Chapter 2. PROJECT APPROACH AND METHODOLOGY

Reefs at Risk in the Caribbean brings together information on the region's coral reefs and on their socioeconomic and physical environment as a basis for a region-wide analysis. The information is consolidated within a geographic information system (GIS) that includes data on coral reef locations (maps), pressures on coral reefs (observed threats, pollution, physical impacts), changes in reef condition, observations of coral bleaching and disease, and information on coral reef management. More than 30 physical and socioeconomic data sources were assembled in support of the analysis—including data on elevation, land cover, bathymetry, population distribution and growth rates, and location of cities, ports, and other infrastructure.

Using these data, the Reefs at Risk project has developed maps showing the distribution of human pressure on coral reefs. These are classed into four broad categories of threat: coastal development, sediment and pollution from inland sources, marine-based sources of threat, and overfishing. These threats are also integrated into a single index of relative human pressure. By utilizing only regional datasets, the Reefs at Risk project ensures consistency in its findings, allowing direct comparison of results across the region. The clear and open model structure also makes it possible to query the findings to establish driving mechanisms.

Both the individual threat indicators and the overarching index of human pressure serve as a basic guide to present and future coral reef conditions across the Caribbean region. Some areas rated as threatened may have already suffered considerable degradation, while all are likely to experience degradation—including reduced live coral cover, increased algal cover, or reduced species diversity—within 10 years.

Two broad areas of threat could not be included in the model—disease pathogens and abnormally high sea surface temperatures. Both of these issues are extremely important and, indeed, have already had major impacts on wide areas of Caribbean coral reefs. However, because of uncertainty about some of the factors contributing to coral vulnerability, as well as a lack of spatial detail in the data sets required for such an analysis, we were not able to develop quantitative indicators and maps to predict future threats. Although these threats are not included in the model, Chapter 3 presents current knowledge and projections on the extent of climate-related threats (including coral bleaching) and disease in the context of the other pressures on Caribbean coral reefs.

TABLE 1. REEFS AT RISK ANALYSIS METHOD

Threat	Analysis Approach	Limitations
Coastal Development	• Threats to reefs evaluated based on distance from cities, ports, airports, and dive tourism centers. Cities and ports stratified by size. • Coastal population density (2000), coastal population growth (1990–2000), and annual tourism growth combined into indicator of "population pressure" treated as an additional stressor. • Thresholds selected for each stressor based on guidance from project collaborators and observations of local damage from coastal development (including sewage discharge). Stressors aggregated into single map layer. • Management effectiveness included as mitigating factor for threats to reefs inside marine protected areas (MPAs).	• Provides a good indicator of relative threat across the region, but is likely to miss some site-specific threats. • Data sets used are the best available, but limitations regarding accuracy and completeness are inevitable. • In particular, rapid growth of tourism sector makes it difficult to capture the most recent developments.
Sediment and Pollution from Inland Sources	• Watershed-based analysis links land-based sources of threat with point of discharge to the sea. • Analysis of sediment and pollution threat to coral reefs implemented for more than 3,000 watersheds discharging to the Caribbean. • Relative erosion rates estimated across the landscape, based on slope, land cover type, precipitation (during the month of maximum rainfall), and soil type.[a] • Erosion rates summarized by watershed (adjusting for watershed size) to estimate resulting sediment delivery at river mouths. • Sediment plume dispersion estimated using a function in which sediment diminishes as distance from the river mouth increases. Estimated sediment plumes calibrated against observed sediment impacts on selected coral reefs.[b]	• Nutrient delivery to coastal waters probably underestimated due to lack of spatial data on crop cultivation and fertilizer application and resulting use of a proxy (sediment delivery) for indirect estimation.[c] • Sediment and nutrient delivery from flat agricultural lands probably underestimated because slope is a very influential variable in estimating relative erosion rates.
Marine-Based Sources of Threat	• Threats to coral reefs from marine-based sources evaluated based on distance to ports, stratified by size; intensity of cruise ship visitation; and distance to oil and gas infrastructure, processing, and pipelines.	• Estimates focus on ships in or near port. Threat associated with marine travel lanes probably underestimated due to lack of sufficiently detailed database on Caribbean shipping lanes.
Overfishing	• Threats to coral reefs evaluated based on coastal population density and shelf area (up to 30 m depth) within 30 km of reef. Analysis calibrated using survey observations of coral reef fish abundance. • Management effectiveness included as mitigating factor for threats to reefs inside marine protected areas (MPAs). • Destructive fishing practices not evaluated, as these are rare in the Caribbean region.	• Local overfishing pressure captured in proxy indicator (based on human population per unit of coastal shelf area), due to lack of spatially-specific data on numbers of fishers, landing sites, fishing method/effort, or fish catch from reef fisheries. • Indicator reflects fishing within 30 km of shore. Impacts of larger-scale commercial fishing pressure, illegal fishing, or movement of fleets not included in analysis.

NOTES:

a. "Relative Erosion Potential" was estimated at WRI using a simplified version of the *Revised Universal Soil Loss Equation*, United States Department of Agriculture (USDA) Agricultural Research Service (Washington, DC: USDA, 1989).

b. Data from Reef Check surveys and expert opinion from the Reefs at Risk workshop were used to calibrate the estimate of threat from inland sources. Data on percent live coral cover and algal cover from Atlantic and Gulf Rapid Reef Assessment (AGRRA) surveys were used to evaluate results.

c. Although phosphorus is often attached to soil particles, nitrogen is highly soluble and moves more independently of soil particles.

THREAT ANALYSIS METHOD

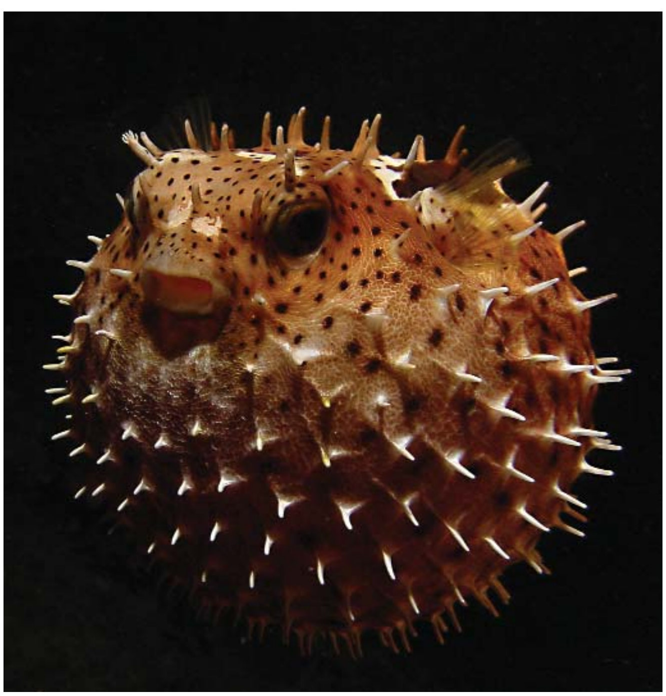
The project's modeling approach involves identifying sources of stress that can be mapped for each threat category. These "stressors" include simple population and infrastructure features, such as population density and location and size of cities, ports, and tourism centers, as well as more complex modeled estimates of riverine inputs. Model rules were developed to build proxy indicators of threat level for these stressors. This involved the development of distance-based rules by which the threat declines as distance from the stressor increases. For ease of interpretation, these threats are simply subdivided into "low," "medium," and "high" categories. Substantial input from scientists in the region contributed to the selection of the stressors and threat rules (thresholds) developed, while the threat indicators were further calibrated against available information on observed impacts on coral reefs.

Table 1 provides a summary of the threat analysis method and limitations for each threat category. Results of the threat analysis are presented in Chapter 3. Appendix B provides a list of the data sources used in the analysis and details of model validation. The full technical notes for the analysis are available online at http://reefsatrisk.wri.org/.

Integrating Threats: The Reefs at Risk Threat Index

The four threats described in Table 1 were integrated into a single index—the Reefs at Risk Threat Index. For each reef unit (a 25-hectare square measuring 500 m on each side), the index is set to the highest threat value ("low," "medium," or "high") recorded for any individual threat. To capture cumulative threat in a given location, the integrated index is designated as "very high" in areas where three or four individual threats were rated as "high." In areas where at least three threats were rated as "medium," the integrated index is set to "high."

The Reefs at Risk Threat Index was used to analyze the economic value of key goods and services provided by Caribbean coral reefs. The methods used for this analysis are described in Chapter 5 and online at http://reefsatrisk.wri.org.



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Nature is complex and sometimes unpredictable.

LIMITATIONS OF THE ANALYSIS

The Reefs at Risk analysis approach is a simplification of human activities and complex natural processes. The model relies on available data and predicted relationships but cannot capture all aspects of the dynamic interactions between people and coral reefs. The threat indicators gauge current and potential risks associated with human activities. A strength of the analysis lies in its use of regionally consistent data sets to develop regionally consistent indicators of human pressure on coral reefs. However, the model is not perfect, and omissions and other errors in the data sets are inevitable.

Fairly limited data are available to calibrate the individual threat layers and validate the overall model results. *(See Appendix B.)* The thresholds chosen to distinguish low, medium, and high threat relied heavily on the knowledge of project collaborators. Their review of model results also served as our most comprehensive validation of results.

Lack of spatial detail in the region-wide physical and oceanographic data sets and some other information gaps, such as causes of coral diseases, prevented us from including the threats of climate change, coral bleaching, and coral disease in the model. Hence, these overarching threats are not accounted for in this analysis. The Reefs at Risk model results should be regarded as our best attempt to evaluate human pressure on Caribbean coral reefs, using currently available sources. These are indicators of current human pressure that, in some areas, has already led to reef degradation and in all areas provides an indication of threat to future condition.