Reefs at Risk Revisited

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Reefs at Risk Revisited is a project of the World Resources Institute (WRI), developed and implemented in close collaboration with The Nature Conservancy (TNC), the WorldFish Center, the International Coral Reef Action Network (ICRAN), the United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC), and the Global Coral Reef Monitoring Network (GCRMN). Many other government agencies, international organizations, research institutions, universities, nongovernmental organizations, and initiatives provided scientific guidance, contributed data, and reviewed results, including:

- Atlantic and Gulf Rapid Reef Assessment (AGRRA)
- Coastal Oceans Research and Development in the Indian Ocean (CORDIO)
- Conservation International (CI)
- Coral Reef Alliance (CORAL)
- Healthy Reefs for Healthy People
- Institut de Recherche pour le Développement (IRD)
- International Society for Reef Studies (ISRS)
- International Union for Conservation of Nature (IUCN)
- National Center for Ecological Analysis and Synthesis (NCEAS)
- Oceana
- Planetary Coral Reef Foundation
- Project AWARE Foundation
- Reef Check
- Reef Environmental Education Foundation (REEF)
- SeaWeb
- Secretariat of the Pacific Community (SPC)
- Secretariat of the Pacific Regional Environment Programme (SPREP)
- U.S. National Aeronautics and Space Administration (NASA)
- U.S. National Oceanic and Atmospheric Administration (NOAA)
- University of South Florida (USF)
- University of the South Pacific (USP)
- Wildlife Conservation Society (WCS)
- World Wildlife Fund (WWF)

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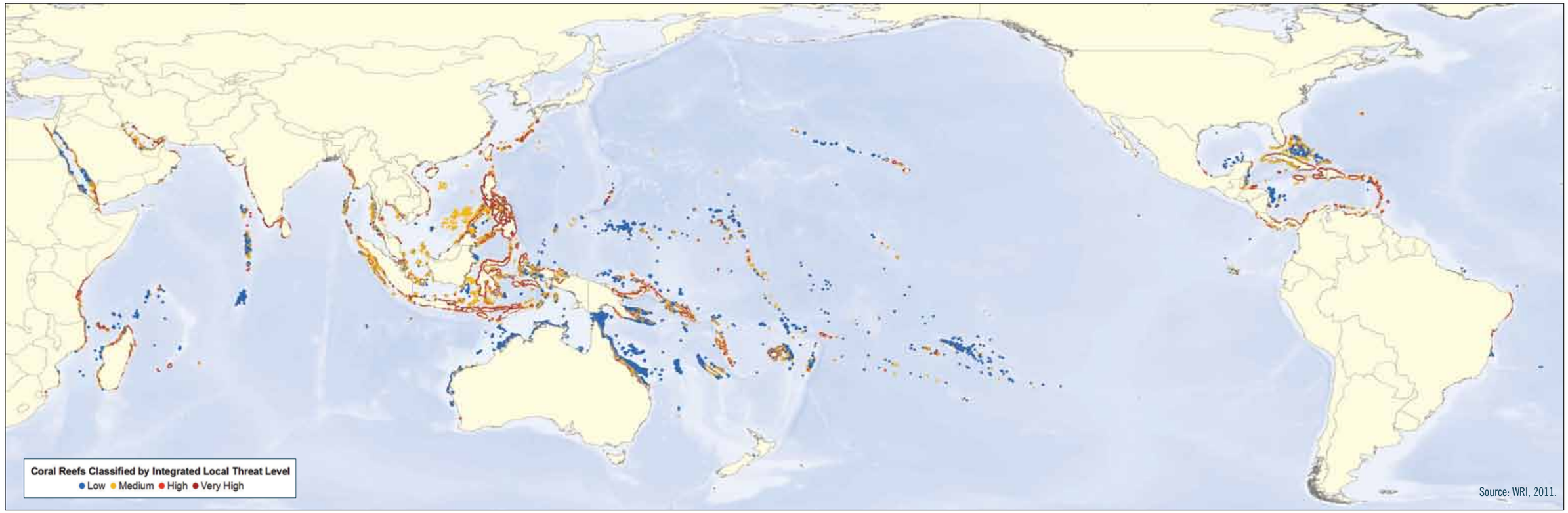
- Netherlands Ministry of Foreign Affairs
- The Ocean Foundation
- Roy Disney Family Foundation
- The Tiffany & Co. Foundation
- U.S. Department of the Interior
- U.S. Department of State

Coral Reefs of the World Classified by Threat from Local Activities



Coral reefs are classified by estimated present threat from local human activities, according to the Reefs at Risk integrated local threat index. The index combines the threat from the following local activities:

- Overfishing and destructive fishing
- Coastal development
- Watershed-based pollution
- Marine-based pollution and damage.

This indicator does not include the impact to reefs from global warming or ocean acidification. Maps including ocean warming and acidification appear later in the report and on www.wri.org/reefs.

Base data source: Reef locations are based on 500 meter resolution gridded data reflecting shallow, tropical coral reefs of the world. Organizations contributing to the data and development of the map include the Institute for Marine Remote Sensing, University of South Florida (IMaRS/USF), Institut de Recherche pour le Développement (IRD), UNEP-WCMC, The World Fish Center, and WRI. The composite data set was compiled from multiple sources, incorporating products from the Millennium Coral Reef Mapping Project prepared by IMaRS/USF and IRD.

Map projection: Lambert Cylindrical Equal-Area; Central Meridian: 160° W

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WORLD RESOURCES INSTITUTE

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Foreword

As anyone who has spent time around the ocean knows—whether diving, conducting research, or fishing—coral reefs are among the world's greatest sources of beauty and wonder. Home to over 4,000 species of fish and 800 types of coral, reefs offer an amazing panorama of underwater life.

Coral reefs supply a wide range of important benefits to communities around the world. From the fisherman in Indonesia or Tanzania who relies on local fish to feed his family, to the scientist in Panama who investigates the medicinal potential of reef-related compounds, reefs provide jobs, livelihoods, food, shelter, and protection for coastal communities and the shorelines along which they live.

Unfortunately, reefs today are facing multiple threats from many directions. 2010 was one of the warmest years on record, causing widespread damage to coral reefs. Warmer oceans lead to coral bleaching, which is becoming increasingly frequent around the globe—leaving reefs, fish, and the communities who depend on these resources at great risk. No one yet knows what the long-term impacts of this bleaching will be. But, if the ocean's waters keep warming, the outlook is grim.

Against this backdrop, the World Resources Institute has produced *Reefs at Risk Revisited,* a groundbreaking new analysis of threats to the world's coral reefs. This report builds on WRI's seminal 1998 report, *Reefs at Risk,* which served as a call to action for policymakers, scientists, nongovernmental organizations, and industry to confront one of the most pressing, though poorly understood, environmental issues. That report played a critical role in raising awareness and driving action, inspiring countless regional projects, stimulating greater funding, and providing motivation for new policies to protect marine areas and mitigate risks.

However, much has changed since 1998—including an increase in the world's population, and with it greater consumption, trade, and tourism. Rising economies in the developing world have led to more industrialization, more agricultural development, more commerce, and more and more greenhouse gas emissions. All of these factors have contributed to the need to update and refine the earlier report.

The latest report builds on the original *Reefs at Risk* in two important ways. First, the map-based assessment uses the latest global data and satellite imagery, drawing on a reef map that is 64 times more detailed than in the 1998 report. The second major new component is our greater understanding of the effects of climate change on coral reefs. As harmful as overfishing, coastal development, and other local threats are to reefs, the warming planet is quickly becoming the chief threat to the health of coral reefs around the world. Every day, we dump 90 million tons of carbon pollution into the thin shell of atmosphere surrounding our planet—roughly one-third of it goes into the ocean, increasing ocean acidification.

Coral reefs are harbingers of change. Like the proverbial "canary in the coal mine," the degradation of coral reefs is a clear sign that our dangerous overreliance on fossil fuels is already changing Earth's climate. Coral reefs are currently experiencing higher ocean temperatures and acidity than at any other time in at least the last 400,000 years. If we continue down this path, all corals will likely be threatened by mid-century, with 75 percent facing high to critical threat levels.

Reefs at Risk Revisited reveals a new reality about coral reefs and the increasing stresses they are under. It should serve as a wake-up call for policymakers and citizens around the world. By nature, coral reefs have proven to be resilient and can bounce back from the effects of a particular threat. But, if we fail to address the multiple threats they face, we will likely see these precious ecosystems unravel, and with them the numerous benefits that people around the globe derive from these ecological wonders. We simply cannot afford to let that happen.

HON. AL GORE

Former Vice President of the United States

Executive Summary

CORAL REEFS: VALUABLE BUT VULNERABLE

Coral reefs, the "rain forests of the sea," are among the most biologically rich and productive ecosystems on earth. They also provide valuable ecosystem benefits to millions of coastal people. They are important sources of food and income, serve as nurseries for commercial fish species, attract divers and snorkelers from around the world, generate the sand on tourist beaches, and protect shorelines from the ravages of storms.

However, coral reefs face a wide and intensifying array of threats—including impacts from overfishing, coastal development, agricultural runoff, and shipping. In addition, the global threat of climate change has begun to compound these more local threats to coral reefs in multiple ways. Warming seas have already caused widespread damage to reefs, with high temperatures driving a stress response called coral bleaching, where corals lose their colorful symbiotic algae, exposing their white skeletons. This is projected to intensify in coming decades. In addition, increasing carbon dioxide (CO_2) emissions are slowly causing the world's oceans to become more acidic. Ocean acidification reduces coral growth rates and, if unchecked, could reduce their ability to maintain their physical structure. With this combination of local threats plus global threats from warming and acidification, reefs are increasingly susceptible to disturbance or damage from storms, infestations, and diseases. Such degradation is typified by reduced areas of living coral, increased algal cover, reduced species diversity, and lower fish abundance.

Despite widespread recognition that coral reefs around the world are seriously threatened, information regarding which threats affect which reefs is limited, hampering conservation efforts. Researchers have studied only a small percentage of the world's reefs; an even smaller percentage have been monitored over time using consistent and rigorous methods. The World Resources Institute's *Reefs at Risk* series was initiated in 1998 to help fill this knowledge gap by developing an understanding of the location and spread of threats to coral reefs worldwide, as well as illustrating the links between human activities, human livelihoods, and coral reef ecosystems. With this knowledge, it becomes much easier to set an effective agenda for reef conservation.

PHOTO: MARK SPALDING

PURPOSE AND GOAL OF *REEFS AT RISK REVISITED*

Under the *Reefs at Risk Revisited* project, WRI and its partners have developed a new, detailed assessment of the status of and threats to the world's coral reefs. This information is intended to raise awareness about the location and severity of threats to coral reefs. These results can also catalyze opportunities for changes in policy and practice that could safeguard coral reefs and the benefits they provide to people for future generations.

Reefs at Risk Revisited is a high-resolution update of the original global analysis, *Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs.*[1] *Reefs at Risk Revisited* uses a global map of coral reefs at 500-m resolution, which is 64 times more detailed than the 4-km resolution map used in the 1998 analysis, and benefits from improvements in many global data sets used to evaluate threats to reefs (most threat data are at 1 km resolution, which is 16 times more detailed than those used in the 1998 analysis). Like the original *Reefs at Risk*, this study evaluates threats to coral reefs from a wide range of human activities. For the first time, it also includes an assessment of climate-related threats to reefs. In addition, *Reefs at Risk Revisited* includes a global assessment of the vulnerability of nations and territories to

coral reef degradation, based on their dependence on coral reefs and their capacity to adapt.

WRI led the *Reefs at Risk Revisited* analysis in collaboration with a broad partnership of more than 25 research, conservation, and educational organizations. Partners have provided data, offered guidance on the analytical approach, contributed to the report, and served as critical reviewers of the maps and findings.

The outputs of *Reefs at Risk Revisited* (report, maps, and spatial data sets) will be valuable to many users. Marine conservation practitioners, resource managers, policymakers and development agencies can use these tools to identify opportunities to protect reefs, set priorities, and plan interventions. Businesses that rely on or affect coral reef ecosystems can use this information to mitigate risks and protect their long-term economic interests. Educators can share this knowledge, thereby planting the seeds for a new generation of marine conservationists. The media can use it for its immediate and important news message, and as a basis for future research and communications. Overall, it is our hope that *Reefs at Risk Revisited* will clearly communicate what is at stake: why coral reefs are critically important and why it is essential that threats to reefs be reduced through better management practices and policies that protect these valuable ecosystems.

BOX ES-1. THREAT ANALYSIS METHOD

Human pressures on coral reefs are categorized throughout the report as either "local" or "global" in origin. These categories are used to distinguish between threats from human activities near reefs, which have a direct and relatively localized impact, versus threats that affect reefs indirectly, through human impacts on the global climate and ocean chemistry.

Local threats addressed in this analysis:

- Coastal development, including coastal engineering, land filling, runoff from coastal construction, sewage discharge, and impacts from unsustainable tourism.
- Watershed-based pollution, focusing on erosion and nutrient fertilizer runoff from agriculture delivered by rivers to coastal waters.
- Marine-based pollution and damage, including solid waste, nutrients, toxins from oil and gas installations and shipping, and physical damage from anchors and ship groundings.
- Overfishing and destructive fishing, including unsustainable harvesting of fish or invertebrates, and damaging fishing practices such as the use of explosives or poisons.

Global threats addressed in this analysis:

- Thermal stress, including warming sea temperatures, which can induce widespread or "mass" coral bleaching.
- Ocean acidification driven by increased CO_2 concentrations, which can reduce coral growth rates.

The four local threats to coral reefs were modeled separately, and subsequently combined in the *Reefs at Risk* integrated local threat index. The modeling approach is an extension and refinement of the one used in our previous analyses, and benefited from the input of more than 40 coral reef scientists and climate experts. For each local threat, a proxy indicator was developed by combining data reflecting "stressors," such as human population density and infrastructure features (including the location and size of cities, ports, and hotels), as well as more complex modeled estimates such as sediment input from rivers. For each stressor, distance-based rules were developed, where threat declines as distance from the stressor increases. Thresholds for low, medium, and high threats were developed using available information on observed impacts to coral reefs.

Local threats were modeled at WRI; data and models for global threats were obtained from external climate experts. Climate-related stressors are based on data from satellite observations of sea surface temperature, coral bleaching observations, and modeled estimates of future ocean warming and acidification. Input from coral reef scientists and climate change experts contributed to the selection of thresholds for the global threats.

Modeled outputs were further tested and calibrated against available information on coral reef condition and observed impacts on coral reefs. All threats were categorized as low, medium, or high, both to simplify the findings and to enable comparison between findings for different threats. In the presentation of findings, "threatened" refers to coral reefs classified at medium or high threat.

Full technical notes, including data sources and threat category thresholds, and a list of data contributors are available online at www.wri.org/reefs. Data sources are also listed in Appendix 2.

KEY FINDINGS

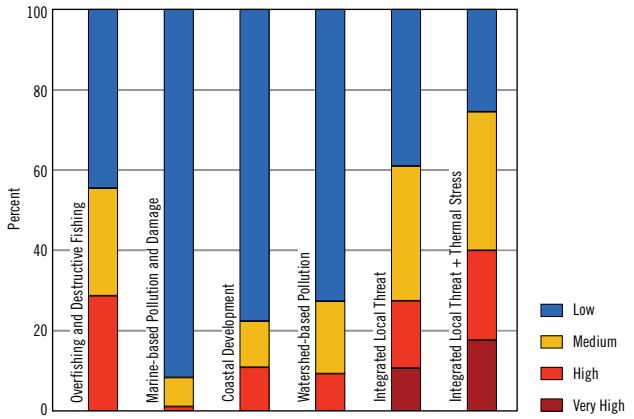
1. The majority of the world's coral reefs are threatened by human activities.

- More than 60 percent of the world's reefs are under immediate and direct threat from one or more local sources —such as overfishing and destructive fishing, coastal development, watershed-based pollution, or marine-based pollution and damage.
- Of local pressures on coral reefs, overfishing—including destructive fishing—is the most pervasive immediate threat, affecting more than 55 percent of the world's reefs. Coastal development and watershed-based pollution each threaten about 25 percent of reefs. Marine-based pollution and damage from ships is widely dispersed, threatening about 10 percent of reefs.
- Approximately 75 percent of the world's coral reefs are rated as threatened when local threats are combined with thermal stress, which reflects the recent impacts of rising ocean temperatures, linked to the widespread weakening and mortality of corals due to mass coral bleaching (Figure ES-1, column 6).

2. Local threats to coral reefs are the most severe in Southeast Asia and least severe in Australia (Figure ES-2).

- Of the six coral reef regions shown in Map ES-1, local pressure on coral reefs is highest in Southeast Asia, where nearly 95 percent of reefs are threatened, and about 50 percent are in the high or very high threat category. Indonesia, second only to Australia in the total area of coral reefs that lie within its jurisdiction, has the largest area of threatened reef, followed by the Philippines. Overfishing and destructive fishing pressure drive much of the threat in this region, followed by watershed-based pollution and coastal development.
- In the Atlantic region, more than 75 percent of reefs are threatened, with more than 30 percent in the high or very high threat category. In more than 20 countries or territories in the region—including Florida (United States), Haiti, the Dominican Republic, and Jamaica—all reefs are rated as threatened. The Bahamas have the largest area of reef rated as low threat in this region. Overfishing is the most pervasive threat, but marine-based pollution and damage, coastal development, and watershed-based pollution also pose significant threats.
- In the Indian Ocean, more than 65 percent of reefs are threatened by local activities, with nearly 35 percent under high or very high threat. The Maldives, the Chagos Archipelago, and the Seychelles have the largest area of reefs under low threat in the region. Overfishing is the most widespread threat, but land-based pollution and coastal development also elevate overall pressure.
- In the seas of the Middle East, 65 percent of reefs are at risk from local threats, with more than 20 percent rated in the high or very high threat category. In Yemen, Qatar, Bahrain, Iran, Djibouti, and Kuwait, more than 95 percent of reefs are threatened. In this region, all four threats add significant pressure.
- Although the wider Pacific region has long enjoyed relatively low pressure on coastal resources, almost 50 percent of reefs are currently considered threatened, with about 20 percent rated as high or very high. French Polynesia, the Federated States of Micronesia, Hawaii (United States), and the Marshall Islands have some of

FIGURE ES-1. REEFS AT RISK WORLDWIDE BY CATEGORY OF THREAT



Notes: Individual local threats are categorized as low, medium, and high. These threats are integrated to reflect cumulative stress on reefs. Reefs with multiple high individual threat scores can reach the very high threat category, which only exists for integrated threats. The fifth column, integrated local threats, reflects the four local threats combined. The right-most column also includes thermal stress during the past ten years. This figure summarizes current threats; future warming and acidification are not included.

MAP ES-1. MAJOR CORAL REEF REGIONS OF THE WORLD AS DEFINED FOR THE *REEFS AT RISK REVISITED* ANALYSIS

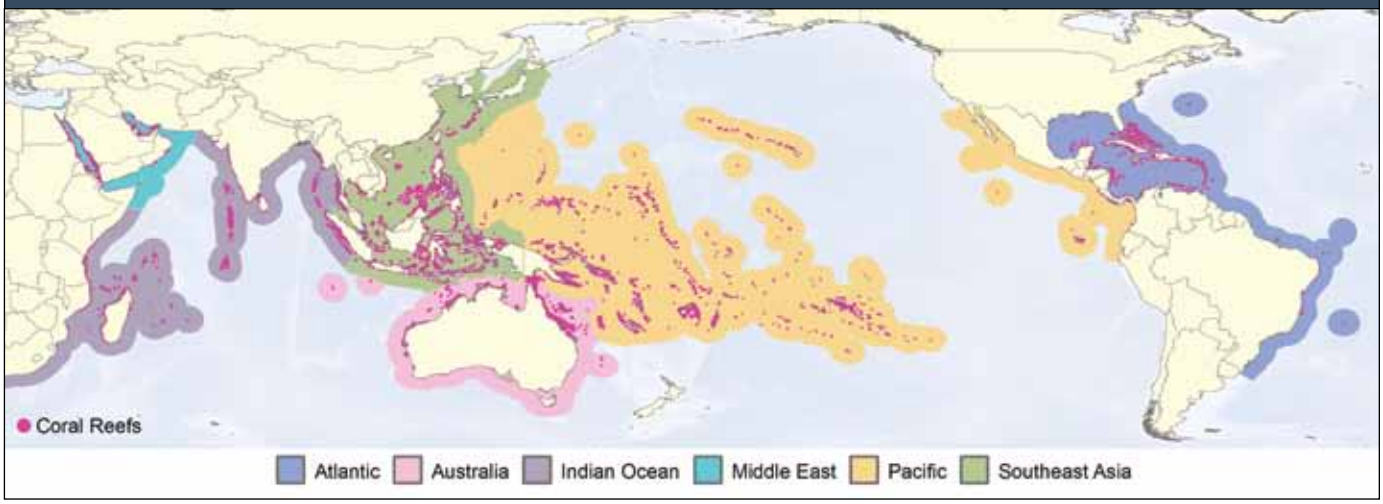
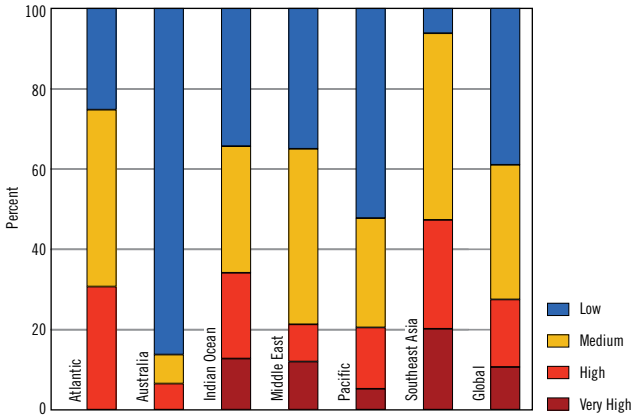


FIGURE ES-2. REEFS AT RISK FROM INTEGRATED LOCAL THREATS BY REGION



Note: Integrated local threats consist of the four local threats—overfishing and destructive fishing, marine pollution and damage, coastal development, and watershed-based pollution.

the lowest overall threat ratings (under 30 percent threatened.) Overfishing and runoff from land-based sources are the predominant threats, though coastal development is also a major pressure in some areas.

- Australia's reefs are the world's least threatened, with an estimated 14 percent threatened by local activities and just over 1 percent at high or very high threat. Our analysis identifies both marine-based pollution and watershed-based pollution as the dominant threats, but vast areas of reef are remote from such impacts.

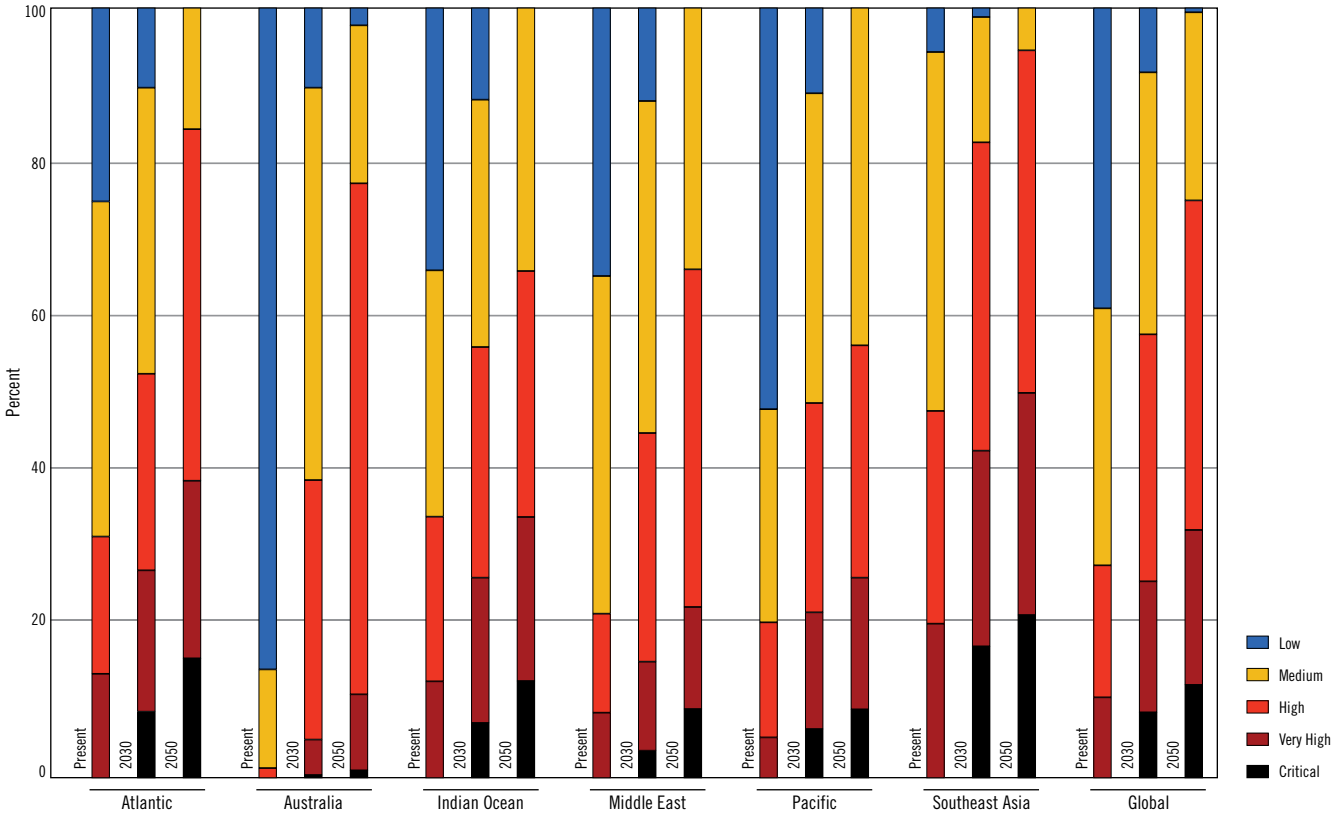
3. Threat levels have increased dramatically over a ten-year period.

- A separate analysis enabling a direct comparison of changes in threats over time shows that the percent of reefs rated as threatened has increased by 30 percent in the 10 years since the first *Reefs at Risk* analysis (comparing data from 1997 and 2007), with increases in all local threat categories and in all regions.
- **By local threat:** The greatest driver of increased pressure on reefs since 1998 has been an 80 percent increase in the threat from overfishing and destructive fishing, most significantly in the Pacific and Indian Ocean regions. This change is largely due to the growth in coastal populations living near reefs. Pressure on reefs from coastal development, watershed-based pollution, and marine-based pollution and damage has also increased dramatically above 1998 levels.
- **By region:** In the Pacific and Indian oceans, many reefs formerly classified as low threat are now threatened, largely reflecting increased overfishing pressure. In the Middle East, Southeast Asia, and the Atlantic over the past ten years, extensive areas of reefs have been pushed from medium threat into higher threat categories through a combination of local threats. Australia had the smallest increase in local pressure on reefs over the ten-year period.

4. Changes in climate and in ocean chemistry represent significant and growing threats.

- **Impact of CO_2**: Rising concentrations of CO_2 and other greenhouse gases in the atmosphere have led to warming of the atmosphere and, as a result, an increase in sea surface temperatures. Mass coral bleaching, a stress response to warming waters, has occurred in every region and is becoming more frequent as higher temperatures recur. Extreme bleaching events kill corals outright, while less extreme events can weaken corals, affecting their reproductive potential, reducing growth and calcification, and leaving them vulnerable to disease. These effects also compound the local threats described above. Managing this threat is particularly challenging because it does not arise from local human actions, but from global changes to the atmosphere as a result of human activities.
- **Thermal stress:** Our projections suggest that during the 2030s roughly half of reefs globally will experience thermal stress sufficient to induce severe bleaching in most years. During the 2050s, this percentage is expected to grow to more than 95 percent. These projections assume that greenhouse gas emissions continue on current trajectories and local threats are not addressed. Although coral reefs can recover from infrequent and mild bleaching, this degree of high, regular stress presents a significant risk of irreversible damage.
- **Rising acidity**: Rising levels of CO_2 in the oceans are altering ocean chemistry and increasing the acidity of ocean water, reducing the saturation level of aragonite, a compound corals need to build their skeletons. By 2030, fewer than half the world's reefs are projected to be in areas where aragonite levels are ideal for coral

FIGURE ES-3. REEFS AT RISK: PRESENT, 2030, AND 2050



Note: "Present" represents the *Reefs at Risk* integrated local threat index, without past thermal stress considered. Estimated threats in 2030 and 2050 use the present local threat index as the base and also include projections of future thermal stress and ocean acidification. The 2030 and 2050 projections assume no increase in local pressure on reefs, and no reduction in local threats due to improved policies and management.

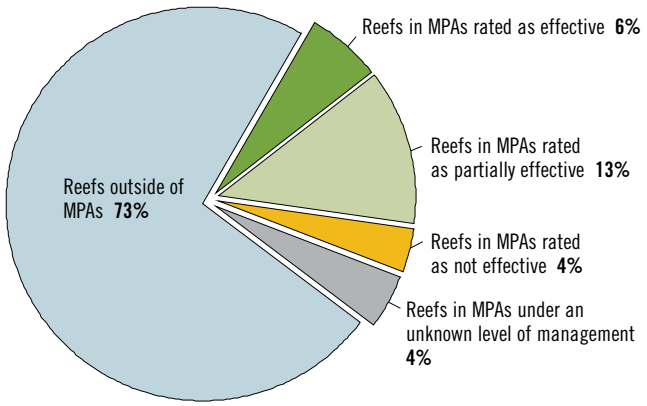
growth, suggesting that coral growth rates could be dramatically reduced. By 2050, only about 15 percent of reefs will be in areas where aragonite levels are adequate for coral growth.

- **Combined impacts**: The combined impacts of ocean warming and acidification will increase the threat levels on more than half of all reefs by 2030, pushing the percentage of threatened reefs to more than 90 percent by 2030. By 2050, nearly all reefs will be affected by warming and acidification and almost all reefs will be classified as threatened, assuming there is no change in local pressure on reefs (Figure ES-3).

5. While over one quarter of the world's coral reefs are within protected areas, many are ineffective or only offer partial protection.

- Approximately 27 percent of the world's reefs are located inside marine protected areas (MPAs). This coverage includes strictly controlled marine reserves, locally managed marine areas, and sites where management controls only one or two types of threat. Of the reef area inside MPAs, more than half is in Australia. Outside Australia, only 16 percent of coral reefs are within MPAs.
- We identified 2,679 MPAs in coral reef areas and were able to rate nearly half, including most of the larger sites, for their effectiveness in reducing the threat of overfishing. Of those rated, 15 percent of sites were rated as effective, 38 percent as partially effective, and 47 percent as ineffective.
- Based on these ratings, only 6 percent of the world's coral reefs are located in effectively managed MPAs and 73 percent are located outside MPAs (Figure ES-4). Increasing the MPA coverage and efficacy thus remains a priority for most areas.
- The coverage of MPAs is strongly biased away from areas of greatest threat, limiting their potential for reducing threats in areas of heavy human pressure.

FIGURE ES-4. CORAL REEFS BY MARINE PROTECTED AREA COVERAGE AND EFFECTIVENESS LEVEL

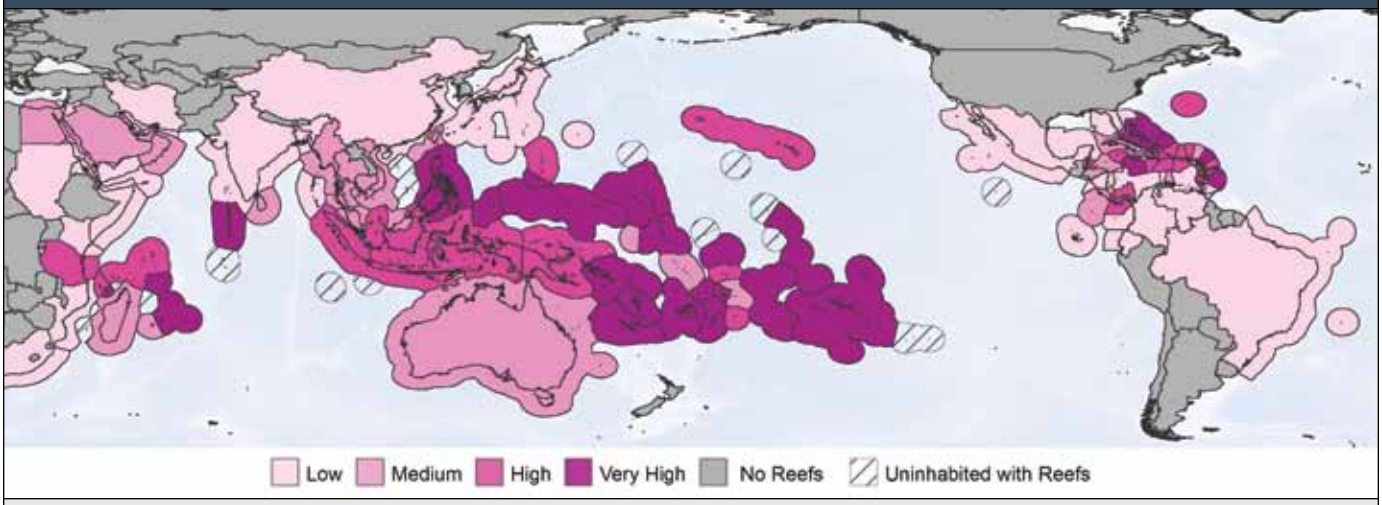


Note: The global area of coral reefs is 250,000 sq km (which represents 100% on this chart), of which 67,350 sq km (27%) is inside MPAs.

6. Dependence on coral reefs is high in many countries, especially small-island nations.

- Worldwide, approximately 850 million people live within 100 km of reefs, many of whom are likely to derive some benefits from the ecosystem services they provide. More than 275 million people reside in the direct vicinity of coral reefs (within 30 km of reefs and less than 10 km from the coast), where livelihoods are most likely to depend on reefs and related resources.
- Of 108 countries and territories studied, the most reef-dependent were almost all small-island states, many located in the Pacific and the Caribbean (Map ES-2).
- Populous Asian nations, such as Indonesia and the Philippines, account for the greatest absolute numbers of reef fishers. Relative to population size, many of the countries with high participation in reef fisheries are in the Pacific.
- At least 94 countries and territories benefit from reef tourism; in 23 of these, reef tourism accounts for more than 15 percent of gross domestic product (GDP).
- More than 150,000 km of shoreline in 100 countries and territories receive some protection from reefs, which reduce wave energy and associated erosion and storm damage.

MAP ES-2. SOCIAL AND ECONOMIC DEPENDENCE ON CORAL REEFS



Note: Reef dependence is based on reef-associated population, reef fisheries employment, nutritional dependence on fish and seafood, reef-associated export value, reef tourism, and shoreline protection from reefs. Countries and territories are categorized according to quartiles.

7. **Degradation and loss of reefs will result in significant social and economic impacts.** Vulnerability to reef loss was assessed for 108 inhabited reef countries and territories, based on exposure to reef threats, dependence on ecosystem services (food, livelihoods, exports, tourism, and shoreline protection), and adaptive capacity (ability to cope with the effects of degradation).

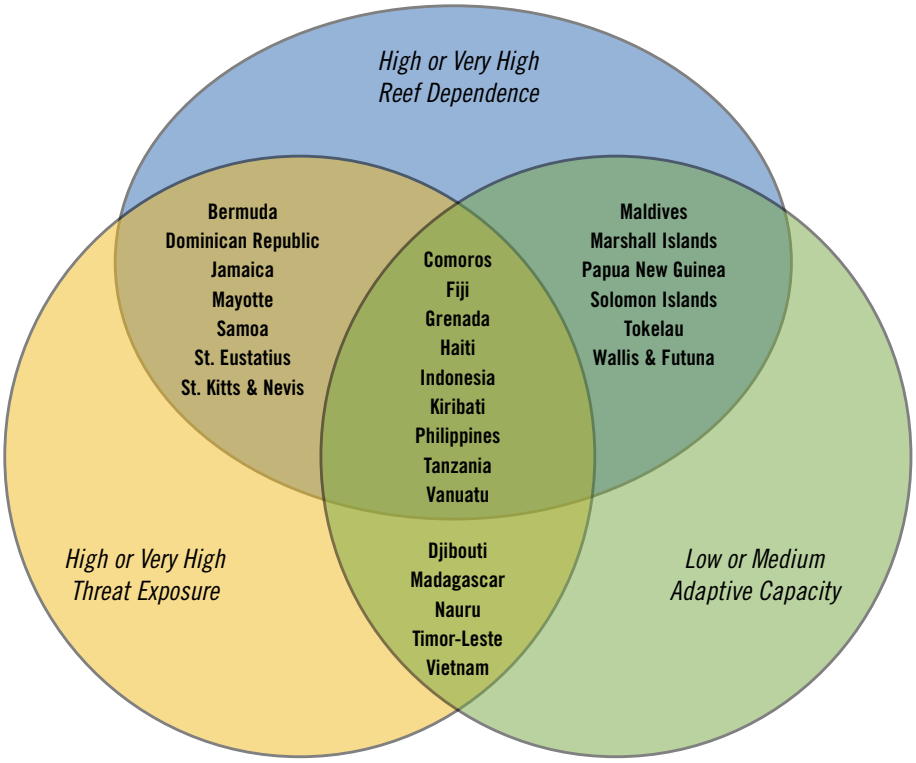
   - The 27 countries and territories identified as highly vulnerable to reef loss are spread across the world's reef regions (Figure ES-5). Nineteen are small-island states.
   - Nine countries—Haiti, Grenada, the Philippines, Comoros, Vanuatu, Tanzania, Kiribati, Fiji, and Indonesia—are most vulnerable to the effects of coral reef degradation. They have high ratings for exposure to reef threat and reef dependence, combined with low ratings for adaptive capacity. These countries merit the highest priority for concerted development efforts to reduce reliance on reefs and to build adaptive capacity, alongside reducing immediate threats to reefs.

CONCLUSIONS AND RECOMMENDATIONS

This report presents a deeply troubling picture of the world's coral reefs. Local human activities already threaten the majority of reefs in most regions, and the accelerating impacts of global climate change are compounding these problems. The extent and severity of threats to reefs, in combination with the critically important ecosystem services they provide, point to an urgent need for action. The report offers reason for hope: reefs around the world have shown a capacity to rebound from even extreme damage, while active management is protecting reefs and aiding recovery in some areas.

However, we need to improve, quickly and comprehensively, on existing efforts to protect reefs and the services they provide humanity. It is encouraging that our collective ability to do so has become stronger, with new management tools, increased public understanding, better communications, and more active local engagement. We hope this new report will spur further action to save these critical ecosystems. The array of measures to deal with the many threats to reefs must be comprehensive. Local threats must be tackled head-on with direct management interventions, while efforts to quickly and significantly reduce greenhouse gas emissions are of paramount concern not only for reefs, but for nature and humanity as a whole. At the same time, we may be able to "buy time" for coral reefs in the face of cli-

FIGURE ES-5. DRIVERS OF VULNERABILITY IN HIGHLY VULNERABLE NATIONS AND TERRITORIES



Note: Countries or territories within the yellow circle are highly or very highly exposed to reef threat; those within the blue circle are highly or very highly reef-dependent; and those within the green circle have low or medium adaptive capacity. Only the 27 very highly vulnerable countries and territories are shown.

mate change, through local-scale measures to increase reef resilience to climate-related threats.

Toward these aims, we recommend the following specific actions involving a broad range of stakeholders at the local, national, regional, and international scales:

- Mitigate threats from local human activities.
  - ***Reduce unsustainable fishing*** by addressing the underlying social and economic drivers of overfishing; establishing sustainable fisheries management policies and practices; reducing excess fishing capacity and removing perverse subsidies; enforcing fishing regulations; halting destructive fishing; improving and expanding MPAs to maximize benefits; and involving stakeholders in resource management.
  - ***Manage coastal development*** through coastal zone planning and enforcement to prevent unsound land development; protecting coastal vegetation; implementing erosion-control measures during construction; improving sewage treatment; linking marine and terrestrial protected areas; and developing tourism in sustainable ways.
  - ***Reduce watershed-based pollution*** by reducing sediment and nutrient delivery to coastal waters through improved agriculture, livestock, and mining practices; minimizing industrial and urban runoff; and protecting and restoring riparian vegetation.
  - ***Reduce marine-based pollution and damage*** by reducing at-sea disposal of waste from vessels; increasing regulation of ballast discharge from ships; designating safe shipping lanes and boating areas; managing offshore oil and gas activities; and using MPAs to protect reefs and adjacent waters.

- **Manage for climate change locally.** A growing body of evidence has shown that by reducing local threats (including overfishing, nutrients, and sediment pollution), reefs may be able to recover more quickly from coral bleaching. Strategic planning to enhance local-scale reef resilience should target critical areas, building networks of protected areas that include (and replicate) different parts of the reef system, as well as include areas critical for future reef replenishment. Such efforts may represent an opportunity to "buy time" for reefs, until global greenhouse gas emissions can be curbed.

- **Develop integrated management efforts at ecosystem scales.** Plans that are agreed to by all sectors and stakeholders and that consider ecological relationships are most likely to avoid waste, repetition, and potential conflicts with other interventions and maximize potential benefits. For reefs, relevant approaches include ecosystem-based management, integrated coastal management, ocean zoning, and watershed management.

- **Scale up efforts through international collaboration**. At all scales, we need political will and economic commitment to reduce local pressures on reefs and promote reef resilience in the face of a changing climate. It is also critical to replicate successful local and national approaches, and work internationally, using tools such as transboundary collaboration and regional agreements, improved international regulations to govern trade in reef products, and international agreements such as the UN Convention on the Law of the Sea, which helps regulate fishing, and MARPOL, which controls pollution from ships.

- **Support climate change efforts**. Reef scientists recommend not only a stabilization of CO_2 and other greenhouse gas concentrations, but also a slight reduction from our current level of 388 ppm (2010) to 350 ppm, if large-scale degradation of reefs is to be avoided. Attaining this challenging target will take time, and require immense global efforts. There is a role to be played by all—individuals and civil society, NGOs, scientists, engineers, economists, businesses, national governments, and the international community—to address this enormous and unprecedented global threat.

- **Build consensus and capacity.** Closing the gap between knowledge and results depends on action within the following key areas:
  - ***Scientific research*** to build understanding of how particular reefs are affected by local activities and climate change and how different stressors may act in combination to affect reef species; to explore factors that confer resilience to reef systems and species; to assess the extent of human dependence on specific reef ecosystem services; and to determine the potential for coastal communities to adapt to expected change.
  - ***Education and communication*** to inform communities, government agencies, donors, and the general public about how current activities threaten reefs and why action is needed to save them, and to highlight examples of replicable conservation success.
  - ***Policy support*** to aid decisionmakers and planners in making long-term decisions that will affect the survival of coral reefs, as well as enhancing the ability of coastal communities to adapt to environmental changes and reef degradation.
  - ***Economic valuation*** to highlight the value of reefs and the losses associated with reef degradation, and to aid in assessing the longer-term costs and benefits of particular management and development plans.


PHOTO: STACY JUPITER

- ***Training and capacity building*** of reef stakeholders, to manage and protect reefs, understand and argue for their value, spread awareness, and reduce vulnerability in reef-dependent regions.
- ***Involvement of local stakeholders*** in the decision-making and management of reef resources.

■ **Individual action.** Regardless of whether you live near or far from a coral reef, you can take action to help coral reefs:

- ***If you live near coral reefs:***

– Follow local laws and regulations designed to protect reefs and reef species.

– If you fish, do it sustainably, avoiding rare species, juveniles, breeding animals, and spawning aggregations.

– Avoid causing physical damage to reefs with boat anchors, or by trampling or touching reefs.

– Minimize your indirect impacts on reefs by choosing sustainably caught seafood and reducing household waste and pollution that reaches the marine environment.

– Help improve reef protection by working with others in your area to establish stronger conservation measures, participating in consultation processes for planned coastal or watershed development projects, and supporting local organizations that take care of reefs.

– Tell your political representatives why protecting coral reefs is important.

- ***If you visit coral reefs:***

– Choose sustainably managed, eco-conscious tourism providers.

– Dive and snorkel carefully, to avoid physically damaging reefs.

– Tell people if you see them doing something harmful to reefs.

– Visit and make contributions to MPAs to support management efforts.

– Avoid buying souvenirs made from corals and other marine species.

- ***Wherever you are***:

– Choose sustainably caught seafood.

– Avoid buying marine species that are threatened or may have been caught or farmed unsustainably.

– Help to prioritize coral reefs, the environment, and climate change issues within your government

– Support NGOs that conserve coral reefs and encourage sustainable development in reef regions.

– Educate through example, showing your family, friends, and peers why reefs are important to you.

– Reduce your carbon footprint.

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