Chapter 5. ECONOMIC IMPLICATIONS OF CORAL REEF DEGRADATION

PHOTOS: FISH AND DIVER BY WOLCOTT HENRY© SHORELINE BY JON MAIDENS

Healthy coral reefs confer significant economic benefits to both coastal communities and national economies. These benefits diminish with coral reef degradation. Key economic and social benefits associated with healthy coral reefs include high fishery yields, high tourism-related incomes, protection from coastal erosion, and good nutrition for coastal communities.[174] The great diversity of life on coral reefs is also being explored for bioactive compounds for pharmaceuticals, and a few high-value products have already been discovered. Degradation of these reefs costs dearly through loss of fishing livelihoods, protein deficiencies and the increased potential for malnutrition, loss of tourism revenue, increased coastal erosion, and the need for investment to stabilize the shoreline.

Many damaging activities—including overfishing, dredging, or sewage discharge 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 pays the cost; for instance, a new development may pollute and degrade an offshore reef, but among those who suffer are the fishers or the divers who visited that reef. Some shortcomings in current management practices stem from inadequate information on the costs and benefits of different activities and management's focus on short- rather than long-term benefits when making decisions. Too often the full range of social and environmental impacts associated with proposed activities are not evaluated.[175] In land-use decisions, for example, rarely is the smothering of reefs by sedimentation associated with land clearing considered, much less compensated.

PURPOSE AND METHODS FOR VALUING CORAL REEF RESOURCES

Economic valuation is a powerful tool for raising awareness about the economic value of natural resources and about the implications of different development or management decisions. Credible valuation studies based on reasonable and fully disclosed assumptions can directly influence planning and development in areas adjacent to coral reefs. Economic arguments are also potent persuaders for a wider audience, convincing communities, politicians, and the general public of the important, lasting benefits of effective management and protection of coral reefs.

Several studies have looked at the economic value of coral reefs within the Caribbean.[176] Some of these studies have been narrowly defined assessments of the value of specific coral reef resources, such as the impact of a marine protected area on revenue from dive tourism in Bonaire,[177]

the effects of changes in coral reefs on fisheries production in Jamaica,[178] and the value of coral reef-related tourism in the Florida Keys.[179] Other economic valuation studies have been broader-based attempts to quantify the diverse ecological services or "total economic value" of coral reefs. Estimates from these studies of the total annual economic benefits from coral reefs have ranged from roughly US$100,000 to US$600,000 per sq km of coral reef, the largest share of which were associated with tourism and recreation followed by shoreline stabilization services.[180] Obviously, the economic valuation of goods and services provided by specific coral reefs varies widely depending upon the area's tourism potential and the nature of the shoreline being protected.[181]

This chapter explores the economic value of Caribbean coral reefs in terms of their contribution to fisheries, tourism and recreation, and shoreline protection services. Estimates of the current value of goods and services derived from coral reefs are presented in terms of gross and net annual benefits and are standardized to the year 2000. Using the Reefs at Risk Threat Index to identify threatened areas likely to degrade within the next 10 years, the study estimated potential losses in the economic value of fisheries, tourism, and shoreline protection services due to coral reef degradation.

A number of limitations and caveats apply to this analysis. First, it is only a preliminary exploration of the economic value of coral reef goods and services on a region-wide basis. Many of the statistics for this analysis were compiled and synthesized from the literature. However, in some cases, particularly the value of shoreline protection services, few data were available. This necessitated many assumptions to extrapolate region-wide estimates of economic values. Thus, the valuation estimates derived are the product of a range of assumptions and are very sensitive to these assumptions. The assumptions incorporated in this analysis represent our best estimates, based on the available literature and expert opinion, about the nature and magnitude of factors that influence the economic value of coral reef goods and services.

This analysis focuses on three important goods and services, but omits many other values, such as bioprospecting, biodiversity, and a range of non-use or "existence" values. In addition, this regional-level valuation does not capture the economic contribution of coral reefs to subsistence livelihoods in many communities across the Caribbean. These values can be quite significant, as coral reefs provide critical sources of employment and food supply, often in places where there are few or no alternatives. Converting into monetary terms this contribution of reefs to nutrition and livelihoods is challenging where life, health, and welfare lie largely outside the cash economy.

PHOTO: MARK SPALDING

Fisheries are a vital source of nutrition and livelihood across the region.

The analysis approach, summarized in this chapter for each goods and service, is provided as technical notes, available online at http://reefsatrisk.wri.org.

FISHERIES

Food production is one of the most direct and tangible benefits associated with coral reefs. Reef fisheries are a vital source of protein for millions of people living in the Caribbean region.[182] Reef fish are popular on tourist menus and support a valuable export industry. The fisheries sector in the Caribbean is predominantly small-scale and artisanal, employing more than 120,000 full-time fishers[183] and many part-time workers. Fisheries also indirectly provide jobs for thousands of people in processing, marketing, boat building, net making, and other support services.[184]

The export value of all fish, crustaceans, and mollusks harvested in the Western Atlantic region (excluding the United States) was approximately US$1.9 billion in 2000,[185] but this includes fish, such as tuna, not directly related to coral reefs. (Available statistics do not distinguish the size or value of reef fish catches from other fish and

TABLE 3. ESTIMATED ECONOMIC VALUE OF FISHERIES PRODUCTION IN THE CARIBBEAN: HEALTHY REEFS VERSUS REEFS DEGRADED BY 2015

Fisheries Production Scenario	Assumed Maximum Sustainable Fisheries Production (mt/km²/yr)	Reef Area (km²)	Fisheries Production for Caribbean (mt/yr)	Gross Revenues (US$ million)	Net Revenues (US$ million)
Healthy reefs (in 2000)	4	26,000	104,000	624	312
Reef degradation by 2015 (using Reefs at Risk Threat Index values)					
Reefs under low threat	4	9,400	37,400		
Reefs under medium threat	2.3–2.9	5,400	12,700–15,600		
Reefs under high threat	0.7–1.7	11,200	7,400–19,200		
Total (in 2015)		26,000	57,500–72,200	346–434	173–217
Decline/Loss		—	**31,700–46,400**	**190–278**	**95–139**

SOURCE: Estimates developed at WRI (2004). Technical notes on methods and data sources available online at http://reefsatrisk.wri.org.

often fail to account for the very large sector of the fishery that operates outside the formal markets, notably for home and local consumption.)

For this analysis of the economic value of coral-reef-related fisheries, the study looked at productivity differentials between fisheries located on healthy and degraded reefs. The Reefs at Risk Threat Index was used as a proxy for future reef condition in 2015 and estimated the area of coral reef in each threat category (high, medium, and low). Based on reports in the literature[186] a productivity coefficient for fisheries on healthy reefs was set at a maximum sustained yield of 4 metric ton (mt) of fish per sq km per year. Yields from reefs rated at medium or high threat were assumed to be significantly lower, ranging from 0.7 to 2.9 mt per sq km per year. *(See Table 3.)*

Using these assumptions, the study estimated maximum sustainable fisheries yield for the 26,000 sq km of Caribbean coral reef at a little over 100,000 mt of fish per year. This estimate focuses on reef crest, which is a smaller area than is typically fished, but assumes that all reefs were fully fished and are in good condition, which is better than the current case. These assumptions are considered to roughly offset one another. Considering reef degradation that has already occurred or is projected to occur in the near future, annual fisheries production could decline from about 100,000 mt to about 60,000 to 70,000 mt by 2015, a loss of some 30 to 45 percent from the estimated maximum catch on healthy reefs. *(See Table 3.)*

At current market prices (about US$6 per kg on average),[187] gross fisheries revenue from healthy Caribbean reefs was estimated at about US$625 million per year. Gross revenue from reefs degraded by 2015 was estimated to be 30 to 45 percent lower, representing potential lost gross revenues of approximately US$190 million to US$280 million.[188]

Net revenues from fishing—adjusted for the costs of vessels, fuel, gear, etc.—are considerably smaller, perhaps only 50 percent of gross revenues.[189] Thus, the study estimated annual net benefits of fisheries on healthy coral reefs at about US$310 million, while annual net benefits from fisheries on reefs degraded by 2015 could fall to around US$175 million to US$215 million, a loss of about US$95 million to US$140 million per year. The loss of millions of dollars worth of annual net benefits from fisheries could have significant consequences for local areas and national economies that rely on fishing to provide livelihoods, meet nutritional needs, and generate export earnings.

TOURISM AND RECREATION

Tourism is the lifeblood of many Caribbean countries, contributing more than 30 percent of GDP in 10 countries or territories within the region.[190] One Caribbean worker in six is employed directly in tourism.[191] In 2000, international tourism receipts in the Caribbean region (excluding the United States) totaled US$25.5 billion. Including supporting and related services, tourism contributes a total of about US$105 billion annually to the Caribbean economy.[192]

With tourism in the Caribbean projected to grow at 5.5 percent a year over the next 10 years,[193] it is an increasingly important source of foreign exchange.

How dependent is tourism on high-quality coral reefs? Many of the values that coral reefs provide to the Caribbean tourism industry are indirect, such as the value of reefs as a major contributor of sand to the region's famed beaches. One way to gauge the economic impacts of coral reef degradation on tourism is to look at a source of tourist revenue that is directly tied to pristine, healthy coral reefs: scuba divers.

Scuba divers look for high-quality coral reef habitats (as indicated by live coral coverage), coral and fish diversity, and water clarity.[194] Half of all diving in the Caribbean occurs within the region's marine protected areas, although these reefs represent a small fraction (about 20 percent) of all reefs within the region.[195] Divers in the region have indicated a willingness to pay an average of US$25 per diver per year to keep the Caribbean coral reefs healthy.[196] Multiplied by the estimated number of divers visiting the region, this translates into $90 million annually, which could be collected as user fees or other contributions in marine protected areas. Divers make up about 10 percent of all visitors but contribute about 17 percent of all tourism revenue.[197] The average diver spends about US$2,100[198] per trip to the Caribbean, compared to US$1,200 for tourists in general.[199] In 2000, the highest tourist expenditures in the Caribbean were reported by the Turks and Caicos Islands, a premier dive destination with high-quality coral reefs.[200]

To derive an economic valuation of coral-reef-related tourism in the Caribbean, the study estimated the number of divers visiting the region; gross revenue associated with these visits (using a base year of 2000), net benefits to the local economy, and losses in revenue from dive tourism associated with projected trends in coral reef degradation.

Market survey reports and other sources[201] indicate that about 3.6 million divers dove in the Caribbean region during 2000—1.2 million in Florida or Texas and 2.4 million in the rest of the Caribbean.[202] The latter group accounted for an estimated US$4.1 billion in gross expenditures.[203] A recent study of recreational reef use in southern Florida (where most diving in the continental United States occurs)

PHOTO: KRISHNA DESAI

Tourism takes many forms across the region and contributes an estimated $105 billion annually to the Caribbean economy.

estimated US$625 million in direct expenditures associated with diving on natural reefs in the year 2000.[204] This combined estimate of US$4.7 billion (i.e., US$625 million in the U.S. and US$4.1 billion in the rest of the Caribbean region) is a conservative one: it understates gross tourism revenue associated with coral reefs because it does not include the value of coral-reef-related tourism to non-diving visitors to the Caribbean, or their contribution to the local economy.

The study estimated net benefits to the local economy by adjusting these estimated gross expenditures for costs such as transportation, fuel, boat expenses, etc. (assumed to be 65 percent of total expenditure) and then accounting for a multiplier effect due to expenditures rippling through the local economy (assumed to be 25 percent).[205] Hence, net annual benefits of dive tourism in the Caribbean in 2000 were estimated at US$2.1 billion (i.e., US$4.7 billion (gross benefit) * 0.35 (net return) * 1.25 (multiplier)).

However, degradation of coral reefs will reduce their value to both divers and other tourists as a result of less interesting diving and snorkeling, less sport fishing, and erosion of beaches. To estimate potential losses in tourism revenue due to projected trends in coral reef degradation, the Reefs at Risk Threat Index was used as a proxy for future reef condition. It assumed a percentage decline in dive tourism (ranging between 1 and 10 percent) and associated lost revenue for reefs at medium or high threat. These percentage declines were conservative best estimates, based on a synthesis of expert opinion. Future gross revenue under a "no degradation" scenario was based on assumed continued growth of dive tourism at 7 percent per year,[206]

TABLE 4. ESTIMATED ECONOMIC VALUE OF CORAL REEF-RELATED TOURISM IN THE CARIBBEAN

Tourism Scenario	Source / Assumptions	Gross Revenues (US$ million)	Net Revenues (US$ million)
Tourism in 2000	• Based on current statistics and market surveys	4,700	2,100
Tourism in 2015 (Healthy Reefs)	• Dive tourism grows at 7 percent per year • No loss of revenue due to reef degradation	13,000	5,700
Tourism in 2015 (Degraded Reefs)	• Degradation of reefs results in loss of divers and revenue from a 7 percent annual growth trajectory • Loss is related to level of threat or degradation – Low threat - no loss – Medium threat - 1–5 percent loss – High threat - 4–10 percent loss	12,400–12,800	5,400–5,600
Annual Loss by 2015 due to degraded reefs		**200–600**	**100–300**

SOURCE: Estimates developed at WRI (2004). Technical notes on methods and data sources available online at http://reefsatrisk.wri.org.

which is higher than the projected annual growth rate of 5.5 percent for general tourism. By 2015, net benefits from diving on healthy reefs might grow to nearly US$6 billion, but with degradation could be US$100 million to US$300 million lower, a loss of 2–5 percent. *(See Table 4.)*

Moreover, these estimates of region-wide loss do not necessarily convey the disproportionately large losses that could be expected in particular locations, as regional dive tourism shifts away from areas with degrading reefs and toward other locations in the Caribbean with a reputation for healthy reefs. Many of the threats to coral reefs—such as poor water quality and increased sedimentation—are also considered undesirable by tourists. The local revenue losses associated with shifts in tourism toward healthy reef areas could be particularly harmful to specific communities and national economies with reefs at high threat of degradation.

SHORELINE PROTECTION

Coastal ecosystems provide important shoreline stabilization services. Coral reefs dissipate wave and storm energy and create lagoons and sedimentary environments favorable for the growth of mangroves and seagrasses. In turn, mangroves and seagrasses help to bind marine and terrestrial sediments, reducing coastal erosion and also supporting clear offshore waters favorable to corals. Decision-makers often undervalue the shoreline protection services afforded by natural landscapes and do not give this service appropriate weight when evaluating development options. One reason for this oversight is the difficulty in quantifying these services. However, the value of shoreline protection can be approximated by estimating the cost of replacing this service through artificial means.

In many parts of the world, efforts and investments to stabilize shorelines artificially have been substantial.[207] In Sri Lanka, for example, US$30 million was spent on revetments, groins, and breakwaters to curtail severe coastal erosion in areas where coral reefs had been heavily mined.[208]

The vulnerability of coastal areas to erosion and storms varies with topography, substrate, habitat types, coastal morphology, and climate. Sandy beaches are much more vulnerable to erosion, for example, than are rocky shorelines. In the Caribbean, hurricanes and tropical storms are a major cause of acute erosion. Increased development in coastal areas often amplifies erosion and storm risk in two ways. First, the destruction of natural habitats (notably mangroves, seagrasses, and coral reefs, but also coastal vegetation) exposes coastal sediments to greater movement, and hence to erosion and loss. Second, the development of the physical infrastructure to protect areas can itself enhance erosion. For example, the building of sea defenses and the canalization of water courses often leads to changed patterns of coastal water movements, with resultant erosion in adjacent areas. Studies of changing beach profiles in the Eastern Caribbean showed that between 1985 and 1995, 70 percent of monitored beaches eroded.[209] Antigua, the British Virgin

TABLE 5. RANGE OF ESTIMATED ECONOMIC VALUES OF SHORELINE PROTECTION SERVICES PROVIDED BY HEALTHY CORAL REEFS IN THE CARIBBEAN IN 2000

Level of Shoreline Development	Definition of Development	Percent of Coastline	Value for Reef-Related Shoreline Protection Services (US$ per km of coastline)[a]	Total value of Reef-Related Shoreline Protection Services (US$ million)
Low	Fewer than 100 people within 5 km	29	2,000–20,000	10–30
Medium	Between 100 and 600 people or a dive center located within 5 km	27	30,000–60,000	120–150
High	More than 600 people within 5 km	44	100,000–1,000,000	620–2000
TOTAL		**100**	**2,000–1,000,000**	**750–2180**

SOURCE: Estimates developed at WRI (2004). Technical notes on methods and data sources available online at http://reefsatrisk.wri.org.

NOTES:

a. Because only a few shoreline segments are likely to be at the high extreme of value, we developed our ranges as follows: Low = 100 percent of shoreline is at low end of value range; High = 75 percent at low end and 25 percent at high end of value range.

Islands, Doinica, Grenada, Nevis, and St. Kitts experienced beach losses ranging from 0.3 to 1.1 m per year.[210]

To analyze the economic contribution of shoreline protection services provided by Caribbean coral reefs, the study estimated the extent of the region's shoreline protected by coral reefs, the value of the shoreline protection services provided by these reefs (based on costs required to replace them by artificial means), and potential losses in the annual benefits of shoreline protection services due to reef degradation.

Using data on shoreline and coral reef location,[211] and identifying coastline within 2 km of a mapped coral reef as "protected" by the reef, the study estimated that coral reefs protect about 21 percent of the coastline of the Caribbean region (about 18,000 km in length). The economic value of the shoreline protection services provided along these coastlines varies with the level of development of the shoreline, its population density, and tourist activity. Values used in this study for annual coastal protection benefits ranged from US$2,000 per km of coastline for protection of less-developed shorelines to US$1,000,000 per km of coastline for highly developed shorelines.[212] Accounting for the length of shoreline in various categories of development (high, medium, and low), the value of annual benefits from the shoreline protection services of healthy coral reefs across the Caribbean region was estimated between US$740 million and US$2.2 billion per year. *(See Table 5.)*

The study used the Reefs at Risk Threat Index as a proxy for future coral reef condition and associated declines in the coastal protection function of reefs. The analysis assumed that shorelines near degraded reefs received 80 to 90 percent as much protection as shorelines near healthy reefs.[213] The study estimated that over 80 percent of the shoreline areas now protected by coral reefs will experience some future reduction in this service (over 15,000 km).[214] Such reductions might not be apparent as quickly as declines in fisheries or recreation because reefs must become severely degraded and eroded before loss of protection occurs. However, within the next 50 years, the net value of lost benefits from reef-associated shoreline protection could be on the order of US$140 million to US$420 million per year.

PHOTO: LAURETTA BURKE

Coral reefs protect shorelines by dissipating wave energy and are an important source of white sand for many beaches.

Summary of Values

Table 6 summarizes the results of preliminary efforts to quantify just a few of the many economic values provided by coral reef ecosystems in the Caribbean. In 2000, coral reefs provided annual net benefits in terms of fisheries, dive tourism, and shoreline protection services with an estimated value between US$3.1 billion to US$4.6 billion. The net benefits from dive tourism were the largest share of this total (US$2.1 billion), followed by shoreline protection services (US$ 0.7 to 2.2 billion), and fisheries (about US$300 million). The study estimates coral reef degradation could result in losses of between 30–45 percent of net benefits from fisheries and 2–5 percent of net benefits from dive tourism by 2015. By 2050, over 15,000 km of shoreline could loose 10–20 percent of current protection services. All told, coral reef degradation could reduce the net benefits derived from these three goods and services by an estimated US$350 million to US$870 million per year. *(See Table 6.)*

OTHER VALUES

Coral reefs provide many other sources of value that are not included in this study. One such source of value is bioprospecting. Coral reefs are one of the most diverse ecosystems known and are an important potential source of bioactive compounds for pharmaceuticals. The prospect of finding a new drug in the sea may be 300 to 400 times more likely than isolating one from a terrestrial ecosystem.[215] If species are lost before they are identified, there is an associated loss of potentially priceless biological information. Products from marine organisms include AZT, an HIV treatment developed from the extracts of a Caribbean reef sponge,[216] and Prialt, a painkiller developed from cone snail venom.[217] In addition, a large portion of new cancer drug research focuses on marine organisms, most of them associated with coral reefs.[218]

TABLE 6. SUMMARY OF ESTIMATED VALUES OF SELECTED GOODS AND SERVICES DERIVED FROM CORAL REEFS IN THE CARIBBEAN (2000) AND ESTIMATED POTENTIAL LOSSES DUE TO CORAL REEF DEGRADATION (BY 2015 AND 2050)

Good/Service and Valuation Method	Estimated Annual Value of Good/Service in 2000	Estimated Future Annual Losses Due to Coral Reef Degradation
Fisheries Annual net benefits of maximum sustainable fish production, estimated from sale of coral reef-associated fish and shellfish	US$312 million[a]	Fisheries productivity could decline an estimated 30–45 percent by 2015 with associated loss of annual net benefits valued at US$100–140 million (in constant-dollar terms, standardized to 2000).[b]
Tourism and Recreation Annual net benefits from dive tourism, estimated from gross tourism revenues	US$2.1 billion[c]	Growth of Caribbean dive tourism will continue, but the growth achieved by 2015 could be lowered by 2–5 percent as a result of coral reef degradation, with the region-wide loss of annual net benefits valued at an estimated US$100–300 million (in constant-dollar terms, standardized to 2000).[d]
Shoreline Protection Annual benefits of coral reef protection based on estimated cost of replacement	US$0.7–2.2 billion[e]	Over 15,000 km of shoreline could experience a 10–20 percent reduction in shoreline protection by 2050 as a result of coral reef degradation. The estimated value of lost annual net benefits is estimated at US$140–420 million (in constant-dollar terms, standardized to 2000).[f]
TOTAL	**US$3.1–4.6 billion**	**US$350–870 million**

SOURCE: Estimate developed at WRI (2004). Technical notes on methods and data sources available online at http://reefsatrisk.wri.org.

NOTES:

a. Fisheries production in 2000 assumes healthy coral reefs produce 4 mt/km^2/yr of fish or shellfish, which sell for an average of $6/kg, and that net revenue is 50 percent of gross revenue.

b. Fisheries production is predicted to decline depending on the level of future reef degradation (using the Reefs at Risk Threat Index as a proxy for future reef condition). This analysis assumes that threatened reefs are more degraded and have lower productivity. Of 26,000 sq km of reefs, the areas rated at low, medium, and high threat are 9,400, 5,400, and 11,200 sq km, respectively. Productivity factors used were 4.0 mt/km^2/yr on low-threat reefs; 2.3 to 2.9 mt/km^2/yr on medium-threat reefs; and 0.7 to 1.7 mt/km^2/yr on highly threatened reefs. Market price of $6/kg was used.

c. Estimates of 3.6 million divers in the Caribbean with associated net benefits of US$2.1 billion are a synthesis and cross-tabulation of data from six sources (see chapter endnotes and technical notes online at http://reefsatrisk.wri.org). Net revenue assumed to be 35 percent of gross revenue (costs are 65 percent). A multiplier of 25 percent was used to capture benefit flows in the economy.

d. Diving shifts within and outside the region based on perceived quality of diving and reef health. Reefs under low threat retain all divers; medium-threat reefs retain 95–99 percent of diving; high-threat reefs retain 90–96 percent of diving and associated revenue. Overall, the region suffers a loss of 2–5 percent of tourism revenue.

e. Coral reefs protect an estimated 21 percent of the Caribbean region's coastline. The estimated value of protection along the coastline varies between US$2,000 and US$1 million per km, depending upon the area's development. (See chapter endnotes and technical notes online at http://reefsatrisk.wri.org.)

f. This estimate is based on cross-tabulation of our estimates of level of development along a given shoreline length and threat estimate of the nearest coral reef. Reefs under low threat are assumed to provide 100 percent of their current coastal protection service; reefs under medium and high threat are assumed to provide 90 percent and 80 percent of current service, respectively.

The potential economic value of bioprospecting on coral reefs is difficult to estimate and such an estimation has not been attempted in this study. Part of the problem in deriving estimated values is that very little can be directly linked to individual reef localities. Biological samples can be taken from reefs at very low cost and screened for bioactive properties far away from the reef. The revenues and profits derived from successful biopharmaceuticals often do not make it back to the communities, or even to the countries, from which the original biological samples were taken. Although the potential economic value of bioprospecting and pharmaceutical development might be very high, given current free-market, free-access approaches to biological resources, these values are not likely to benefit local or even national populations associated with coral reefs.

Other sources of reef-associated economic value not accounted for in this study include the harvesting of non-food resources (aquarium fish, curios), the role of these ecosystems as places for research and education, the role of reefs in supporting adjacent coastal and oceanic ecosystems, and the contribution of coral reefs to regional and global oceanographic and climatological processes. A value that is only recently receiving recognition is the role of healthy coral reef ecosystems in maintaining and restoring stressed or degraded reefs. Healthy reefs can serve as a supply of coral larvae to other locations, increasing the recovery chances of stressed or degraded reefs lying downstream. As the total extent of degraded reefs increases, the restoration value of healthy reefs nearby will grow considerably.

Also extremely important, but notoriously difficult to translate into economic statistics are a range of non-use or "existence" values for natural resources, based on aesthetic, spiritual, cultural, or intrinsic value. Coral reefs are valued by many as places of beauty, excitement, and adventure. They are also seen as places of enlightenment and inspiration. Reefs have cultural significance through their role in ongoing traditions, notably fishing. Many argue that coral reefs and other natural treasures have intrinsic value that exists independent of human perceptions. Such values are, by their nature, unmeasurable.

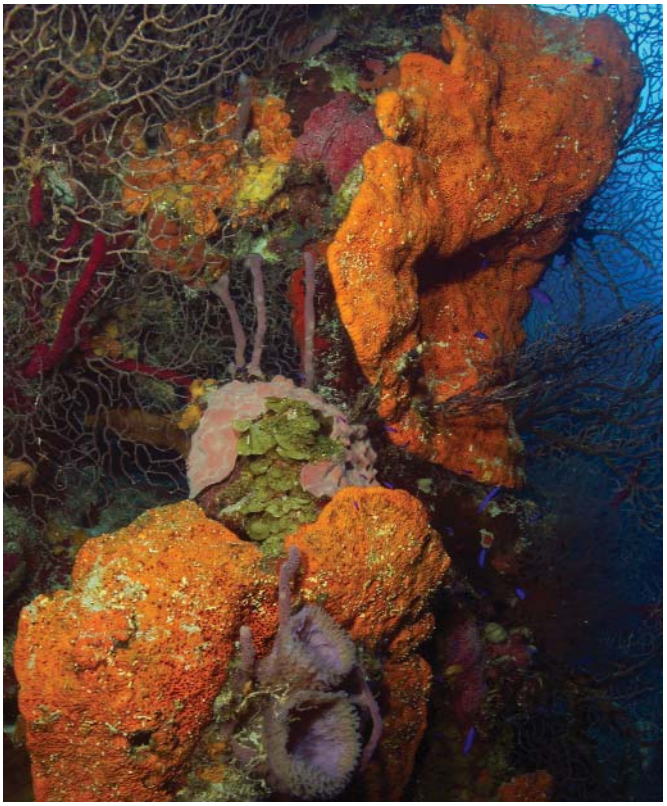

PHOTO: WOLCOTT HENRY©

There is tremendous unrealized genetic potential in coral reef ecosystems.

AREAS FOR FUTURE RESEARCH AND ANALYSIS

This study represents a preliminary attempt to quantify the region-wide economic value of coral reefs in terms of fisheries, dive tourism, and shoreline protection. Further research is needed to improve these estimates and provide greater detail on a country-by-country basis. As more standardized coral reef maps become available, estimates of the value of goods and services per unit area can be refined. However, better statistics are needed on fish catch, by species and area, to improve estimates of productivity and changes in productivity resulting from changes in reef condition. Also sorely needed is better information on shoreline erosion in areas where coral reefs have degraded, and on investments in shoreline stabilization. In addition, better supporting data and means of evaluating potential bioprospecting value and non-use values are needed in order to develop fuller estimates of the total economic value of coral reefs. Application of standardized methods is important so that estimates from different areas or countries can be compared. Such survey and analysis is vital to our ability to make better informed decisions on the protection and management of these valuable resources.