Value of Coral Reefs & Mangroves in the Caribbean

-- Economic Valuation Methodology V3.0--

World Resources Institute
January 2009

This document contains a methodology for assessing economic value of three 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, and provides a brief overview of economic valuation methods. Next, we present our current approach for valuing three important coral-reef associated goods and services: recreation and tourism, fisheries, and shoreline protection. The World Resources Institute (WRI) piloted this method in St. Lucia and Trinidad and Tobago, and in 2007 adapted it for Belize. In Belize, we look at the contribution of coastal mangroves in addition to coral reefs. This methodology was developed in collaboration with local partners in the three countries, and was reviewed through workshops and other consultative processes in each country.

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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 the Caribbean. This document provides background on methods of economic valuation, and outlines the current approach being used by this project.

The following economic valuation methodology is a draft version that is open for comment from project partners and collaborators. The method will continue to evolve along with the project, and this paper serves as a basis for further input and discussion. To see examples of the methodology in practice, please visit http://www.wri.org/project/coral-reefs to download *Coastal Capital: Belize*, or our pilot study, *Coastal Capital: Tobago and St. Lucia*.

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 provide important sources of income for the tourism, fishing, and pharmaceutical industries and play a critical role in protecting coastlines from erosion, flooding and storm damage. These reefs form the foundation of much of the Caribbean tourism industry—the region's most important economic sector—supplying sand for its beautiful beaches and luring divers and snorkelers from around the world. 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 (Burke and Maidens 2004). 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 bears the cost. For example, a new development may pollute and degrade an offshore reef, but those who suffer are the 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. There is also a 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 allowing land clearing 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

The Coastal Capital project uses the concept of "ecosystem services"—the tangible benefits provided by ecosystems that sustain and fulfill human life—as the basis for measuring the value of coral reefs. The Millennium Ecosystem Assessment (MA, 2005) identifies four categories of services provided by ecosystems: provisioning, regulating, cultural, and supporting services (see Figure 1 for the breakdown of goods and services provided by 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 on that reef will be lower than biodiversity on a reef with abundant food.

Figure 1. Goods and Services Provided by Coral Reefs

Provisioning Services *-Products obtained from ecosystems-*	**Regulating Services** *-Benefits obtained from regulation of ecosystem processes-*	**Cultural Services** *-Nonmaterial benefits obtained from ecosystems-*
food – fish and shellfish genetic resources natural medicines and pharmaceuticals ornamental resources building materials	erosion control storm protection	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

The Coastal Capital project has focused on three key coral reef-associated goods and services for which it is feasible to develop realistic values—fisheries, tourism and recreation, and shoreline protection services. There are many other economically important goods and services that are not included in this economic valuation, including ornamental resources, biochemical, natural medicines and pharmaceuticals, aesthetic values, cultural heritage values and sense of place.

Project Purpose and Methodology

WRI's economic valuation method is a simple and transparent approach that can be repeated using largely existing data. The services included in this economic valuation represent only a portion of the many goods and services provided by coral reefs; instead of capturing total value, the project focuses on a few components that are a) relatively easy to measure using published information and b) especially important to local economies. The method was pilot tested in two sites, Tobago and St. Lucia, and then expanded to Belize, where we added mangroves to the assessment. As of December 2008, the project has begun work in two new locations—Jamaica and the Dominican Republic.

Without an estimate of the values that coral reefs provide to society, coastal resource management and development decisions may exclude or fail to recognize the significant contributions of coral reefs. By providing information about the economic contribution of coral reefs to island economies, as well as the potential losses that could stem from further degradation, this project aims to improve the current and future management of coral reef resources. This information can also be used to evaluate tradeoffs in ecosystem management and in development decisions.

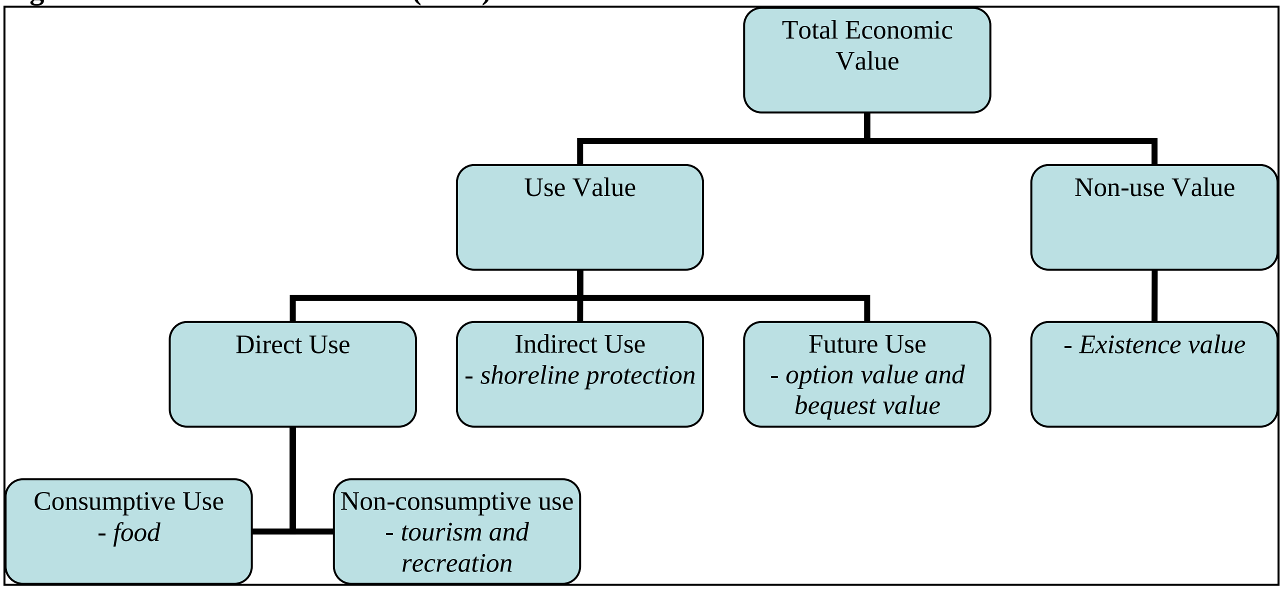
While there are many economic valuation methods and techniques in the literature (see Box 1, Page 5 for some examples), many of them require surveys, specialized data collection methods and/or statistical capabilities. Bearing in mind that governments and researchers often lack the time, financial resources, or statistical capacity to routinely implement these methodologies, we attempted to devise a simple and reliable methodology that can be implemented at low cost in Caribbean countries, using existing data. The methodology should also be able to accommodate different levels of data availability, and can be re-applied as data improve. The immediate goal is to be able to support informed estimates so that better management decisions can be made even in relatively data-poor situations.

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 services are typically 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

An **economic impact analysis** assesses the impacts of spending (revenues, wages, taxes, etc.) related to market-based uses of an ecosystem good or service. **Direct** economic impact can be estimated by calculating gross revenues associated with a service (for instance, diving and snorkeling). **Indirect** economic impact (impacts on the wider economy spurred by direct spending) can be calculated using a country- or sector-specific multiplier (see Box 2).

The **effect on productivity** method estimates a change in value by assessing the change in a provided good or service that results from a change in the environmental resource. For example, 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 flows in the economy from market-based uses of the reef. Unlike an economic impact analysis, operating costs are subtracted from all revenue calculations to arrive at net rents.

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, or products that need to be purchased, 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.)

II. Overview of the Economic Valuation Methodology

Overview: This method evaluates the economic contribution of reef-associated recreation and tourism (a cultural service), fisheries (a provisioning service), and shoreline protection (a regulating service).

1) **Tourism and Recreation.** This methodology can be used to calculate either gross or net annual revenues from reef-associated tourism.[1] Reef-related tourism activities include accommodation, reef recreation and tours, and other spending by tourists on reef-associated days. Where information is available, there is also the option of adding an assessment of local recreation and / or consumer surplus values, producing a more complete picture of the value of reef-related tourism and recreation.

2) **Fisheries.** The contribution of fisheries to the economy is also evaluated by collecting information on gross or net revenues from the reef-dependent portion of the sector. We assess formal and informal sales of reef-associated fish and shellfish, as well as "value added" from cleaning and processing.

3) **Shoreline Protection.** The shoreline protection services provided by coral reefs are evaluated in a geographic information system (GIS). The assessment 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 or mangroves.

In Belize, Jamaica and the Dominican Republic, the economic contribution of coastal mangroves has been added to the project method. Our shoreline protection method evaluates the independent contributions of reefs and mangroves to coastal protection, but the tourism and fisheries components currently assess the collective value of mangroves and coral reefs. In Belize, we followed the collective assessment with a rough estimate of the independent contribution of each habitat (see Box 3, Page 16).

Limitations

The accuracy of the valuation analysis will ultimately be limited by the quality and availability of data for the study site. This methodology was designed to utilize existing data in order to increase its replicability and transparency. However, where data are poor or scarce, we have had to rely upon the grey literature and expert opinion to fill in the gaps; where there was uncertainty around particular variables, we applied a sensitivity analysis.

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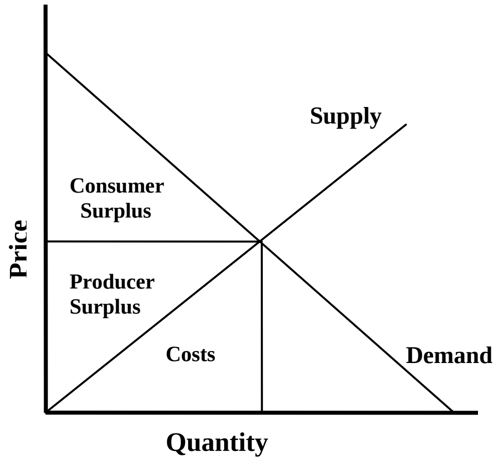
[1]The decision to use net or gross revenues is up to the user. *Gross revenues* are an indicator of economic impact. Information on the gross revenues associated with an ecosystem service can be used to support national-level decision-making, and can be usefully compared to GDP. In addition, poor data availability on operating costs for many reef-dependent sectors means gross revenues are often the only option for an assessment. *Net revenues* (gross revenues minus costs) can be useful for assessing tradeoffs (for instance, conducting cost-benefit analyses) and assessing incentives to change behaviors, such as over-fishing. Net revenue, or "producer surplus," represents a portion of the value of the service. To assess the full value of reef-related tourism or fisheries, net revenues would need to be added to an estimate of consumer surplus (the value of the enjoyment consumers receive above what they have paid (see Figure 3)). In the absence of the latter—which is assessed using survey-based methods—net revenues are widely used to represent at least a portion of value.

Figure 3: Supply and demand curve



It is also important to note that this analysis provides only a snapshot of current levels of reef use. It does not take into account whether these resources are being used at a sustainable level, and does not address the damage that overcrowded dive sites, inadequate waste treatment, and fishing at current levels may be doing to the reefs and mangroves. Similarly, this study does not assess the *potential value* of sites that are currently protected but not heavily used, especially for tourism. With an assessment of the sustainable level of visitors that a protected area or a dive site can support, it would be possible to conduct a similar analysis of the potential revenues the site could draw in the future.

Some of the implementation challenges for the valuation methodology include:

a) Distinguishing reef-related visitors from non-reef-related visitors (a key step for 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.
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.

III. RECREATION AND TOURISM

Introduction

This methodology employs a very basic assessment of the economic value of reef-related tourism and recreation by examining the flow of money (revenues, wages, taxes, etc.) generated by the use of coral reefs. This only represents a portion of the *value*, or well-being, that society gains from this natural resource—specifically, the portion that is captured by the economy. This document also includes a brief discussion of consumer surplus (the additional satisfaction a consumer receives over and above the price paid in the market—see Figure 3) as well as the value of local reef use; both of these values of coral reefs are not captured by the economy, and can only be assessed using survey-based or revealed preference methods (see Box 1, Page 5). The Coastal Capital project will expand to include some of these methods in the Dominican Republic and Jamaica.

Despite the fact that it underestimates the value of reef-related tourism, the basic assessment of economic contribution is still extremely useful for many Caribbean countries. Even where reef-based tourism is a critical part of the economy, development and management decisions that impact coral reefs are often made without assessing the impacts on people and industries that rely directly on reef health. Therefore, even a conservative underestimate of reef ecosystem value can be helpful in promoting better policies.

To assess the economic value of reef-related tourism, collect information on revenues from all tourist spending on "reef associated" days, including accommodation, reef recreation, and other expenses (transportation, food, etc.), and subtract operating costs to arrive at net revenue.[2] If conducting an economic impact assessment, or if information on costs is not available, gross revenues can be used instead. Since consumer surplus is typically fairly high for reef-related tourism (Arin and Kramer, 2002; Green and Donnelly, 2003), gross revenues should still be an *underestimate* of the value of this service (i.e. Gross Revenues < Net Revenues + Consumer Surplus).

Step 1: assessing reef-related tourism

The first—and in many instances, most difficult—question to address in the tourism analysis is: how many tourists are visiting the country to use the reefs? And, more specifically—what portion of all "tourist nights" can be attributed to days spent using the reefs? This question has to be addressed differently in almost every country, due to differences in how (or whether) data are collected on tourist activities. In St. Lucia and Tobago, where very little official information was available, WRI's assessment had to rely upon limited exit surveys, expert opinion from marine tour guides, and MPA visitation records to estimate the percent of tourists who come to visit the reefs. In Belize, which has a clear division between marine and terrestrial tourism, we were able to use published accommodation information to assess *where* tourists were staying, and applied expert opinion to estimate what percent of "tourist nights" in each accommodation region could be associated with coral reef and mangrove use.

It is important to try to establish a tourism profile for the study site: what percentage of visitors are coming for sea, sun, and sand? What percentage of visitors are coming for ecotourism or scuba diving? What percentage of tourists are visiting on all-inclusive package vacations? These characteristics greatly influence how much the local economy benefits from a tourist's visit and reflects how important coral reefs and coastal environmental quality are for the choice of destination. The proportion of all-inclusive visitors is also important to know because it helps to avoid double-counting in later stages of the analysis.

The percentage of reef-related visitors will be used to pro-rate some of the revenues in the sections below, including accommodation and other tourist spending.

Step 2: calculating reef-associated tourism value

a) Accommodation

As mentioned above, before beginning the accommodation calculation, it is important to establish the percentage of total tourist nights that can be attributed to coral reef-related activities. For the countries we have assessed thus far, we include coralline beach use as a reef-related activity, along with the marine

[2] The pilot studies in St. Lucia and Tobago applied a modified financial analysis to assess the value of reef-related tourism. This involved calculating the gross revenue of tourism and recreation, and then subtracting the best available information on operating costs to arrive at net revenue. The pilot studies also explored the broader implications of reef-related tourism for national economies, by adding labor costs and tax revenues back into a final estimate of economic contribution.

recreation activities assessed below. Depending upon the data available, hotel revenues can either be assessed by categorizing by accommodation type (hotel, guesthouse, etc.); or by using aggregated data on number of rooms, room rates, and occupancy rates (or simply annual hotel revenues). If possible, information on foreign versus domestic ownership and type of clientele they attract (e.g. primarily divers) should also be collected. Ideally, information for each establishment offering accommodation will be used. However, 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, average room rate and the occupancy rate.

The approach used for determining the accommodation revenue will depend on the availability of data. If possible, all data should come from one study year or be normalized to that year (e.g. in the case of room rates).

In addition to revenues from hotels on land, it is important to account for tourists who stay on liveaboards or yachts, many of whom come to dive or snorkel on the reef. These businesses are often treated separately from other accommodation, and revenues will have to be calculated by estimating the number of guests, average length of stay, and average rates for yachts and liveaboards in the study year.

Since many tourists may not visit the country for the coral reefs or only utilize the reef during a portion of their visit, accommodation revenue is prorated to account for only those nights that are associated with reef-related activities.

Accommodation costs can be broken down into labor and non-labor operating costs, and ideally will be based on the operation and maintenance costs for each category of establishment (e.g. villas, bed and breakfasts, large hotels, etc.). Most likely, more aggregated data will have be used to estimate these costs, as data often do not exist at this level.

b) Reef Recreation

Reef recreation includes use of the reef for diving, snorkeling and reef tours, and sport fishing by foreign and local users. As with the accommodation sector, company-level information would be ideal. However, we recognize that it may only be possible to obtain more aggregated information. Surprisingly, none of the study sites WRI has worked in thus far collect—or at least provide to the public—data on the volume of reef recreation. If there are recent exit surveys on visitor activities, these can be a good alternative to data on use (this is what we relied on for Belize). Failing that, the last option is to establish the number of reef recreation operators in the country, and estimate average annual revenues for the different activities.

Revenues are estimated individually for the three reef recreation components:

1. Snorkel and reef tour 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, or the number of divers, number of dives per diver and the price of the average dive package;
3. Sport fishing revenue is based on the number of fishing charters and the average fishing charter price.

In addition, dive shops may earn revenue from offering dive certifications, and all of the different operators may also rent equipment. For each activity, it is important to collect information on the percent of trips that are purchased as part of all-inclusive packages. To avoid double-counting, revenues from these trips are subtracted from the total. This assumes that the room prices in the accommodation section include package rates. If room prices do *not* include package rates, double-counting will not be a problem, and all reef recreation can be counted here.

As was the case for the accommodation sector, the costs for reef recreation can be broken down into labor and non-labor operating costs, and will most likely have to be based on average costs for the industry.

c) Other Tourist Spending

This methodology counts all expenditures (including food, transportation, etc.) on the day that a person visits a coral reef as "reef-associated." To estimate these other categories of spending in the three original study sites, the project used information from tourism ministries or outside sources, such as the World Travel and Tourism Council, to estimate average tourist spending (per day or per trip). Using the findings from the previous sections, it is possible to subtract spending on accommodation and reef recreation from total daily expenditures to estimate revenues from other tourist expenditures. If assessing net revenues, an estimate of typical operating costs as a percent of total revenues for likely industries (restaurants, taxis and other transportation, for instance) will have to be used to produce a rough estimate of costs.

d) Cruise Ships

Cruise ships are an important part of the tourist economy for a number of Caribbean countries. However, a majority of cruise ship passengers are most likely not choosing particular cruise lines based on the reef-related activities they offer, but rather for the whole amenity package provided by cruises. Furthermore, a majority of passengers may not participate in any of the offered reef-related activities. In Belize, it was possible to determine the number of cruise visitors that engaged in reef-related activities using the results of a fairly comprehensive survey administered at the exit port. Marine Protected Area records can be another source of information if cruise passengers visit MPAs. For example, Hol Chan Marine Reserve in Belize differentiates between cruise ship tourists and overnight tourists in its visitation records. Nevertheless, determining the number of cruise passengers engaging in reef-related activities, and thus the associated revenues and costs from the cruise industry, may prove to be difficult in many places.

Where cruise tourism is included in the assessment, the analysis should include both reef recreation revenues and any head tax or docking fee applied to cruise passengers who visit the reef. We did not attempt to calculate other spending by reef-associated cruise tourists, as it was expected to be minimal.

Note: The economic benefits from cruise tourists visiting the reefs may well be outweighed by the costs of supporting them, both in terms of infrastructure and the environmental impacts caused by the ships and large volumes of tourists snorkeling at one time. A separate analysis of costs would be a useful complement to this study, and would be helpful for decision-makers.

e) Taxes and Fees

This method includes taxes and fees in the estimate of reef-related economic impact. In general, we calculate taxes and service charges as we assess each industry (accommodation, reef recreation, etc.). Especially when using advertised room rates and activity rates to calculate revenues, it is important to know if taxes are generally included or added on top of advertised rates for a particular industry. In Belize, for example, the 9% hotel tax is generally added on top of the advertised room rate (government records of average room rate are also before tax). However, the reef recreation sector (which includes diving, sport fishing, etc.) generally includes general sales tax in advertised tour prices. Therefore, to avoid double-counting, we subtracted the 10% GST from the estimate of recreation revenue and included it under taxes and fees.

Other taxes and fees might include:

1. Departure tax, prorated by the number of reef-associated visitors or visitor nights (e.g. in Belize, 64 percent of all tourist nights can be associated with coral reefs and mangroves, so we count 64 percent of departure tax revenues as reef-associated);
2. Marine Protected Area fees; and
3. Head taxes from cruise passengers visiting the reef.

f) Local Recreation

Coral reefs and reef-based amenities are also used by local populations and often play an important role in local life. Unless previous assessments have been conducted for the study site, surveys are needed to estimate local use. In Tobago and St. Lucia, the project incorporated local use surveys designed and implemented by a local partner. The surveys were used to estimate the amount of time (measured in average hours per year) spent by local residents on coralline beaches or boating and fishing (for recreation) outside of paid tours. To estimate the value of local reef use, average hourly wage is used as a proxy for the value (or opportunity cost) of this time. This is an aspect of coral reef use that falls outside of the money economy, yet is nonetheless highly valued by local populations. Local recreation estimates would not be included in an estimate of the economic impact of coral reefs, but should be included in an economic valuation (see Box 2, Page 13 for a further discussion of value versus impact).

g) Consumer Surplus

To calculate Consumer Surplus it is necessary to estimate a demand function, which relates consumers' willingness to pay to the price of the good or service in question (see Figure 3, Page 8). Demand functions can be calculated in two ways: by directly asking tourists what their willingness to pay for a service would be at different prices, or by using data showing how the costs of traveling to a destination affect the number of visits (the travel cost method; see Box 1). The first approach requires interviewing tourists and can be expensive if interviewers need to travel to administer the surveys. However, this approach may be necessary if data on travel costs are difficult to obtain.

Box 2: Direct and Indirect Economic Impact of Reef-associated Tourism

Depending on the needs and data available at a particular study site, it may make sense to assess the **economic impact** of reef-associated tourism, rather than **economic value**. Value represents the well-being that society gains from a resource, while economic impact is simply the flow of money (revenues, wages, taxes, etc.) generated by the use of that resource (see Pendleton 2008). The direct economic impact of reef-related tourism can be estimated by calculating gross revenues from the accommodation, reef recreation, and other tourist spending categories above. This does not include any values not captured by the economy.

In addition to **direct impacts** to the tourism sector, there are impacts on the wider economy from spending by reef-associated visitors. For example, food purchased by visitors may be sourced from local farmers; fuel used for transportation is purchased from local fuel distributors, etc. If conducting an economic impact analysis, it is possible to estimate the magnitude of these **indirect** (or "secondary") **impacts** by applying a tourism multiplier. A multiplier of 1.6, for example, represents 60 cents of additional (indirect) impact for every dollar in direct tourist expenditure. The size of the multiplier is influenced by the portion of goods and services used in the tourism sector that is produced domestically, such as linen, beverages, food, dive equipment, construction materials, etc. If no published multiplier exists for the study site, a multiplier (or range) from a similar economy can be used to get a reasonable estimate, but such estimates should be treated with caution.

IV. FISHERIES

The economic contribution of reef-associated fisheries is assessed by collecting information on gross or net revenues from the reef-dependent portion of the sector. Fisheries can be assessed at the country, island, or site-specific level. The methodology calculates revenues from both the commercial fishing and processing industries, and, where necessary, further divides the commercial fishing industry into large-scale and small-scale (or artisanal) fishing. As with recreation and tourism, it will be useful to first determine a profile of the fishing industry for the study site. Are there predominately pot fishers, seine fishers, etc.? What commercially relevant fish and shellfish species are related to the reef? Where and how is the fish catch sold or used? How large a role does informal and / or subsistence fishing play?

The method for estimating gross revenues from reef-associated fisheries has been developed to be flexible in the absence of reliable fisheries catch data for a given study area (as often is the case throughout the Caribbean, especially in less developed areas). In cases where consistent fisheries catch data are unavailable, the amount of fish caught will need to be estimated based on abundance of reef fisheries in similar areas. While not as robust as collected catch data by fisherman or by landing site, this will give an "order of magnitude" estimate for fish catch. If assessing net revenues, information on costs will have to be collected or estimated by fishing method (for instance, in Belize, reef-based fishermen either fish in groups on sailboats, or alone or in pairs in small motor boats).

As with the tourism sector, revenues will need to be disaggregated in many cases to include only reef-associated fisheries. For the fisheries sector, revenues are often already disaggregated by species.

Step 1: estimating revenues for reef-related fishing industries

a) Commercial Fisheries

In areas where there is an established commercial fisheries industry, it typically constitutes a significant portion of the overall value of the reef fisheries sector. However, since reliable estimates of commercial fish catch may not be available, the methodology includes several ways for calculating the value of commercial fisheries.

The revenue from commercial fisheries is based on the fish catch and the fish price in each market (e.g. export, restaurant, or local retail). There are four ways to calculate the commercial fisheries value:

1. *Species catch data by landing site.* If catch data is available by landing site, this is the recommended way to calculate the value of commercial fisheries. In this instance data is collected (usually by the Fisheries Department) at each landing site. Typically, a Fisheries Department official will sample a portion of the catch at each landing site. The data are scaled up to estimate total commercial catch.

2. *Catch data by fisherman/boat.* If data is available for all or a subset of fishermen or boats catching reef fish, but official statistics are not collected, a sample of fishermen or boats can be used to calculate total value of the commercial fisheries sector. In this instance, data for a subset of fishermen (or boats) can be scaled to estimate total catch for the island. It is important to ensure that the sampled data are representative of the larger island.

3. *Fisheries abundance by reef area*. In the absence of catch data by landing site or by fishermen/boats, calculating abundance by reef extent may be a useful third option. For fisheries abundance calculations, information on the extent (area) of the reef and the productivity (or amount of fish caught per unit area) is necessary. Those employing this method can use available statistics on reef extent and regional calculations on fisheries abundance in deriving statistics of fish catch.

4. *Expert opinion*. In areas where there exist experts familiar with the fisheries sector and otherwise reliable data is not available, expert opinion can be used to estimate the fish catch. Experts can provide estimates of the number of fishermen or boats at each landing site, as well as the number of fishing trips and average catch by species. Expert opinion can also be a valuable supplement to other sources of data—for instance, providing knowledge on the sources and limitations of official fisheries statistics.

Note: For some study sites, it may be important 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 and Cleaning (Value Added)

In some countries, the fish processing industry may be a valuable source of foreign income and/or a major employer. Fish processing facilities will also sometimes act as a purchaser of last resort for fishermen who cannot find another buyer for their catch. In addition to processing facilities, there is often informal fish cleaning at landing sites.

Fish processors typically purchase and sell both reef and non-reef fish, so it will be important to disaggregate the value of reef-associated fish. The difference between the price paid to fishermen for their catch and the final sale price of processed fish is the value added from processing.

Instead of buying processed fish, buyers for hotels, restaurants or personal consumption will often pay for fish to be cleaned at a landing site. Cleaning value added can be calculated similarly to processing—if information is available on the local price of whole fish versus cleaned fish (by species, if possible), and also on the percentage of catch that is sold after cleaning at landing sites, it is straightforward to calculate cleaning values. If this information is not available, it is also possible to estimate the earnings of independent cleaners by gathering information on:

1. the number of independent fish cleaners in the study site;
2. average hours worked per week / year (weighted by season if necessary); and
3. average hourly earnings.

Average operating costs for processing factories will need to be subtracted from final sale revenues if assessing net revenues.

Issues: If a value added multiplier is used in the economy-wide section below, avoid double counting estimates of value added in this section.

c) Subsistence Fishing

The local informal economy and subsistence fishing are important aspects of the fisheries sector in many countries, and provide a safety net for poorer people in many areas, allowing for income smoothing when other wage labor is not available. However, the informal sector also presents substantial challenges in terms of data collection and analysis. There is rarely good information available on the magnitude of fishing for personal consumption. One option is to use replacement cost methods (see Box 1, Page 6) to estimate the economic value of subsistence fishing. This method is based on the premise that if subsistence users were deprived of their source of livelihood (e.g., fish), they would have to *purchase* products of similar quality, thus incurring a cost. Localized surveys or expert opinion can be used to estimate the amount of fish that fishermen keep for subsistence use over the course of an average year. In many places, the fish kept for consumption are of slightly lower than market quality. Hence, a price slightly below market value can be used to estimate the equivalent market value of subsistence fish (Schumann and Macinko, 2007).

If time and funding permit, another option is to undertake a "local use" survey to directly measure the extent to which residents are engaging in these activities. This survey will measure the proportion of the population that is fishing for consumption, including both commercial fishermen and the wider population, and how much fish they catch for subsistence in a given year.

d) Challenges and Limitations

Fisheries tend to have the smallest economic contribution of the three services evaluated, but there are a number of social and cultural services associated with the fishing industry that are not captured by this assessment, including:

- The social and cultural value associated with the fishing tradition and for being employed in the fishing industry; and

- The social value to having people employed rather than unemployed and potentially causing social problems. This would include the value of fishing to residents when other income sources are not available.

This approach also calculates fishing benefits based on the productivity of the fishery today. However, if the fishery is being overfished, these benefits will not be sustainable in the medium- to long-term. To ascertain if overfishing is occurring, it is important to determine the maximum sustainable yield of the fisheries by species and note that fisheries may continue to decline if exploited at current levels. Even if the fishery is at maximum sustainable yield (which is unlikely with open access) it may be at a point beyond its maximal economic yield.

Data limitations have proven to be an additional challenge in the fisheries sector, and there are considerable differences in data richness in different parts of the Caribbean. While reliable estimates of fish catch exist in some areas, many parts of the Caribbean (for example, the island of Tobago, one of our pilot sites) have no reliable records of fish catch. In these cases, rough estimates of catch can be estimated either through fishing effort or reef productivity. Some areas will have commercial fish processing plants where data are routinely collected, while in other areas, individual processors will need to provide data. Finally, our experience to date has been that there exists very little information on local and subsistence fishing in much of the Caribbean.

Box 3: Assessing the value of coastal mangroves

Coral reefs and mangroves are highly interconnected habitats, physically supporting each other and providing habitat for fish species. For example, mangroves filter sediment and pollutants from coastal runoff, supporting the clean water favored by corals. Many fish species important to fisheries and tourism rely upon mangrove habitat for a portion of their life-cycle.

Starting in Belize, the Coastal Capital project began evaluating the economic value of coastal mangroves in addition to coral reefs. The method used is similar to the one described here, except that it is expanded to consider mangrove-related tourism activities (such as wildlife tours) and mangrove-dependent fish species. Our shoreline protection method evaluates the independent contributions of reefs and mangroves to coastal protection, but the tourism and fisheries components currently assess the collective value of mangroves and coral reefs. We did a spatial analysis to produce a rough estimate of the independent contribution of each habitat to fisheries and tourism in Belize. For the tourism estimate, we used a GIS to examine the proximity of mangroves and coral reefs at sites across the country to estimate the portions of revenues that a) rely exclusively on coral reefs, b) rely exclusively on mangroves, and c) depend upon both. For the fisheries sector, we assessed which fish species are primarily reef dependent, mangrove dependent, or depend heavily on both, and allocated fisheries revenues accordingly.

WRI's shoreline protection analysis differentiates between the protection provided by mangroves and reefs from the outset. Mangroves play an especially important role in buffering against storm surge and reducing erosion.

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, geographers, or geomorphologists 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 in coastal areas;
- 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 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); and
- level of development or future development if an area is currently not developed.

A modified "avoided damages" approach is used to estimate the value of this service along coastal segments protected by coral reefs or mangroves. This involves estimating the likely economic losses (in property value) to a coastal area from a given storm event, both with and without the reefs and mangroves present. This difference represents the "avoided damages" owed to the presence of reefs and mangroves. The method developed jointly by the Institute of Marine Affairs (IMA) in Trinidad and Tobago and WRI 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 that can support informed coastal planning and development.

Although the Coastal Capital project has not yet produced scenario results, it is also possible to develop scenarios to assess the shoreline protection value offered under different conditions of reef health, or different climate change scenarios. If looking at future scenarios, it will be important to establish an appropriate time frame and discount rate for the analysis.

The current shoreline protection methodology involves five steps, which are implemented within a geographic information system (GIS):

1) **Identify land which is vulnerable to wave-induced erosion and storm damage.** Vulnerable lands were defined as those within 1 km of the coast which are lower than the combined height of the storm surge and wave height expected during a 25 year storm event (which is 5 m in the case of Belize).[3] Storm surges can easily intrude 1 km inland, so this distance is conservative. Storm surge and wave height estimates can be adjusted to include predictions of future sea level rise, or for changes related to projected changes in storm regime.

2) **Identify coastline which is protected by coral reefs or by mangroves.** In general, the methodology defines coastal land as "protected" by coral reefs if it lies within 100m of a fringing reef, or is enclosed by a barrier reef. In Belize, where the barrier reef and coral atolls occur far from the mainland coast, these structures still provide some attenuation of waves reaching the mainland. These features also protect the many cayes found inside of the barrier reef. Shoreline with windward facing coast in areas enclosed by the barrier reef or in the "wind shadow" of a reef or atoll is classified as

[3] Data on predicted storm surge and wave height come form: 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.

"protected" by coral reef. Shoreline in close proximity (i.e. 20 to 50 m) to mapped mangrove is classified as protected by mangrove.

3) **Estimate the relative stability of the shoreline based on a range of physical factors.** The relative stability (resistance to erosion) of each shoreline segment is evaluated based on the integration of up to nine physical factors.[4] The factors are: coastal geomorphology; geology; coastal protection (such as protection by an atoll or a sea wall); a coral reef index (which integrates reef type, continuity and distance from shore); [5] wave energy; frequency of hurricane events (by category); coastal elevation; coastal vegetation; and presence of damaging anthropogenic activities, such as sand mining. Each individual factor can range in value from 0 to 4 (with 4 being the highest stability). The nine factors and their associated values are provided in Table 1 at the end of this document. The relative stability of the shoreline is calculated by taking the average of all factors for which data are available for the entire study area.[6] The sum of these factors is used as the basis for comparison of the relative contribution of coral reefs and mangroves to shoreline stability.

4) **Determine the share of shoreline stability which is attributed to coral reefs or to mangroves.** The share of shoreline stability contributed by coral reefs or mangroves was estimated by virtually "removing" the coral reef or the mangrove from the map and recalculating the sum of factors contributing to the stability of the shoreline.[7] The sum of the factors from the shoreline stability estimation (above) is compared to the similar sum with mangroves or reefs removed and the percentage difference is calculated. For example, if the seven factors for which data area available sum to 24, but only sum to 18 with mangroves "removed", mangroves contribute a 25% share to the protection of that segment of shoreline.

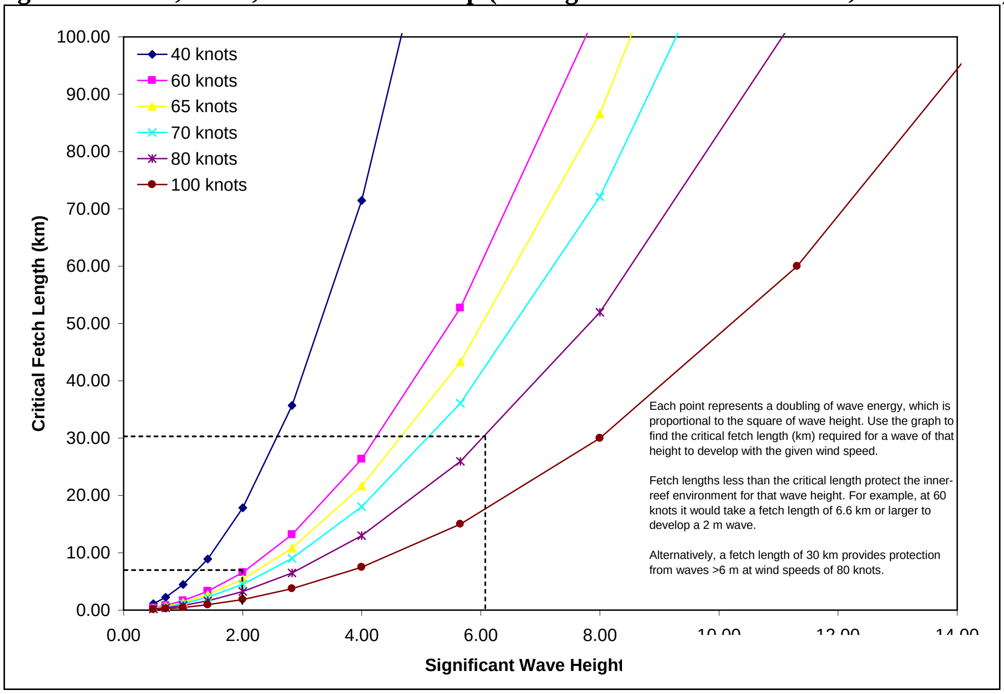
[4] As comprehensive data are not always available for all nine factors, one should include as many factors as possible (above a bare minimum of five).

[5] Within the coral reef index, higher protection values are associated with reefs which are close to shore, reefs which are continuous rather than interrupted, and with emergent reefs such as the barrier reef or the windward side of an atoll as compared with patch reefs. A nomogram developed by Chris Houser of Texas A&M University was used to establish the critical thresholds for reef distance offshore. The nomogram links wave heights with wind speed and fetch length (distance wind blows over open water) to allow estimation of the wave heights possible given the reefs proximity to the shore (See figure 4).

[6] Where data are missing for some locations, data can be filled in based on best assumptions for the area, as to not have to drop the entire factor from the analysis.

[7] In the case of coral reefs, the coral reef index variable is reset to one. Where mangrove covered atolls are present, the factor reflecting coastal protection structures is halved, reflecting the possibility that some mangrove-covered cayes could persist for some period even without the coral reefs (a generous, conservative assumption). Mangroves are similarly "removed" by resetting the coastal geomorphology factor (from 2 for mangrove) to the category of the nearest non-mangrove category, and resetting the coastal vegetation factor (from 4 for mangrove) to the average value for all other coastal vegetation. (See the factor table (Table 1))

Figure 4 - Wind, Fetch, Wave Relationship (Nomogram from Chris Houser, Texas A&M)



5) **Estimate the "damages avoided" due to the presence of coral reefs (or mangroves) based on the value of property (land and built structures) in vulnerable land protected by coral reefs (or mangroves).** Property values for both undeveloped and developed properties in vulnerable areas across the study area are needed. Average property values for distinct locations are required (ideally differentiated between land adjacent to the coast (within 100m) and further inland). Values are summed as follows:

- The average property value in areas classified as vulnerable (based on the 25 year storm event), and classified as protected by a coral reef are combined with (multiplied by) the share of coastal protection attributed to coral reefs (for the nearest shoreline segment).
- The sum of these values is then multiplied by 4% (the probability of the 25 year storm event occurring in a given year). This reflects the "damages avoided" due to the presence of coral reefs in an average year.

Notes and Limitations

This innovative methodology provides a useful means for evaluating potential avoided damages afforded by coral reefs and mangroves, 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 and mangrove locations and coastal elevation (these are the most important), a variety of data sets on coastal characteristics, as well as expertise in GIS. The method compares wave-induced damage with and without the presence of coral reefs or mangroves. It does not estimate the protection value which might be lost during the gradual degradation of a coral reef. Such an analysis would require scenarios of reef degradation over time, coupled with estimates of the reduced wave mitigation associated with the reef at different stages of degradation.

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 reflect the uncertainty surrounding these estimates, ranges (such as +/- 20%) can be established around the central estimates.

Table 1 - Coastal Protection Factors
Source: Institute of Marine Affairs (IMA) and WRI, adapted for Belize

Factor	*Level Of Coastal Protection*								
	Very High 4		**High 3**		**Medium 2**		**Low 1**		**None 0**
Coastal Geomorphology	Rocky, Cliffed Coastline Or Sea Wall		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	Significantly protected by a large atoll or 2 prominent headlands		Protected by atoll, or by headlands		Slightly protected by atoll		Protected by one or two small headlands		No protection by atoll or headlands
Coral Reef Index *(sum of 3 factors / 10 *4)* **Reef Type**	Emergent Reef (barrier or windward side of atoll)		Fringing and Leeward side of atoll		Patch		--		No reef present
Reef Distribution	---		---		Continuous		Discontinuous		No reef present
Reef Distance Offshore (m)	< 250 m	250 – 500m	.5 – 1 km	1 - 2 km	2 – 4 km	4 – 8 km	8 – 16 km	> 16 km	No reef present
Wave Energy (~ Max. Wave Height)	< 25 cm		25 – 50 cm		50 – 100 cm		1 – 2 m		> 2 m
Storm/Hurricane Events	Affected by at least a category 1 every 25 years		Affected by at least a category 2 every 25 years		Affected by at least a category 3 every 25 years		2 or more category 3 or higher expected every 25 years		N/A
Coastal Elevation (m)	> 12		6 - 12		2 - 5		0 - 1		< 0 (N/A) **
Coastal Vegetation *)* **Type**	Mangroves		Forest / Coastal Woodlands		Shrub and Thicket		Savannah and Wetlands		None
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

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