and recreation provide the largest values. The estimates of direct impact are more reliable than those for indirect impact, because there is significant uncertainty associated with multipliers. In addition, indirect impacts reflect national effects, so the indirect impacts for Tobago apply to both Trinidad and Tobago, while the indirect benefits in St. Lucia are specific to the island. It is not surprising that St. Lucia, which is a larger island with a larger tourism economy, also has larger estimated coral reef-associated values—direct impacts of about US$91.6 million in 2006 (about 11 percent of GDP), as compared with US$43.5 million for Tobago (about 15 percent of GDP). The local use value is considerably larger for St. Lucia (US$52 – $109 million as compared with US$13 – 44 million in Tobago.) This is driven by the larger population size in St. Lucia (about three times as large) and higher average wages. In both countries, beaches and reefs are an important part of the culture.

The value of shoreline protection provided by coral reefs is also large for both islands—it is estimated at between US$28 and 50 million for St. Lucia and US$18 and 33 million for Tobago in 2007. St. Lucia is about twice as large as Tobago (610 vs. 300 sq km.), but a larger percentage of land was classified as vulnerable in Tobago (6% of Tobago vs. 4% of St. Lucia). In addition, slightly more of Tobago's coast was classified as protected by coral reef (50% for Tobago versus 44% for St. Lucia). With these factors combined, both countries have about 10 sq. km of land area classified as both vulnerable to wave-induced erosion and protected by a coral reef (this is about 3% of all land in Tobago and 1.5% of St. Lucia). It is worth noting that there are "vulnerable lands" not protected by a coral reef which are not considered in this study. The estimated value of shoreline protection is higher for St. Lucia in part due to estimated property values (US$ 25–30 per sq. ft in St. Lucia, versus US$18–22 in Tobago). However, the relative role of coral reefs varies along these coastlines, so it is many factors coming together that influence these values. Along coasts where coral reefs are present, they are estimated to provide at least 20 percent of the shoreline stability. In some areas, this share is over 40 percent.

As compared with coral reef-associated tourism and shoreline protection services, the economic contribution of coral reef-associated fisheries is relatively small. The total economic impact of reef-associated fisheries in Tobago is estimated to be between US$0.8 and US$1.1 million. This estimate is dominated by the direct economic impacts of commercial fishing and fish processing (which total US$0.6 – $0.9 million). A conservative estimate of US$0.1 – 0.2 million in indirect impacts contributes to the overall total. In St. Lucia, the total economic impacts of coral reef-associated fisheries are estimated to be between US$0.5 and $0.8 million. The estimated value for the local use (non-commercial) fishing of coral reefs in St. Lucia is between US$0.2 and $0.8 million. As a result of the different data available and the different methods for estimation, it is not possible to directly compare the fisheries results for the two islands.

Table 15 provides a comparison of estimates for the three ecosystem goods and services for Tobago and St. Lucia.

Table 15 - Coral Reef-associated Tourism and Recreation Valuation Summary - Tobago and St. Lucia

	Tobago	St Lucia
Island GDP (for reference)	US$286 million (2006)	US$825 million (2005)
Coral Reef-associated Tourism and Recreation	($US million)	($US million)
Percent of visitors classified as visiting at least in part due to the coral reef	*40%*	*25%*
Total Direct Impact	**43.5**	**91.6**
Indirect economic impact	58 – 86 [a]	68 – 102
Total Impact (Direct and Indirect)	**$101 – 130**	**$160 – 194**
Other Values		
Consumer Surplus	1.0	2.2 – 2.4
Local Use	13 – 44	52 – 109
Coral Reef-associated Fisheries		
Total Direct Impact	**0.7 – 1.1**	**0.4 – 0.7**
Indirect economic impact	0.1 – 0.2	0.1 – 0.2
Total Impact (Direct and Indirect)	**US$0.8 – 1.3 million**	**US$0.5 – 0.8 million**
Local Use Value	Estimate not reliable; probably small.	.2 – .8
Shoreline Protection by Coral Reefs		
Land Area (sq km)	300 km^2	610 km^2
Vulnerable Land Area (sq km)	6%	4%
Vulnerable Area Protected by reefs (sq km)	3%	1.50%
Potentially Avoided Damages (annual value for 2007)	**US $18 – 33 million**	**US $28 – 50 million**

[a] Indirect economic impacts are a benefit to both Trinidad and Tobago.

7. Policy Applications

Value matters

The importance of coral reefs to local economies is frequently underappreciated. A clear presentation of the magnitude of these economic impacts can support policy, investment, and development decisions. Decisions on land use, including the removal of mangroves and other wetlands, development along the coast, construction of roads, and management of agriculture can all have significant negative effects on coastal water quality and coral reef health. Managing the pressures from fisheries and tourism is also a delicate process with important consequences for reef condition. In many areas, coastal and marine management policies and regulations exist to limit pressure on coastal ecosystems, including coral reefs. But these regulations are often not enforced—even in Marine Protected Areas—often due to a lack of resources for enforcement, such as staff, boats, and fuel. At the heart of many of these management

concerns is the problem of assessing trade-offs—investing in better enforcement, capping tourist numbers, or limiting coastal development—as each has economic consequences for individuals and for the economy. However, longer-term revenue streams and societal benefits from the goods and services provided by healthier reefs are often not included in the decision. Adding these factors to the decision-making process is an important step toward more sustainable resource management. Although not explicitly addressed in this study, economic valuation can also draw attention to distributional concerns. In the eyes of citizens and policy-makers, the question of who captures the benefits of healthy reefs or suffers most from their decline can be as important a concern as the total value of the services they produce.

The economic valuation of coral reef-associated tourism, fisheries, and shoreline protection services for both St. Lucia and Tobago demonstrates the high values associated with these ecosystems. Awareness of these values can help to encourage better management of coastal resources. Economic valuation can also be used to examine the costs and benefits of specific policy, management and development decisions. In some cases, these discussions can help to produce a middle ground that attempts to reconcile short- and long-term economic prospects. For example, an analysis of the potential economic losses from a planned coastal development or industrial facility could be used to require the developers to mitigate impacts and pay for third-party monitoring. This could be an effective supplement to administering fines, which are often treated by large projects as a cost of business. Fines—for ship groundings, land-use violations and other infractions—can also be made more appropriate with the help of economic valuation. Valuation results can also lead to better-informed discussions on land use, adding weight to arguments for limiting or otherwise managing development in sensitive areas. .

Policy Applications

Working with our partners over the course of this project, a number of policy-relevant applications of the coral reef valuation methodology were identified. These include:

Common Applications

1. To evaluate tourism carrying capacity and limits of acceptable environmental change;
2. To evaluate the economic impact of coral reef goods and services relative to total economic activity;
3. To evaluate the economic impact of MPAs and assess options for sustainable financing;
4. To examine changes in fisheries management and their impact on short-term livelihoods versus long-term benefits.
5. To evaluate effectiveness of policy decisions or management measures, as these relate to coral reef health.

Tobago-specific Applications

6. To evaluate the costs and benefits of investing in more active management of Buccoo Reef Marine Park;
7. To evaluate the benefits of investment in improved sewage treatment in southwest Tobago;
8. To evaluate the impact of establishment of a user fee at Pigeon Point Heritage Park, Tobago;
9. To evaluate appropriate damage compensation for groundings or damage of shallow coral reefs in Tobago.

St. Lucia-specific Applications

10. To evaluate potential changes resulting from proposed Marina developments along the central west and east coasts of St. Lucia;
11. To guide management planning for the Soufriere Marine Management Area (SMMA);

12. To guide future development in St. Lucia—including examining the impacts of coastal development and population growth;
13. To evaluate the loss of local use value resulting from resort development along the coast of St. Lucia;
14. To evaluate the benefits of investment in improved sewage treatment in St Lucia;
15. To evaluate future benefits (benefits currently not being derived);

Using a Valuation Tool to assess Scenarios

A Valuation Tool has been developed to help guide the implementation of the tourism and fisheries valuations. The Tool can be used to produce value estimates for a specific time period—such as those presented in this report—and it can be used to look at changes in value over time, including estimating the effects of different policy, management or development scenarios. There are several steps involved in applying the economic valuation method and Tool to examine policy scenarios:

1) Define the policy or development scenarios to compare (including a baseline scenario reflecting current condition or current trends);
2) Determine the time period for consideration;
3) Estimate the change in coral reef condition likely to result from the policy or management options under consideration (this will be based on existing studies coupled with expert opinion);
4) Derive estimates of the change in ecosystem services due to the estimated change in coral reef condition (this will be based on existing studies, expert opinion, or guidance in the Tool). Such estimates can include:
    a. the likely change in tourist behavior, including changes in visitor numbers, duration of stay, or recreational activities due to the change in reef quality;
    b. the expected change in fisheries productivity in the study area;
    c. whether there will be a change in the shoreline protection services provided by the reef.
5) Apply the tool to estimate the resulting changes in coral reef-associated economic value.

Box 4 provides an example of policy options and economic valuation for Buccoo Reef Marine Park (BRMP) in Tobago.

Box 4. Policy Application for Buccoo Reef Marine Park

The Buccoo Reef area in Southwest Tobago is an important focal point for marine-based tourism. A 2003 exit survey suggests that more than 60 percent of all visitors to Tobago visit the reef on glass-bottom boat and snorkeling trips (PRDI and THA, 2004). The Buccoo Reef encloses the Bon Accord lagoon. Sewage discharge and nutrient and sediment runoff into the lagoon are major problems, resulting in the poor condition of the inner reef, while the outer reef is relatively healthy. The Buccoo Reef Marine Park (BRMP) was established in 1973 as a no-fishing area, with authorization for entrance fees. However, at present, the no-fishing restrictions are not enforced, and fees have never been instituted.

The policy scenario to be explored for BRMP includes several distinct policies which would promote increased reef health, and thereby support sustainable tourism and recreation. The policy scenario includes:

1) **Enforcement of the No-Fishing Area established for BRMP.** This would lead to higher levels of fish and conch inside the reserve, larger fish, and more appeal for snorkeling and diving. This would lead to increased tourism revenue in Tobago, as has generally been seen in other Caribbean islands with well-managed no-fishing areas.[a] Enforcement would likely have benefits to fisheries outside of the reserve as well.
2) **Re-routing of a drain currently coming into Bon Accord Lagoon.** The Bon Accord Integrated Development Drain currently discharges both sewage and fish processing waste into

the lagoon in an area between Buccoo village and Pigeon Point. This drain could be diverted into a wetland area called the Pigeon Point Ponds. The effluent could then be filtered by the wetlands, before discharging into more open water.

3) **Integrated watershed management.** Nutrient and sediment delivery to the Buccoo Reef area and Bon Accord Lagoon could be reduced through the installation of sediment traps, and by routing sewage discharge and nutrient-laden runoff through wetlands. The GEF-funded, Integrating Watershed and Coastal Area Management in Small Island Developing States of the Caribbean (IWCAM) project is currently focused on such management issues in this area.
4) **Sewage Treatment.** Communities near Bon Accord Lagoon lack adequate sewage treatment, though the Water and Sewage Authority (WASA) has plans to develop a sewage treatment plant in the area. This large infrastructure project will likely not occur for another five or six years. In the meantime, additional development is proceeding, and there is potential that the new developments might incorporate sewage treatment sooner.

Three of the four management options described above could be implemented at relatively moderate cost within the next one to two years. Enforcement of the no-fishing regulations at BRMP would require increasing the staff (through hiring a park manager), effective maintenance of boats, as well as an institutional commitment to enforcement of the regulations. These modest costs could be financed through the implementation of a visitor fee to the park. Re-routing of the drain in Bon Accord would require only moderate engineering, with likely benefits significantly outweighing costs (see below). Improvements in overall watershed management, with a focus on sediments and nutrients, can be achieved under the funding provided by the IWCAM project.

Development of sewage treatment infrastructure for the area will take more time and represents a much larger investment. Although improved sewage treatment is essential for the long-term health of the Buccoo Reef, adding a park manager, rerouting the drain, and making improvements in watershed management would begin to improve the health of the reef. These improvements include: increased species diversity, greater resiliency to coral bleaching and disease, a more productive reef with higher numbers and larger fish. These changes would lead to short-term economic gain through both a recreational benefit inside BRMP and a fisheries benefit outside the park. The changes would also promote the long-term sustainability of the reef, fostering a sustained shoreline protection benefit.

Costs of Losing Buccoo Reef

The values presented in this report provide a strong incentive to implement policies that will help to protect the Buccoo Reef. Due to a lack of information on the costs of specific interventions or the marginal improvement of reef quality that might result from each intervention, it is instructive to look at the extreme case of a total loss of the services provided by the Buccoo Reef and the financial losses that could result. Because the reef protects a large, low-lying and developed section of the island, its shoreline protection value alone is very high: “damages avoided” due to the presence of the Buccoo Reef are estimated at between US$140 and 250 million over a 25-year time period. In addition, the economic impact of current tourism and recreation associated with the Buccoo Reef is estimated to be between US$7.2 and $8.8 million a year (in 2006),[b] which equates to about US$128 to $156 million in net present benefits over a 25-year time period.[c] The direct economic effects of glass bottom boat and snorkel tours alone are approximately US$1.4 million per year. Even without taking into account fisheries spillover benefits, increases in tourism that could result from improvements in reef quality, or the value of local use of Buccoo Reef, the economic benefits of the reef over a 25-year period are likely to be over $250 million. The specific costs of the interventions such as re-routing the drain in Bon Accord or of increasing enforcement of regulations in BRMP are not currently available, but will be significantly smaller in comparison to these estimated benefits. The SMMA in St. Lucia, for example, which is similar in size to BRMP, has total operating costs of under US$150,000 per year.

The policies considered above make good economic sense—both to protect the current financial value of the Buccoo Reef, as well as to increase that value as the reef quality improves.

a. Personal communication with Owen Day (Buccoo Reef Trust).
b.This estimate is based on about 60% of visitors to Tobago visiting the Buccoo Reef (based on the 2003 exit survey); coupled with visitors staying an average of about 10 nights in Tobago, and just one of these nights being associated with Buccoo Reef. As such, we took 6% of the coral reef associated recreation and tourism value (60% of visitors, one tenth of nights) for accommodation, miscellaneous expenditures and indirect benefits, plus the full value of snorkel trips to Buccoo.
c. This estimate assumes a 3% discount rate.

8. Conclusions

The methodology outlined in this study represents a replicable framework for looking at the value of three key ecosystem goods and services provided by coral reefs. This approach does not attempt to assess the "total" value of coral reef ecosystems—omitting, among other things, the research and educational value of reefs, the supporting role they play for nearby oceanic and coastal ecosystems, and most non-use values, including the "existence" value of coral reefs and "option" value of retaining them for the use of future generations. This study has instead examined the values that can be more reliably evaluated and that policy-makers tend to be most interested in—the economic impacts of goods and services from coral reefs. (An exception to this is the inclusion of an estimate of consumer surplus from reef recreation. Partners in both pilot sites felt that omitting this value neglects an important uncaptured benefit of the reefs. It also represents an intangible element that may influence visitors' decision to come to a country with coral reefs, and their decision of whether to return again.)

The goal of this approach is to produce practical, consistent results that can be used to inform policy and management decisions, to arm NGOs and resource users with a new type of information, and to encourage industries that rely on the continuing health of the reefs to take a proactive approach to securing their future. As was demonstrated in the valuation findings for the two study sites, even a subset of the ecosystem services provided by coral reefs can have a significant economic impact. Nevertheless, it is important to note that the economic argument for sustainable resource use is only one part of a much bigger picture. On its own, the economic impact of coral reefs is an important measure—and, particularly for tourism-dependent small island states, often a compelling one—but it in no way manages to capture the full value of these resources. These results should be viewed as a supplement to the biological, social, and moral arguments that are already being put forward for better management of coral reefs.

Many of the studies in this field, including this one, are hindered by a lack of reliable data. In particular, better information on reef use by visitors, tourist responses to changes in reef quality, fishing effort, total fish catch, and more complete data on coral reef locations, coastal characteristics and land values would improve estimates of the economic impact of coral reefs. Better data collection on fishing effort and catch in Tobago, for example, would both improve estimates of economic value of fisheries, as well as improve the basis for fisheries management. In the meantime, the methodology is designed to offer several options for estimating this information consistently across different countries. By making the assumptions and calculations as transparent and consistent as possible, it is hoped that future estimates can continue to improve as the data does, and that the current results can be applied with a good understanding of their limitations.

Box 5. About WRI and Coastal Valuation

St. Lucia and Tobago were the pilot sites in the World Resources Institute's ongoing **Economic Valuation of Coral Reefs in the Caribbean** project. The first phase of this project involved developing an economic valuation methodology and applying it in the two pilot sites, with an eye toward further applications in the region in the future. The broader goals of the project are to:

- Increase regional capacity to perform ecosystem valuation and to use these estimates in planning and decision-making;
- Make the economic case for better coastal and land management, as well as for increased investment in Marine Protected Areas, so that these are viewed as investments in the future of the country and their economic and societal benefits are maximized;
- Arm NGOs and marginalized resource users with powerful information, enabling them to achieve greater voice in local decision-making.

We are also releasing shorter, country-specific versions of the results of this study for use by policy-makers and others in the field. In addition, there will be further opportunities to apply the Valuation Tool to policy applications, and to continue to train users of the method and the Tool in St. Lucia and Tobago, and in additional countries as the project expands.

The Economic Valuation of Coastal Resources project is continuing to evolve and has expanded to include three additional countries—Belize, Jamaica, and the Dominican Republic. In implementing the methodology in these sites, we will be expanding the scope of the analysis to include an assessment of mangroves and to look in greater depth at scenarios, including assessing the potential impacts of climate change. We will also look in greater depth at the benefits of marine protected areas and at options for financing them sustainably. Finally, the methodology itself will continue to evolve as we receive feedback from users and as new challenges arise.

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Appendix 1. Data Sources for Tobago Valuation

Tourism and Recreation in Tobago

Accommodation
The list of accommodation providers in Tobago was compiled from information provided by the Tobago House of Assembly and internet searches. A total of 461 accommodation providers were identified, of which 158 were villas. The remaining providers were classified as apartments, bed and breakfasts, condominiums, cottages, guesthouses, hotels and inns. The number of villas is likely to be underestimated because of the informal nature of this market.

Room rates were based on the 2006-2007 advertised internet rates for each accommodation provider. Where rates from that year were not available earlier years were used. The rate used was for a standard double room for two people. Rate information was obtained for 70 percent (or 325) of the accommodation providers. Average rates for each category of accommodation were used for the 136 providers without rate information. The occupancy rates are based on expert opinion.[60] During the peak season the average occupancy was 85 percent, and 50 percent in the low season. The annual average occupancy was 65 percent.

Costs comprised of wages, hotel taxes, service charges and other operating and maintenance costs. An average of 1.5 employees per room[61] was used and this was based on feedback from a project workshop conducted in Tobago in 2006. The wage used was based on an informal survey of wage rates for hotel staff—US$1.67/hour. The additional non-labor operating costs were estimated as 30 percent of the gross accommodation revenue. The government hotel or value added (VAT) tax was ten percent and the service charge was ten percent.

Reef Recreation

Diving
The number of divers on Tobago was estimated as ten percent of total visitors to the island.[62] Dive prices were based on average prices from 12 of the known 17 dive shops on the island. Two dive prices were used—approximately US$83 for the two-dive package and US$227 for the six-dive package (which includes the government tax). At a project workshop in 2006, participants estimated that 80 percent of divers took six or more dives while the remainder took a two-dive package. Dive certification and refresher courses are not included in the dive valuation.

The costs included wages, government taxes (15 percent VAT), credit card fees (3.75 percent of gross revenue), Green Levy (0.1 percent of gross revenue) and all other operating costs. The Green Levy is an additional government levy to be used for environmental remediation purposes.

Average wages were based on a mid-sized dive operation with two instructors (US$750/instructor/month), two dive masters (US$583/dive master/month) and a boat captain (US$333/captain/month). Non-labor operating costs were unknown and were estimated to be approximately 30 percent (excluding wages, service charges, taxes and other fees). Consumer surplus was estimated at 19 percent of the cost of undertaking the dive trip (see Box 1.1).

[60] Chris James, a hotel proprietor and chairman of the Travel Foundation provided his estimate of average island occupancy rates. These are based on the knowledge of his own hotels and what other hoteliers were experiencing. These rates were validated in a project workshop in Tobago in 2006.
[61] Exception was where there were 2 or fewer rooms then it was assumed there was only 1 employee and small guesthouses and B&Bs had no staff.
[62] Based on feedback from a project workshop in Tobago in 2006.

Box 1.1 Estimating Consumer Surplus
The consumer surplus estimates are based on consumer surplus data collected for diving and snorkeling on coral reefs in Hawaii (Cesar et. al., 2002).

	Real Expenditures (US$/person)	Consumer Surplus (US$/person)	Consumer Surplus as Percent of Real Expenditures (%)
Snorkeling	$35.55	$9.59	26.98
Diving	$55.75	$10.64	19.09

Snorkeling
The numbers of visitors snorkeling is based on an informal survey of two glass bottom boat operators—Hewlett Hazel (Buccoo Reef) and Top Ranking Boats (Speyside reefs). It was assumed that all people taking glass bottom boat tours also snorkeled. Any snorkeling from the beach was not included. The glass bottom boat passengers include both international and domestic tourists. However, the Trinidadians and Tobagonians are the biggest market for glass bottom boat tours (Hewlett Hazel, Hew Tours, pers. Comm., March 2006). It was estimated that approximately 174,000 people took a glass bottom boat tour (including both domestic and foreign visitors). Revenue was based on $15 per passenger for the Buccoo Reef tours and $20 for the Speyside and Charlottesville glass bottom boat tours. Operating costs included wages (US$3.33/hour), equipment costs (approximately $150/boat/year) and other operating costs (40 percent of gross revenue). Glass bottom boat operators do not pay a VAT tax, only income tax. A consumer surplus of 27 percent was used for snorkelers (see Box 1.1).

Any value from recreational reef fishing tours was excluded as it was not considered a large source of revenue for Tobago. Reef fishing by locals is included in the fishing value.

Additional miscellaneous expenditures
Additional miscellaneous expenditures includes departure taxes, entertainment, land transport, shopping and any remaining expenses.

Departure taxes were US$16.67 per person and the other visitor expenditure was derived from the percent of total spending on these goods or services in 2002 (see Table 1.1). It was assumed these expenditure patterns were unchanged in 2006.

Table 1.1: Visitor expenditure as percent of total spending

Visitor Expenditures	Percent of total spending (%)
Entertainment	14
Land Transportation	9.1
Shopping	6.2
Other expenses	7.1

Source: Tourism Intelligence International, 2002.

Local Use
Local use values are based on the results of a local use survey implemented by the University of West Indies/Sustainable Economic Development Unit (UWI/SEDU) as part of this project.[63] This survey surveyed 300 people across 6 communities in Tobago. Fifty people in each community were surveyed, of which, three were near coral reefs (Buccoo, Pigeon Point, and Speyside) and three were further inland (Mt. Pleasant, Roxborough, and Patience Hill). The local use value of beaches is based on the average number of visits Tobago residents make to the beach each year, the average duration of the visits, and average hourly wage in Tobago.

[63] "Local Use Values of Beaches and Reefs in the Caribbean – Case Studies of Saint Lucia and Tobago," a report to the World Resources Institute submitted by the Sustainable Economics Development Unit (SEDU), University of the West Indies (UWI), St. Augustine, Trinidad. Oct 10, 2007. (Available from the WRI web site)

Shoreline Protection – Tobago

Data sources for identifying vulnerable lands and shoreline protected by coral reefs:

1. **Elevation** – Elevation data (in meters) were developed under a collaboration of Buccoo Reef Trust (BRT), the Institute of Marine Affairs (IMA) and the World Resources Institute (WRI) based on elevation data (contours in feet) provided by the Tobago House of Assembly (THA). A subset of these contours were extracted for processing, and split to make processing easier. Processing was done in ArcMap using the Spatial Analysts Topo to Raster function. The DEM was clipped to a coastline extent provided by IMA, and converted from feet to meters.
2. **Shoreline** – Vector shoreline provided by IMA.
3. **Coral Reefs** – Coral reef data set was developed under this project. Coral Reef Data from Millennium Coral Reef Mapping Project and R. Laydoo. Updated at WRI based on reef observations from Trinidad Institute of Marine Affairs (IMA).

Implementation of the shoreline protection framework for Tobago:

1. **Geomorphology** – Based on IMA's Coastal Type variable. Shorelines of unknown geomorphology were classed as 2 (medium), which will not always be accurate, but minimizes the error.
2. **Geology** – Based on IMA's Geologic Map. Southwest Tobago, which is coralline in origin, was classified as 2 (sedimentary), while the rest of Tobago was classified as 3 (metamorphic).
3. **Wave energy** – Wave energy was classified based on IMA data on maximum breaker height (MBH). Areas without data were classified as 3 (20-40 cm MBH), as this was the predominant value in other areas.
4. **Coral Reef Index** – Coral reef map integrated under this project (see above). Distance to Reef was calculated, and categories assigned. Reef Index = (Reef_Type_value + Reef_Continuity_value + Reef_Distance_value) * 4 / 10. (The sum is multiplied by 4 for scaling, and divided by 10, as that is the maximum possible sum.)
5. **Storms** – to get at storm frequency, we used historic data from "Storm CARIB" the Caribbean hurricane network, at http://stormcarib.com/climatology/ECAR_map_bathy.htm. Tobago has had only two Category 3 Hurricanes in the past 150 years, and seven Category 1 or higher. As such, we selected Storm level 2 (affected by at least one Category 1 Hurricane every 25 years.)
6. **Coastal Elevation** – GRID data based on contours provided by THA. Data developed by BRT and WRI.

Appendix 2. Data Sources for St. Lucia Valuation

Reef-Related Tourism and Recreation

Accommodation

The information gathered for the tourism valuation came from the St. Lucia Hotel Association and internet searches. This information was collected prior to the 2007 World Cup so the number of accommodation providers on the island may have increased because of the expected increase in demand for accommodation during that period.

In St. Lucia, 226 accommodation providers were identified. They were classified as all-inclusive hotel, large hotel, small hotel, guesthouse, inn, apartments, bed and breakfast or villa. Of these, 61 were classified as villas. Because the villa market tends to be more informal, the villas available for rent are mostly likely underestimated.

Room rates were based on the advertised internet rates for each hotel, guesthouse, villa, etc. Where possible the hotel rates from 2006-2007 were used. Some rates, however, were from earlier years as the rates had not been updated on websites. Because most types of accommodation had a mix of different room types, the room rate was based on the predominant room type in each place. This was typically a standard double room for two people. Of the 226 accommodation providers identified we were not able to obtain information for 32 of them. For those 32 accommodation providers either the average number of rooms or room rate for the respective accommodation class was used to fill in the missing gaps. An average occupancy rate from the St. Lucia Tourist Board for the respective types of properties was used. The average occupancy rates ranged from 62 percent for small and large hotels to 67 percent for all-inclusive hotels.

Costs for the accommodation sector were decomposed into wages and other operating and maintenance costs. An average of 1.75 employees per room[64] was used based on feedback from a project workshop in St. Lucia in 2006. A US$2.80/hour wage was used as the average for men and women in the hotel and restaurant trade in St. Lucia (St. Lucia Statistics, 2006). As accurate operating costs were unknown, we did sensitivity analysis around the assumed non-labor operating costs of 40 percent of gross revenue. An 8 percent government tax and 10 percent service charge were also included.

To be conservative, the percent of tourists that chose to come to St. Lucia to visit the reefs was estimated at 25 percent. This was based on Sandals Dive Shop estimates of the percent of Sandals guests that went diving or snorkeling. A survey by Barker and Roberts (2001) found that over 40 percent of visitors to St. Lucia stated that they came to St. Lucia to dive or snorkel, but anecdotal reports indicate that this seemed high.

Reef Recreation

Diving
The Soufriere Marine Management Area (SMMA) has detailed information on diving activities, but this only reflects a portion of the dive numbers and revenue for the island. Even though most diving activity occurs in the SMMA, there are dive locations outside of the SMMA which dive operators visit. The Sandals Resorts, for instance, only visit the SMMA four days a week. The Sandals Resorts also negotiate a one time yearly fee for admission to the SMMA irrespective of the number of divers they take into the area. Therefore, dive volume for St. Lucia was estimated based on expert opinion,[65] rather than using SMMA diver numbers or an estimate of the percent of visitors that may dive. It was estimated there is approximately 45,000 divers visiting St. Lucia in 2006.

[64] An exception was made where there were 2 or fewer rooms then it was assumed there was only 1 employee and small guesthouses and B&Bs had no staff.
[65] Kai Wulf, manager of the SMMA provided estimates of number of divers each dive operator would take out each day. This information was validated against an informal survey conducted for the project by Laverne Walker (Sustainable Development Unit of the Government of St. Lucia.)

The price divers pay to dive depends on the dive package that is purchased and is based on the number of dives they wish to take—the more dives then the lower the per dive cost. It was assumed that divers would either purchase a two-dive package or a six-dive package. The percentage of divers purchasing each type of package was based on SMMA data on the number of daily versus annual dive permit purchased, where 58 percent of divers purchased a daily permit of two dives and 42 percent purchased an annual permit of six dives.[66] Dive package prices were based on the average prices from eleven dive operators—approximately US$84 for two dive package and US$227 for six dive package. Dive certification and refresher courses are not included in the dive valuation. It was also assumed that all divers hired their dive equipment.

Estimated operating costs included wages, taxes, service charges, and credit card fees with the additional non-labor operating costs estimated as a percent of gross revenue. Average wage rates for the various crew on a dive boat was based on information from the Sandals Resorts. These were US$1140/month for a dive instructor, US$950/month for a dive master and US$798/month for a boat captain.

A 10 percent government tax, 10 percent service charge and 3.75 percent credit card fee was included in the operating costs. The operating costs that were not actually calculated were assumed to be 40 percent of the gross dive revenue.

Consumer surplus, or the "additional satisfaction derived from the dive experience that is above and beyond the actual cost of the experience" was based on Cesar et al.'s (2002) report on coral reefs in Hawaii (see Box 1.1 in Appendix 1). Consumer surplus was estimated at 19 percent of real expenditures (or the cost of diving) and applied to the cost paid by divers to dive in St. Lucia.

Snorkeling
The number of visitors snorkeling is based on the number of SMMA snorkel permits sold (25,850 in 2005) and an estimate of the number of people snorkeling off the beach (69,189 in 2006). Guests at hotels situated on beaches near reefs frequently have free access to snorkeling equipment. Based on feedback from our project workshop in 2006 it was assumed that all guests staying at accommodation adjacent to beaches with a reef will try snorkeling at least once. Snorkeling prices were estimated as the average price of snorkel packages from the known snorkel operators—US$47. A consumer surplus of 27 percent of real expenditures was also included (Cesar et al., 2002) for snorkelers who purchased a tour (see Box 1.1 in Appendix 1). For those snorkeling from hotel beaches, a consumer surplus of US$3-5 was used. Wages were assumed to be approximately 18 percent of gross revenue[67] and the remaining operating costs were estimated at 40 percent of gross snorkel revenue. A ten percent government tax and service charge was included.

Other Recreation Activities
The value attributed to reefs from yachting activity was only included as revenue from yachts anchoring in the SMMA. Any value from recreational reef fishing tours was excluded as it was not considered a large source of revenue for St. Lucia. Reef fishing by locals is included in the fishing value.

Marine Parks
Marine park revenue from the SMMA is based on revenue and expenditure data collected by the SMMA. Some all-inclusive resorts (e.g. Sandals Group) pay a yearly user fee regardless of the number of visitors they bring to the SMMA. This is already included in the revenue reported by the SMMA. The SMMA snorkel permit is EC$3 (~US$1.14), daily dive permit is US$5 and annual dive permit is US$15.

Additional Miscellaneous Expenditures
Departure taxes, wedding licenses and other visitor expenditure were also included in the valuation. These were all adjusted by reef visitation (25 percent). Other visitor expenditure for meals and drinks, shopping, entertainment and car rental/ground transportation was based on estimated percentages of overall visitor expenditure spent on these

[66] The two- and six-dive assumptions are based on the opinion of dive operators on the island and was confirmed in a project workshop conducted in 2006.
[67] Based on a informal survey of three dive companies conducted by Laverne Walker (St. Lucia Department of Planning).

goods or services for visitors that stayed in all-inclusive hotels and other hotels (see Table 2.1). The other visitor expenditure value was also adjusted for non-labor operating costs estimated at 40 percent.

Visitor expenditure patterns differ between those staying at all-inclusive hotels versus those at other hotels. In 1998, payments to all-inclusive hotels in St. Lucia made up about 81% of expenditures by those visitors. Visitors to other hotels only spent about 63% of their total expenditures on accommodation. It was assumed these expenditure patterns were unchanged in 2006.

Table 2.1. Tourist spending as a percent of expenditure for various expenditure categories.

Tourist Expenditure Categories	All-inclusive Hotels	Other Hotels
Accommodation	81.4	63.3
Other meals and drinks	3	16.9
Transportation	2.3	8.7
Entertainment	1.7	1
Handicrafts	2.4	2.5
Duty free shopping	3.4	0.9
Other shopping	2.7	1.5
All other spending	3.2	5.2
TOTAL	100.1	100

Source: CTO 2000, The impact of 1998 visitor expenditure on the economy of St. Lucia

Local Use

The value of local residents' use of coralline beaches is based on the "local use" survey implemented through this project by UWI/SEDU. 300 people were surveyed in 6 communities in St. Lucia, equating to 50 people in each community. Three communities were classified as being near a coral reef or a coralline beach (Soufriere, Vieux Fort, and Anse La Raye) and three were classed not being close to a coral reef or coralline beach (Castries Town, Gros Islet, and Dennery/Micoud).

The local use value for coralline beaches was estimated using the average number of visits residents make to a coralline beach each year, the average duration of the visits, and average hourly wage within the surveyed communities (this is used as a proxy for the value of leisure time). (See Table 2.2).

Because only six communities were surveyed, we report the local use values as a range to reflect the uncertainty associated with this estimate. To determine the local use values, we derived the average annual per person value from number of times people visit a coralline beach each year, the average duration of each visits and the average hourly wage as a proxy for the value of leisure time. These average annual per person values were then multiplied by number of people living in near a reef or coralline beach (15,499 people) and living further from a reef or coralline beach (134,674 people).

Table 2.2 Parameters used to estimate the local use value for the reef and coralline beaches.

	Communities close to a reef or coralline beach	Communities at a distance from a reef or coralline beach
Number of beach visits per year	37 – 55 visits	31 – 46 visits
Average duration of beach visit	2.5 hours	3 hours
Average hourly wage	US$2.07 – 3.55 per hour	US$3.94 - $5.47 per hour

Shoreline Protection – St. Lucia

Data sources for identifying vulnerable lands and shoreline protected by coral reefs:

1. **Elevation** – a 25m resolution DEM was derived at WRI based on elevation contours provided by the St. Lucia Planning Department (then the Ministry of Physical Planning Environment and Housing -MPDEH). Most elevation data are from 1992 aerial survey done by the Survey and Mapping department of MPDEH, but a few coastal areas were missing. These data were converted to 25m resolution raster at WRI, and the missing elevation data were filled in with elevation data from The University of the West Indies (UWI).
2. **Shoreline** – data provided by the St. Lucia Department of Planning.
3. **Coral Reefs** – Coral reef data set was developed under this project, based on data from the *Millennium Coral Reef Mapping Project*, the University of the West Indies, and the Government of St. Lucia.

Factor Implementation for St. Lucia:

Data for eight of ten factors were integrated. Data were not available for Coastal Protection Structures (sea walls, break waters, headlands) or coastal anthropogenic activities (sand mining, etc).

1. **Geomorphology** – Mapped features of cliffs and beaches from St. Lucia Planning Dept. were overlaid with shoreline to develop a map of cliffed (4) or beach (1) coast. All other areas were set to 2.5.

2. **Geology** – Based on soils data from dept of planning and map of Geology of St. Lucia from "St. Lucia Development Atlas," Dept. of Regional Development, General Secretariat, OAS, 1987. Data on geology were transferred to soils map for most coastal polygons. Volcanic = 4; Sedimentary (even unconsolidated) = 2; all others = 3.

3. **Wave energy** – Windward vs. Leeward coasts were used as a proxy for wave height data. Windward coasts was classified as 1; Leeward as 2.

4. **Coral Reefs** – The coral reef index is based on the reef distance from shore (measured distance between the coral reef and shoreline data described above); the reef type (all were classified as fringing); and reef continuity (all were classified as continuous). (See Table 2 in section 2 for specific values.) The Reef Index = (Reef_Type_value + Reef_Continuity_value + Reef_Distance_value) * 4 / 10. (The sum is multiplied by 4 for scaling, and divided by 10, as that is the maximum possible sum.)

5. **Storm** – Storm frequency is based on historic data from "Storm CARIB" the Caribbean hurricane network, at http://stormcarib.com/climatology/ECAR_map_bathy.htm. In the last 100 years, St. Lucia had at least 24 tropical storms, four Category 1 Hurricanes, two Category 2 Hurricanes, and one Category 4. As such, we selected Storm level 2 (affected by at least one Category 1 Hurricane every 25 years.)

6. **Coastal Elevation** –The 25m raster elevation data set (DEM) described above was reclassified into classes (<1m, 1-5m, 5-12m, >12m). The vector shoreline data set was assigned the elevation class of the nearest raster cell.

7. **Slope** – The average percent slope was derived over a 2500 m stretch (1000m inland and 1500 m out from shore) based on the elevation (from the DEM described above) and a bathymetry data set developed at WRI from C-MAP soundings data. (Percent slope was derived using both minimum and mean depth within 1500 m of shore, and both mean and max elevation within 1000 m of shore.) These percents were reclassified as follows:
   - 0 = 0-1 percent slope
   - 1 = 2-3 percent slope
   - 2 = 4-5 percent slope
   - 3 = 6-7 percent slope

- 4 = over 7 percent slope.

8. **Vegetation** – Coastal vegetation was extracted from land cover data provided by the St. Lucia Department of Planning. Land cover descriptions were assigned vegetation type category and a vegetation distribution category, which are then averaged to arrive at the vegetation index (see table 2.3 below). (Table 2 in section 2 of this report provides the descriptions for these codes.)

Table 2.3 – Factors for Vegetation Index (by vegetation type)

DESCRIPION	MAJOR CATEGORY	VEG_ TYPE	VEG_ DISTR	VEG_ INDEX
Densely Vegetated Farming	Ag	0.0	3.0	1.5
Eroded Agricultural Land	Ag	0.0	1.0	0.5
Flatland Intensive Farming	Ag	0.0	2.0	1.0
Grasslands and Open Wood	Grass and Open	3.0	3.0	3.0
Intensive Farming (25%Fo	Ag	0.0	2.0	1.0
Mangrove	Mangrove	4.0	4.0	4.0
Mixed Farming (Forest/In	Mixed	2.0	2.5	2.3
Natural Tropical Forest	Forest	3.0	4.0	3.5
Plantation Forest	Plantation Forest	2.5	2.5	2.5
Rock and Exposed Soil	Exposed	0.0	0.0	0.0
Rural Settlement	human	0.0	1.0	0.5
Scrub Forest	Scrub Forest	2.5	2.5	2.5
Urban Settlement	human	0.0	1.0	0.5
Water	water	0.0	0.0	0.0