WORLD RESOURCES INSTITUTE

Economic Valuation of Coral Reefs
Methodology v2.1
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WRI's economic valuation methodology provides a simple and replicable method for estimating the value of coral reefs and mangroves in the Caribbean. The methodology uses the concept of "ecosystem services"– the tangible benefits ecosystems provide which sustain and fulfill human life—as the basis for measurement. The approach looks primarily at the direct economic benefits provided by these resources; it does not attempt to calculate the Total Economic Value (TEV) of coral reefs and mangroves, which would include non-use values (for instance, the 'existence value' non-users place on the presence of the reef). The methodology focuses instead on three important ecosystem goods and services associated with coral reefs: fisheries, tourism, and shoreline protection services. These services comprise an integral part of many Caribbean economies. The methodology also offers guidance on estimating the wider (indirect) impact on the economy of these resources, the consumer surplus associated with their use, and the potential losses or gains in value associated with changes in ecosystem condition.

1) Coral Reef Associated Fisheries

A financial analysis approach is used for assessing the value of reef and mangrove-associated fisheries. This approach involves totaling the revenues from the commercial fishing and fish processing industries, and subtracting the costs of theses activities, arriving at net financial benefits. Wages, taxes, and fees are treated as "pass-throughs" to the economy, and are included in total benefits. Three elements of local (non-commercial) fishing are also assessed – fishing for consumption, sale, and pleasure. The methodology also assigns a multiplier to estimate the wider economic benefits associated with the fishing industry. Ultimately, the methodology will assess how future changes in ecosystem condition will affect the economic value of fisheries through changes in the productivity of the reef and mangroves.

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

Fish Processing Industries – The value added from fish processing is estimated using the sale price minus purchase price of fish and the quantity purchased by facilities. Operating costs are subtracted to arrive at net benefits. Informal on-site cleaning is estimated based on earnings associated with cleaning at landing sites.

Local Fishing – the values from local fishing for consumption, local sale, and pleasure are calculated separately using estimates of the percent of the population engaging in these activities, the time spent fishing, and the market prices of reef fish. The value of leisure time, based on average local wages, is used to estimate the enjoyment value from local fishing.

2) Coral Reef Associated Tourism

The value of coral reef-associated tourism is also assessed using a financial analysis approach. This requires totaling the gross revenues (accommodation, reef recreation and tours, miscellaneous expenditures) captured by service providers and subtracting the costs of providing these services to arrive at a net benefit. Wages, taxes, and fees are counted as "pass-throughs" to the economy, and are included in total benefits.

Accommodation – Identifying the "reef-associated" share of accommodation expenditures requires compiling standard information on hotel room rates, occupancy rates, operating costs, taxes and service charges, as well as determining whether a visitor is present at least in part due to the area's coral reefs. Depending upon data availability, information can be compiled by individual hotel, by accommodation type (hotel, guest house, etc.), or based on average values for the country, region, or study area. For each, an estimate of the "percent of visitors using the reef" is specified, which is used to pro-rate accommodation credited to the reef. In addition,

foreign versus domestic ownership of hotels is specified, supporting the estimation of the amount of net revenue that is likely to remain in the country.

Reef Recreation -- Reef recreation includes foreign and local use of the reef for snorkeling, diving and sport fishing. The value of reef-related activities is estimated by totaling gross revenues and subtracting the costs. This can be estimated based on company-level information, or based on the price of specific activities (dive or snorkel trips, etc.) coupled with the number or percent of visitors who engage in this activity.

Marine Protected Areas – MPAs are an important draw for tourists as well as an important tool for managing coastal resources and protecting coral reefs. Revenues from visitor fees and other relevant fees (mooring, diving, etc.) are totaled, and the cost of collecting fees is subtracted from the total. In places where MPAs have good reef recreation data, these can also be used as a starting point for estimating reef use.

Additional expenditures and economy-wide effects -- Tourists typically spend additional money on restaurants and shopping as part of their visit. An estimate of these additional direct expenses by reef-related tourists will be made based on information on the tourism industry (e.g. for each dollar spent on accommodation, forty additional cents go towards expenditures such as food and entertainment). The methodology also gives the option of using a multiplier to measure the wider (indirect) economic benefits associated with reef-related tourism. Users can choose to exclude the estimates of wider economic impact from the final value.

3) Shoreline Protection Services

Evaluation of the shoreline protection services provided by coral reefs requires an understanding of the protection afforded by different types of coral reefs in different coastal settings, under different storm scenarios, coupled with information on property values in areas receiving at least some protection from coral reefs. A modified “avoided damages” approach is used to estimate the value of this service along coastal segments protected by coral reefs. This involves estimating the likely damage (and associated economic losses) to a coastal area from a given storm event, both with and without the reef present. The difference is the “avoided damages.”

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

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

Within this analysis we focus on storms likely to occur within a 25 year period for a given area.

1) Storm Regime

Information on tropical storms and hurricanes is the most relevant aspect of the storm regime, as these are the most damaging storms. The typical wave heights associated with the storms is essential for prediction of likely damage, and determining which lands are most vulnerable to wave-induced erosion or storm damage. Historic information on erosion and property damage from particular storms are also important for validating predictions of future losses, so should be collected if possible.

2) Vulnerable Lands

The elevation and slope of coastal land influences how vulnerable the area might be to damage from waves. Higher elevation and increased distance from shore both lessen the potential damage from waves and storm surges. The definition of vulnerable lands is based on the sum of the average storm surge and wave heights associated with a 25 year storm event along a given coastline (obtained from *Atlas of Probable Storm Effects in the Caribbean Sea* - http://www.oas.org/CDMP/document/reglstrm/index.htm). Within our pilot implementation of the methodology for St. Lucia and Tobago, for example, "vulnerable lands" were defined as any areas of 5m or less in elevation which are within 1 km of the coast, and all areas immediately adjacent to the coast (within 25 m resolution coastal grid cells).

3) Reef Protected Shorelines

Coral reef occurrence, type and distance from shore depend on biological and physical characteristics of the area. Much less than half of Caribbean coastline length is protected by a coral reef.[1] Within the methodology, shoreline segments "protected" by coral reefs were defined as those within 100m of a fringing reef, or enclosed by a barrier reef.

4) Coastal Protection and Coral Reefs

The Institute of Marine Affairs in Trinidad developed a coastal protection classification scheme (index) which integrates ten physical characteristics to estimate the relative resistance of each coastal segment to wave-induced erosion and damage from storms. This scheme can also be used to evaluate the role coral reefs (and mangroves) play in reducing vulnerability to erosion and storm damage. The coastal protection index integrates data on coastal geomorphology (limestone cliff, beach, etc.); coastal geology (igneous, metamorphic, etc.); coastal exposure (protected by headland, seawall, or riprap, or exposed); wave energy (typical maximum wave height); storm frequency (frequency of tropical storms and hurricanes); coral reef characteristics (reef type, continuity, and distance from shore); coastal vegetation (mangroves, wetlands, etc.); coastal elevation (m); coastal slope (percent); and the presence of erosive anthropogenic activities occur, such as sand mining.

The relative total coastal protection (RTCP) for a particular coastal segment is the average value for the ten factors combined[2]. This integration of individual factors is done in a geographic information system (GIS).The calculation can be repeated with the coral reef variable set to "no reef" to examine the change in RTCP due to the reef.

In addition, the relative contribution of coral reefs to RTCP can be specifically evaluated through one of two formulas.

a) The "Standard Reef Effort" (SRE) for a location can be calculated by dividing the Reef Index by the sum of all (ten) factors. This approach is sensitive to the number of factors used in the analysis (which might be less than 10), and typically results in a value which is considered low compared with the observed effect a reef typically has in reducing wave energy.[3]
b) The "Relative Reef Contribution" (RRC) for a location is a scaled percentage of the reef contribution, relative to all other factors. This adjustment serves to increase the apparent relative contribution (making it closer to observed values)[4] and reduces the effect of potential changes in the number of

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[1] Burke, L. and J. Maidens, 2004. *Reefs at Risk in the Caribbean*, WRI.

[2] *Tech notes: The classification scheme has been modified slightly to allow application in the two pilot areas - St. Lucia and Tobago. The full scheme involves integration of 10 factors, but can be adjusted if data for all factors are not available. A minimum of 5 factors is recommended (for results to be meaningful.) If data are incomplete for a factor, a middle or most likely value can be substituted.*

[3] A high degree of wave energy (on the order of 75-95%) is typically mitigated by coral reefs. From Brander, R.W., Kench, P.S. and Hart, D. (2004) Spatial and temporal variations in wave characteristics across a reef platform, Warraber Island, Torres Strait, Australia. *Marine Geology* 207, 169–184. Evaluation of standard reef effort (SRE) will typically result in SRE between 13% and 30%, which is low compared to measured attenuation.

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

factors considered (due to data not being available for some). RRC is calculated by taking the square root of the Standard Reef Effort (SRE) divided by relative total coastal protection (RTCP) (as follows):

Relative Reef Contribution At Location X (RRC_x) = $$\sqrt{\frac{[SRE_x]}{[RTCP_x]}} \times 100\%$$

5) Property Values

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

6) Damages Avoided Attributed to Coral Reefs

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

There are inevitably uncertainties associated with a multi-stage modeling approach designed to emulate complex physical processes. The analysis can be implemented using ranges to reflect some of these uncertainties. A range of values can be used to reflect estimates of property values. In addition, the RRC values along coastal segments can be varied (by + and – 20%, for example) to develop an uncertainty range, rather than a single value. Results should be evaluated using available information on historic wave-induced storm damage in the study area or a similar area.

This overview summarizes a more detailed methodology for economic valuation of coral reefs developed by the World Resources Institute, in collaboration with many partners in the Caribbean region. A spreadsheet based Tool will soon be released to guide implementation of this methodology. To access additional materials on Economic Valuation of Coastal Ecosystems, please visit: http://www.wri.org/project/valuation-caribbean-reefs.

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