Value of Coral Reefs in Caribbean Islands

-- Draft Economic Valuation Methodology --

World Resources Institute
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This discussion paper is intended to provide background and promote discussion on the development of a methodology for economic valuation of goods and services provided by coral reef ecosystems in the Caribbean. The paper begins with a background on the importance of coral reefs and ecosystem goods and services, as well as providing a brief overview of economic valuation methods. Next, a preliminary proposed approach for valuation of three important coral-reef associated goods and services is presented —recreation and tourism, fisheries, and shoreline protection. This preliminary method was developed by the World Resources Institute (WRI) with input from project partners in St. Lucia and Trinidad and Tobago. This preliminary method will be the focus of review workshops held in St. Lucia (March 14-15, 2006) and Tobago (March 21-22, 2006). St. Lucia and Tobago are the pilot locations for implementation of the economic valuation methodology.

Table of Contents

I. BACKGROUND

Introduction

Coral reefs are critically important ecosystems for coastal communities. Valuing them in economic terms can, in many cases, lead to better management and more sustainable resource use. In collaboration with project partners, the World Resources Institute is leading a project focused on valuing coral-reef-related goods and services in St. Lucia and Tobago. This document provides background on methods of economic valuation, outlines the preliminary approach proposed for project, and describes how valuation estimates can be used to influence policy. A technical appendix describes the technical details for implementation of the proposed methodology.

The following economic valuation methodology is a draft version that is open for comment from project partners and collaborators. This paper is the basis for further discussion on the development of an economic valuation methodology. We welcome suggestions for alternative approaches to estimating these ecosystem services as well as any services that have been omitted but should be considered. This methodology will continue to be modified according to data availability, reliability of "input" datasets, and feedback from participants at workshops in St. Lucia and Tobago in March, 2006.

Importance of Coral Reefs

Coral reefs occupy less than one quarter of one percent of the Earth's marine environment, yet they contain a wealth of biodiversity. Reefs are home to more than one quarter of all known marine fish species and tens of thousands of other species, many of which are found nowhere else on earth. Caribbean coral reefs are vital and valuable natural resources that contain a wealth of biodiversity including over 60 species of coral and 1,500 different species of fish – many of which are found nowhere else on earth.

Coral reefs are crucial sources of income for the tourism, fishing, and pharmaceutical industries and play a crucial role in protecting coastlines from erosion, flooding and storm damage. These reefs form the foundation of the thriving Caribbean tourism industry, the region's most important economic sector, supplying much of the sand for its beautiful beaches and luring divers and snorkelers from far and wide to explore the reefs' colorful and mysterious depths. Yet, despite their importance, many coral reefs are at risk. In the Caribbean, nearly 70% of coral reefs are threatened by human activities – including overfishing, dredging, sewage discharge, increased runoff from agricultural activities, and coastal development.[1] Degradation of Caribbean reefs not only results in a tremendous loss of biodiversity but also leads to lost revenue from declining tourism and fishing, increased poverty and malnutrition, and increased coastal erosion.

Many of these damaging activities—including overfishing, dredging, or discharge of sewage near reefs—occur because an individual or group seizes an immediate benefit, without knowing or caring about the long-term consequences. Often, the party who gains is not the one who bares the cost. A new development may pollute and degrade an offshore reef, but those who suffer are the

[1] *Reefs at Risk in the Caribbean*, World Resources Institute, 2004

fishers or the divers who utilized that reef. Some shortcomings in current management practices stem from the inadequacy of information on the economic and social costs and benefits of different activities and management's focus on short- rather than long-term benefits. Decision makers frequently do not evaluate the full range of social and environmental impacts associated with proposed activities. In land-use decisions, for example, decision makers rarely consider how the decision to clear more land for agricultural development leads to increased sedimentation of coral reefs, which can lead to biodiversity loss and a negative impact on the livelihoods of coastal communities.

Ecosystem Goods and Services

We propose to value coral reefs by focusing on ecosystem goods and services—the benefits people obtain from ecosystems. The Millennium Ecosystem Assessment (MEA, 2005) outlines four categories of services provided by ecosystems—provisioning services, regulating services, cultural services and supporting services. Box 1 provides a more detailed description of the services in each category.

Box 1. Services provided by ecosystems

Provisioning Services	**Regulating Services**	**Cultural Services**
-products obtained from ecosystems- -food and fiber -fuel -genetic resources -biochemicals, natural medicines and pharmaceuticals -ornamental resources -freshwater	-Benefits obtained from regulation of ecosystem processes- -air quality maintenance -climate regulation -water regulation -erosion control -water purification and waste treatment -regulation of human disease -biological control -pollination -storm protection	-Nonmaterial benefits obtained from ecosystems- -cultural diversity -spiritual and religious values -knowledge systems -educational values -inspiration -aesthetic values -social relations -sense of place -cultural heritage values -recreation and ecotourism
Supporting Services -Services necessary for the production of all other ecosystem services- -soil formation -nutrient cycling -primary production		

Source: adapted from MEA (2005)

We are initially focusing on three key important coral-reef-associated goods and services for which we think it might be possible to develop realistic values – food (fish and shellfish), tourism and recreation, and shoreline protection services. We recognize that there are other important coral reef goods and services and are open to ideas on how to approach estimating their values. Other services that may be important for some island economies that are not included in this economic valuation include ornamental resources, biochemical, natural medicines and pharmaceuticals, aesthetic values, cultural heritage values and sense of place.

While recognizing that the services we have included in our economic valuation is not the full suite of services provided by coral reefs, we aim to capture much of the value that coral reefs provide. We focus on imputed values for which we believe realistic, replicable estimates are possible. We are striving to develop a simple, yet robust and reliable, methodology based largely on existing data. We fear that attempting to value services such as “existence value,” sense of place, or natural medicines and pharmaceuticals would introduce a level of complexity that likely could not be routinely replicated, and also introduce significant uncertainty into the value coral reefs provide. As comparisons across multiple countries in the Caribbean is one of our goals, we are developing standard methods which can be applied in several countries at a relatively low cost. For these reasons, we are restricting our methodology to those key services where ‘relatively’ reliable information is available and a methodology that will enable governments and researchers to routinely update the input information and resulting coral reef values estimates.

The services we have identified as important can be valued using methods where direct observation of human and natural activity can be directly observed (see *Economic Valuation Methods* section below). It is those services where human behavior cannot be directly observed (such as a stated “Willingness to Pay” for something) that we have excluded from our valuation methodology. Many of the methods based on indirect observed behavior—such as “travel cost” and “contingent valuation” methods—require substantial time and resources to implement, and therefore are not easily replicated.

Were we to attempt to value some of the “non-use” services (such as “existence value” or “cultural value”), one possible proxy for, say, cultural heritage values associated with natural habitats may be the investment in heritage or cultural foundations (such as Saint Lucia National Trust in St. Lucia). However, the investment related to coral reefs will still need to be separated from terrestrial and other marine ecosystem values. There may be other statistical approaches for establishing cultural values, however, few (if any) studies are available that assess the cultural value of coral reefs.

In this framework, biodiversity is not viewed as an ecosystem service that can be valued. Rather, it is a consequence of the quality and quantity of ecosystem goods and services that are available. For instance, if there is little food being produced by a coral reef system, then most likely biodiversity will be lower than a reef with abundant food.

Purpose of Project and Proposed Methodology

This project is designed to create a simple and replicable economic valuation methodology to estimate the benefits from coral reef resources in two initial locations—Tobago and Saint Lucia. Without an estimate of the values that coral reefs provide to society, coastal resource management and development decisions may exclude or fail to capture the significant contributions of coral reefs. By providing information about the economic losses from coral reef degradation and destruction and the value these reefs provide to island economies, this project aims to improve the current and future management of these coral reef resources and provide information essential to evaluate tradeoffs in ecosystem management and in potential development decisions.

While there are many economic valuation methods and techniques in the literature (see Box 2 for some examples), many of them require surveys, specialized data collection methods and/or statistical capabilities. Bearing in mind that governments and researchers often lack the time, financial resources, or statistical capacity to routinely implement these methodologies, we are attempting to devise a simple, yet reliable, methodology that can be implemented at low cost in several Caribbean countries, and re-applied in the future with existing data. Our aim is a methodology which can accommodate different levels of data availability (as will clearly be the case were this methodology to be applied in other countries). Improved data can lead to more accurate and robust estimates, but our goal is to be able to make informed assumptions so that we can create estimates even in relatively data-poor situations.

Over time as human capital and financial resources improve, island governments may wish to implement more ambitious and expensive economic valuation methodologies. However, given that most Caribbean islands are not routinely measuring the services provided by coral reefs it is unlikely that complicated and expensive valuation estimates will be made without a clear understanding the value such information could provide to their decisions regarding island development and coral reef protection.

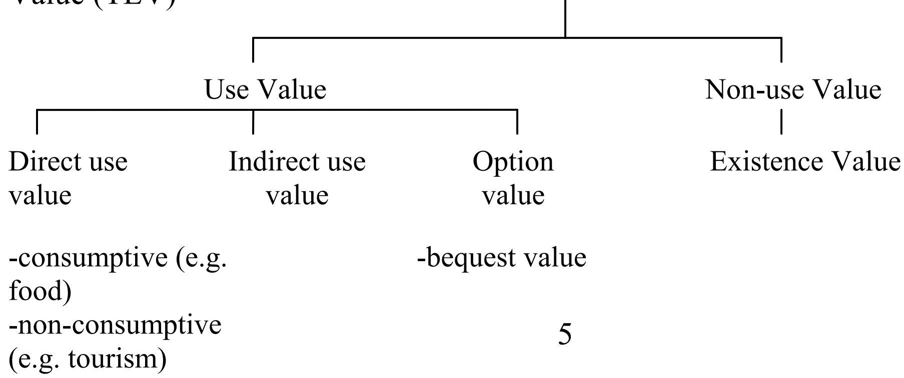
The methodological characteristics we are striving for are simplicity and the ability to use currently available data. One benefit of this approach is that the methodological workings can be subsumed into a valuation tool in which users enter data (fill out various spreadsheets) and valuation estimates will be automatically calculated. The tool which we are envisioning would allow for various levels of data specificity and reliability. Even with a paucity of data, estimates of ecosystem goods and services would be calculated; as the data improved, the calculations would improve in accuracy and robustness. We anticipate the need for significant input from in-country partners as to the framework, design, and interface of the tool.

Economic Valuation Methods

The economic valuation of ecosystems goods and services attempts to estimate the value of those services which are provided by natural resources. Resources have both use and non-use values, which when summed can be referred to as the Total Economic Value (TEV). Use values are generally divided into direct use, indirect use and option values. Direct use includes provision of food (a consumptive use) and opportunities for tourism and recreation (a non-consumptive use). Indirect use values include ecosystem services such as water filtration and storm protection. Option values are derived from preserving the option to use ecosystem services in the future either by you or by heirs or others (which is sometimes called bequest value.) Non-use values include values such as existence values, i.e., the values humans place on the fact that a resource exists, even if they might never visit or use it. In many studies, these are frequently the most controversial values, often representing significant portions of the TEV. These values also have the greatest uncertainty attached to them.

As ecosystem services are typically not traded in conventional markets, a variety of methods have been developed to estimate their value. Box 2 summarizes some of the economic valuation methods that have been used to quantify the benefits of ecosystem services.

Figure 1. Total Economic Value (TEV)



Box 2. Some economic valuation methods

Methods based directly on the observed behavior of humans

The **effect on productivity** approach uses the change in a provided service that results from a change in the environmental resource. An example where this may be applied is where fish productivity is projected to decrease after damage or destruction of a coral reef. A significant challenge of this approach is determining and modeling the relationship between damages to environmental resources and their impact on the production of a specified service.

Methods based indirectly on the observed behavior of humans

Hedonic pricing uses the attributes of a given site to determine its value. Environmental attributes can be used in this model and consequently analyzed for their impact on the market price of the site. This technique has been used to investigate the impact of negative environmental effects such as air pollution on land values. A challenge with the technique is ensuring that all attributes are included in the analysis, causing potentially large 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., beach. This method is primarily used to ascertain recreational use values of a resource based on its attributes. A key challenge of this approach is the considerable amount of detailed data required for estimation of accurate values.

Replacement cost techniques value environmental services by determining the cost that would be required to replace the service that is provided by the environment in its current state. This technique is frequently used to assess values such as nutrient removal by wetlands and shoreline protection. Use of this approach relies on the assumption that the society in question would actually pay to replace the service.

Avoided damages techniques look at the costs that are avoided as a result of having a given level of an environmental service. This technique is often used to estimate the damages avoided by having protection against natural disaster events such as earthquakes, hurricanes, and flooding. The challenge of this technique may be in determining the value to place on areas that are threatened as well as the hypothetical natural disaster scenario.

Methods based on the hypothetical behavior of humans

The **contingent valuation** method attempts to place a value on ecosystem services by directly asking respondents to state their willingness-to-pay (WTP) for a specific set of ecosystem services or for changes in those environmental services. This method is most useful in assessing the non-use values associated with ecosystem services such as the value of simply knowing that a coral reef exists, even if you never intend to visit or use it. Challenges of using this technique include the need for careful survey design and complex statistical analysis required for results. To achieve these is typically expensive and requires personnel with these kinds of survey and analytical skills.

II. Overview of Economic Valuation Methodology

Overview: within this economic valuation methodology, we propose evaluation of three important ecosystem goods and services associated with coral reefs. Reef-associated recreation and tourism, reef-associated fisheries and shoreline protection services provided by coral reefs.

1) **Tourism and Recreation** – A financial analysis approach will be used to evaluate the current benefit of coral reef associated tourism and recreation to the local and national economy. This approach summarizes gross revenues (accommodation, reef recreation and tours, miscellaneous expenditures) captured by service provider and subtracts the costs of providing the services. We will also examine the change in economic valuation resulting from changes in coral reef condition through scenarios of future reef condition.

2) **Fisheries** – The benefits of Fisheries to the economy will also be evaluation through a financial analysis approach. The formal and informal revenues and values from commercial fishing, local subsistence fishers, and fish processing for coral reef associated fish and shellfish will be summarized minus the cost of these activities. Future changes in coral reef condition will effect the economic valuation of fisheries through changes in the productivity of a coral reef.

3) Evaluation of **Shoreline Protection Services** provided by coral reefs requires understanding of the protection afforded by different types of coral reefs in different coastal settings, under different scenarios, coupled with information on property values in areas receiving at least some protection from coral reefs.

III. RECREATION AND TOURISM

Introduction

This economic valuation methodology is seeking to assess the net economic benefits to each of the islands resulting from reef-related recreation and tourism. As the type of tourists and nature of activities they engage on vary widely, the project is developing tourism profiles for each island. As an initial step in developing a picture of the tourism industry in each of the three countries, we will develop a visitor profile for each island—what percentage are coming for sea, sun, and sand? What percentage are coming for ecotourism or scuba diving? What percentage are taking part in all-inclusive package vacations? These characteristics greatly influence how much the local economy benefits from the tourist visit and reflect how important coral reefs and coastal environmental quality are for the choice of destination.

The value of reef-related tourism for each island will be estimated as total revenues minus the total costs, with revenues and costs being derived for accommodation, recreation, miscellaneous expenditures, cruise ships, and local recreational use. We are making assumptions to prorate visitor expenditure to only capture the portion of a visit considered “reef-related”.

a) Accommodation

The accommodation revenue and costs will be categorized where possible by accommodation type (hotel, guesthouse, etc.), foreign and domestic ownership, and by type of cliental they attract (e.g., primarily divers). Ideally, information will be collected for each establishment offering accommodation on each island. If such information is not available then more aggregated information will be used.

The two approaches for estimating the gross or total accommodation revenues are:
(1) Estimating revenue based on the number of guests, how much each guest spends on accommodation per night and how long they stay, or
(2) Estimating revenue based on the number of rooms, room rate and the occupancy rate.

The approach used for determining the accommodation revenue will depend on the availability of data.

Accommodation costs will be based on the operation and maintenance costs for the various establishments. Where necessary, aggregated data can be used to estimate these costs.

As many tourists may not come for the coral reefs or only utilize the reef for a portion of their visit, the accommodation revenue and cost estimation will need to be prorated to those revenues and costs that are associated with reef-related activities (see challenges section below).

b) Reef Recreation

Reef recreation includes foreign and local users of the reef for snorkeling, diving and recreational fishing. The value of recreational services provided by coral reefs is estimated by evaluating the net revenues from snorkeling, diving, and recreational fishing, and subtracting the costs. As with 'accommodation', company level information would be ideal. However, we recognize it may only be possible to obtain more aggregated information.

The revenues will be estimated individually for the three reef recreation components:
(1) Snorkel revenue is based on the number of people taking snorkeling trips and the average snorkeling trip price;
(2) Dive revenue is based on the number of dive trips and the average dive trip price;
(3) Recreational fishing revenue is based on the number of fishing charters and the average fishing charter price.

The costs of tourism recreation will also be estimated for the individual components—snorkeling, diving, and recreational fishing—and will be based on operating costs.

c) Miscellaneous Expenditures, e.g., restaurants, shopping

Tourists also spend money on restaurants and shopping while engaged in reef-related activities. As these values will be difficult to estimate based on collected data we will use established multipliers to estimate the miscellaneous expenditures associated with reef-related activities. These multipliers will show how much additional expenditure can be expected (e.g. for each dollar spent diving, forty additional cents will go towards miscellaneous expenditures such as food and entertainment).

d) Cruise Ships

For some islands, cruise ships may be an important source of foreign income. However, it is also perhaps the most tenuous tourism valuation component for coral reefs as a majority of cruise ship passengers are most likely not choosing cruise ship companies for reef-related activities, rather the whole amenity package provided by cruises. Furthermore, a majority of passengers may not participate in any of the offered reef-related activities. Determining the number of passengers engaging in reef-related activities and thus the associated revenues and costs from the cruise industry may prove to be difficult.

Reef-related revenues from cruise ships will be based on the number of passengers per ship that visit an MPA and the MPA visitor fee; and a portion of the ships docking fee (based on percentage of passengers visiting the MPA). If an island does not have an MPA, some other proxy will have to be devised to determine the portion of the docking fee that may be attributed to the coral reef.

The costs to the island associated with cruise ship visits will be based on the cost for each island to host cruise ships, and prorated by the number of passengers that visit the MPA.

Key Issues:
(1) There may be difficulty in ascertaining the importance of coral reefs in passengers' choice of a particular cruise.
(2) Each passenger spends money when visiting the islands on food, shopping, etc. There is a multiplier that could be used to estimate the revenue related to day visitors (taking in account the number undertaking reef activities

e) Local Recreation Use

Coral reef and reef-based amenities are also used by the local population and add significant economic value. The two local recreation uses we are attempting to estimate are local reef use (exclusive of the local population that uses reef tour companies) and local beach use. Local reef use revenue will be based on how many locals visit the reef, how long they spend on the reef, and the typical hourly wage rate (as a proxy for the value of their leisure time). Similarly, local beach use revenue will be based on how many locals visit coralline or coral-protected beaches, how long they spend at the beach and their hourly wage rate. We expect a significant local reef use to be fishing.

f) Challenges

The key challenge for valuing reef-related tourism is deriving those expenditures that can be attributed to the presence of coral reefs. If the area being studied contains one or more MPAs, one approach may be to use the number of visitors to the MPA(s) to estimate the percent of total visitors to the island that visit the reef. This percent could then be applied to the accommodation values to obtain reef-related accommodation revenues and costs, and perhaps to the miscellaneous expenditures. Another approach is to include a percentage of a tourist's expenditure based on the tourist's profile or category ('sun, sea or sand'). For example, all the "dive" tourists' expenditure is attributed to the reef, while only a low percentage of a "sun and sand" tourist expenditure is attributed to the reef.

IV. FISHERIES

The economic valuation methodology will estimate the value of coral reef-associated fisheries for each island. Information on revenues derived from these fisheries and the costs associated with fishing for reef-related species will be necessary. To estimate the value from fisheries we have divided the fishing industry into commercial fisheries, processing industries, local informal economy/subsistence fishing, and the economy-wide economic impact of the fishing industry. As with recreation and tourism, it may be beneficial to first determine a profile of the fishing industry for each of the three islands. If possible, a profile of the fishers in each island would be useful. Are there predominately pot fishers, seine fishers, etc.? What fish and shellfish species are the most commercially relevant that are related to the reef? Where and how is the fish catch sold or used?

The overall method to determine the value of fisheries will subtract the costs for the commercial, processing, and subsistence fisheries from the revenues that accrue to these sectors.

a) Commercial Fisheries

Commercial fisheries value will be calculated by tallying the revenue gathered and subtracting costs. The revenue from commercial fisheries is based on the fish catch and the fish price in each market (export, restaurant, local retail), while fishing costs will be based on the costs associated with the different fishing methods and the quantity of fish caught using each method.

Issues:
We are uncertain how important it is to disaggregate the commercial fishing value by markets. This could be important if there was a large variation in fish prices and/or there was large difference in the quantities of fish sold into the various markets.

b) Fish Processing Industries

In some islands, the fish processing industry could be valuable source of foreign income and/or a major employer on the island.

The value of the industry is based on its associated revenue and costs, with revenue being derived from the price of the processed reef fish and the amount of reef fish that is processed. Costs are associated with the expense of processing the fish and the amount of fish that is processed.

c) Local Informal Economy/Subsistence Fishing

The local informal economy and subsistence fishing sector is expected to be an important aspect in the total value of the fishing industry. It also presents substantial challenges in terms of data collection and analysis.

The revenue from reef-related subsistence fishing is based on the amount of reef fish that are caught by subsistence fishers and the price of those fish in the retail market. Costs are based on the amount of reef fish that are caught by subsistence fishers and the cost to the subsistence fishers to catch those fish. The cost of subsistence fishing would include the opportunity cost of fishing for fishers. This would be based on their wage rate (or, if available, their likely alternative wage rate).

d) Economy-Wide Benefits of Fishing

To estimate the wider economic benefits associated with the fishing industry, we will look to published reports and previous studies for multipliers on associated employment and general economy-wide benefits will be used.

e) Challenges

There are a number of social/cultural service values associated with the fishing industry that may be important that are not captured in the above categories, including:

- Social relations – the social and cultural value associated with the fishing tradition and for being employed in the fishing industry
- A social value to having people employed rather than unemployed and potentially causing social problems.

To estimate these social/cultural values would most likely require survey methods which we are not planning for this economic valuation at this time. At the current time we are focusing on four families of reef-related fish, Holocentridae, Lutjanidae, Scaridae, and Serranidae.

We are also calculating the benefits associated with the fishing industry on the productivity of the fishery today. However, if the fishery is being overfished, these benefits may not be sustainable in the medium to long term. To ascertain this, we may have to determine the maximum sustainable yield of the fisheries by species or at least take this fact into account. Even if the fishery is at maximum sustainable yield (which is highly unlikely with open access) it may be at a point beyond its maximal economic yield.

Data will be the other challenge, as most likely there will be differences in data richness in different parts of the island, especially for the subsistence fishery. Therefore, we may need to extrapolate information

V. SHORELINE PROTECTION

While it is generally accepted that coral reefs provide a significant amount of protection for nearby coastal areas, shoreline protection services for each island are perhaps the most difficult services to value. This is due to the fact that this ecosystem service cannot be directly observed the way that, for instance, dive tourism can be. In developing this element of the methodology, consultation with ecologists and geographers knowledgeable of local areas will be essential.

There are a number of important assumptions regarding factors, which need to be made based upon the best available information:

- probability of a storm event occurring that damages the coastal areas;
- the physical setting of the beach / shoreline, degree of openness of coast, type, depth, and relative position of coral reef;
- amount of routine erosion that would occur from waves and storms with or without the coral reef;
- impact of different intensity storm events on the coastal areas;

- impact on the loss of a coral reef will have on shoreline protection. (Reef condition varies between locations, and even in degraded reef systems the entire reef does not disappear at once. Also, even a dead reef will provide some measure of shoreline protection for some time);
- level of development or future development if an area is currently not developed.

We plan to use the "avoided damages" approach to valuing shoreline protection services. This technique looks at the costs that are avoided as a result of having a given level of an ecosystem service (in this case a coral reef protecting the shoreline and properties contained on it). Deriving values for this requires a substantial amount of data as to the types of storms, physical characteristics of the shoreline and coral reefs, as well as what type of land is being protected. If there is applicable information on how costal areas are zoned (commercial, residential, etc), categories of values could be used. If not, data on land pricing would need to be collected and perhaps land classifications could be derived from satellite imagery.

Our estimation methodology is based on the probability of various storm events occurring, the amount of protection that is afforded by coral reefs, the damage that is likely to occur at different elevations, and the value of the land in its various uses along the coast. For instance, reefs protecting lands which contain high value properties and buildings situated at low altitudes will have relatively high values for shoreline protection, while those which protect unused land will have low values (though over a long time spam these values may be significant if development is planned).

Future shoreline protection values will depend on the protection afforded by the coral reefs in each area, assuming that the reef condition in various areas changes and therefore the degree of protection will change.

VI. SCENARIO DEVELOPMENT

Currently it is envisioned that at least three scenarios will be evaluated using the economic valuation methodology. These scenarios will be useful in guiding decisions related to reef management, as they integrate both the threats reefs face (overfishing, sedimentation, pollution) and the services they provide (fisheries, tourism, shoreline protection).

- Scenario 1 - status quo
- Scenario 2 - further degradation of coral reefs
- Scenario 3 - improvement in coral reef quality

These scenarios will be developed in coordination with the GIS threat assessment analysis to get a more accurate idea of how the reef will respond to various threat levels, and the determination of existing reef condition.

Two issues to consider when assessing these scenarios are:

- Use of net present value (NPV) or annual losses – Losses can be assessed as annual values or the net present value of losses over a given time period. We need to determine which is the most appropriate for our analysis.
- Timeframe for analysis – for a net present value approach, we need to determine the appropriate timeframe and discount rate to use. Sensitivity analysis will be conducted around the discount rate.

Sensitivity analysis will also be performed around those parameters that are highly uncertain to ensure that data quality does not skew or provide valuations that not reliable or robust.

VII. APPLYING GIS

Our aim with this valuation methodology was to connect the spatial bio-physical data with the economic valuation estimates to spatially reference the losses from coral reef degradation or, conversely, the gains from coral reef preservation. In order to do this, a variety of data would be required. The availability of the data will determine the scale that spatially referenced economic data can be presented.

The key aspects of the spatial relationships between coral reefs and the economic values being evaluated by the methodology are:

1) Fisheries Production – The spatial extent and health of the surrounding coral reefs are key factors in fisheries production. The location of fisherfolk and fishing villages are important indicators of where fishing is likely to occur.
2) Reef Recreation – The spatial extent, depth and quality of the coral reefs are key factors influencing which are the most desirable destinations for diving, snorkeling and recreational fishing. The location of diving, snorkeling, and fishing charter operations, will also influence where these activities are most likely to occur.
3) Beach Recreation – The location (proximity), extent (length and depth) of the beach, quality of the beach, and nature (and source) of the sand are important factors influencing the desirability of a beach. Whether or not the beach is protected by a coral reef will affect erosion rates and the amount of surf and calmness of the waters.
4) Shoreline Protection - The bathymetric profile of the area, extent of the coral reef, distance from shore, nature of the shoreline (mangrove, sand, dirt road, concrete, etc.) will influence the protection afforded by coral reefs.
5) Threats to Coral Reefs – Threats to coral reefs can come from runoff from the land or from marine-based activities. Important factors and components include:
    a. density of population and development along the coastline
    b. location of roads
    c. level of treatment of sewage
    d. discharge from industry
    e. location and size of ports
    f. management of waste from ships and regulations on discharge
    g. watershed-based threats from land-cover change and application of fertilizer and pesticide
6) Protection of Coral Reefs – Presence of a well-managed MPA can be an important factor mitigating threats to coral reefs.

General GIS Requirements

- Village locations
- Beach locations and beach amenities
- Population density
- Airport locations
- Location of deep sea ports

- Beach locations by origin (i.e., coralline vs. non-coralline beaches)
- Reef locations

Specific GIS Data Requirements for Tourism

- Location of accommodation, categorized by accommodation type and number of rooms
- Location of dive operators/snorkel operators
- Cruise routes

Specific GIS Data Requirements for Fisheries

- Characterization of each village by number of fishers; number of boats, nets, etc.; fish landings by species; and proximity to reef
- Fishing grounds for each village
- Any indicators of overfishing (change in composition of fish caught, increase in algae cover)

Specific GIS Data Requirements for Shoreline Protection

- Categorization of coastal land by slope, land cover and soil type
- degree/type of development on coastal lands
- land-use zoning on coastal lands
- bathymetry

VIII. USING VALUATION ESTIMATES

One of the main advantages of using economic valuation for ecosystem goods and services is that the resultant estimates can be used in policy planning processes. Four distinct categories of valuation support policy analysis:

1) determining the value of the total flow of benefits from an ecosystem (e.g., total economic valuation)
2) determine the net benefits of interventions that alter ecosystem conditions (e.g., evaluating the value of investing in a marine protected area)
3) examining how the costs and benefits of an ecosystem are distributed (e.g., identifying beneficiaries)
4) identifying potential financing sources for conservation.

The estimation of the values that ecosystems provide allows for:

- comparative statistics between reef value under different scenarios
- comparative statistics between islands
- actual value of reefs compared to other island resources (e.g., agricultural land, industrial plants, etc.)

While we cannot anticipate all of the policy applications of deriving ecosystems values, we hope and anticipate that they will be widely used within island decision-making processes.

Possible policy applications include

- The introduction of user fees to enable monitoring and protection of coral reef resources (e.g., in areas where reefs are not closely monitored (such as Tobago), the knowledge of the number of reef users could be used to calculate possible revenue stream from user fees. This, in turn, could be directly used to monitor reef condition)

- Inform development decisions, e.g., outfalls of sewage pipes, hotel development such that reef resources are not degraded
- regulate number of reef visitors, or devise rules (e.g., no reef walking)
- Greater promotion, and therefore use, of reef resources by local and foreign visitors. (For instance, in furtherance of Tobago's "Clean, Green, Safe and Serene" campaign.)
- Hotels protected by reefs could be asked to pay a fee that is used to monitor and protect the ecosystem.
- Fishing quotas, etc., could be placed on extraction of certain reef species
- Establishment of an MPA

TECHNICAL ANNEX on Economic Valuation Methods

I. Recreation and Tourism

Introduction

Our economic valuation methodology is seeking to assess the benefits and costs to each of the islands resulting from coral reef-related tourism. The value of reef tourism is estimated as total revenues minus the total costs. Revenue and cost equations will be derived for individual components of the tourist industry—accommodation, recreation, miscellaneous expenditures, and cruise ships—all of which are components of the value of coral reefs to tourism.

Value of Tourism_y =

> Revenue_y[accommodation, reef recreation, misc expenditures, cruise ships, local recreation use] –
> Costs_y [accommodation, reef recreation, misc expenditures, cruise ships, local recreation use]

If possible, all data for tourism should come from the same year (y).

a) Accommodation

The revenue and costs will be categorized where possible by accommodation type (hotel, guesthouse, etc.) and by foreign and domestic ownership. Ideally, information will be collected for each establishment offering for each island, and then disaggregated into according to accommodation and ownership types.

There are two alternatives for determining the gross or total accommodation revenues. One approach, shown in the first equation (1) below, is to multiply the number of guests by the expenditure per guest and the length of stay of the guests. A second approach, shown in the second equation (2) below, would multiply the number of rooms by the room rate and occupancy rate. Both alternatives can use more aggregated information on each accommodation type or disaggregated information on individual accommodation providers (e.g., each hotel, guest house, etc.). The alternative used will depend on data availability.

(1) Accommodation $\text{Revenue}_y = \sum_{x,}[(\text{Guests}_{x,y}) \text{ x } (\text{Guest expenditure}_{x,y}) \text{ x } (\text{Length of stay}_{x,y})]$

> Where
> $\text{Guests}_{x,y}$ = number of guests in hotel *x* in year *y*
> $\text{Guest expenditure}_{x,y}$ = average guest expenditure per night in hotel *x* in year *y*
> $\text{Length of stay}_{x,y}$ = average number of nights each guests stays in hotel *x* in year *y*

OR

(2) Accommodation $\text{Revenue}_y = \sum_{x,}[(\text{Rooms}_{x,y}) \text{ x } (\text{Room rate}_{x,y}) \text{ x } (\text{Occupancy rate}_{x,y})]$

> Where

Rooms $_{x,y}$ = number of rooms in hotel *x* in year *y*
Room rate $_{x,y}$ = average room rate per night in hotel *x* in year *y*
Occupancy rate $_{x,y}$ = average number of rooms per night that are occupied in hotel *x* in year *y*

Accommodation costs will be estimated by multiplying the average daily cost of operations in a hotel by the number of days in the year. This information may not be available for each individual hotel and may only be available on the aggregate level or may already be aggregated on an annual basis.

$$\text{Accommodation Costs}_y = \sum_{x,}[(\text{employee}_{x,y} * \text{wage}_{x,y}) + \text{fixed costs}_{x,y} + \text{OM cost}_{x,y}]$$

Where
$\text{employee}_{x,y}$ = average number of employees in hotel *x* in year *y*
$\text{wage}_{x,y}$ = average wage for employees in hotel *x* in year *y*
$\text{fixed costs}_{x,y}$ = average fixed costs for hotel *x* in year *y*
$\text{OM cost}_{x,y}$ = average operating (excluding employee wages) and maintenance costs for hotel *x* in year *y*

The data listed below are those that would be required to use the equations above. If any of these data are not available, modifications to the methodology will be necessary or proxy data may be identified.

Revenue Data Requirements for accommodation
For equation 1:
- Average number of guests in each hotel, guesthouse, etc.
- Average guest expenditure per night in each hotel, guesthouse, etc.
- Average length of stay per guest in each hotel, guesthouse, etc.

OR
For equation 2:
- Number of rooms in each hotel, guesthouse, etc.
- Average room rate in each hotel, guesthouse, etc.
- Occupancy rate in each hotel, guesthouse, etc.

This may vary seasonally and may need to be incorporated into the methodology.

Cost Data Requirements for accommodation
- Average wage in industry
- Average number of employees in each hotel, guesthouse, etc.
- Average maintenance expenditures in each hotel, guesthouse, etc.
- Average operation costs (excluding wages) in each hotel, guesthouse, etc.

With both revenue and cost calculations, these calculations will need to be prorated to those accommodation revenues and costs related to reef-related activities such as only counting the days where the person is engaged in reef-related activity.

b) Reef Recreation

The value of recreational services provided by coral reefs is estimated by evaluating the net revenues from snorkeling, diving, and recreational fishing. Costs will be subtracted from the gross revenues from tourism recreation activities. Company level data would be preferred, but recognize it may only be possible to obtain aggregated information.

The revenues will be estimated individually for the three reef recreation components—snorkeling, diving, and recreational fishing, and aggregated.

$$\text{Recreation Revenue}_{j,y} = \sum_j [(\text{Snorkel revenue}_{j,y}) + (\text{Dive revenue}_{j,y}) + (\text{Rec fishing revenue}_{j,y})]$$

Where:

Snorkel revenue $_{j,y}$ = (Number of people snorkeling with company *j* in year *y*) x (price per person to snorkel in company *j* in year *y*)

Dive revenue $_{j,y}$ = (Number of dive trips in company *j* in year *y*) x (price per dive trips in company *j* in year *y*)

Rec fishing revenue[2] $_{j,y}$ = (Number of fishing charters in company *j* in year *y*) x (price per fishing charter in company *j* in year *y*)

The costs of tourism recreation will also be estimated for the individual components—snorkeling, diving, and recreational fishing. Snorkel, diving and recreational fishing costs will be based on the operating costs for each company.

$$\text{Recreation Costs}_{y} = \sum_j [(\text{Snorkels Costs}_{j,y}) + (\text{Dives Costs}_{j,y}) + (\text{Rec fishing costs}_{j,y})]$$

Where

Snorkel costs $_{j,y}$ = (Number of snorkels in company *j* in year *y*) x (cost per snorkel for company *j* in year *y*)

Dive costs $_{j,y}$ = (Number of dives in company *j* in year *y*) x (cost per dive for company *j* in year *y*)

Rec fishing costs $_{j,y}$ = (Number of fishing charters in company *j* in year *y*) x (cost per fishing charter in company *j* in year *y*)

Revenue Data Requirements for snorkeling, diving and recreational fishing

- Number of dives or dive trips by company (if dive trips rather than dives are used will need to adjust above equations)
- Number of people diving and snorkeling by company (this will be used to determine % of visitors that visit reef)
- Price per dive trip per person
- Price per snorkel trip per person
- Number of fishing charters by company (and number of persons per charter, if possible)
- Price per fishing charter

Cost Data Requirements by company for snorkeling, diving and recreational fishing

- Overall operating costs per company

OR

- Average cost of equipment maintenance by company
- Average operation costs of boats (including fuel, insurance, etc.) by company
- Average salary of employees

[2] This assumes that the fishing charter is based on a price per trip. If the price is on a per person basis, this calculation will have to be adjusted appropriately.

- Number of employees per company
- Cost of food, etc. (provided ‘free of charge’ to guests)
- Average cost of maintaining land facilities (including docks, boat storage, office space, etc.)
- Average miscellaneous operating costs (including phone, marketing)

Assumptions:
Some islands have MPAs that charge user fees. This methodology currently assumes that the user fee is subsumed into the price of the snorkel or dive. It also does not currently capture people who visit the MPA that do not snorkel or dive. It is also assumed that snorkeling numbers include those only doing a glass bottom boat trip.

c) Miscellaneous Expenditures, e.g., restaurants, shopping

In addition to the above revenues, there are also expenditures by tourists who use restaurants and shopping while engaging in reef-related activities.

The values from these sources will be difficult to derive using primary data. Therefore, two multipliers will be used to capture these values:

- Multiplier for a direct tourist expenditure for food and shopping by overnight and day visitors
- A general economy multiplier (incorporates people directly employed in the tourist industry and those employed in services that depend on the tourist industry)

Possible sources of data:

- The Caribbean Tourism Organization (CTO) may have multipliers for tourism as well as the national tourism offices,
- The project will also look to previous economic valuation studies which may have used established multipliers for similar countries.

d) Cruise Ships

The revenue from cruise ships will be calculated by multiplying the number of visitors per ship in a given year by the percent of passengers visiting an island, or if available, the percentage of people visiting an MPA (as this may focus more closely on the reef-related cruise ship visits) and the fee charged per person for visiting an MPA in that year. This will be added to the number of ships docking in a given year multiplied by the docking fee per ship in order to arrive at an estimate of the total cruise revenue to the local economy. It is possible that there may be variability in the types of fees collected from cruise ships in each of the countries; equations will be adjusted by either adding terms to or substituting terms from the equation below.

$$\text{Cruise revenue}_y = [(\text{visitor}_y) \times (\text{ships}_y) \times (\text{MPA fees}_y)] + [(\text{ships}_y) \times (\text{docking}_y)]$$

Where
visitor_y = Average numbers of passengers per ship that visit MPAs in year y
Ships_y = Number of ships visiting MPAs in year y
MPA fees_y = MPA user fee per person in year y
Docking_y = docking fee per ship in year y

The costs to the island associated with cruise ship visits will be based on the cost for each island to host cruise ships and will be calculated on an individual basis. In order to isolate those costs that are associated with the reef, the previous value will be multiplied by the number of passengers per that visit MPAs in that year. If necessary, aggregated information can be used to get an average number of passengers per ship that visit MPAs.

Cruise costs_y = [host cost_y/(passengers_y x ships_y)] x visitors_y

Where
Host cost_y = Total costs to the island for hosting cruise ships in year *y*
Passengers_y = Average number of passengers per cruise ship in year *y*
Ships_y = Number of cruise ships docking in year *y*
Visitor_y = Average number of passengers per ship that visit MPAs in year *y*

N.B. Hosting costs may be difficult to quantify but may include:
- Costs associated with additional port facilities and maintenance of port facilities
- Costs associated with additional tourist visits such as road use, etc.
- Costs associated with environmental damages from cruise ship presence, e.g., debris collection, waste discharge

Assumptions:
The assumption used here is that MPA visits will proxy for the number of visitors per ship that participate in reef-related activities. For islands without MPAs, we may use data from those islands with MPAs to estimate (or provide proxies for) these values.

We could also use the number of passengers that undertook reef activities like snorkeling or diving. However, if local operators were used this revenue would already be captured in the recreation value.

e) Local Recreational Use

There are two values being derived for local recreational use, one associated with the use of the reef and the other associated with beach use. This data may be difficult to obtain as it may not be routinely collected by government agencies.

i) Local Reef Use

To avoid double counting, local reef use as specified below does not include local users who pay tour operators for diving or snorkeling on the reefs. This is captured under the reef recreation value in b) above.

Local reef use revenue_y = (visits_y) x (pop_y) x (reef hours_y) x (wage rate_y)

Where
visits_y = average number of visits to the reef by local people in year *y*
pop_y = island population in year *y*
reef hours_y = average number of hours spent on the reef by locals per visit in year *y*
wage rate_y = average wage rate for local people in year *y*

Local reef use $cost_y$ = ($visits_y$) x (pop_y) x (recreation $cost_y$)

Where
$visits_y$ = average number of visits to the reef by local people in year *y*
pop_y = island population in year *y*
recreation $cost_y$ =
average cost of visiting reef by locals in year *y* (includes travel costs, user fees, etc.)

ii) Local Beach Use

Since some of the beaches on Caribbean islands may be derived from coral, it could be argued that the coral reefs contribute to the recreational value of beaches on those islands. Only beaches of coralline origin would be included in estimated economic value. It may also be prudent to include those beaches that only exist because of reef protection.

Local beach use $revenue_y = \sum_b[(visits_{b,y})$ x (beach $hours_{b,y}$)] x (pop_y) x (wage $rate_y$)

Where
$visits_{b,y}$ = average number of visits to coralline beach *b* by local people in year *y*
pop_y = island population in year *y*
beach $hours_y$ = average number of hours spent on beach *b* by locals per visit in year *y*
wage $rate_y$ = average wage rate for local people in year *y*

Issues:
There could be double counting issues arise if locals visit both the beach and reef at the some time and it is not possible to disaggregate the information. There may also be some double counting when locals visit more than one beach in a given day.

If local beach visits to coralline or coral reef-protected beaches are to be included, it may also be appropriate to include tourist visits to this same set of beaches.

II. Fisheries

We are trying to capture the economic benefits of coral reefs for fish and shellfish production. For this reason, we limit our examination to fish and shellfish species which depend on a coral reef for at least a portion of its life cycle. These include the following families: Holocentridae, Lutjanidae, Scaridae Serranidae.
The overall equation to determine the value of fisheries will subtract the costs for the commercial, and subsistence fisheries and fish processing industry from the revenues that accrue to these sectors. Ideally, data for use in the equations would be from the same year.

Value of $Fisheries_y$ =
$Revenue_y$[commercial, processing, subsistence] –
$Costs_y$ [commercial, processing, subsistence]

a) Commercial Fisheries

The revenue from commercial fisheries is based on the fish catch and the fish price in each market (export, restaurant, local retail, processing, if available). This equation will be modified depending on the data availability for each market.

Fishing $Revenue_y = \sum_{m,s}$ [(fish $price_{m,s,y}$) x ($catch_{m,s,y}$)]

Where
Fish $price_{m,s,y}$ =
Average market price of fish species *s* in market *m* in year *y* ($/kg)
$Catch_{m,s,y}$ = Quantity of fish species *s* sold in market *m* in year *y*
[this may have to be modified to total amount of each fish species caught in a year as data on a per market basis may not be available]

Different markets may include export, restaurant, local retail, processing, etc.

Fishing costs will be based on the costs associated with the different fishing methods and the quantity of fish caught in each using each method.

Fishing $Costs_y = \sum_s [\sum_f$ (fisher $cost_{f,s,y}$) + $\sum_b$ (fisher $cost_{b,s,y}$)]

Fisher $cost_{bs,y} = boats_{bs,y}$ x {op_$hrs_{bs,y}$ x [op_$cost_{bs,y}$ + (b_$fishers_{bs,y}$ x f_wage)]}
+ fix_$costs_{bs,y}$ + equip_$costs_{bs,y}$

Where,
fisher $cost_{bs,y}$ = Cost of catching fish species *s* using technique *b* in year *y* ($)

$boats_{bs,y}$ = Average number of boats using technique *b* fishing for fish species *s* in year *y*
op_$hrs_{bs,y}$ = Average number of hours each boat using technique *b* fishes for fish species *s* in year *y* (hrs)
op_$cost_{bs,y}$ = Average cost of operating a boat using technique *b* for fish species *s* in year *y* ($/hr)
b_$fishers_{bs,y}$ = Average number of fishers per boat using technique *b* (including owner/operator) in year *y*
f_wage = Average wage for fisher in year *y* ($/hr)
fix_$costs_{bs,y}$ = Average fixed costs for a boat using technique *b* for fish species *s* in year *y* ($)
equip_$costs_{bs,y}$ = Average cost for equipment for a boat using technique *b* for fish species *s* in year *y* ($)
technique *b* = all fishing techniques requiring a boat

Fisher $cost_{f,s,y} = fishers_{f,s,y}$ x (f_hrs x f_wage) + equip_$costs_{f,s,y}$

fisher $cost_{f,s,y}$ = Cost of catching fish species *s* using technique *f* in year *y* ($)
$fishers_{f,s,y}$ = Average number of fishers using technique *f* for fish species *s* in year *y*
f_hrs = Ave number of hours each fisher spending fishing for fish species *s* using technique *f* in year *y*
f_wage = Average wage for fisher in year *y* ($/hr)
equip_$costs_{f,s,y}$ = Average cost for equipment for a boat using technique *f* for fish species *s* in year *y* ($)
technique *f* = all fishing techniques not requiring boats, e.g., siene nets, pots, shore fishing (rods off the beach)

Revenue Data Requirements for Fisheries

- Different coral reef associated fish and shellfish markets in each island
- Market price of each fish species in each of the identified markets
- Quantity of each fish species sold in each market (OR total amount of each fish species caught if the quantity of each species sold in each market is not available).

Cost Data Requirements for Fisheries

- Quantity of each fish species caught using each fishing technique (long line, seine net, pots, etc.)
- Number of hours spent fishing for each fishing technique
- Number of boats used to catch each fish species
- Average number of fishers employed per boat (may not need this one)
- Cost of operating boats per hour (fuel, maintenance, labor, etc.)
- Cost of nets, pots, or other fishing gear
- Average wage by sector in each island

b) Fish Processing Industries

Net revenue from processing of reef-related fish is based on the revenues less the costs of processing reef fish.

Fish processing revenue is calculated from the price received for processed fish and the quantity of fish processed. Preferably this information would be for each processing facility but more aggregated information can be used if necessary.

Processing $\text{Revenue}_y = \sum_{s,j}$ [(processed fish $\text{price}_{s\,j,y}$) x ($\text{output}_{s\,j,y}$)]

Where
Processed fish $\text{price}_{s\,j,y}$ =
Average price received for processed fish for each species *s* for company *j* in year *y* ($/kg)
$\text{Output}_{s\,j,y}$ = Quantity of processed fish for each species *s* sold by company *j* in year *y*

The costs of fish processing are estimated using the quantity of fish processed and the cost of processing fish. The cost of processing the fish would include the cost of inputs (the fish themselves as well as other necessary inputs) as well as capital, investment and maintenance costs for the processing plant.

Processing $\text{costs}_y = \sum_{s,j}$ [fish $\text{qty}_{s\,j,y}$ x (fish $\text{cost}_{s\,j,y}$ + input $\text{cost}_{s\,j,y}$)] +
$\sum_j$ [($\text{workers}_{j,y}$ x $\text{wage}_{j,y}$) + capital $\text{cost}_{j,y}$]

Where
fish $\text{qty}_{s\,j,y}$ = quantity of fish species *s* processed by company *j* in year *y* (kg)
fish $\text{cost}_{s\,j,y}$ = average cost of fish species *s* processed by company *j* in year *y* ($/kg)
input $\text{cost}_{s\,j,y}$ = average cost of other inputs needed for processing fish species *s* by company *j*
in year *y* ($/kg fish)
$\text{workers}_{j,y}$ = number of employee in company *j* in year *y*
$\text{wage}_{j,y}$ = average wage for employees in company *j* in year *y* ($/yr)
capital $\text{cost}_{j,y}$ = average capital and maintenance costs for company *j* in year *y* ($/yr)

Revenue Data Requirements for Processing Industry

- Quantity of processed fish sold by each facility (by species if possible)
- Average price received for processed fish (by species if possible) by facility

Cost Data Requirements for Processing Industry

- Quantity of each species processed each year in each facility
- Cost of fish purchased for processing
- Cost of other inputs used for processing fish
- Number of employees in each processing facility
- Average wage for employees in each processing facility
- Capital and maintenance costs for each processing facility

c) Local Informal Economy/Subsistence Fishing

The revenue from the subsistence fishing industry is estimated using the average quantity of subsistence catch for each fisher, the retail market price for fish, and the number of subsistence or local (own consumption) fishers.[3]

Subsistence Revenue$_y$ = $\sum_s$ [(fish price$_{s,y}$) x (sub catch$_{s,y}$)] x (fishers$_y$)

Where
Fish price$_{s,y}$ =
Average retail market price for each species *s* in year *y* ($/kg) (note: fishers may not purchase fish, only consume self caught fish)
Sub catch$_{s,y}$ = Average quantity of each fish species *s* caught in year *y* per fisher
Fishers$_y$ = Number of subsistence or local (own consumption) fishers in year *y*

Subsistence costs are derived from the quantity of subsistence catch, the cost of subsistence fishing and the number of subsistence fishers.

Subsistence Costs$_y$ = $\sum_s$ [(sub catch$_{s,y}$) x (sub fishing cost$_{s,y}$)] x (fishers$_y$)

Where
Sub catch$_{s,y}$ = Average quantity of each fish species *s* caught in year *y* per fisher
Sub fishing cost$_{s,y}$ =
Cost of subsistence fishing for each species in year *y* ($/kg), including the opportunity cost of fishing by fishers (wage * hours spent fishing)
Fishers$_y$ = Number of subsistence or local (own consumption) fishers in year *y*

Revenue Data Requirements for Subsistence Fishing

- Average number of subsistence fishers by year
- Average retail market price for the different fish
- Average quantity of fish caught by species by fisher
- Do fishers purchase additional fish from the retail market if they don't catch sufficient fish?

Cost Data Requirements for Subsistence Fishing

- Average number of subsistence fishers by year

[3] Only need this information if the quantity of subsistence catch is recorded on a per fisher basis.

- Average quantity of fish caught by species by fisher
- Cost of equipment used for fishing
- Average hours spent fishing (per fisher)
- Average wage for alternative employment for fishers

d) Economy-Wide Benefits of Fishing

The multipliers used to determine the wider benefits of fishing to the island economy include:

- Multiplier Employment/income related to fishing (boat makers, net repairs, fuel distributors, etc.)
- A general economy multiplier (incorporates people directly employed in the fishing industry and those employed in services that depend on the fishing industry, e.g., boat/net makers, net repairs, fuel distributors, etc.)

IV. Shoreline Protection

The methodology for estimating shoreline protection values we will employ will be a hybrid of various methodologies, including the OECS methodology for valuing sand resources in Grenada and a methodology for valuing the damage of storm or flood events (see Box 3 for a short description of these methodologies).

A similar equation will be used for reefs of various qualities. The equation for a healthy reef is:

Shoreline Protection Value = $\sum_j [\sum_a(\delta_a \text{ x } H\_Prot_{a,j}) \text{ x } \sum_k(area_{k,j} \text{ x } lvalue_{k,j})]$

Where
δ_a = probability of category *a* storm occurring in 25† year time horizon
$H\_Prot_{a,j}$ = degree of protection provided by a healthy reef against a category *a* storm for elevation *j*
$area_{k,j}$ = area of coast zoned for land-use *k* at elevation *j*
$lvalue_{k,j}$ = value of land in use *k* at elevation *j*
a = categories of different storm intensities
j = elevation categories that the coastal area is delineated by (e.g., 0-2 meters, 2-5 meters, etc.)
k = types of land-use zoning (e.g., commercial, residential, industrial, etc.)
q = category of shoreline and coral reef
† this time horizon may be modified once we have obtained climatic information for the region

This valuation may need to be further disaggregated for the various coastal areas on the islands, depending upon shoreline type, profile and the different types and settings of coral reefs, and if the reefs in different areas are in varying condition or if the value of the land changes between areas. The values would be a sum of benefits across the range of strom intensities and range of shoreline segments.

We will need to make a number of assumptions for this analysis. The exact assumptions will be determined once we have collected the relevant information. We may also be able to be more specific in terms of where damage occurs within given coastal areas. The ability to do this will depend on the damage information we can obtain for various storm events.

Some of the assumptions or *a priori* estimations required include:

- Probability of a storm of category *a* occurring
- Degree of protection for different land elevations provided by different categories of coral reefs in various conditions (e.g., healthy, fair, poor, dead), and in different coastal settings (e.g., wide, steep beaches on leeward coast). e.g., healthy reef on setting *q* will provide *w* percent protection against a category *a* storm for elevation *j*

Data requirements:

- Coastal elevation data (GIS format preferably)
- Storm frequency and intensity (may be from NOAA) to obtain storm categories and probability of storms in different categories occurring.
- Area of different zoned land-uses in coastal areas (e.g., area of land zoned as commercial, residential, industrial, etc.)
- Value of different land-uses at the various elevations (e.g., value of commercial land at elevation 0-2 meters) for the various coastal areas
- Health of coral reefs in each coastal areas
- Shoreline category (exposure, slope, coastal composition).
- Rules for linking coral reef type, coral reef location, and shoreline category with level of protection.

Box 3: Methodologies used to derive the shoreline protection methodology

<u>Outline of the OECS valuation methodology for sand resources used in Grenada</u>

This methodology essentially:

- Divided coast into various relevant land use types
- Distinguished the area at risk within 0-5 feet elevation and area at risk within 5-25 elevation of the shore
- Defined a unit area cost for each type of land use
- Multiplied the area at risk for each land type by the unit value of each land type to determine the value at risk in each area
- Assumed losses for two different storm types (1 year in 5, 1 year in 10)

<u>Avoided Damages Sample Methodologies</u>

Avoided damages methodologies rely on the assumption that not having to pay to repair damages represents the benefits of the natural resource in question (coral reefs, in this case) and that individuals would actually undertake the repair process. An example of avoided damages can be looking at the damages that are avoided from wave damage or erosion by having a functioning coral reef.

An example equation for estimating damage from storm or flood events may be:

$$V = a(X \text{ x } P_x) + b(Y \text{ x } P_y) + c(Z \text{ x } P_z)$$

Where

V = value of the coral reef
X = amount of coral reef-protected residential land
Y = amount of coral reef-protected commercial land
Z = amount of coral reef-protected industrial land (additional land types can be included, such as agricultural, mixed, etc. depending on the data availability on each island).
P_x, P_y, P_z, = average value per unit area of each land type

Instead of simply using land values (since we are interested in the buildings that lie on the land), this measure should ideally be an index that includes the value of the houses, factories, equipment, etc. on each land type, which can result in significant data requirements. The parameters a, b and c may be the percentage of each respective land type affected under each flood or erosion scenario. This may be the simplest way of looking at the shoreline protection benefits of coral reefs.

Hypothetical scenario
Suppose that the following information is available for a segment of coastline that has 30 hectares of residentially zoned land, 20 hectares of commercially zoned land, and 10 hectares of industrially zoned land:

Average value of residential land, buildings, and contents = $15/hectare
Average value of commercial land, buildings and contents = $30/hectare
Average value of industrial land, building and contents = $45/hectare

If the chosen storm event would have flooded 10% of residential land, 25% of commercial land, and 30% of industrial land, by these damages would be avoided by the protection afforded by reefs, the equation would look as follows:

V = (.10 (15 X 30)) + (.25 (30 X 20)) + (.30 (45 X 10)) = 45 + 150 + 150 = $345

So the value of the reef, for this storm event, is $345 in avoided damages.

References:

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: A Framework for Assessment. Island Press

Organization of Eastern Caribbean States (OECS). Valuation of Sand Resources In Grenada July 2001.