Status and Trends of Caribbean Coral Reefs: 1970-2012

EXECUTIVE SUMMARY

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"Perhaps the most striking aspect of plant life on a coral reef is the general lack of it. It seems anomalous to even the casual observer that tropical reefs, notable for their dazzling profusion of animal life, are almost devoid of conspicuous plants."

Sylvia Earle, 1972

INTRODUCTION

Sylvia Earle's early observations upon Caribbean reefs describe a forgotten world. Caribbean coral reefs have suffered massive losses of corals since the early 1980s due to a wide range of human impacts including explosive human population growth, overfishing, coastal pollution, global warming, and invasive species. The consequences include widespread collapse of coral populations, increases in large seaweeds (macroalgae), outbreaks of coral bleaching and disease, and failure of corals to recover from natural disturbances such as hurricanes. Alarm bells were set off by the 2003 publication in the journal *Science* that live coral cover had been reduced from more than 50% in the 1970s to just 10% today. This dramatic decline was closely followed by widespread and severe coral bleaching in 2005, which was in turn followed by high coral mortality due to disease at many reef locations. Healthy corals are increasingly rare on the intensively studied reefs of the Florida reef tract, US Virgin Islands, and Jamaica. Moreover, two of the formerly most abundant species, the elkhorn coral *Acropora palmata* and staghorn coral *Acropora cervicornis*, have been added to the United States Endangered Species List. Concerns have mounted to the point that many NGOs have given up on Caribbean reefs and moved their attentions elsewhere.

It was against this gloomy backdrop that this study was undertaken to assess more rigorously than before the extent to which coral reef ecosystems throughout the wider Caribbean may have suffered the same fate, and if they have not, to determine what were the factors responsible. Various reports suggested that reefs in the southern Caribbean were in better ecological condition than elsewhere, with more live coral and reef fish. If this were true, understanding why some reefs are healthier than others would provide an essential first step for more effective management to improve the condition of coral reefs throughout the entire Caribbean region.

STRATEGY AND SCOPE OF THE PRESENT REPORT

Previous Caribbean assessments lumped data together into a single database regardless of geographic location, reef environment, depth, oceanographic conditions, etc. Data from shallow lagoons and back reef environments were combined with data from deep fore-reef environments

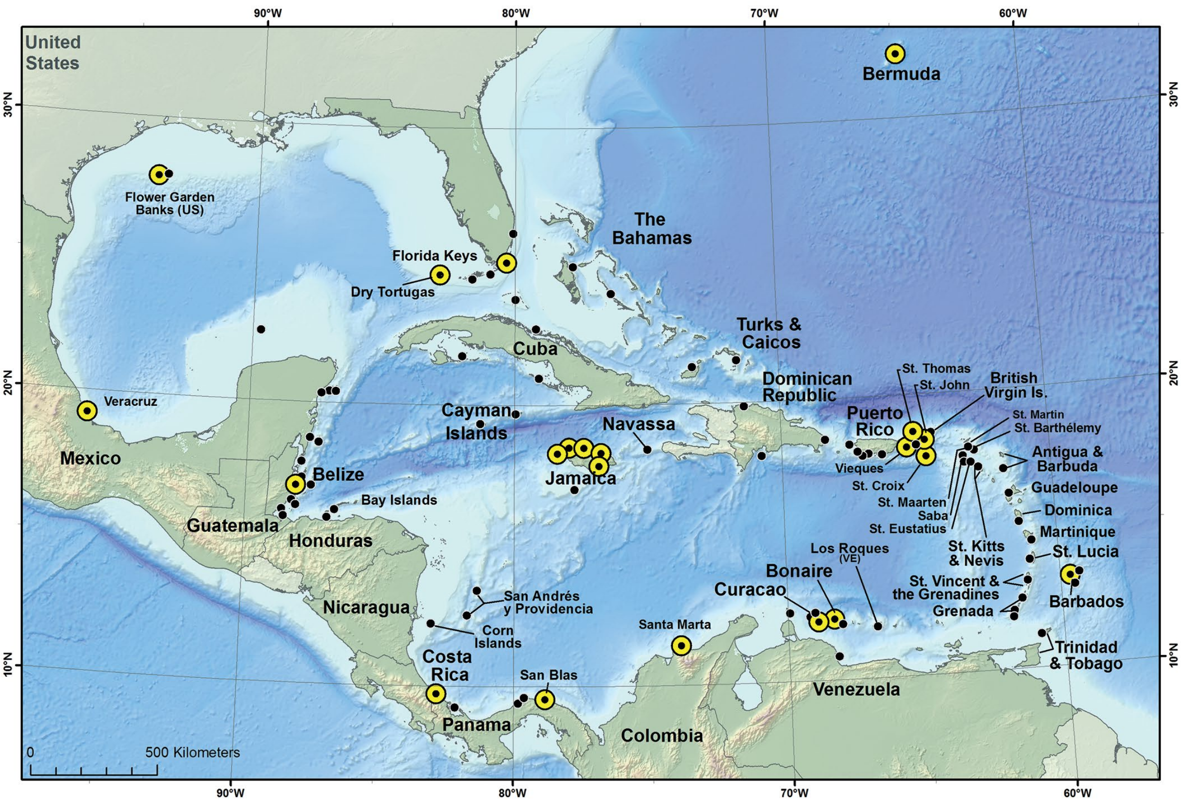

FIGURE 1. Distribution of 90 reef locations analyzed for this study. The large circles indicate 21 locations with the most complete time series data for analysis of long-term trends in coral cover.

and atolls. Geographic coverage was uneven, reflecting primarily the most studied sites with the most easily accessible data. Only total coral cover was recorded, with no attempt to assess the fates of different coral species. Nor was there any attempt to compile records of macroalgae, sea urchins, and fishes that are well known to have significant ecological interactions with corals.

We addressed these methodological problems by a detailed analysis of the status and trends of reef communities at distinct reef locations throughout the wider Caribbean. We also compiled essential metadata on the nature of the reef environment, depth, and history of human population growth, fishing, hurricanes, coral bleaching, and disease at each location. The quality of biological information varied among locations, but wherever possible data were obtained for coral and macroalgal cover, abundance of the critically important grazing sea urchin *Diadema antillarum*, and biomass of fishes, most importantly large grazing parrotfish.

Most of the quantitative data for Caribbean reefs is unpublished or buried in gray literature and government reports. To obtain these data, we contacted hundreds of people in all the countries of the Caribbean via several thousand emails, requests for data posted on relevant websites, and through presentations and interviews at international conferences. We also corresponded with managers of all the large monitoring programs in the region. In the end, we obtained data for corals, macroalgae, sea urchins, and fishes from a total of more than 35,000 quantitative reef surveys from 1969 to 2012. This is the largest amount of quantitative coral reef survey data ever compiled and exceeds by several fold that used for earlier Caribbean assessments.

Data are distributed among 90 reef locations in 34 countries (Fig. 1). Most of the data are from fore-reef and patch-reef environments in depths between 1-20 meters that are the focus of this study. Data are sparse up until the mass mortality of the formerly ubiquitous sea urchin *Diadema antillarum* in 1983-1984 when several monitoring programs first began. Data for corals are extensive

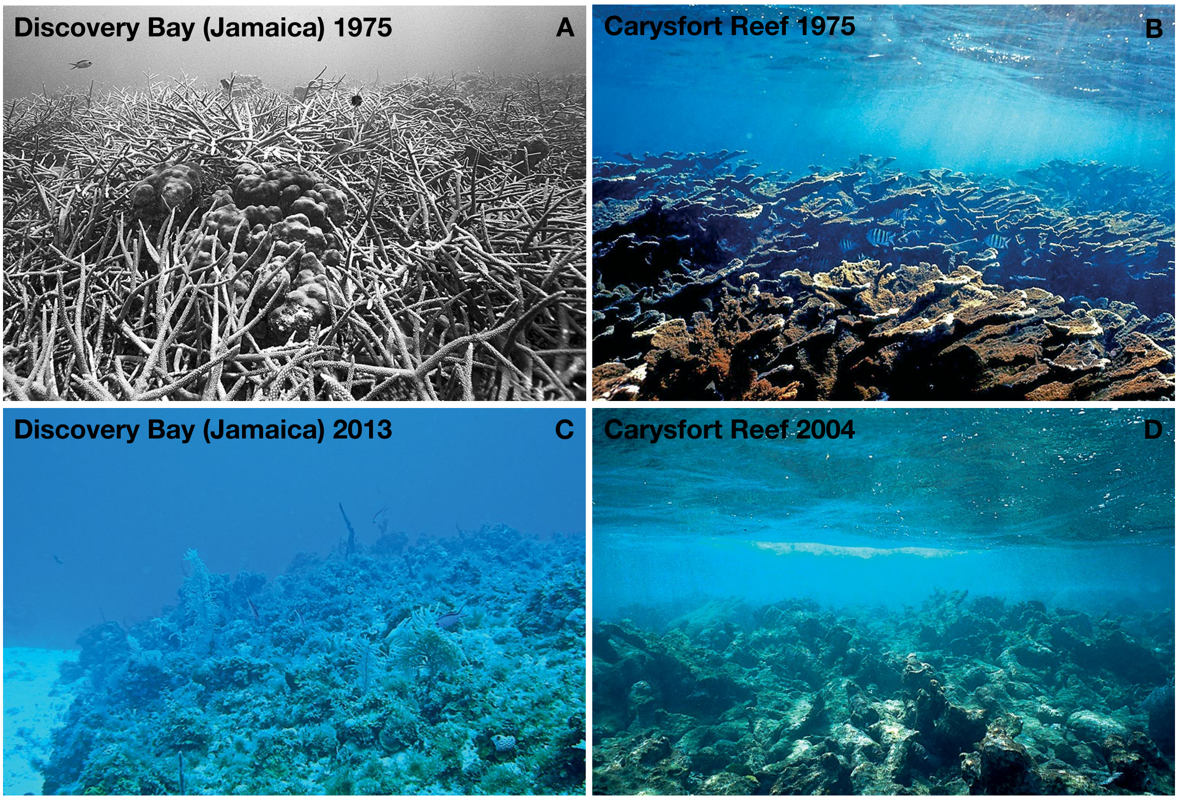

FIGURE 2. Phase shift from dominance by corals to dominance by macroalgae on the shallow fore-reefs in the northern Florida Keys and north coast of Jamaica. (A) Discovery Bay, Jamaica in 1975 and (C) the same location in 2013. (B) Carysfort Reef within the Florida Keys National Marine Sanctuary in 1975 and (D) in 2004 ((A, B, D by Phillip Dustan, and C by Robert Steneck).

and range from 1970 to the present. *Diadema* data are more limited up until mass mortality reduced its abundance to near zero and scientists realized what they had lost. Data for macroalgae are the most problematic because of inconsistent monitoring and taxonomy so that much of the data had to be discarded from our analysis. Quantitative data for both size and abundance of reef fishes needed to estimate fish biomass are unavailable until 1989 but are extensive after that.

The longest time series from the same reefs are large photo quadrats from 1973 to the present for fixed sites at Curaçao and Bonaire, with newer time series from the same islands beginning in the 1990s. Comparably long time series extending back into the early 1970s to early 1980s are available from the northern Florida Keys, Jamaica, St. John and St. Croix in the US Virgin Islands, and Panama. However, these records were compiled by different workers at different times and are therefore not as consistent or complete as data from the Dutch Caribbean.

Intensity of sampling varied greatly in time and space. We therefore partitioned the data into three time intervals of 12-14 years each based on major ecological events that extended throughout the wider Caribbean. These are:

1. 1970-1983: Interval from the oldest data up until and including the mass mortality of the formerly abundant sea urchin *Diadema antillarum* in 1983, as well as the first reports of White Band Disease (WBD) in the mid 1970s and early 1980s.
2. 1984-1998: From just after the *Diadema* die-off up to and including the widely reported 1998 extreme heating event.
3. 1999-2011: The modern era of massively degraded coral reefs.

PATTERNS OF CHANGE FROM 1970 TO 2012

Average coral cover for the wider Caribbean based on the most recent data for all the locations with coral data is 16.8% (range 2.8–53.1%). Taking into account the great variation among locations and data sets reduces this estimate to 14.3% (+2.0, -1.8). Even this more rigorously refined mean is 43% higher than the 2003 regional estimate of 10% cover. Nevertheless, coral cover declined at three quarters of the locations with the greatest losses for locations that were surveyed earliest and for the longest time.

Average coral cover for all 88 locations with coral data declined from 34.8% to 19.1% to 16.3% over the three successive time intervals, but the disparity among locations was great. In contrast, macroalgal cover increased from 7% to 23.6% between 1984-1998 and held steady but with even greater disparity among locations since 1998. The patterns were similar for the 21 locations with coral data from all three intervals highlighted by circles in Fig. 1. These opposite trends in coral and macroalgal cover constitute a large and persistent Caribbean phase shift from coral dominated to macroalgal dominated communities that has persisted for 25 years (Figs. 2 and 3), a pattern also strongly supported by ordination analyses of benthic community composition.

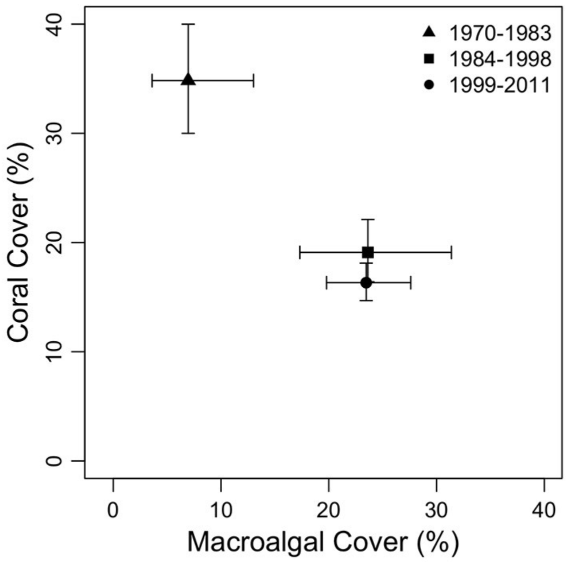

FIGURE 3. Large-scale shifts from coral to macroalgal community dominance since the early 1970s. Symbols and confidence intervals represent means and standard deviations for 3 time intervals that take into account variability due to location, and datasets using a mixed modeling framework.

The greatest overall changes in coral and macroalgal cover occurred between 1984 and 1998, after which there was little overall change at the great majority of locations except for places most strongly affected by the extreme warming events of 2005 and 2010. The same was true for formerly abundant elkhorn and staghorn *Acropora* that began to decline in the 1960s, the mass mortality of the sea urchin *Diadema antillarum* in 1983-1984, and the extreme overfishing of large parrotfish at most locations in the early to middle 20th century. Thus the largest and most damaging changes on Caribbean reefs occurred before most coral reef scientists and managers had begun to work on reefs, a classic example of the Shifting Baselines Syndrome and a harsh reminder that the problems of today are just the latest chapter in a much longer story of decline.

Looking beyond this general picture, however, long-term trends at the 21 highlighted locations in Fig. 1 exhibit three strikingly contrasting patterns of change in coral cover (Fig. 4). Trajectories for nine of the locations resemble a hockey stick with precipitous declines of 58-95% between intervals 1 and 2 followed by no change (Fig. 4A). In contrast, five other locations exhibited comparable decline that was spread out approximately equally between intervals 1 and 2 and between intervals 2 and 3 (Fig. 4B). The third group of seven locations exhibited much greater stability with overall changes (increase or decrease) of just 4-35% (Fig. 4C).

DRIVERS OF CHANGE

The drivers of the ecological degradation of Caribbean reefs need to be understood in the context of the highly unique situation of the Caribbean compared to other tropical seas. The Caribbean is effectively a Mediterranean sea that is the most geographically and oceanographically isolated tropical ocean on the planet. Isolation began tens of millions of years ago with the gradual break-up on the once circumtropical Tethys Seaway, the widening of the Atlantic Ocean, and ultimately isolation from the Eastern Pacific by the closure of the Panamanian Seaway 5.4 to 3.5 million years ago.

Consequently, Caribbean reef biotas are also highly distinctive. Many coral genera once combined with Pacific taxa have proven to belong to uniquely Atlantic evolutionary lineages based on molecular genetics. Moreover, acroporid corals that make up more than a third of Indo-Pacific coral diversity are represented by only two

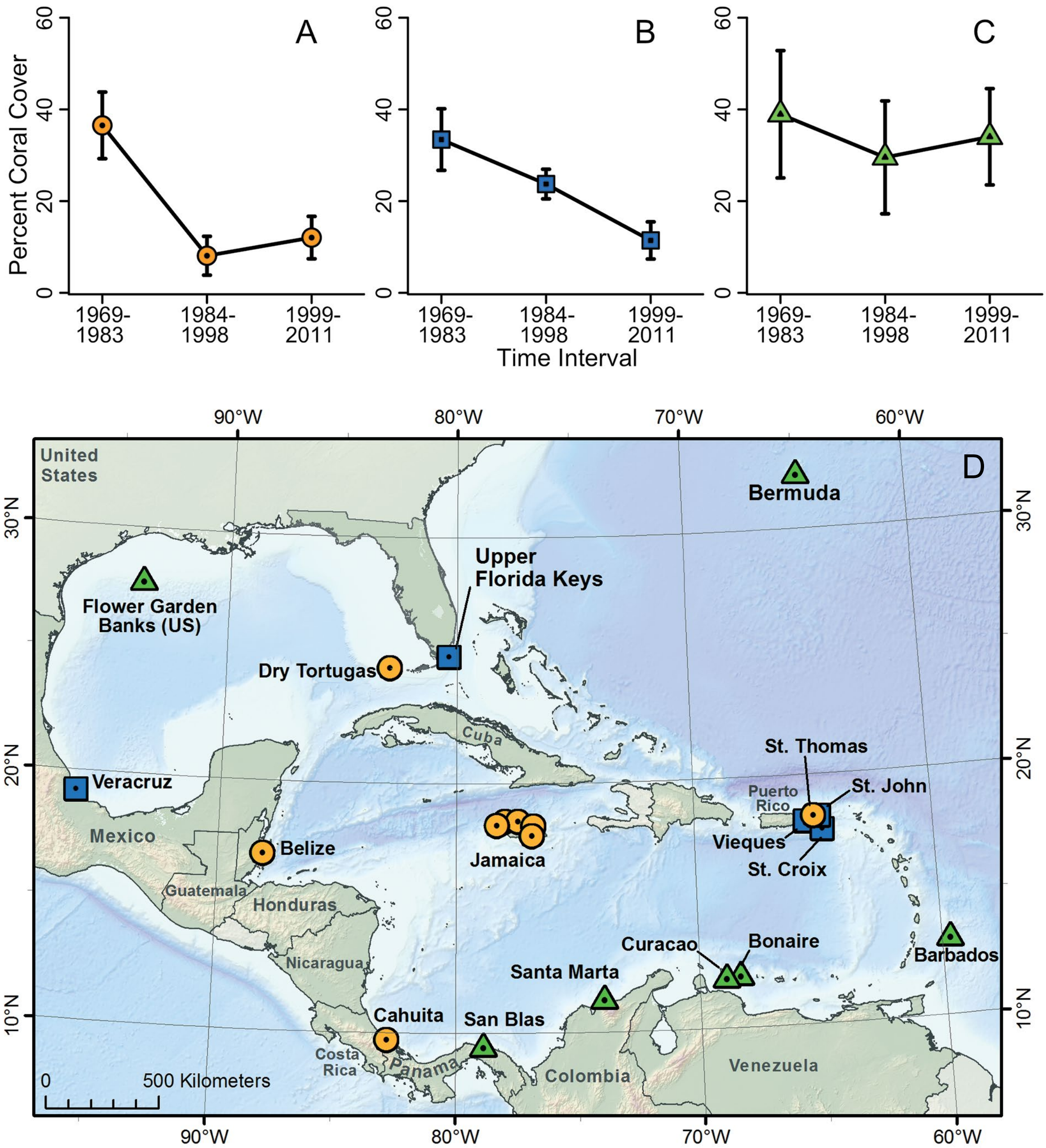

FIGURE 4. Trajectories of coral cover at 21 reef locations, grouped on the basis of the total amount of change over all three intervals and the tempo of change. (A) Hockey stick pattern with a steep decline between the first two intervals followed by little or no change. (B) Approximately continuous decline over all three intervals. (C) Comparative stability with smaller net changes in cover.

Caribbean species. Taxonomic diversity and ecological redundancy are low and the potential for rejuvenation from other regions is essentially nil. Caribbean species also had no evolutionary experience for dealing with exotic species and disease before the advent of people.

We focused on potential anthropogenic drivers of decline for which there were data for meaningful comparisons. Drivers were treated separately for ease of analysis and discussion, but they are inextricably linked. In particular, coral disease is a complex and poorly understood symptom of several forms of human disturbance rather than a direct driver of change. Thus disease is treated in relation to several different drivers including introductions of alien species, ocean warming, coastal pollution, and overfishing. Overall, results are stronger for evaluating effects of human population increase, overfishing, and ocean warming because there are more data, and less so for coastal pollution and invasive species.

FIGURE 5. Examples of mass tourism in the Caribbean. (A) Large cruise ships with thousands of passengers arrive every day in the Caribbean, shown here is St. Thomas, the US Virgin Islands (Source: Calyponte, Wikipedia). (B) Numerous hotel resorts offer ever more tourists the opportunity to stay in the Caribbean Sea, as here at Cancún Island, Mexico (Source: Foto Propia, Photo by Mauro I. Barea G., Wikipedia). (C) High density of tourists line South Beach, Miami, Florida (Source: Photo by Marc Averette, Wikipedia).

Too many people

Tourism is the lifeblood of many Caribbean nations (Fig. 5). However, our evidence demonstrates that extremely high densities of both tourists and residents are harmful to reefs unless environmental protections are comprehensive and effectively enforced. Unfortunately, this is only rarely the case. Numbers of visitors per square kilometer per year range from a low of 110 in the Bahamas to an astounding 25,000 at St. Thomas. All locations with more than the median value of 1,500 visitors per square kilometer per year have less than the median value of 14% coral cover except for Bermuda with 39% cover and Grand Cayman with 31%. The exceptional situation at Bermuda most likely reflects progressive environmental regulations in place since the 1990s and the infrastructure required to make them work. Otherwise, the harmful environmental costs of runaway tourism seem to be inevitable.

Overfishing

Artisanal fishing for subsistence is crucial to most Caribbean economies but the consequences have been catastrophic for coral reefs. Overfishing caused steep reductions in herbivores, especially large parrotfishes, which are the most effective grazers on Caribbean reefs but vulnerable to all gear types except hook and line.

Nevertheless, the consequences of overfishing parrotfish for coral survival were little understood until the abrupt demise of the sea urchin *Diadema antillarum* due to an unidentified disease in 1983-1984. Until then, *Diadema* had increasingly become the last important macro-herbivore on Caribbean reefs due to overfishing. *Diadema* and parrotfish strongly compete for food, and variations in their abundance were inversely proportional until 1983. This inverse relationship provides a rigorous proxy to assess the consequences of historical overfishing of parrotfish for coral cover in the absence of quantitative data for parrotfish biomass before 1989.

Our analysis of overfishing focused primarily on 16 of the 21 highlighted reefs in Fig. 1 for which quantitative data on *Diadema* abundance were available before the die-off in 1983/84, in addition to coral cover for all three of the time intervals in Fig. 3. Nine of these reefs were classified as overfished for parrotfishes by 1983, with *Diadema* densities ranging from 6.9-12.4 per square meter, whereas the other seven reefs were classified as less fished with *Diadema* densities of just 0.5-3.8 per square meter. This ranking agreed well with the qualitative literature. Reefs where parrotfishes had been overfished before 1984 suffered greater subsequent decreases in coral cover and increases in macroalgae than reefs that still had moderately intact populations of parrotfish. Coral and macroalgal cover were independent of *Diadema* densities before 1984 when either the sea urchin or parrotfish grazed down macroalgae to extremely low levels. All that changed, however, after the *Diadema* die-off when coral cover declined in proportion to historical *Diadema* abundance, a trend that has continued to the present day.

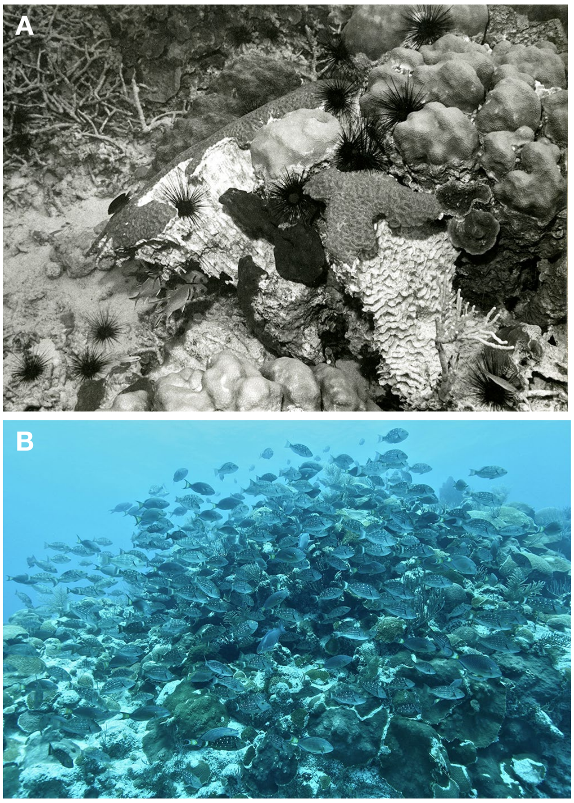

FIGURE 6. Formerly abundant grazers on Caribbean reefs. (A) Dense aggregation of the sea urchin *Diadema antillarum* on the west forereef at Discovery Bay, Jamaica in about 10 meters a year before the massive die-off in 1983/1984 (Photo by Jeremy Jackson). (B) Large school of Stoplight Parrotfish *Sparisoma viride* on the south shore of Bermuda where fishing on parrotfish is banned (Photo by Philippe Rouja). Such large numbers of parrotfish are rare to absent today on the great majority of Caribbean reefs.

There is also strong field and experimental evidence for persistent indirect effects of the increase in macroalgae, including decreased larval recruitment and survival of juvenile corals and increased coral disease. Coral recruitment sharply declined after 1984, at least in part due to a decline in the parental brood stock. But there is also strong evidence for active interference by macroalgae. Larval settlement onto the tops of experimental panels in Curaçao declined five-fold between identical experiments in 1979-1981 and 1998-2004. Crustose coralline algae, that are a preferred substrate for larval settlement, covered the entire upper surfaces of the panels in the earlier experiment and macroalgae were absent. In contrast, upper surfaces in the later experiment were entirely covered by macroalgae.

Other experiments demonstrate that coral larvae actively avoid substrates where macroalgae are present and larval recruits suffer increased mortality and growth inhibition due to physical interference by macroalgae. But the strongest evidence for macroalgal interference comes from recent large increases in coral recruitment and juvenile survival on reefs where *Diadema* have partially recovered or parrotfish have increased in marine protected areas. Experiments also demonstrate that macroalgae induce a wide variety of pathological responses in corals including virulent diseases. Release of toxic allelochemicals by macroalgae also disrupts microbial communities associated with corals sometimes causing bleaching or death.

FIGURE 7. Dense growths of macroalgae with surviving branch tips of *Porites* protruding through the algal canopy in the top right corner and previously overgrown dead branches of *Porites* and *Acropora cervicornis* in the bottom left (Dry Tortugas, 2000, Photo by Mark Chiappone).

Overfishing may have also indirectly affected the capacity of reefs to recover from damage by hurricanes; something they have routinely done for millions of years before or reefs would not exist. Over the past few decades, however, corals have increasingly failed to become reestablished on many reefs after major storms. We investigated this apparent shift using data for the 16 reefs with coral and *Diadema* data from before 1984. Coral cover was independent of the long-term probability of hurricanes before 1984 but not afterwards. Overfishing of parrotfish may have decreased the ability of corals to recover after hurricanes. Reefs protected from overfishing at Bermuda experienced four hurricanes since 1984 with no loss in average coral cover, whereas recently overfished reefs on the Central Barrier in Belize declined by 49% after 3 hurricanes.

FIGURE 8. Overfishing severely reduced fish biomass and diversity in the Caribbean. (A – C) Decline in the composition and size of coral reef trophy fish in the Florida Keys since the 1950s (modified from McClenachan 2008). (D – F) Parrotfish were the most important grazers on Caribbean reefs: (D) Stoplight parrotfish (*Sparisoma viride*) caught in a gill net. (E) A typical day of spearfishing off southeast Curaçao. (F) Fishing boats at Barbuda's Coco Point (Photos by Ayana Elizabeth Johnson).

Coastal pollution

Limited comparative data for water transparency based on secchi disk observations at three CARICOMP sites (Caribbean Coastal Marine Productivity Program by UNESCO) show that water quality is declining in areas of unregulated agricultural and coastal development. In particular, water transparency steeply declined over 20 years at Carrie Bow Cay in Belize due to huge increases in agriculture and coastal development from Guatemala to Honduras such as illustrated in Fig. 9C. A similar pattern was observed at La Parguera on the west coast of Puerto Rico. In contrast, water quality improved in Bermuda.

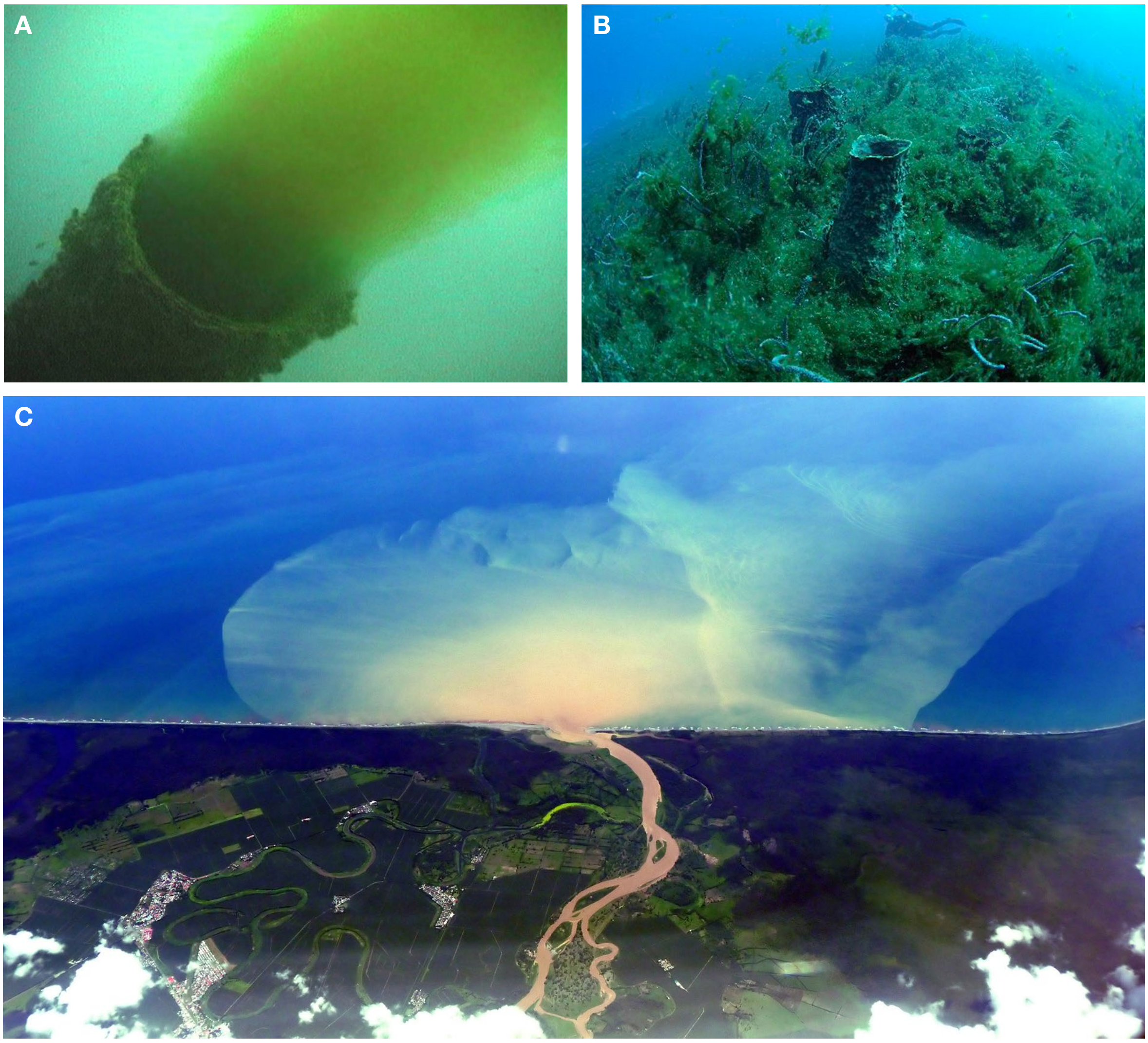

FIGURE 9. Impacts of coastal pollution on Caribbean reefs. (A) Sewage outfall in Delray Beach, Florida that discharges 13 million gallons per day of treated sewage up-current of a coral reef. (B) Macroalgae carpeting dead corals near the sewage outfall (Photos by Steve Spring, Marine Photobank). (C) Massive discharge of sediment loads by a river entering the Caribbean Sea off the Meso-American Coast (Photo by Malik Naumann, Marine Photobank).

Coral disease has been linked to excessive organic pollution but the data are spotty and limited in scope. In general there is a pressing need for more systematic and extensive monitoring of water quality throughout the wider Caribbean.

Ocean warming

Our first analyses were based on the Reefbase compilation of extreme bleaching events that showed no significant relationship between the numbers of extreme events per locality and coral cover at locations across the wider Caribbean, Gulf of Mexico and Bermuda. Because of the subjectivity of such bleaching assessments, however, we obtained data for degree heating weeks (DHWs) for all 88 localities with coral cover from NOAA Coral Reef Watch.

We then used these data to assess the effects of the 1998, 2005, and 2010 extreme warming events on coral cover by calculating the proportional changes in coral cover for the two years following each event in relation to the two years before the event, and then plotting the proportional change in relation to the numbers of degree heating weeks (DHWs) experienced at each locality. There is a weak but insignificant negative correlation between changes in coral cover and numbers of DHWs, regardless of whether the data were analyzed for each warming event or combined, or whether we included all the localities or restricted

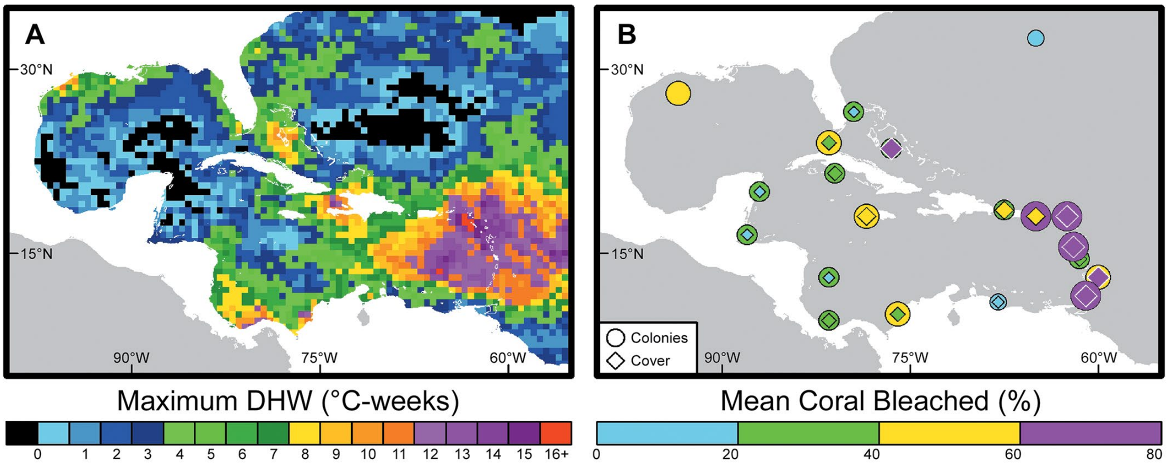

FIGURE 10. Extreme heating event and associated coral bleaching that most severely impacted the eastern Caribbean in 2005. (A) Degree heating weeks from Pathfinder Satellite observations. (B) Reports of the intensity of coral bleaching compiled from field observations (Courtesy Mark Eakin and colleagues).

the analysis to include only localities that experienced at least 8 DHWs. Moreover, the greatest losses in coral cover occurred at reef locations with less than 8 DHWs.

We caution that our results do not mean that extreme heating events are unimportant drivers of coral mortality due to coral bleaching and disease, as they clearly have been in the USVI, Puerto Rico, Florida Keys, and elsewhere. Moreover, increasingly severe extreme heating events will pose an even greater threat to coral survival in future decades. But our results do belie any regionally consistent effects of extreme heating events up to now and strongly imply that local stressors have been the predominant drivers of Caribbean coral decline to date.

Potentially deleterious effects of ocean acidification have not been treated here because of the lack of comparative data. If present trends of decreased pH continue, however, the ability of corals and other calcareous reef species to deposit skeletons will be increasingly compromised.

Invasive species

The explosion of exotic Pacific lionfish throughout the wider Caribbean (Fig. 12) has wreaked havoc in Caribbean fish communities. But as serious as the potential long-term consequences may be, they pale in comparison to the introduction of the unidentified pathogen that caused the die-off of *Diadema antillarum* or the effects of "White-band disease" (WBD) on acroporid corals. *Diadema* mass mortality began only a few km from the Caribbean entrance of the Panama Canal. That, coupled with orders of magnitude increases in bulk carrier shipping in the 1960s and 1970s, strongly suggests that *Diadema* disease was introduced by shipping. The same may be true of coral diseases although their earliest occurrences were widespread throughout the Caribbean.

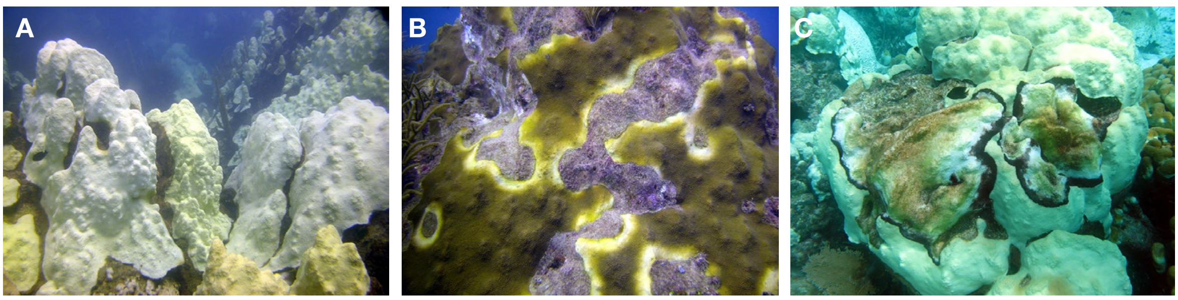

FIGURE 11. Effects of coral bleaching and disease on the formerly abundant coral *Orbicella faveolata*. (A) Bleached corals (Turrumote, Puerto Rico, 2005). Extensive partial colony mortality due to infection by (B) Yellow Band Disease (Turrumote, Puerto Rico, 2005) and (C) Black Band Disease (Los Roques Venezuela, 2010). (Photo A by Ernesto Weil; B & C by Aldo Cróquer).

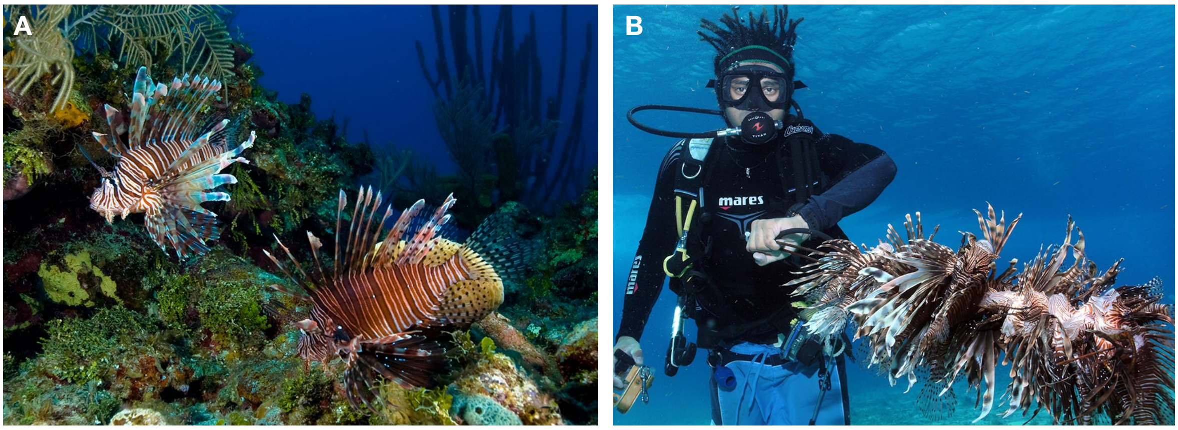

FIGURE 12. Population explosion of the highly successful Pacific lionfish (*Pterois volitans*) introduced into the Caribbean sometime between the 1980s and the early 1990s. (A) Abundant invasive lionfish on the reefs in the Cayman Islands (Photo courtesy of Niel Van Niekerk, with permission from IFAS, University of Florida). (B) Lionfish speared as part of a widespread effort to control the populations in the Dry Tortugas (Photo courtesy of ICRI).

Because of their isolation for millions of years, and by analogy to the fates of Native Americans after their first contact with Europeans, Caribbean species should be exceptionally prone to the impact of introduced diseases. And this appears to be the case. We know of no examples of the virtual elimination due to disease of any marine species throughout the entire extent of the Indian or Pacific oceans comparable to the demise of Caribbean *Diadema* and *Acropora*. This interpretation is also consistent with the apparent lack of any major environmental shift in the 1970s that might have triggered the outbreak of disease. Most importantly, the emergence of these diseases occurred many years before the first reported extreme heating events.

It would be possible to test this introduced species hypothesis for WBD since the pathogen is known and available for DNA-sequencing. It may also be possible for *Diadema* even though the pathogen is unknown by genetic analysis of entire frozen specimens of *Diadema* that died from the disease. This is not an entirely academic exercise: the two pivotal events in the demise of most Caribbean reefs are as much a mystery today as they were when they first occurred 30 or more years ago.

SUMMARY

Outbreaks of *Acropora* and *Diadema* diseases in the 1970s and early 1980s, overpopulation in the form of too many tourists, and overfishing are the three best predictors of the decline in Caribbean coral cover over the past 30 or more years based on the data available. Coastal pollution is undoubtedly increasingly significant but there are still too little data to tell. Increasingly warming seas pose an ominous threat but so far extreme heating events have had only localized effects and could not have been responsible for the greatest losses of Caribbean corals that had occurred throughout most of the wider Caribbean region by the early to mid 1990s.

In summary, the degradation of Caribbean reefs has unfolded in three distinct phases:

1. Massive losses of *Acropora* since the mid 1970s to early 1980s due to WBD. These losses are unrelated to any obvious global environmental change and may have been due to introduced pathogens associated with enormous increases in ballast water discharge from bulk carrier shipping since the 1960s.
2. Very large increase in macroalgal cover and decrease in coral cover at most overfished locations following the 1983 mass mortality of *Diadema* due to an unidentified and probably exotic pathogen. The phase shift in coral to macroalgal dominance reached a peak at most locations by the mid 1990s and has persisted throughout most of the Caribbean for 25 years. Numerous experiments provide a link between macroalgal increase and coral decline. Macroalgae reduce coral recruitment and growth, are commonly toxic, and can induce coral disease.
3. Continuation of the patterns established in Phase 2 exacerbated by even greater

overfishing, coastal pollution, explosions in tourism, and extreme warming events that in combination have been particularly severe in the northeastern Caribbean and Florida Keys where extreme bleaching followed by outbreaks of coral disease have caused the greatest declines.

IMPLICATIONS FOR MANAGEMENT

Our results contradict much of the rhetoric about the importance of ocean warming, disease, and hurricanes on coral reefs and emphasize the critical importance of historical perspective for coral reef management and conservation. The threats of climate change and ocean acidification loom increasingly ominously for the future, but local stressors including an explosion in tourism, overfishing, and the resulting increase in macroalgae have been the major drivers of the catastrophic decline of Caribbean corals up until today.

What this means is that smart decisions and actions on a local basis could make an enormous difference for increased resilience and wellbeing of Caribbean coral reefs and the people and enterprises that depend upon them. Thus, four major recommendations emerge from this report:

1. **Adopt robust conservation and fisheries management strategies** that lead to the restoration of parrotfish populations, including the listing of the parrotfish in relevant annexes of the Protocol concerning Specially Protected Areas and Wildlife (SPAW protocol) of the UNEP Caribbean Environment Programme. A recommendation to this effect was passed unanimously at the October 2013 International Coral Reef Initiative Meeting in Belize (see Box).
2. **Simplify and standardize monitoring** of Caribbean reefs and make the results available on an annual basis to facilitate adaptive management.
3. **Foster communication and exchange of information** so that local authorities can benefit from the experiences of others elsewhere.
4. **Develop and implement adaptive legislation and regulations** to ensure that threats to coral reefs are systematically addressed, particularly threats posed by fisheries, tourism and coastal development as determined by established indicators of reef health.

We understand that action upon these recommendations will be a matter of local and national socioeconomic and political debate. But the implications of our scientific results are unmistakable: *Caribbean coral reefs and their associated resources will virtually disappear within just a few decades unless all of these measures are promptly adopted and enforced.*

RECOMMENDATION

on addressing the decline in coral reef health throughout the wider Caribbean: the taking of parrotfish and similar herbivores

Adopted on 17 October 2013, at the 28th ICRI General Meeting (Belize City)

Background

The latest report of the Global Coral Reef Monitoring Network (GCRMN), entitled: *Status and Trends of Caribbean Coral Reefs: 1970-2012* is the first report to document quantitative trends of coral reef health based on data collected over the past 43 years throughout the wider Caribbean region.

The results of the study clearly show:

- Coral reef health requires an ecological balance of corals and algae in which herbivory is a key element;
- Populations of parrotfish are a critical component of that herbivory, particularly since the decline of *Diadema* sea urchins in the early 1980s;
- The main causes of mortality of parrotfish are the use of fishing techniques such as spearfishing and, particularly, the use of fish traps.

The Report further identifies that overfishing of herbivores, particularly parrotfish, has been the major drivers of reef decline in the Caribbean to date, concluding that management action to address overfishing at the national and local levels can have a direct positive impact on reef health now and for the future. *In some areas of the wider Caribbean (for example Bermuda and the Exuma Cays Land and Sea Park in the Bahamas, and more lately in Belize and Bonaire), active management including bans on fish traps, has led to increases in parrotfish numbers and consequent improvement in reef health and resilience to perturbations including hurricanes. This is in contrast to other areas within the Caribbean, where heavily fished reefs lacked the resilience to recover from storm damage.*

Positive impacts on reef health demonstrably have spill over effects on local economies, including the potential for alternative livelihoods to fishing, thanks to increased tourism revenues, replenishment of fish stocks and restoration of ecosystem services such as shoreline protection.

It is recognised that in the Caribbean there are varying levels of community reliance on fishing in general and the taking of parrotfish in particular. However, in light of the evidence now available, and in accordance with ICRI's Framework for Action cornerstone of 'integrated management' (which includes fisheries management), the International Coral Reef Initiative would like to highlight the benefits of strong management to protect reefs from overfishing, and urges immediate action to effectively protect parrotfish and similar herbivores.

Accordingly, the International Coral Reef Initiative urges Nations and multi-lateral groupings of the wider Caribbean to:

1. ***Adopt*** conservation and fisheries management strategies that lead to the restoration of parrotfish populations and so restore the balance between algae and coral that characterises healthy coral reefs;
2. ***Maximise*** the effect of those management strategies by incorporating necessary resources for outreach, compliance, enforcement and the examination of alternative livelihoods for those that may be affected by restrictions on the take of parrotfish;
3. ***Consider*** listing the parrotfish in the Annexes of the SPAW Protocol (Annex II or III) in addition to highlighting the issue of reef herbivory in relevant Caribbean fisheries fora;
4. ***Engage*** with indigenous and local communities and other stakeholders to communicate the benefits of such strategies for coral reef ecosystems, the replenishment of fisheries stocks and communities' economy.