Reefs at Risk Revisited in the Coral Triangle

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Reefs at Risk Revisited in the Coral Triangle was developed by the World Resources Institute (WRI) in close collaboration with the USAID-funded Coral Triangle Support Partnership (CTSP). This report was adapted from WRI's 2011 global analysis of threats to coral reefs, *Reefs at Risk Revisited*, produced in partnership 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, non-governmental organizations and initiatives provided scientific guidance, contributed data, and reviewed results for these reports, including:

- Atlantic and Gulf Rapid Reef Assessment (AGRRA)
- Coastal Conservation and Education Foundation (CCEF)
- Coastal Oceans Research and Development in the Indian Ocean (CORDIO)
- Conservation International (CI)
- Coral Reef Alliance (CORAL)
- Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF)
- Healthy Reefs for Healthy People
- International Society for Reef Studies (ISRS)
- International Union for the Conservation of Nature (IUCN)
- L'Institut de Recherche pour le Développement (IRD)
- 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)
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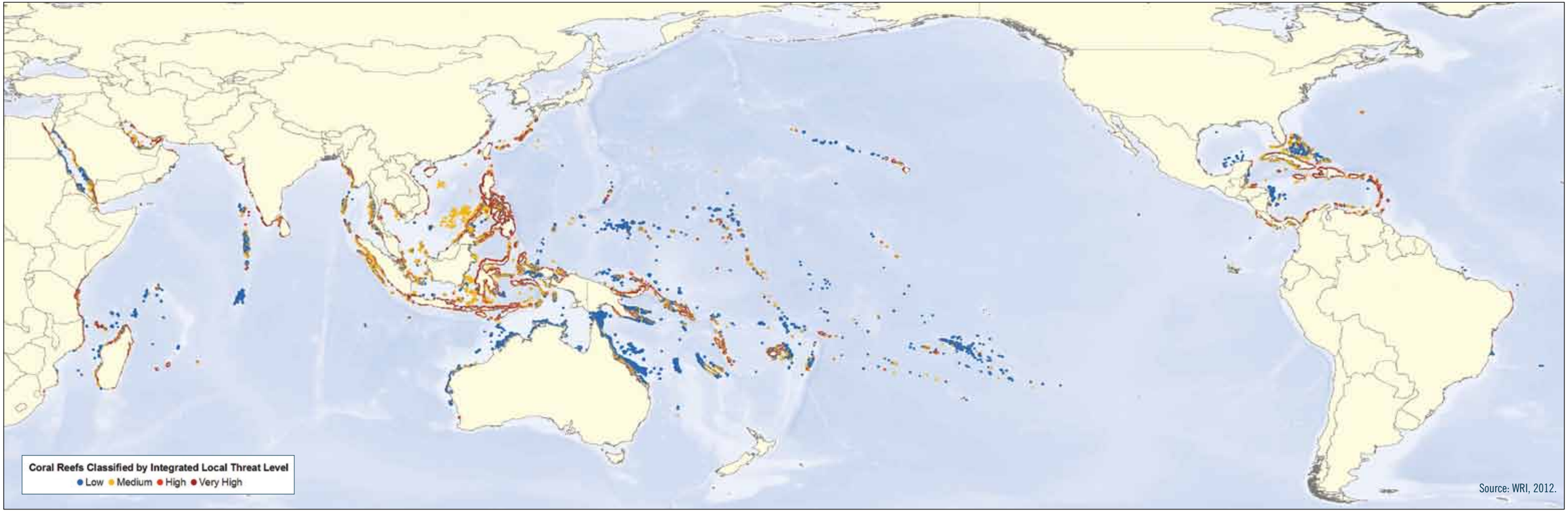
Coral Reefs of the World Classified by Threat from Local Activities



Coral reefs are classified by estimated present threat from local human activities, according to the Reefs at Risk integrated local threat index as developed for the Reefs at Risk Revisited report. 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 map reflects new data and information collected for the Coral Triangle region as part of this report and is an updated version of the global Reefs at Risk Revisited map for this region. The index shown on this map 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

Reefs at Risk Revisited in the Coral Triangle

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PHOTO: WOLCOTT HENRY

Spanning the marine waters of Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste, the Coral Triangle is the global heart of coral reefs. This magnificent area, often called the "Amazon of the Seas," contains nearly 30 percent of the world's coral reefs and 75 percent of all known coral species. It is home to more than 3,000 species of fish—twice the number found anywhere else in the world. The region's coral reefs produce natural resources that sustain the lives of more than 130 million people living within the Coral Triangle and millions more worldwide. But these precious resources are at risk. Overfishing, destructive fishing, coastal development, and pollution threaten more than 85 percent of the Coral Triangle's reefs.

Recognizing the importance of preserving this valuable ecosystem, the six countries of the Coral Triangle (the CT6) banded together in 2009 under the largest and most important regional marine governance effort in the world—the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF). This collaboration aims to preserve the wealth of resources that the Amazon of the Seas provides to communities around the world. Other nations are now joining the effort by committing their own support to CTI-CFF.

This report, *Reefs at Risk Revisited in the Coral Triangle,* is adapted from the World Resources Institute's 2011 global report *Reefs at Risk Revisited*. It builds on the global report to investigate and answer many of the specific questions that the CTI-CFF faces in its efforts. The report reveals a new reality about the Coral Triangle's reefs and the increasing stresses they face. Using the latest global data and satellite imagery, it highlights the impacts of local problems such as overfishing and pollution, and reflects our greater understanding of the effects of climate change as a growing threat to the health of coral reefs.

Reefs at Risk Revisited in the Coral Triangle serves as a call to action for policy makers, scientists, nongovernmental organizations, and the private sector to confront the challenge of coral reef management in the world's richest marine ecosystem. After all, we must remember that successful management of marine ecosystems comes from successfully managing human activities that affect the ecosystem.

When I was young, I was taught that we need to live in harmony with our surroundings. Since then, I learned that harmony comes from maintaining the balance of an ecosystem. The good news is that reefs are incredibly resilient, with the ability to recover from many types of damage. But we too must do our part to rectify the imbalances. If we fail to address the multiplying threats now, we will likely see this critical marine ecosystem unravel, and with it the numerous benefits on which so many people depend.

No other marine area on Earth matches the Coral Triangle for biodiversity, economic productivity, and beauty. This report reminds us that we must not take these precious natural gifts for granted, and we must take action now so that we may give them to our children.

SUSENO SUKOYONO

Executive Chair, CTI-CFF Interim Regional Secretariat

Abbreviations and Acronyms

CO_2	Carbon dioxide
COREMAP	Coral Reef Rehabilitation and Management Program
COTS	Crown-of-thorns starfish
CPUE	Catch per unit effort
CTI	Coral Triangle Initiative
CTI-CFF	Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security
CTMPAS	Coral Triangle Marine Protected Area System
CTSP	Coral Triangle Support Partnership
DHW	Degree heating week
EEZ	Exclusive economic zone
FAO	Food and Agriculture Organization of the United Nations
GCRMN	The Global Coral Reef Monitoring Network
GDP	Gross domestic product
GIS	Geographic Information System
ICRI	International Coral Reef Initiative
IMaRS/USF	Institute for Marine Remote Sensing, University of South Florida
IPCC	Intergovernmental Panel on Climate Change
IRD	Institut de Recherche pour le Développement
IUCN	International Union for Conservation of Nature
LDC	Least developed country
LEAP	Local Early Action Plans
LMMA	Locally managed marine area
LRFFT	Live reef food fish trade
MARPOL	International Convention for the Prevention of Pollution from Ships
MMA	Marine managed area
MMAF	Ministry of Marine Affairs and Fisheries (Indonesia)
MPA	Marine protected area
NASA	U.S. National Aeronautics and Space Administration
NGO	Nongovernmental organization
NIPC	Nuakata Iabam Pahalele Community
NOAA	U.S. National Oceanic and Atmospheric Administration
PNG	Papua New Guinea
ppm	Parts per million
REAP-CCA	Region-Wide Early Action Plan for Climate Change Adaptation
sq km	Square kilometers
SST	Sea surface temperature
TMP	Tun Mustapha Park
TNC	The Nature Conservancy
TRNP	Tubbataha Reefs Natural Park
UNEP-WCMC	United Nations Environment Programme-World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WCS	Wildlife Conservation Society
WDPA	World Database of Protected Areas
WRI	World Resources Institute
WWF	World Wildlife Fund

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The report was edited by Maggie Barron and Bob Livernash; Maggie Powell provided the layout and design of the publication. Credit for the many striking photographs throughout the report goes to: Mohd Yusuf Bin Bural, Bruce Bowen, Ciemon Caballes, Suchana Chavanich/MPB, Christopher J. Crowley, Robert Delfs, Mark Godfrey, Alison Green, Wolcott Henry, Jun Lao, Angela Lim, James Morgan, Freda Paiva, Peri Paleracio, Jharendu Pant, PATH Foundation, Cheryl Ventura, David Wachenfeld, Rebecca Weeks/MPB, Alan White, Daniel and Robbie Wisdom, and Jeff Yonover. Photo credits with the label "MPB" were acquired through Marine Photobank (marinephotobank.org).

Key Findings

GLOBAL 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 local sources—such as overfishing, destructive fishing, coastal development, watershed-based pollution, or marine-based pollution and damage (see map inside front cover).
- Approximately 75 percent of the world's coral reefs are rated as threatened when local threats are combined with thermal stress. This 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).

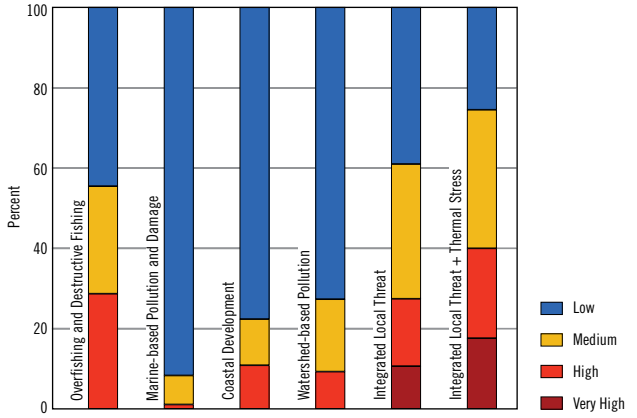
2. Changes in climate and ocean chemistry represent significant and growing threats.

- *Coral bleaching:* Rising greenhouse gas emissions are warming the atmosphere and, as a result, increasing sea surface temperatures. Mass coral bleaching, a stress response to warming waters that can weaken or kill coral, has occurred in every coral reef region. It is becoming more frequent as higher temperatures recur.
- *Ocean acidification:* Increasing carbon dioxide in the ocean is altering ocean chemistry and making the water more acidic, which can slow coral growth rates and ultimately weaken coral skeletons.
- If local and global threats are left unchecked, the percentage of threatened reefs is projected to increase to more than 90 percent by 2030 and to nearly all reefs by 2050.

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

- *People:* Worldwide, approximately 850 million people live within 100 km of coral reefs; many of whom are likely to derive some benefits from the ecosystem services the reefs provide. More than 275 million people reside in the direct vicinity of 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.
- *Food:* A healthy, well-managed reef in the Indian or Pacific Oceans can yield between 5 and 15 tons of seafood per square kilometer per year in perpetuity.
- *Shorelines:* Coral reefs protect 150,000 km of shoreline in more than 100 countries and territories, helping to defend against storms and erosion.
- *Tourism:* At least 94 countries and territories benefit from tourism related to reefs; in 23 reef countries, tourism accounts for more than 15 percent of gross domestic product (GDP).
- *Disease Prevention:* Many reef-dwelling species have the potential for forming life-saving pharmaceuticals, including treatments for cancer, HIV, malaria, and other diseases.

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.

4. Degradation and loss of reefs will result in significant social and economic impacts.

- Of the 27 countries and territories most vulnerable to coral reef degradation and loss, 19 (70 percent) are small-island states, where people are more likely to depend on reefs.
- Nine countries—Comoros, Fiji, Grenada, Haiti, Indonesia, Kiribati, the Philippines, Tanzania, and Vanuatu—are most vulnerable to the effects of coral reef degradation. In these countries, reefs face high threat levels, people are highly dependent on reefs, and their capacity to adapt to reef loss is limited.

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

- Approximately 28 percent of the world's coral reefs are within marine protected areas (MPAs). Of the reef area inside MPAs, more than half is in Australia.
- Based on our compilation of expert-based ratings of the management effectiveness of these MPAs, we find that only 6 percent of the world's coral reefs are located in MPAs that are effectively managed. Fourteen percent are in MPAs rated as only partially effective at achieving management goals.

6. Policy makers, government officials, resource managers, and others need to take action to protect reefs, and to manage risks locally and globally.

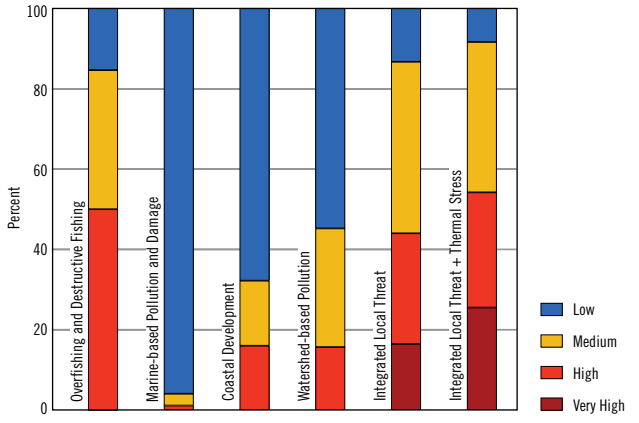
- Reefs are resilient—they can recover from coral bleaching and other impacts—particularly if other threats are low.
- Reducing local pressures on reefs—overfishing, coastal development, and pollution—offers the best way to "buy time" for reefs. Doing so would help reefs survive warming seas and ocean acidification while the global community works to reduce emissions of greenhouse gases, particularly carbon dioxide.

KEY FINDINGS FOR THE CORAL TRIANGLE REGION

1. Threats to coral reefs in the Coral Triangle Region are much higher than the global average.

- More than 85 percent of reefs within the Coral Triangle Region are currently threatened by local stressors, which is substantially higher than the global average of 60 percent. Nearly 45 percent are at high or very high threat levels.
- The most widespread local threat to coral reefs in this region is overfishing, including destructive fishing, which threatens nearly 85 percent of reefs. Watershed-based pollution is also pervasive, threatening 45 percent of reefs. Impacts from coastal development threaten more than 30 percent of the region's reefs (see figure ES-2).
- When the influence of recent thermal stress and coral bleaching is combined with these local threats, the percent of reefs rated as threatened increases to more than 90 percent, which is substantially greater than the global average of 75 percent (see figure ES-2, column 6.)

FIGURE ES-2. REEFS AT RISK IN THE CORAL TRIANGLE REGION BY CATEGORY OF THREAT

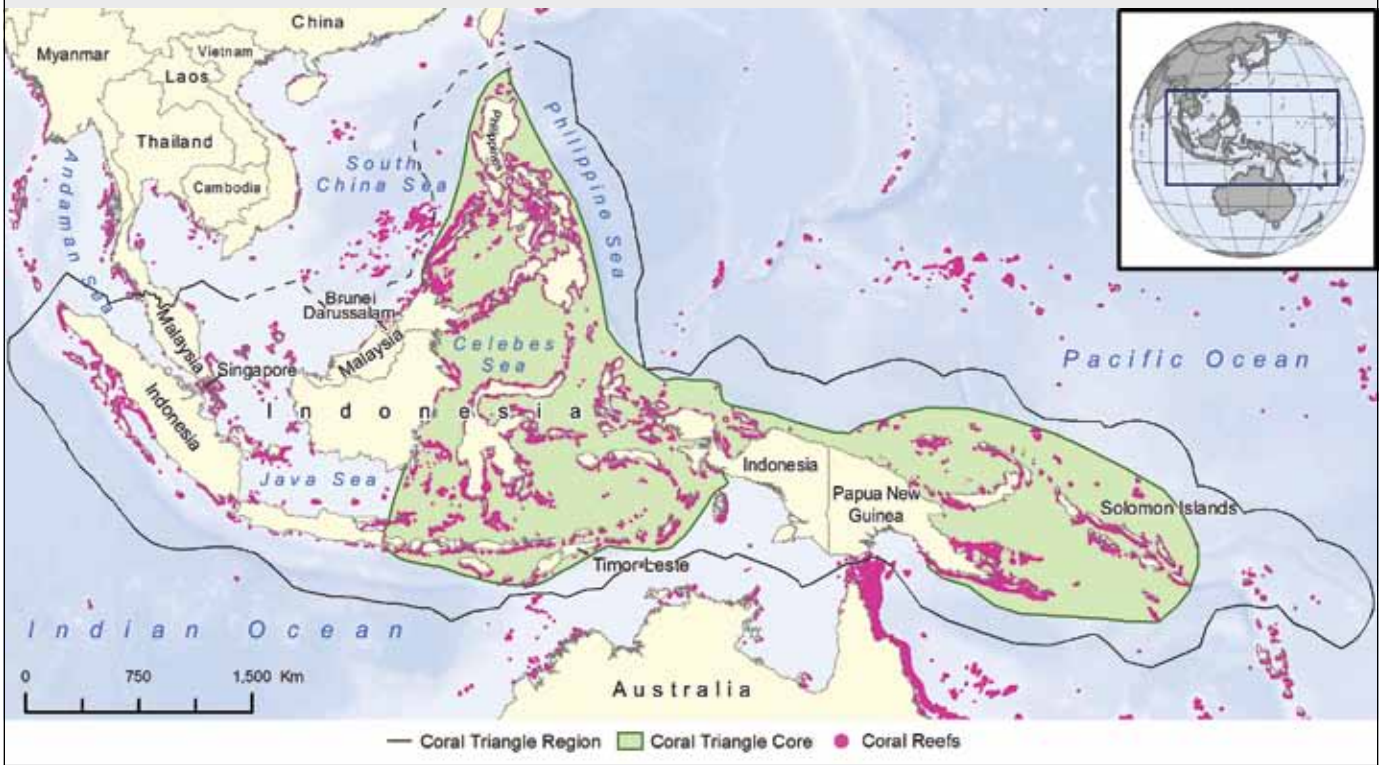


Note: Individual local threats are categorized as low, medium, and high. These threats are integrated to reflect cumulative stress on reefs. The fifth column, integrated local threats, reflects the four local threats combined. Reefs with multiple high individual local threat scores can reach the very high threat category, which only exists for integrated threats. 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.

BOX ES.1. THE CORAL TRIANGLE REGION

The Coral Triangle, an area that encompasses parts of Southeast Asia and the western Pacific, is the world's center of marine biodiversity. It has a greater concentration of coral and reef fish species than anywhere else on earth.[1] The ecological boundary of the Coral Triangle (shown in green on the map below), so named because of its distinct triangular shape, contains nearly 73,000 sq km of coral reefs (29 percent of the global total), and spans parts of six countries: Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste.

In this report, we refer to the area within the ecological boundary as the Coral Triangle Core. However, because the Coral Triangle Core is defined entirely by biological, and not political, considerations, we have based this report on a broader, politically defined area we call the Coral Triangle Region (shown with a dashed line in map below). The Coral Triangle Region includes the full exclusive economic zones (EEZs) of the six countries mentioned previously, which is the implementation area agreed upon by these countries for the six-nation Coral Triangle Initiative, plus the adjacent nations of Brunei Darussalam and Singapore. The Coral Triangle Region includes more than 86,500 sq km of coral reef area (35 percent of the global total.)

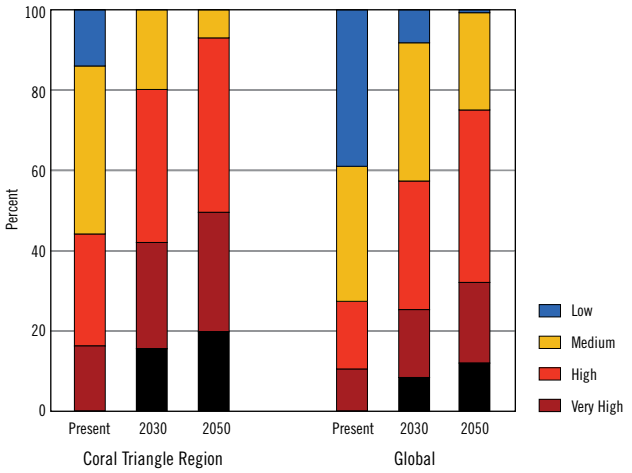


Note: The "Coral Triangle Region" as defined in this report includes the full exclusive economic zones (EEZs) of the six countries of the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF), which is the official CTI-CFF Implementation Area, plus the adjacent nations of Brunei Darussalam and Singapore. The dashed line represents disputed EEZ boundaries; a boundary for Brunei Darussalam is not known. The "Coral Triangle Core" as defined in this report represents the scientific boundary of highest coral biodiversity in the world (more than 500 species). Boundaries are presented here for illustrative purposes and are not legally binding in any way.

2. Rising levels of carbon dioxide and other greenhouse gases in the atmosphere will further threaten reefs in the Coral Triangle Region, as warming water prompts coral bleaching and more acidic water slows coral growth.

- By 2030, almost all reefs in the Coral Triangle Region are projected to be threatened, with 80 percent in the high, very high, or critical categories.
- By 2050, all reefs in the Coral Triangle Region are projected to be threatened, with more than 90 percent in the high, very high, or critical categories (see figure ES-3).

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.

3. Dependence on coral reefs for food, livelihoods, and shoreline protection is high across most of the Coral Triangle Region.

- *People:* Thirty-one percent of people in the Coral Triangle Region – about 114 million people—reside in the direct vicinity of reefs (within 30 km of reefs and less than 10 km from the coast) and are likely to have a high dependence on reefs, especially in rural areas.
- *Food and livelihoods:* The three countries in the world with the greatest numbers of people who fish on reefs are in the Coral Triangle Region: Indonesia, the Philippines, and Papua New Guinea. In both Indonesia and the Philippines, more than one million people are dependent on reef fisheries for their livelihood. In Solomon Islands, more than 80 percent of households engage in fishing.
- *Shoreline protection:* Across all countries of the Coral Triangle Region, coral reefs protect about 45 percent of shorelines from storm damage and erosion. The proportion is highest in Solomon Islands (about 70 percent) and the Philippines (about 65 percent).
- *Tourism:* In both Malaysia and Solomon Islands, tourism is a rapidly expanding segment of the economy and contributed to about 9 percent of each country's gross domestic product (GDP) in 2009. The share of GDP from tourism is about 3 percent in Timor-Leste, 2 percent in the Philippines, and just over 1 percent in Indonesia. In Papua New Guinea, tourism accounts for less than 1 percent of GDP.

4. Social and economic vulnerability to coral reef degradation and loss is extremely high across the Coral Triangle Region.

- Five countries—Indonesia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste—rated in the highest category of vulnerability to coral reef degradation and loss within a global context. The state of Sabah in Malaysia was also rated as having high vulnerability.
- Within the Coral Triangle Region, the Philippines is the most highly vulnerable country because of its highly threatened reefs, very high economic dependence on reefs, and low capacity to adapt to the loss of goods and services provided by reefs.
- Singapore and Brunei Darussalam have low vulnerability to coral reef degradation and loss, owing to their medium dependence on reefs and high capacity to adapt to reef loss.
- The coverage of coral reefs within marine protected areas (MPAs) in the Coral Triangle Region is low compared to the global average, and the management effectiveness of MPAs is generally poor across the region.
- About 16 percent of coral reefs are inside MPAs in the Coral Triangle Region, as compared to the global average of 28 percent.
- Less than 1 percent of reefs are in MPAs rated as effectively managed and only 5 percent are in MPAs rated as partially effective. Eight percent of reefs are in MPAs rated ineffective, and 4 percent are in MPAs with an unknown level of management effectiveness.

Section 1. INTRODUCTION

PHOTO: JEFF YONOVER

CORAL REEFS: VALUABLE BUT VULNERABLE

Coral reefs are among the most biologically rich and productive ecosystems on earth. They provide critical benefits to millions of people living near the coast. 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 overfishing, coastal development, agricultural runoff, and shipping. In addition, the global threat of climate change has begun to compound these more local threats in multiple ways.

Warming seas have already caused widespread damage to reefs.[2-6] High temperatures drive a stress response called coral bleaching, where corals lose their colorful symbiotic algae, exposing their white skeletons and leaving them vulnerable to disease and death. This phenomenon is projected to intensify in coming decades.[7-10]

In addition, increasing carbon dioxide (CO_2) emissions are slowly causing the world's oceans to become more acidic.11 Ocean acidification reduces coral growth rates and, if unchecked, could reduce the reefs' ability to maintain their physical structures.[12-16]

The combination of local threats plus global threats from warming and acidification leads to increasingly degraded reefs. Signs include reduced areas of living coral, increased algal cover, reduced species diversity, and lower fish abundance.[17-19] Degradation of coral is often accelerated by other local impacts from storms, infestations, and diseases.

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 has been monitored over time. The World Resources Institute (WRI) initiated its *Reefs at Risk* series 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.

PURPOSE AND GOAL OF *REEFS AT RISK REVISITED*

Under the *Reefs at Risk Revisited* project, WRI and its partners have developed a new, high-resolution 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 and catalyze changes in policy and practice that could safeguard coral reefs and the benefits they provide to 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. 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 map used in the 1998 analysis. New data on threats are also much improved, with many sources detailing information at 1-km resolution, which is 16 times more detailed than that used in the 1998 analysis.

Like the original *Reefs at Risk,* the new 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 to the loss of reef ecosystem services.

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 (see the acknowledgments for a full list of contributors).

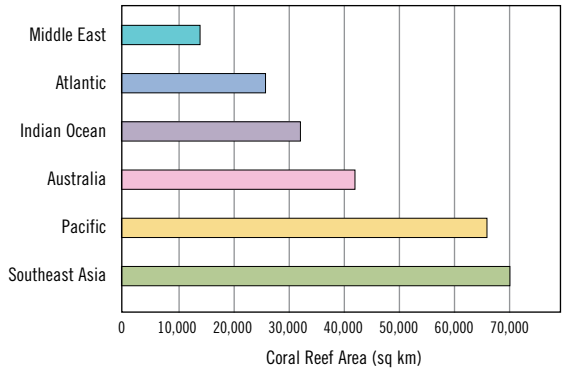
This report provides a summary of *Reefs at Risk Revisited* results for the world, but provides more detailed results for the countries in the Coral Triangle Region, which is the global center of coral diversity. It is intended to support the six national governments of the Coral Triangle Initiative to achieve their regional and national plans of action, which include designating and effectively managing priority seascapes; applying an ecosystem-based approach to management of fisheries and other marine resources; establishing marine protected areas (MPAs), including a region-wide MPA system; achieving climate change adaptation measures; and improving the status of threatened species. A complete description of these goals and other aspects of the six-nation Coral Triangle Initiative can be found at www.coraltrianglei-nitiative.org.

The outputs of *Reefs at Risk Revisited* (report, maps, and spatial data sets), will be valuable to many users, including marine conservation practitioners, resource managers, policy makers, educators, and students. These materials are available on the *Reefs at Risk Revisited* website at www.wri.org/reefs, as well as the Coral Triangle Atlas website ctatlas.reefbase.org.

CORAL REEFS: RAINFORESTS OF THE SEA

Coral reefs are one of the most productive and biologically rich ecosystems on earth. They extend across about 250,000 sq km of the ocean—less than one-tenth of 1 percent of the marine environment—yet they may be home to 25 percent of all known marine species.[20] About 4,000 coral reef-associated fish species and 800 species of reef-building corals have been described to date,[21] though these numbers are dwarfed by the great diversity of other marine species associated with coral reefs, including sponges, urchins, crustaceans, mollusks, and many more (see box 1.1: What is a coral reef?). Figure 1.1 shows the distribution of the world's coral reefs by the regions used in the global *Reefs at Risk Revisited* analysis, depicted in map 1.1.

FIGURE 1.1. GLOBAL DISTRIBUTION OF CORAL REEFS BY REGION



Note: Area of coral reefs (sq km) for each coral reef region of the world. The regions are shown in Map 1.1.

Sources: IMaRS/USF, IRD, NASA, UNEP-WCMC, WorldFish Center, WRI 2011.

BOX 1.1. WHAT IS A CORAL REEF?

Coral reefs are physical structures built by the actions of many tiny coral animals that live in large colonies and lay down communal limestone skeletons. Over millennia, the combined mass of skeletons build up into huge reefs, some of which are visible from space. There are some 800 species of reef-building corals and they have exacting requirements, needing bright, clear, and warm waters. The individual coral animals, known as polyps, have a tubular body and central mouth ringed by stinging tentacles, which can capture food. Living within their body tissues are microscopic algae (zooxanthellae) that need sunlight to survive. These algae convert sunlight into sugars, which produces energy to help sustain their coral hosts. These same algae also provide the corals with their vibrant colors.

The complex three-dimensional surface of the reef provides a home to many other species. Some 4,000 species of fish are found here (approximately one-quarter of all marine fish species), along with a vast array of other life forms—mollusks, crustaceans, sea urchins, starfish, sponges, tube-worms and many more. There are perhaps 1 million species found in a habitat that covers a total of about 250,000 sq km (roughly the area of the United Kingdom).[22]

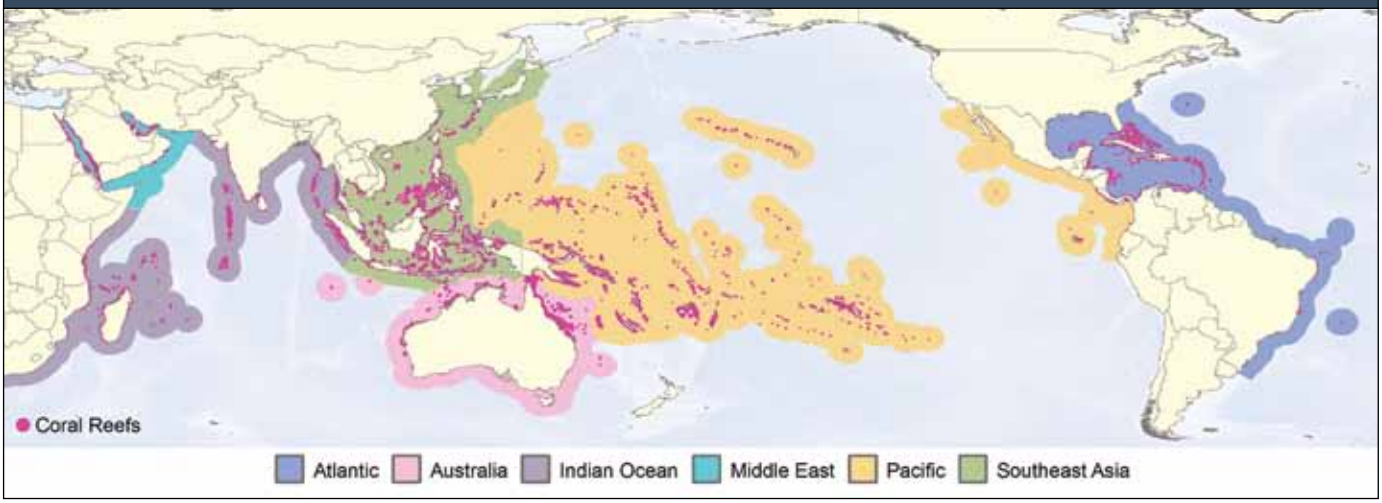

PHOTO: MARK GODFREY

THE CORAL TRIANGLE: THE CENTER OF MARINE BIODIVERSITY

Spanning parts of insular Southeast Asia and the western Pacific, the Coral Triangle is recognized as the global center of marine biological diversity, with the highest coral diversity in the world—76 percent of all coral species—as well as the highest diversity of coral reef fishes in the world—37 percent of all species.[1] The area within the ecological boundary of the Coral Triangle (shown in green in map 1.2) contains nearly 73,000 sq km of coral reefs—29 percent of the global total—and spans parts of six countries: Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste. These six countries have signed and agreed to a regional plan of action called the Coral Triangle Initiative, a collaboration that aims to protect this important area, and each have developed national plans of action that are aligned with the regional plan. Together, the regional and national plans serve as the road map for joint and cooperative action to achieve the goals of the Coral Triangle Initiative, which focus on reducing threats in order to preserve the marine, coastal, and small-island ecosystems of this area (see section 6 for additional information about the Coral Triangle Initiative).

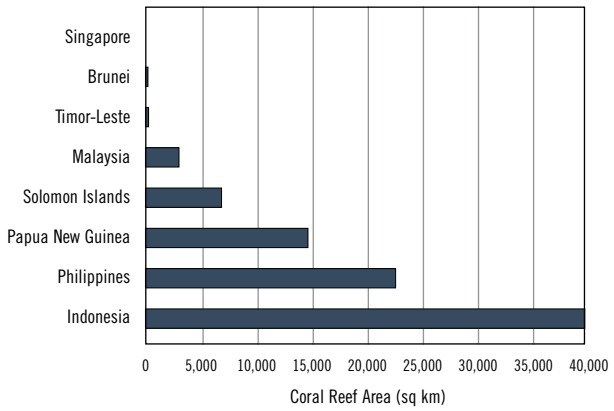
In this report, we refer to the area within the ecological boundary of the Coral Triangle, which designates the area of the world's highest marine biodiversity, as the Coral Triangle Core. However, because the Coral Triangle Core is defined entirely by biological and not political considerations, we have based this report on a broader, politically

MAP 1.1. MAJOR CORAL REEF REGIONS OF THE WORLD AS DEFINED FOR THE GLOBAL *REEFS AT RISK REVISITED* ANALYSIS



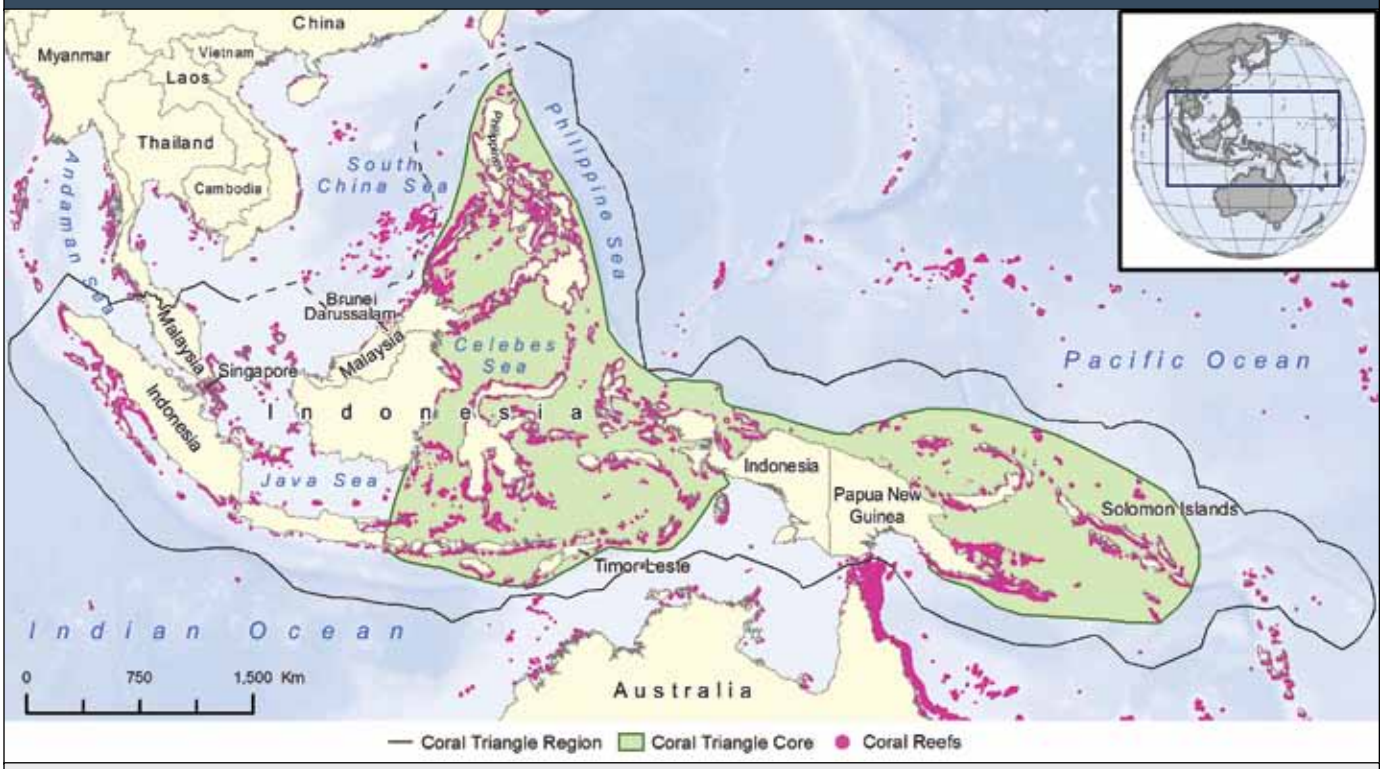
defined area we call the Coral Triangle Region (shown with a dashed line in map 1.2). The Coral Triangle Region includes the full exclusive economic zones (EEZs) of Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste, which make up the official implementation area of the Coral Triangle Initiative as agreed by these nations under the 2009 Coral Triangle Initiative Declaration. As defined in this report, the Coral Triangle Region also includes the adjacent nations of Brunei Darussalam and Singapore, which are not a part of the Coral Triangle Initiative. These eight countries are included on all maps and in regional summary statistics in this report. The Coral Triangle Region contains more than 86,500 sq km of coral reef area, which represents 35 percent of the global total (figure 1.2).

FIGURE 1.2. CORAL REEF AREA PER COUNTRY IN THE CORAL TRIANGLE REGION



Sources: IMaRS/USF, IRD, NASA, UNEP-WCMC, WorldFish Center, and WRI, 2011.

MAP 1.2. THE CORAL TRIANGLE REGION



Note: The "Coral Triangle Region" as defined in this report includes the full exclusive economic zones (EEZs) of the six countries of the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security (CTI-CFF), which is the official CTI-CFF Implementation Area, plus the adjacent nations of Brunei Darussalam and Singapore. The dashed line represents disputed EEZ boundaries; a boundary for Brunei Darussalam is not known. The "Coral Triangle Core" as defined in this report represents the scientific boundary of highest coral biodiversity in the world (more than 500 species). Boundaries are presented here for illustrative purposes and are not legally binding in any way.

WHY REEFS MATTER

Dynamic and highly productive, coral reefs are not only a critical habitat for numerous species, but also provide essential ecosystem services upon which millions of people depend.

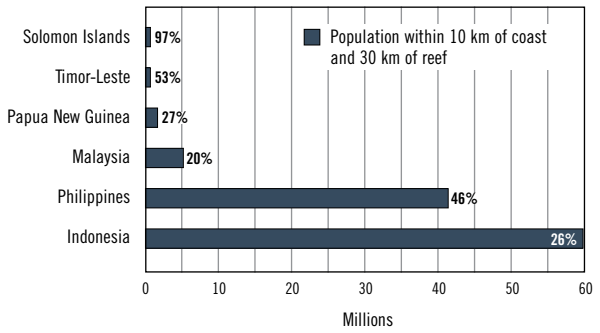
- *Food and livelihoods.* One-eighth of the world's population—roughly 850 million people—live within 100 km of a coral reef and are likely to derive some benefits from the ecosystem services that coral reefs provide. More than 275 million people globally live very close to reefs (less than 10 km from the coast and within 30 km of reefs), where dependence on coral reefs for food and livelihoods is high.[23] In such areas, reef fish species are an important source of protein, contributing as much as one-quarter of the total fish catch in some developing countries.[24] A healthy, well-managed reef in the Indian or Pacific Oceans can yield between 5 and 15 tons of seafood per sq km per year.[25,26]

  Within the countries of the Coral Triangle Region, the proportion of people who depend on coral reefs is much higher. Eighty-eight percent of people in this region—nearly 320 million people—live within 100 km of a coral reef. Thirty-one percent of the population—about 114 million people—live very close to reefs (within 30 km) and are likely to have a high dependence on reefs (figure 1.3).

- *Tourism.* Coral reefs are vital to tourism interests in many tropical countries. They attract divers, snorkelers, and recreational fishers, and also provide much of the white sand for beaches. Globally, more than 100 countries and territories benefit from tourism associated with coral reefs. Tourism contributes more than 15 percent of GDP in more than 20 of these countries.[27,28]

  Among countries of the Coral Triangle Region, in both Malaysia and Solomon Islands tourism is a rapidly expanding segment of the economy and contributed about 9 percent of GDP in 2009. The share of GDP from tourism is about 3 percent in Timor-Leste, 2 percent in the Philippines, and just over 1 percent in Indonesia, where tourism has grown rapidly over the past five years.[29] In Papua New Guinea, tourism accounts for less than 1 percent of GDP.[30]

FIGURE 1.3. NUMBER OF PEOPLE IN THE CORAL TRIANGLE REGION LIVING NEAR CORAL REEFS IN 2007



Note: Percentages represent proportion of total national population that is within 10 km of coast and 30 km of reef.

Source: WRI, using Landscan 2007 population data.

- *Shoreline protection.* Beyond their biological value, the physical structures of coral reefs protect an estimated 150,000 km of shoreline in more than 100 countries and territories.[31] Reefs dissipate wave energy, reducing routine erosion and lessening inundation and wave damage during storms. This function protects human settlements, infrastructure, and valuable coastal ecosystems such as seagrass meadows and mangrove forests.[32,33] Some countries—especially low-lying atolls such as the Maldives, Kiribati, Tuvalu, and the Marshall Islands, as well as the Carteret Islands in Papua New Guinea and many other small islands throughout the Coral Triangle—have been built entirely by coral reefs and would not exist but for their protective fringe.

  Across the Coral Triangle Region, about 45 percent of shorelines are protected by coral reefs. The proportion of protected shoreline is highest in Solomon Islands (70 percent) and the Philippines (65 percent).[34] The annual net economic benefits of shoreline protection from reefs was estimated at $387 million for Indonesia and $400 million for the Philippines in 2000 (converted to US$ 2010).[35] These values are likely much higher today due to increased development, and hence increased numbers of coastal properties at risk.

- *Treatments for disease.* Many reef-dwelling species have developed complex chemical compounds, such as venoms and chemical defenses, to aid their survival in these highly competitive habitats. Many such compounds have

BOX 1.2. METHOD FOR ANALYZING THREATS TO REEFS

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 are:

- Coastal development, including coastal engineering, runoff from coastal construction, sewage discharge, and impacts from unsustainable tourism.
- Watershed-based pollution, focusing on erosion and nutrient fertilizer runoff from agriculture delivered to coastal waters from rivers.
- 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.

Each of the four local threats were modeled separately and subsequently combined in the Reefs at Risk integrated local threat index. For each local threat, an indicator was developed using data reflecting various "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. Threat diminishes with distance from each stressor. 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.

The analysis method is of necessity a simplification of human activities and complex natural processes. The model relies on available data and predicted relationships, but cannot capture all aspects of the dynamic interactions between people, climate, and coral reefs. Climate change science, in particular, is a relatively new field in which the complex interactions between reefs and their changing environment are not yet fully understood. The threat indicators gauge current and potential risks associated with human activities, climate change, and ocean acidification. A strength of the analysis lies in its use of globally consistent data sets to develop global indicators of human pressure on coral reefs. We purposefully use a conservative approach to the modeling, in which thresholds for threat grades are set at reasonably high levels to avoid exaggeration.

Full technical notes, including data sources and threat category thresholds, and a list of data contributors are available online at http://www.wri.org/reefs.

the potential to form the basis of life-saving pharmaceuticals. Explorations into the medical application of reef-related compounds to date include treatments for cancer, HIV, malaria, and other diseases.[36] Since only a small portion of reef life has been sampled, there is still vast potential for new pharmaceutically valuable discoveries.[36]

Section 2. LOCAL AND GLOBAL THREATS TO CORAL REEFS

PHOTO: WOLCOTT HENRY

Despite their importance, coral reefs in the Coral Triangle Region and around the world face unprecedented threats throughout most of their range. Some threats are highly visible and occur directly on reefs. For example, levels of fishing are currently unsustainable on a large proportion of the world's reefs,[26,37] and have led to localized extinctions of certain fish species, collapses and closures of fisheries, and marked ecological changes.[38-40] Other threats are the result of human activities that occur far removed from the reefs. Forest clearing, crop cultivation, intensive livestock farming, and poorly planned coastal development have increased sediments and nutrient runoff into coastal waters, smothering some corals and contributing to overgrowth of algae.

Beyond these extensive and damaging local-scale impacts, reefs are increasingly at risk from the global threats associated with rising concentrations of greenhouse gases in the atmosphere. Even in areas where local stresses on reefs are relatively minimal, warming seas have caused widespread damage to reefs through mass coral bleaching, which occurs when corals become stressed and lose, *en masse*, the zooxanthellae that normally live within their tissues and provide the coral with food.

Increasing concentrations of carbon dioxide (CO_2) in the atmosphere, the result of deforestation and the burning of fossil fuels, are also changing the chemistry of ocean waters. About 30 percent of the CO_2 emitted by human activities is absorbed into the surface layers of the oceans, where it reacts with water to form carbonic acid.[11] This subtle acidification has profound effects on the chemical composition of seawater, especially on the availability and solubility of mineral compounds such as calcite and aragonite, which corals and other organisms need to build their skeletons.[12-16] Initially these changes to ocean chemistry are expected to slow the growth of corals, and may weaken their skeletons. Continued acidification will eventually halt all coral growth and begin to drive a slow dissolution of carbonate structures such as reefs.[41]

It is rare for any reef to suffer only a single threat. More often the threats are compounded. For instance, overfishing eliminates key herbivores that graze on algae, while runoff from agriculture supplies nutrients that cause algal blooms; together, these impacts reduce the abundance or impair the growth of coral. A reef left vulnerable by one threat can be pushed to ecological collapse by the addition of a second.[17,18]

These threats cause ecological imbalances that can leave corals more exposed to other, more "natural" types of threats. For instance, crown-of-thorns starfish (COTS), which prey on corals, occur naturally on many reefs, but outbreaks of COTS (i.e., sudden, significant increases in density) are now occurring with increased frequency, often in conjunction with other threats or following coral bleaching events. Additionally, corals that are already under stress are more vulnerable to disease. Although diseases are a natural feature in any ecosystem, coral diseases have increased in both prevalence and geographic distribution in recent years.[42] The drivers of these increases are still not clearly understood, but it is probable that corals have become more susceptible to disease as a result of degraded water quality and warming seas.[43] There is also strong evidence that disease outbreaks have followed coral bleaching events.[44] Given that diseases are often more problematic where corals are already under stress, management measures such as protecting water quality, preserving functional diversity, and reducing other threats to reefs may help to lessen the occurrence and impacts of disease.[45] Such efforts to reduce local threats also promote resilience in coral reefs—increasing the likelihood of recovery after coral bleaching.[46,47]

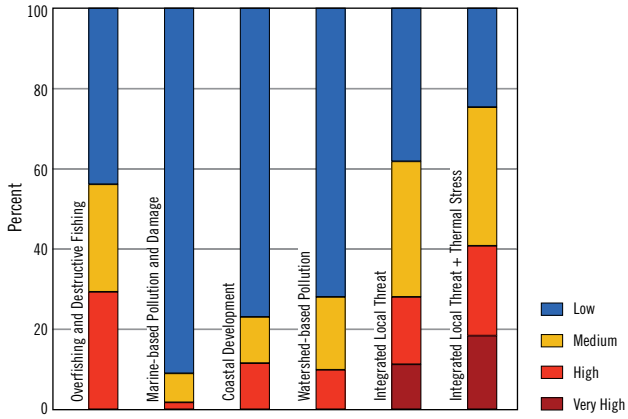
The following sections provide (1) summaries of the distribution and severity of threats to coral reefs globally and in the Coral Triangle Region; (2) details of local threats to reefs in the Coral Triangle Region; and (3) a summary of future threats to reefs for the world and for the Coral Triangle Region.

PRESENT THREATS TO CORAL REEFS—GLOBAL SUMMARY

Our analysis indicates that more than 60 percent of the world's reefs are under immediate and direct threat from one or more local sources, including overfishing and destructive fishing, coastal development, watershed-based pollution, and marine-based pollution and damage (see map inside front cover).

- 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 the world's reefs.

FIGURE 2.1. REEFS AT RISK FROM INDIVIDUAL LOCAL THREATS AND ALL THREATS INTEGRATED



Note: The first four columns reflect individual, local threats to the world's coral reefs. The fifth column (integrated local threat) reflects the four local threats combined, while the sixth column also includes past thermal stress.

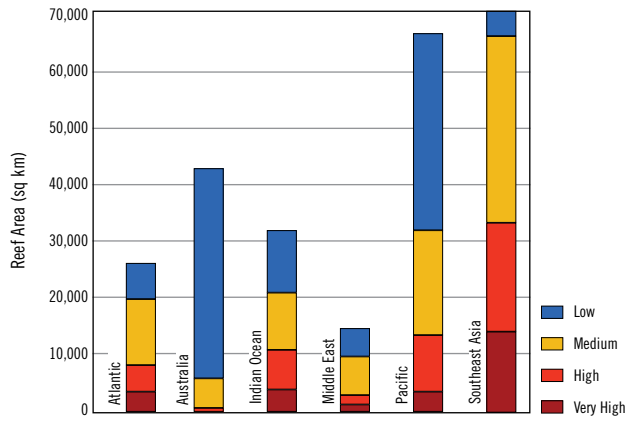
- Marine-based pollution and damage from ships is widely dispersed, threatening about 10 percent of reefs globally (figure 2.1).

Mapping of past thermal stress on coral reefs (1998–2007) suggests that almost 40 percent of coral reefs have experienced water temperatures warm enough to induce severe coral bleaching on at least one occasion since 1998. Approximately 75 percent of the world's coral reefs are rated as threatened when local threats are combined with thermal stress (figure 2.1, column 6), which reflects the recent impacts of rising ocean temperatures, linked to the widespread weakening and mortality of corals due to mass coral bleaching.

Table 2.1 provides a summary of integrated threat to coral reefs by region, both globally and for the countries of the Coral Triangle Region.

- Southeast Asia, where most of the Coral Triangle Region's reefs are located, is the region most affected by local threats. In Southeast Asia, 95 percent of reefs are threatened (figure 2.2).
- Australia is the region with the lowest percentage of threatened reefs (14 percent).
- The Pacific, where about 50 percent of reefs are threatened, has experienced the largest increase in threat over the past ten years.

FIGURE 2.2. REEFS AT RISK FROM INTEGRATED LOCAL THREATS (by area of reef)



Note: Amount of reef area (in sq km) in each region classified by integrated local threat.

PRESENT THREATS TO CORAL REEFS IN THE CORAL TRIANGLE REGION

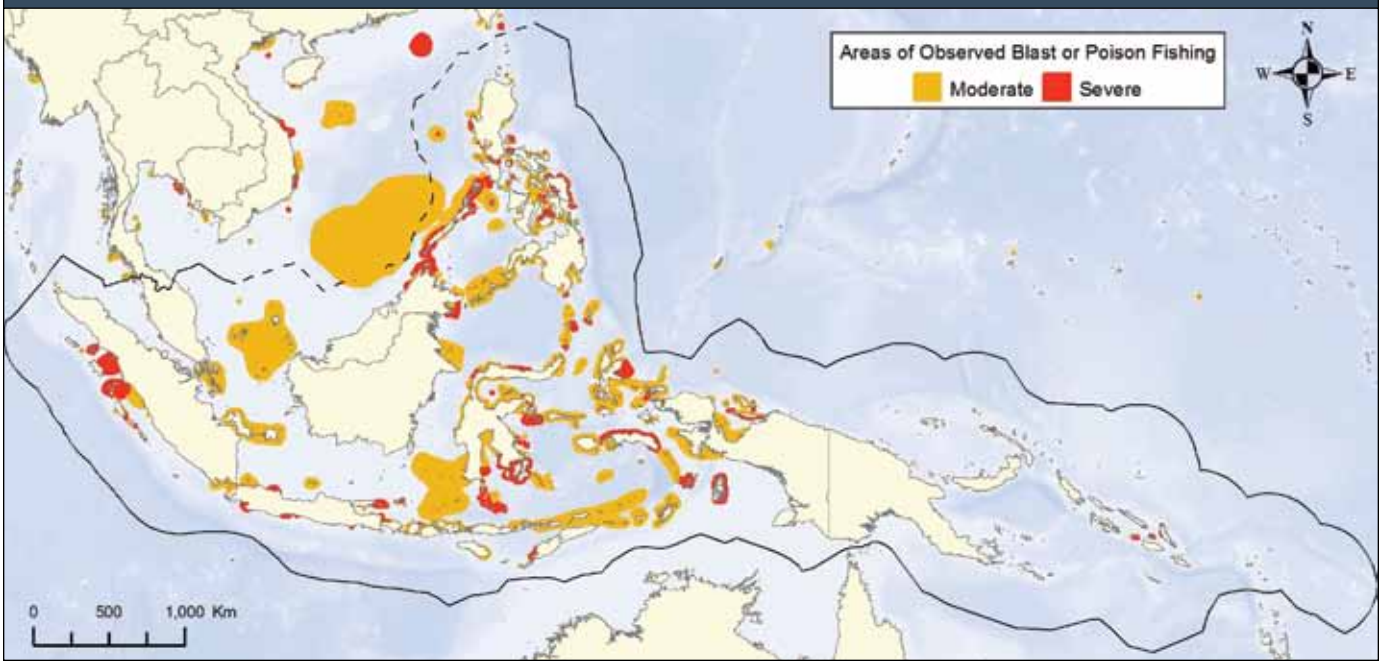
Local pressure on coral reefs within the Coral Triangle Region is high compared to the global average. Within the countries of this region, more than 85 percent of reefs are rated as threatened, with nearly 45 percent at high or very high risk (map 2.2). Overfishing, including destructive fishing, is the most pervasive and damaging threat, affecting nearly 85 percent of reefs. Destructive fishing—the use of explosives and poisons to kill or capture fish—is common throughout much of the Coral Triangle Region, particularly in East Malaysia, the Philippines, and Indonesia, threatening nearly 60 percent of the region's reefs (map 2.1).

Threats emanating from land-based sources contribute significantly to overall threat as well. Watershed-based pollution threatens 45 percent of the region's reefs, while coastal development threatens more than 30 percent. Marine-based pollution and damage are the least pervasive threats across the Coral Triangle Region, threatening fewer than 5 percent of reefs (figure 2.3).

When the effects of recent thermal stress and coral bleaching are combined with local threats, the estimate of threat to reefs across the region increases to more than 90 percent, with the percent of reefs rated at high or very high increasing to nearly 55 percent (column 6 of figure 2.3).

In the Philippines, Malaysia, and Timor-Leste, nearly all reefs are rated as threatened by one or more local threats. In Indonesia, this measure is only slightly lower, at about 93 percent. Solomon Islands and Papua New Guinea have lower percentages of threatened reefs, at about 70 percent and 55 percent, respectively (figure 2.4). Table 2.1 provides a summary of threat for the eight countries in the Coral Triangle Region. Map 2.2 reflects the distribution of present integrated local threat to reefs. These threats have increased significantly across the region over the past ten years (box 2.1).

MAP 2.1. OBSERVATIONS OF BLAST OR POISON FISHING IN THE CORAL TRIANGLE REGION



MAP 2.2. REEFS AT RISK IN THE CORAL TRIANGLE REGION

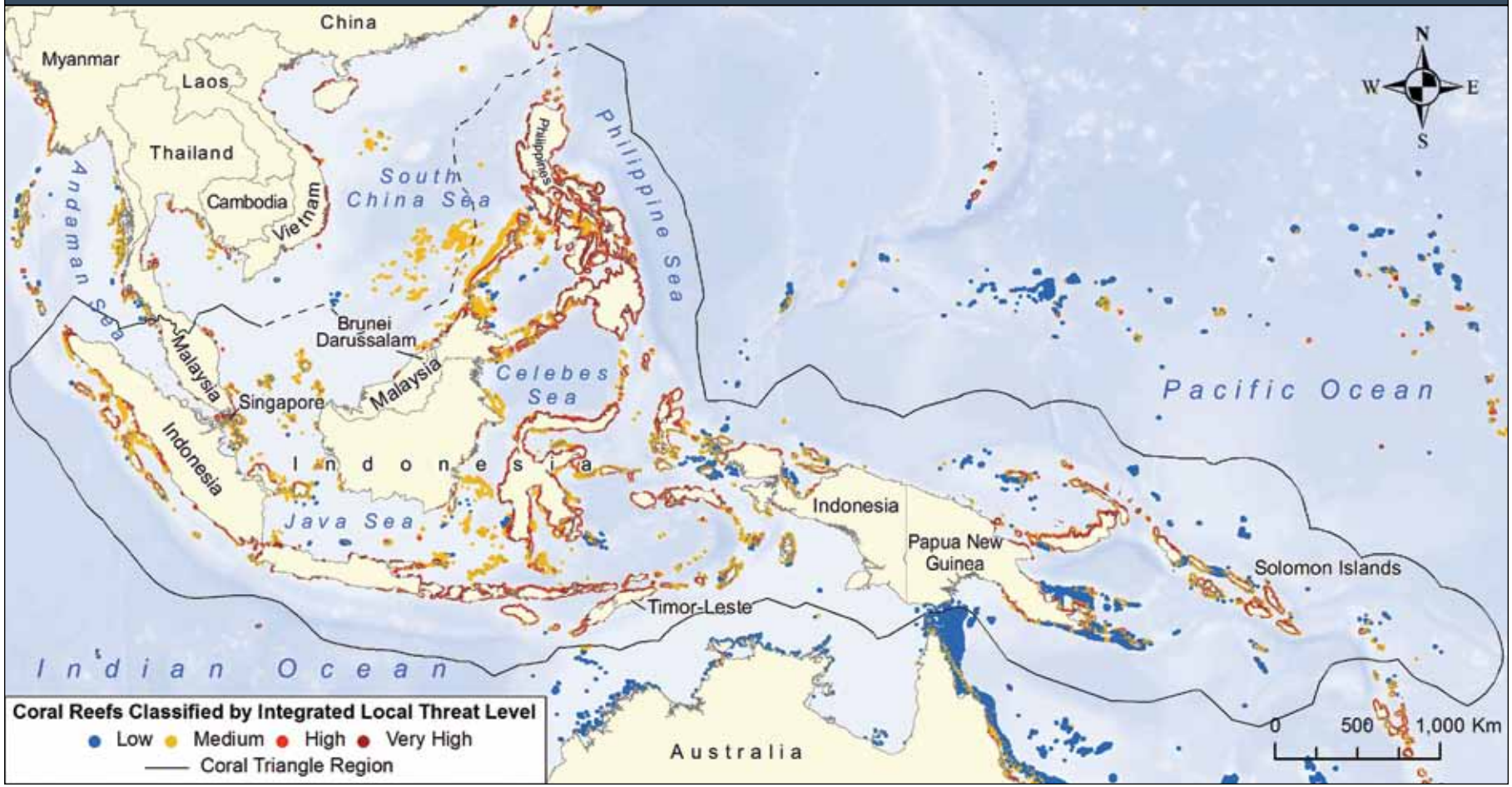


TABLE 2.1 INTEGRATED THREAT TO CORAL REEFS FOR GLOBAL "REEFS AT RISK" REGIONS AND FOR THE COUNTRIES OF THE CORAL TRIANGLE REGION

Region	Reef Area (sq km)	Reef area as percent of global	Integrated Local Threat					Severe thermal stress (1998 – 2007) (%)	Integrated Local + Thermal Threat (medium or higher) (%)	Coastal Population (within 30 km of reef)[a] '000	Reef Area in MPAs (%)
			Low (%)	Medium (%)	High (%)	Very High (%)	Threatened (medium or higher) (%)				
Atlantic	25,849	10	25	44	18	13	75	56	92	42,541	30
Australia	42,315	17	86	13	1	0	14	33	40	3,509	75
Indian Ocean	31,543	13	34	32	21	13	66	50	82	65,152	19
Middle East	14,399	6	35	44	13	8	65	36	76	19,041	12
Pacific	65,972	26	52	28	15	5	48	41	65	7,487	13
Southeast Asia	69,637	28	6	47	28	20	94	27	95	138,156	19
Global	**249,713**	**100**	**39**	**34**	**17**	**10**	**61**	**38**	**75**	**275,886**	**28**
Countries of the Coral Triangle Region											
Brunei Darussalam	109	<1	0	94	6	0	100	49	100	323	<1
Indonesia	39,538	16	7	55	26	12	93	16	93	59,784	29
Malaysia[b]	2,935	1	1	56	34	9	99	9	100	5,065	7
Papua New Guinea	14,535	6	45	26	22	7	55	54	78	1,570	5
Philippines[b]	22,484	9	2	30	34	34	98	47	99	41,283	7
Singapore	13	<1	0	0	0	100	100	100	100	4,497	6
Solomon Islands	6,743	3	29	42	24	6	71	36	82	540	6
Timor-Leste	146	<1	0	8	48	43	100	0	100	564	0
Coral Triangle Region	**86,503**	**35**	**14**	**43**	**27**	**16**	**86**	**32**	**92**	**113,626**	**16**

Notes:

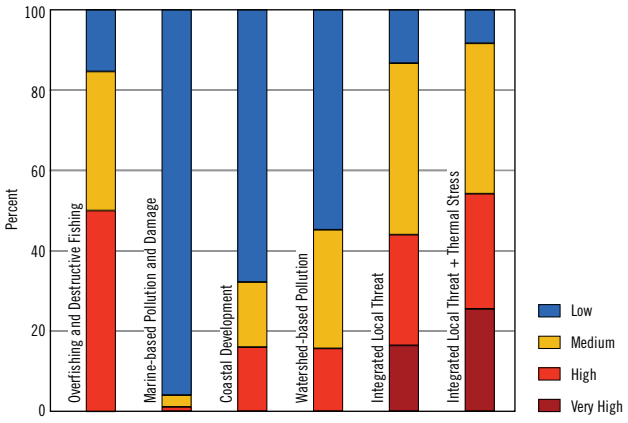
a. Population statistics represent the human population living less than 10 km from the coast as well as within 30 km of a coral reef.

b. Statistics for the Philippines and Malaysia do not include disputed territory in the South China Sea.

Sources:

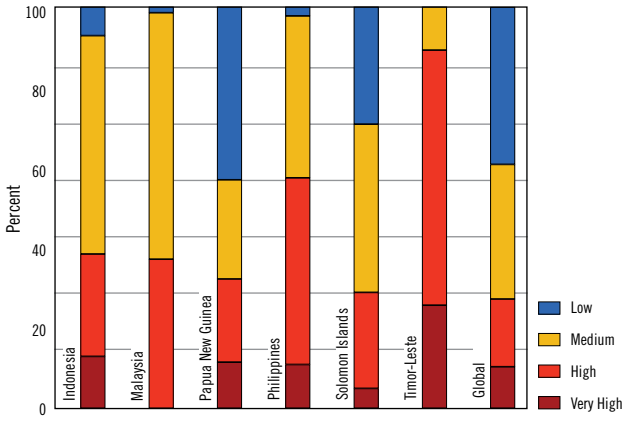
1. **Reef area estimates:** Calculated at WRI based on 500-m resolution gridded data assembled under the Reefs at Risk Revisited project from Institute for Marine Remote Sensing, University of South Florida (IMaRS/USF), Institut de Recherche pour le Développement (IRD/UR), UNEP-WCMC, The World Fish Center, and WRI (2011).
2. **Coastal population within 30 km of reef:** Derived at WRI from LandScan population data (2007) and World Vector Shoreline (2004).
3. **Number of MPAs:** Compiled at WRI from the World Database of Protected Areas (WDPA), ReefBase Pacific, The Nature Conservancy, the Coral Triangle Atlas, the Indonesian Ministry of Marine Affairs and Fisheries, and the Great Barrier Reef Marine Park Authority.

FIGURE 2.3. REEFS AT RISK FROM INDIVIDUAL LOCAL THREATS AND ALL THREATS INTEGRATED IN THE CORAL TRIANGLE REGION



Note: The first four columns reflect individual, local threats to the region's coral reefs. The fifth column (integrated local threat) reflects the four local threats combined, while the sixth column also includes past thermal stress.

FIGURE 2.4. REEFS AT RISK FROM INTEGRATED LOCAL THREATS FOR THE COUNTRIES OF THE CORAL TRIANGLE 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.

LOCAL THREATS TO CORAL REEFS IN THE CORAL TRIANGLE REGION

Coastal Development

Development in the coastal zone—linked to human settlements, industry, aquaculture, or infrastructure—can have profound effects on nearshore ecosystems. Impacts of coastal development on the reef can occur either through direct physical damage such as dredging or land filling, or indirectly through increased runoff of sediment, pollution, and sewage.

Development along the coast threatens more than 30 percent of the Coral Triangle Region's reefs, with more than 15 percent of reefs under high threat. Threat is particularly high in the Philippines, where dense coastal populations and development threaten more than half of reefs (map 2.3).

Watershed-based Pollution

Human activities far inland can impact coastal waters and coral reefs. As forests are cut or pastures plowed, erosion adds sediment to rivers. In the Coral Triangle Region, where land clearing and cultivation frequently occur on steep slopes and in places with heavy rainfall, this effect is even more pronounced.

Runoff of fertilizers and pesticides also flow via rivers to reefs. Livestock can compound these problems through overgrazing or runoff of livestock waste. Once they reach the coast, sediments, nutrients, and pollutants disperse into adjacent waters.[48] Mangroves and seagrass beds, which can help to trap sediments and remove nutrients from the water, can reduce these impacts on reefs.[49,50]

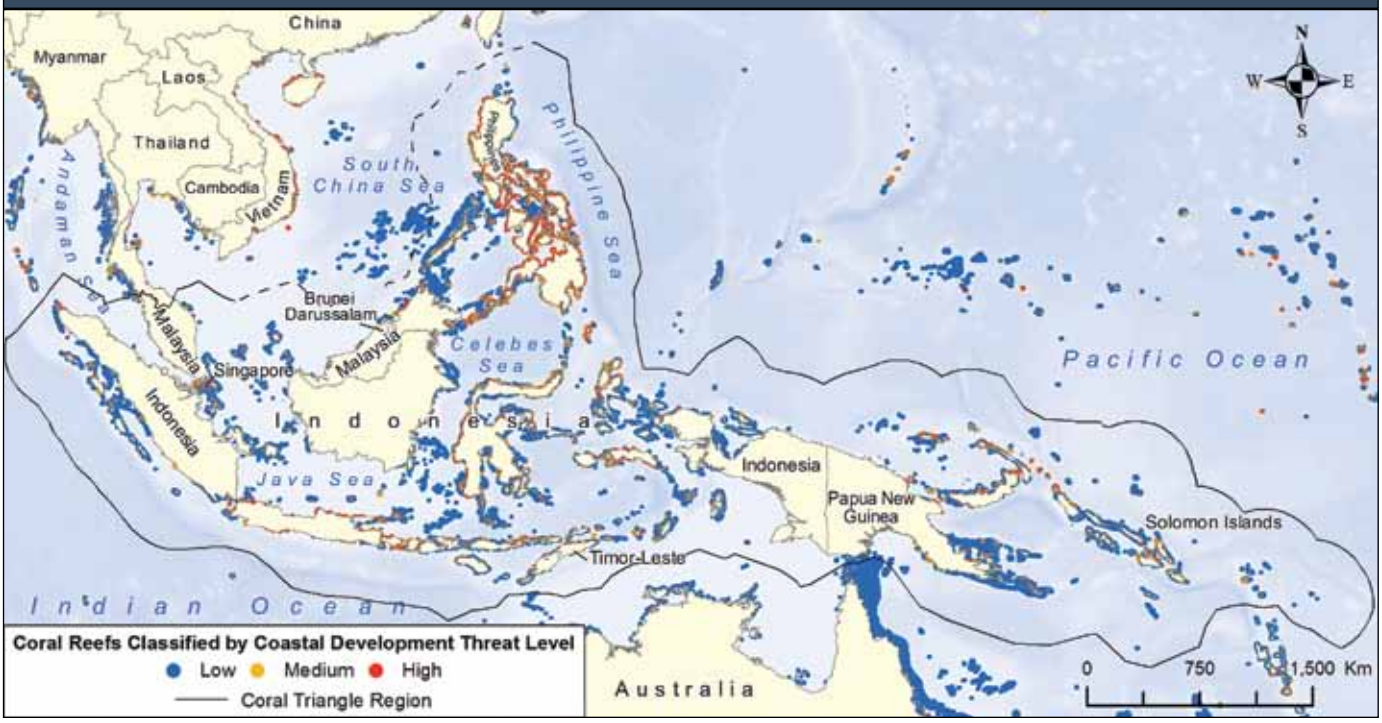
More than 45 percent of the Coral Triangle Region's reefs are threatened by watershed-based sediment and pollution, with more than 15 percent considered to be highly threatened. This threat is particularly high in much of the Philippines, central Indonesia, Timor-Leste, and parts of Solomon Islands (map 2.4).

Marine-based Pollution and Damage

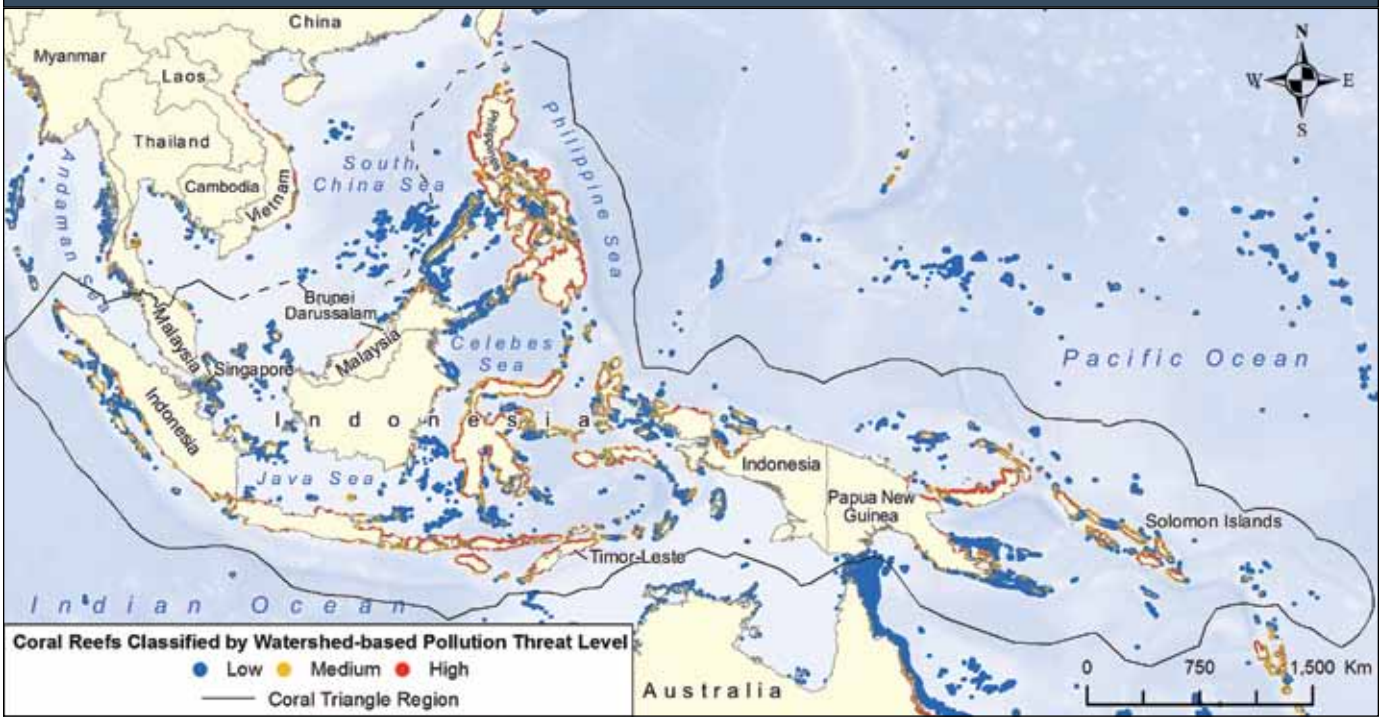
Commercial, recreational, and passenger vessels can threaten reefs with contaminated bilge water, fuel leakages, raw sewage, solid waste, and invasive species. In addition, reefs are exposed to more direct physical damage from groundings, anchors, and oil spills.

Marine-based sources of pollution and damage threaten an estimated 4 percent of reefs across the Coral Triangle Region. This pressure is widely dispersed, emanating from ports and widely distributed shipping lanes. In the region, Singapore

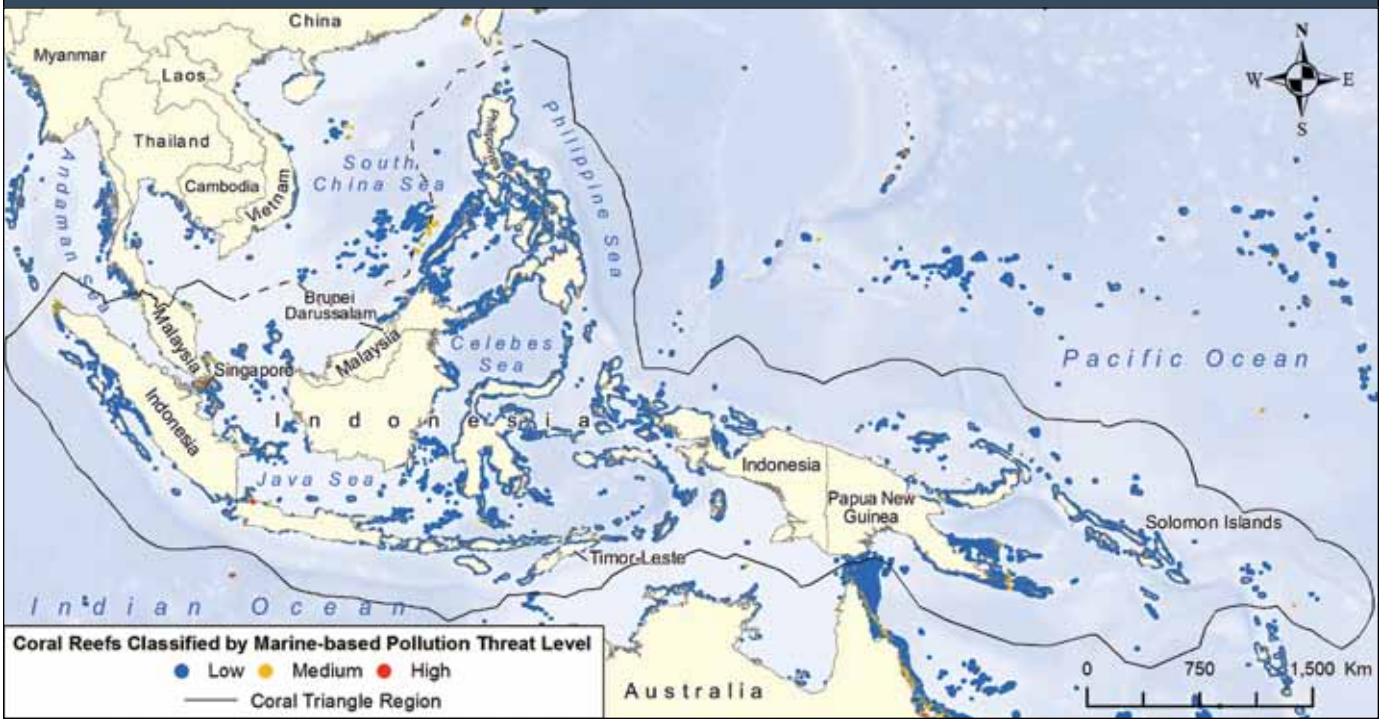
MAP 2.3. REEFS THREATENED BY COASTAL DEVELOPMENT IN THE CORAL TRIANGLE REGION



MAP 2.4. REEFS THREATENED BY WATERSHED-BASED POLLUTION IN THE CORAL TRIANGLE REGION



MAP 2.5. REEFS THREATENED BY MARINE-BASED POLLUTION AND DAMAGE IN THE CORAL TRIANGLE REGION



and Brunei Darussalam are the countries with the highest percentages of reefs threatened by marine-based stressors. The threat to reefs in Timor-Leste, the Philippines, and Malaysia is also above the average for the Coral Triangle Region (map 2.5).

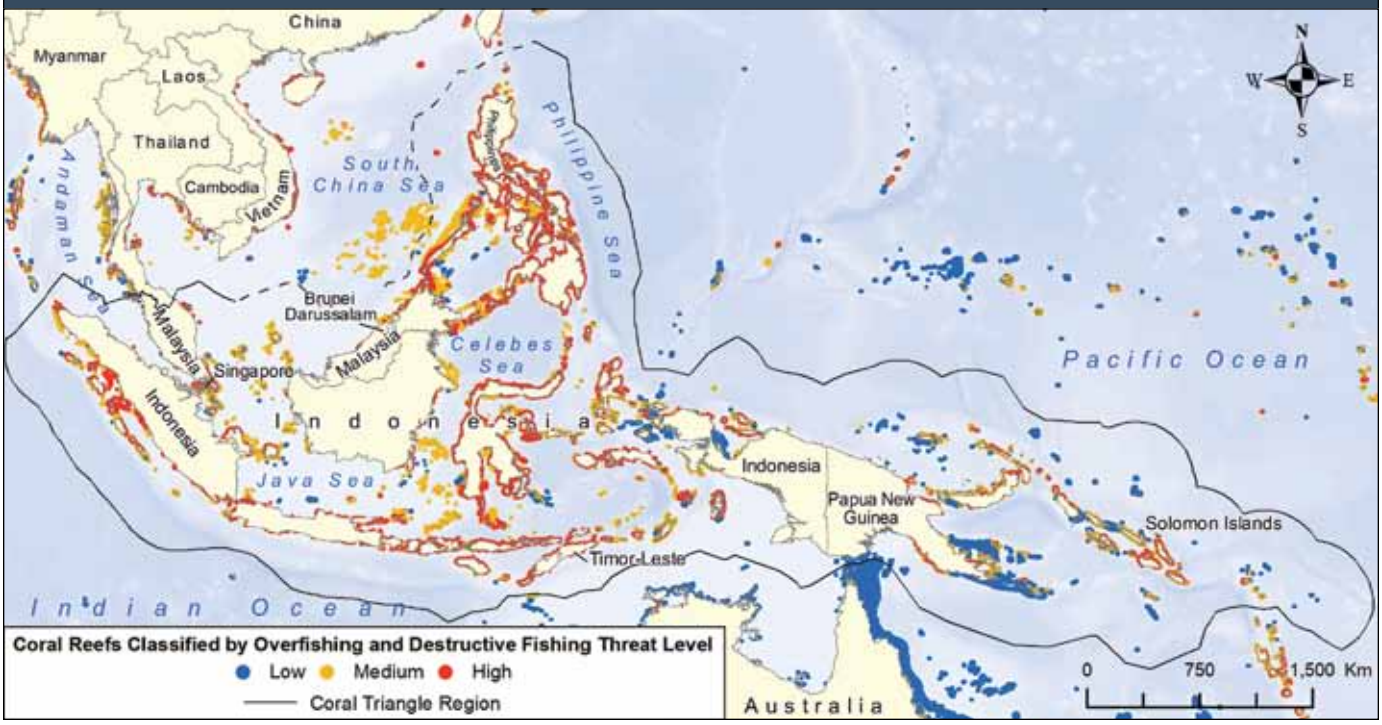
Overfishing and Destructive Fishing

Within the Coral Triangle Region, nearly 114 million people live on the coast within 30 km of a coral reef;[53] as a result, fishing pressure is high on many reefs. Although well-managed reef fisheries can be a sustainable resource, growing coastal populations, more efficient fishing methods, and increasing demands from tourism and international markets have significantly impacted fish stocks throughout the region.[54-56] Heavily fished reefs are left with mostly small fish and are prone to algal overgrowth due to the absence of larger herbivores to graze the algae. Overfished reefs also appear to be generally less resilient to stressors, more vulnerable to disease, and slower to recover from other human impacts.[57-59]

Destructive fishing methods, such as the use of explosives to kill fish, often destroy coral reefs in the process.[60] Although illegal in many countries, blast (or dynamite) fishing remains a persistent threat, particularly in the Coral Triangle.[61,62] Poison fishing is also destructive to corals. This practice typically involves using cyanide to stun and capture fish alive for the lucrative live reef food fish or aquarium fish trades. The poison can bleach corals and kill polyps. Fishers often break corals to extract the stunned fish, while other species in the vicinity are killed or left vulnerable to predation.[63,64]

Unsustainable fishing is the most pervasive of all local threats to coral reefs across the Coral Triangle Region. Nearly 85 percent of reefs are threatened by overfishing and/or destructive fishing, with 50 percent considered highly threatened. Destructive fishing alone threatens nearly 60 percent of the region's reefs (map 2.1). Virtually all reefs in the Philippines, Malaysia, and Timor-Leste are rated as threatened by unsustainable fishing. Only Papua New Guinea and Solomon Islands have significant areas of reef under low levels of threat from unsustainable fishing due to their remoteness from major population centers (map 2.6).

MAP 2.6. REEFS THREATENED BY OVERFISHING AND DESTRUCTIVE FISHING IN THE CORAL TRIANGLE REGION

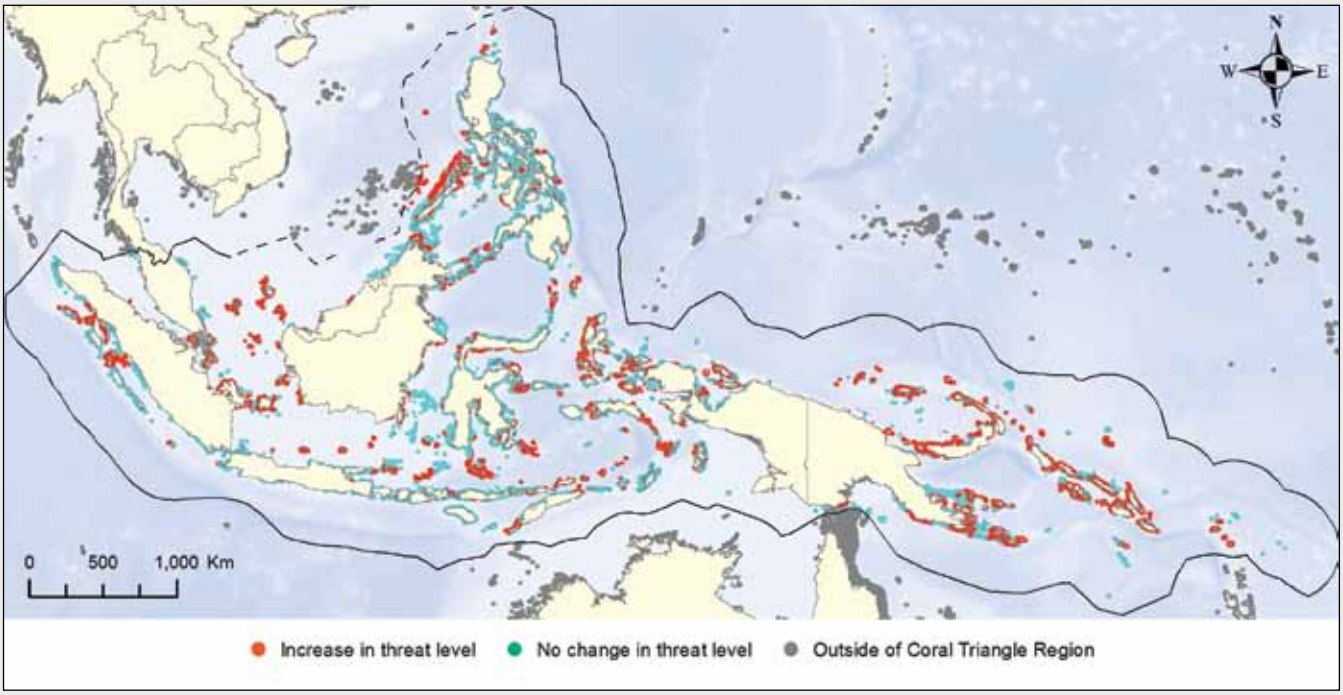


BOX 2.1. TEN YEARS OF CHANGE IN THE CORAL TRIANGLE REGION

Human pressures on reefs have increased significantly within the Coral Triangle Region in the 10 years since the first Reefs at Risk report was released in 1998. Comparing data from 1998 and 2007, we found that the level of threat from local activities increased on about 40 percent of reefs during this period. Fifteen percent of reefs in the Coral Triangle Region that were not considered threatened in 1998 are now rated as threatened, and 25 percent of reefs that were already threatened shifted to a higher threat category. The increase in threat was particularly extensive around Papua New Guinea and Solomon Islands, where threat ratings increased on more than 60 percent of reefs. Map 2.3 indicates where the threat rating for integrated local threats increased between 1998 and 2007.

The greatest driver of increased pressure on reefs since 1998 has been an increase in overfishing and destructive fishing. This change is largely due to the growth in coastal populations living near reefs. In addition, threats to reefs from coastal development and watershed-based pollution have increased since 1998.

MAP 2.7. CHANGE IN LOCAL THREAT BETWEEN 1998 AND 2007 IN THE CORAL TRIANGLE REGION



Note: These results use the 1998 modeling methodology, with new coral reef and threat data.

BOX 2.2 REEF STORY

Philippines: Community Preservation of Mangroves Creates an Eco-Tourism Destination

Ang Pulo is a small, uninhabited island located just off the coast of Calatagan in the province of Batangas, Philippines. Over several decades, the island, which once supported a dense and thriving mangrove forest, became more like a desert due to the continued removal of mangrove trees for fuel and building materials. At the same time, local fishers began reporting smaller catches around the degraded coastline. The local community, led by youth leader Hannah Esguerra, initiated an effort to reclaim the island's former beauty and the services that mangroves provide, such as habitat for valuable fisheries species and coastal protection from erosion and storm surges. They successfully lobbied the barangay (local government unit) to declare the island a protected area, leading to the establishment of the Ang Pulo Mangrove Conservation Park in 2009.

Since then, community-led replanting and conservation efforts have transformed the barren island into a thriving mangrove forest once again. Supported by the Coral Triangle Support Partnership, Conservation International is working with the municipal government to rehabilitate the mangrove forest and construct a deck and walkway around the island that allows tourists to explore the mangroves. The park's eco-tourism potential provides additional income opportunities for villagers in Calatagan who have started new ventures, which include ferrying and guiding visitors to the island and selling souvenirs and food to tourists. Since the mangrove rehabilitation began, fishers have also seen their catches improve. Such benefits have made community members highly protective of the park and active in its operation. The park regularly hosts local volunteers, students, and youth campers who visit the island to learn about nature and participate in mangrove replanting activities. The success at Ang Pulo has already inspired the declaration of other protected mangrove areas in the nearby towns of San Juan and Lobo in Batangas, and Calapan City in Silangang Mindoro.[51,52]

PHOTO: CHERYL VENTURA/CTSP-CI

FUTURE THREATS TO CORAL REEFS

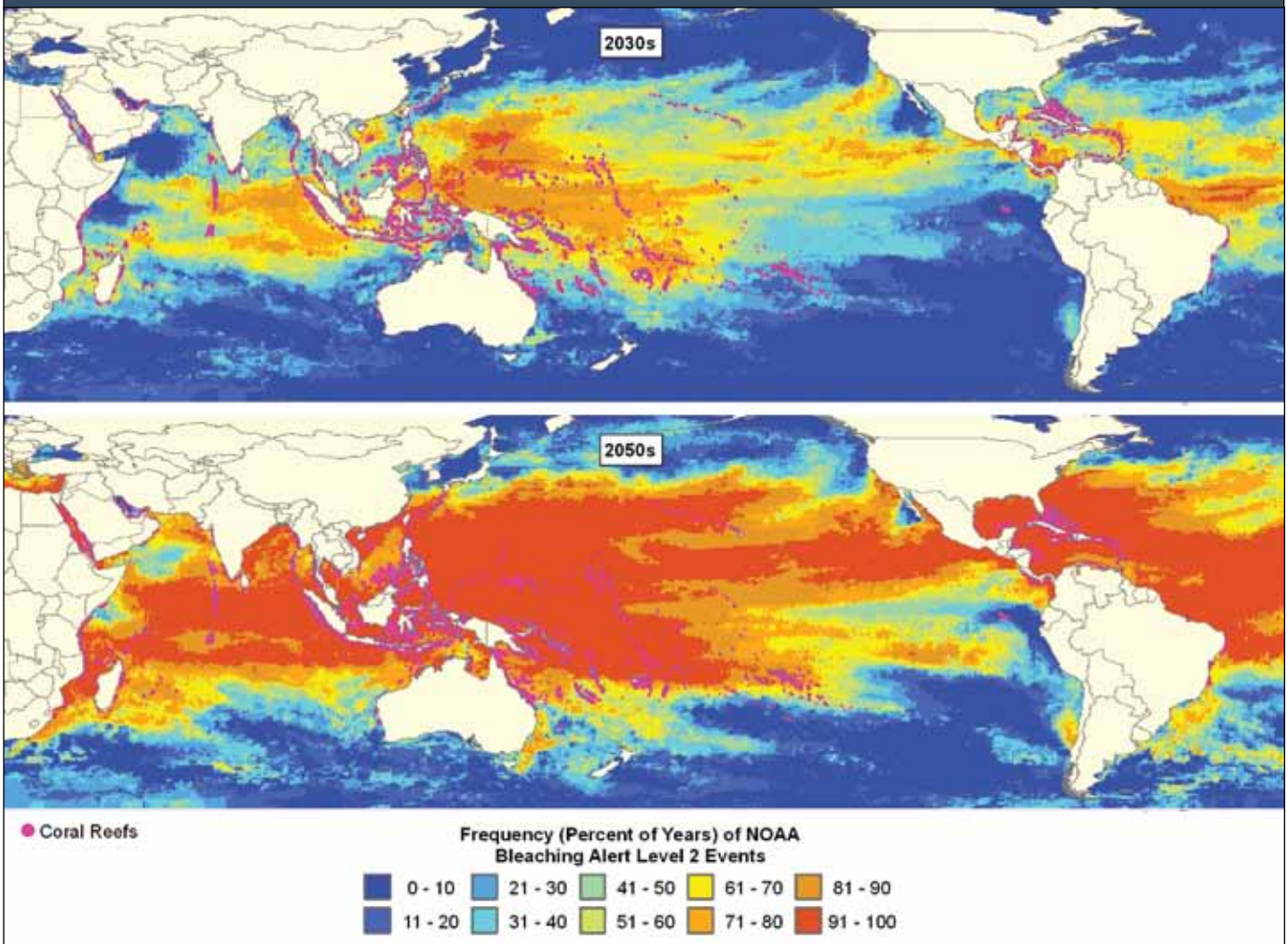
Population growth, increased demand for fish and agricultural products, and further development along coasts will escalate pressures on coral reefs in the future. However, the single greatest growing threat to coral reefs is the rapid increase in greenhouse gases in the atmosphere, including carbon dioxide (CO_2), methane, nitrous oxide, and halocarbons, with CO_2 contributing most to both warming and acidification. Since preindustrial times, atmospheric concentrations of all of these greenhouse gases have increased significantly. In terms of CO_2-equivalents, total greenhouse gas emissions increased by 70 percent between 1970 and 2004.[65]

Mass coral bleaching, a stress response to abnormally warm waters across wide expanses of coral reefs, is becoming more frequent, more intense, and more widespread as higher temperatures recur.[8,66,67] Severe or prolonged bleaching events can kill corals outright, while less extreme events can weaken corals by reducing their growth rates and reproductive potential, and leave them more vulnerable to disease. While corals can recover from bleaching, studies have found that other local stressors, such as pollution, diminish their resilience.[68-71]

Under a "business-as-usual" emissions scenario, our projections suggest that roughly 50 percent of the world's reefs will experience thermal stress sufficient to induce severe bleaching in at least five out of ten years during the 2030s. In the Coral Triangle Region, more than 80 percent of reefs are projected to reach this level of thermal stress during the 2030s. During the 2050s, this percentage is expected to grow to more than 95 percent for both the Coral Triangle Region and the world (map 2.8). 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.

In addition, increasing CO_2 emissions are dissolving into the oceans and changing the chemical composition of seawater. Increased CO_2 elevates the acidity of seawater and reduces the saturation state of aragonite, the mineral that corals use to build their skeletons. Increased acidity means a reduction in the availability of aragonite, causing slower coral growth. The best available data suggests that by 2030, fewer than half of the world's reefs will be in areas where aragonite levels are adequate for coral growth; that is, where

MAP 2.8. FREQUENCY OF FUTURE CORAL REEF BLEACHING EVENTS IN THE 2030s AND 2050s



Note: Frequency of future bleaching events in the 2030s and 2050s, as represented by the percentage of years in each decade where a NOAA Bleaching Alert Level 2 is predicted to occur. Predictions are based on an IPCC A1B ("business-as-usual") emissions scenario and adjusted to account for historical temperature variability, but not adjusted by any other resistance or resilience factors. Source: Adapted from Donner, S.D. 2009. "Coping with Commitment: Projected thermal stress on coral reefs under different future scenarios."PLoS ONE 4(6): e5712.

the aragonite saturation state is 3.25 or higher. By 2050, only about 15 percent of reefs will be in areas where aragonite levels are adequate for growth (map 2.9).

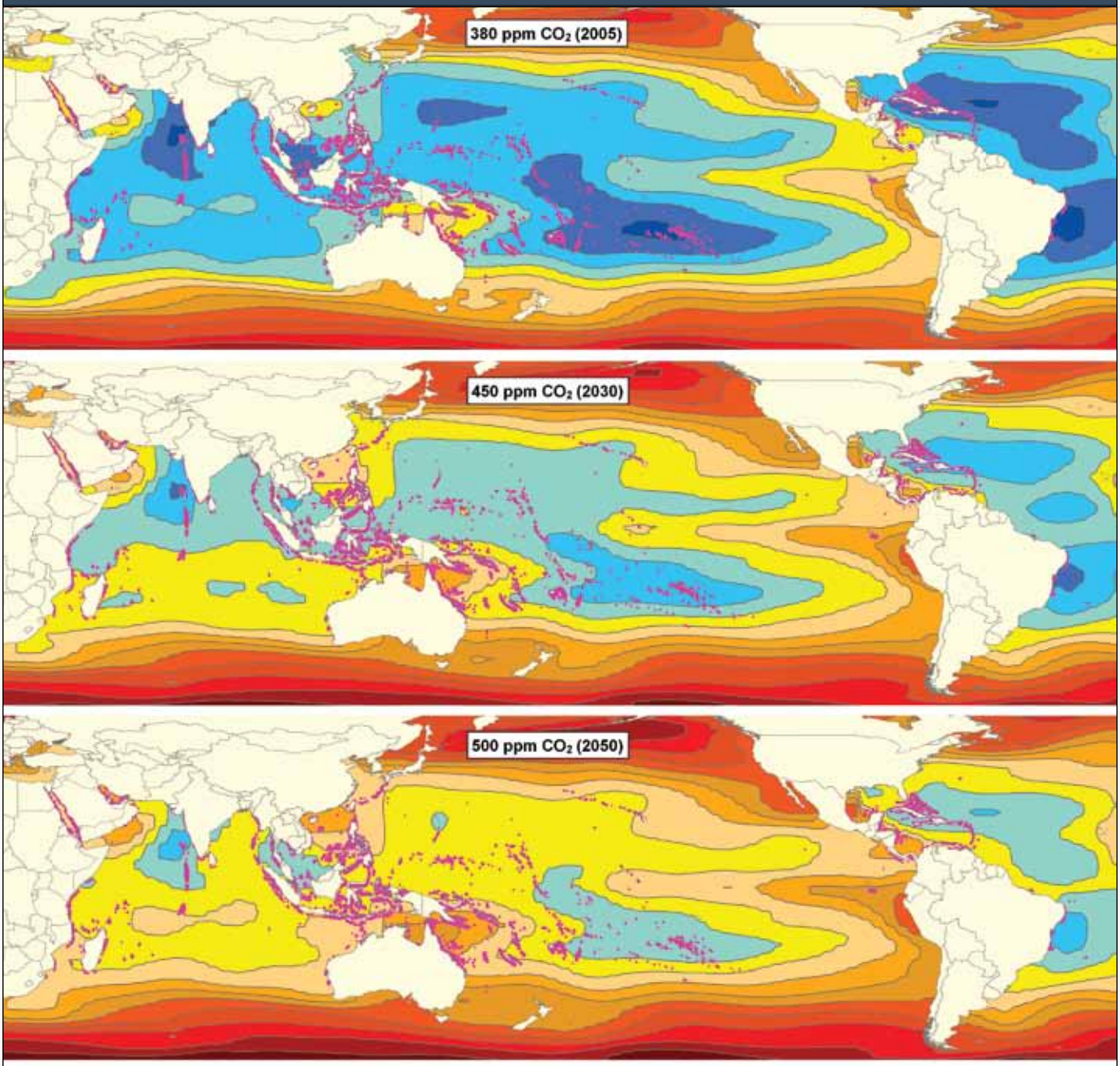
The reefs of the Coral Triangle Region are particularly sensitive to climate change because of the extent to which they are already threatened by local stressors. The projected increases in ocean temperature and acidity, which are evaluated in this report, will compound pressures on already-stressed ecosystems. Other factors associated with climate change, such as sea level rise, increased intensity of cyclones and typhoons, and changes in rainfall patterns (prolonged flood and drought cycles) are also projected to impact coastal ecosystems in the region,[19] though these were not included in this assessment.

Threat in 2030

Global results. By the 2030s, our estimates predict:

- More than 90 percent of the world's reefs will be threatened by local human activities, warming, and acidification, with nearly 60 percent facing high, very high, or critical threat levels.
- Thirty percent of reefs will shift from low threat to medium or higher threat due specifically to changes in climate or ocean chemistry.
- An additional 45 percent of reefs that were already impacted by local threats will shift to a higher threat level due to climate or ocean chemistry changes.

MAP 2.9. THREAT TO CORAL REEFS FROM OCEAN ACIDIFICATION IN THE PRESENT, 2030, AND 2050



Note: Estimated aragonite saturation state for CO_2 stabilization levels of 380 ppm, 450 ppm, and 500 ppm, which correspond approximately to the years 2005, 2030, and 2050 under the IPCC A1B (business-as-usual) emissions scenario. Source: Adapted from Cao and Caldeira, Geophysical Research Letters, 2008.

- Thermal stress is predicted to play a larger role in elevating threat levels than acidification by 2030, though about half of all reefs will be threatened by both conditions.

Results for the Coral Triangle Region. By the 2030s our estimates predict:

- Virtually all coral reefs in the Coral Triangle Region will be threatened by a combination of local human activities, ocean warming, and acidification, with more than 80 percent facing high, very high, or critical threat levels.
- More than 40 percent of reefs will be at very high or critical threat levels.
- The increased threat will be particularly significant in Papua New Guinea, where the area of reef threatened will rise from 55 percent today to 100 percent by 2030.
- In the Philippines and Timor-Leste, more than two-thirds of reefs will shift to the high or critical categories (map 2.10b and figure 2.5).

Threat in 2050

Global results. By the 2050s, our estimates predict that almost no reefs will be under low threat and only about one-quarter will be under medium threat, with the remaining 75 percent at high, very high, or critical threat levels (figure 2.5, right-most column). A few small areas of reef are projected to remain under low threat in Australia and the South Pacific.

Results for the Coral Triangle Region. By 2050, all reefs in the Coral Triangle Region are projected to be threatened, with more than 90 percent at high, very high, or critical levels. Roughly half of the reefs in the region will be in the very high or critical categories. The increase in threat ratings is estimated to be greatest in Papua New Guinea and Solomon Islands (map 2.10c and figure 2.5).

These projections assume that current local threats remain constant in the future, and do not account for potential changes in human pressure, management, or policy, which could influence overall threat ratings. If future population growth, coastal development, and agricultural expansion were considered, the projections of the threat to reefs would be even higher.

Moreover, the results presented here are projections and not foregone conclusions. Coral reefs are resilient: they can and do recover from coral bleaching and other impacts, particularly if other threats are low (boxes 2.3 and 2.4). This analysis highlights the urgent need for global action to curtail greenhouse gas emissions, in parallel with local actions to lessen the immediate pressures on coral reefs. Controlling local threats to coral reefs will be critical to ensuring their resilience and survival in the face of heavy human pressure in coastal regions, and growing threats from climate change and ocean acidification.

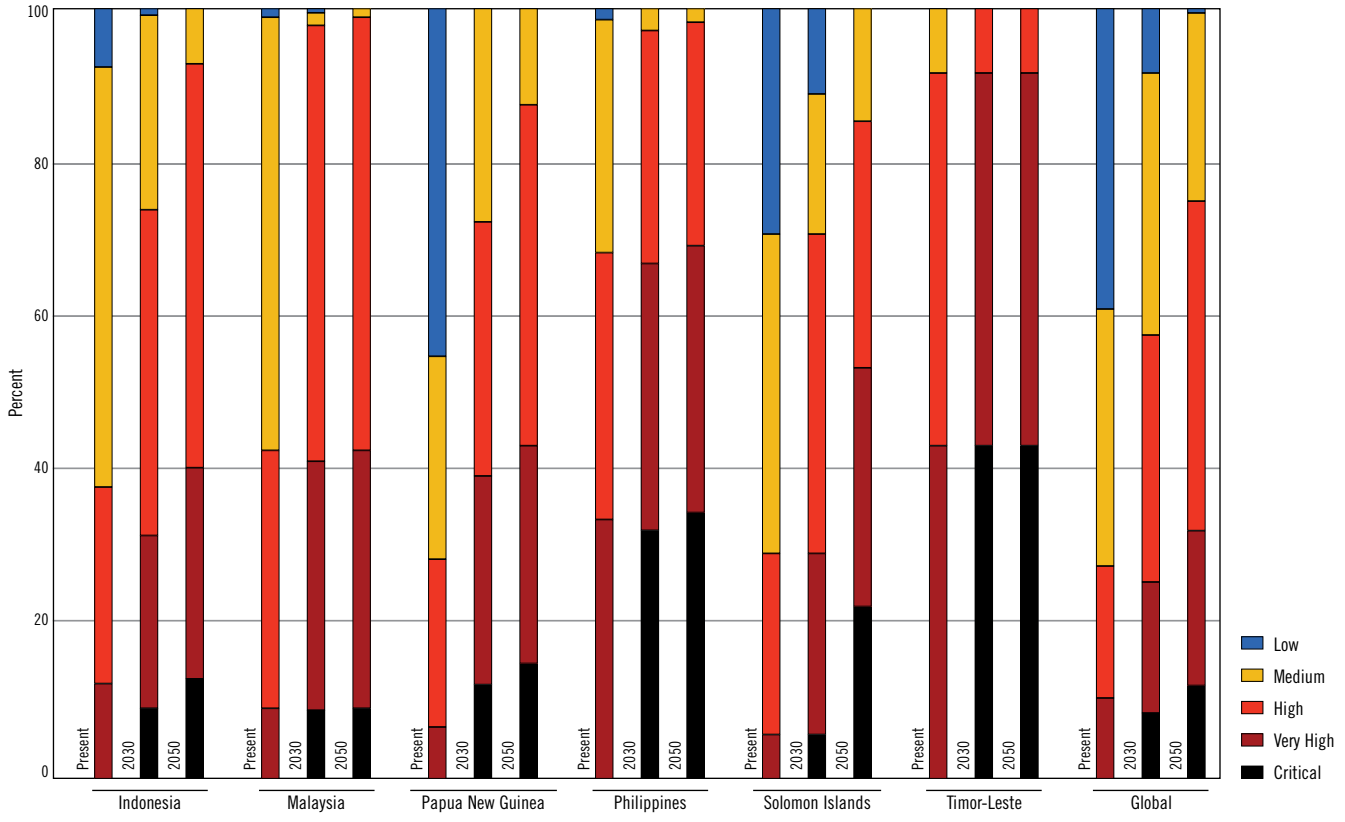
BOX 2.3 REEF STORY

Papua New Guinea: Marine Protection Designed for Reef Resilience in Kimbe Bay

Located off the island of New Britain in Papua New Guinea, the rich marine habitat of Kimbe Bay is a vital part of the local culture and economy. However, Kimbe Bay's coral reefs are particularly threatened by land-based pollution, overfishing, and coral bleaching. In response, local communities and government agencies are working together with The Nature Conservancy to design and implement one of the first marine protected area (MPA) networks that incorporates both socioeconomic considerations and the principles of coral reef resilience to climate change. These principles include: selecting sites that represent and replicate major habitats; incorporating biological patterns of connectivity to promote the exchange of larvae between reefs; and protecting unique locations such as fish spawning sites. The lessons learned from this pilot MPA network will help to give coral reefs around the world a better chance to survive climate change. See full story online at http://www.wri.org/reefs/stories.

PHOTO: ALISON GREEN

FIGURE 2.5 REEFS AT RISK: PRESENT, 2030, AND 2050 FOR THE COUNTRIES OF THE CORAL TRIANGLE REGION



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.

BOX 2.4 REEF STORY

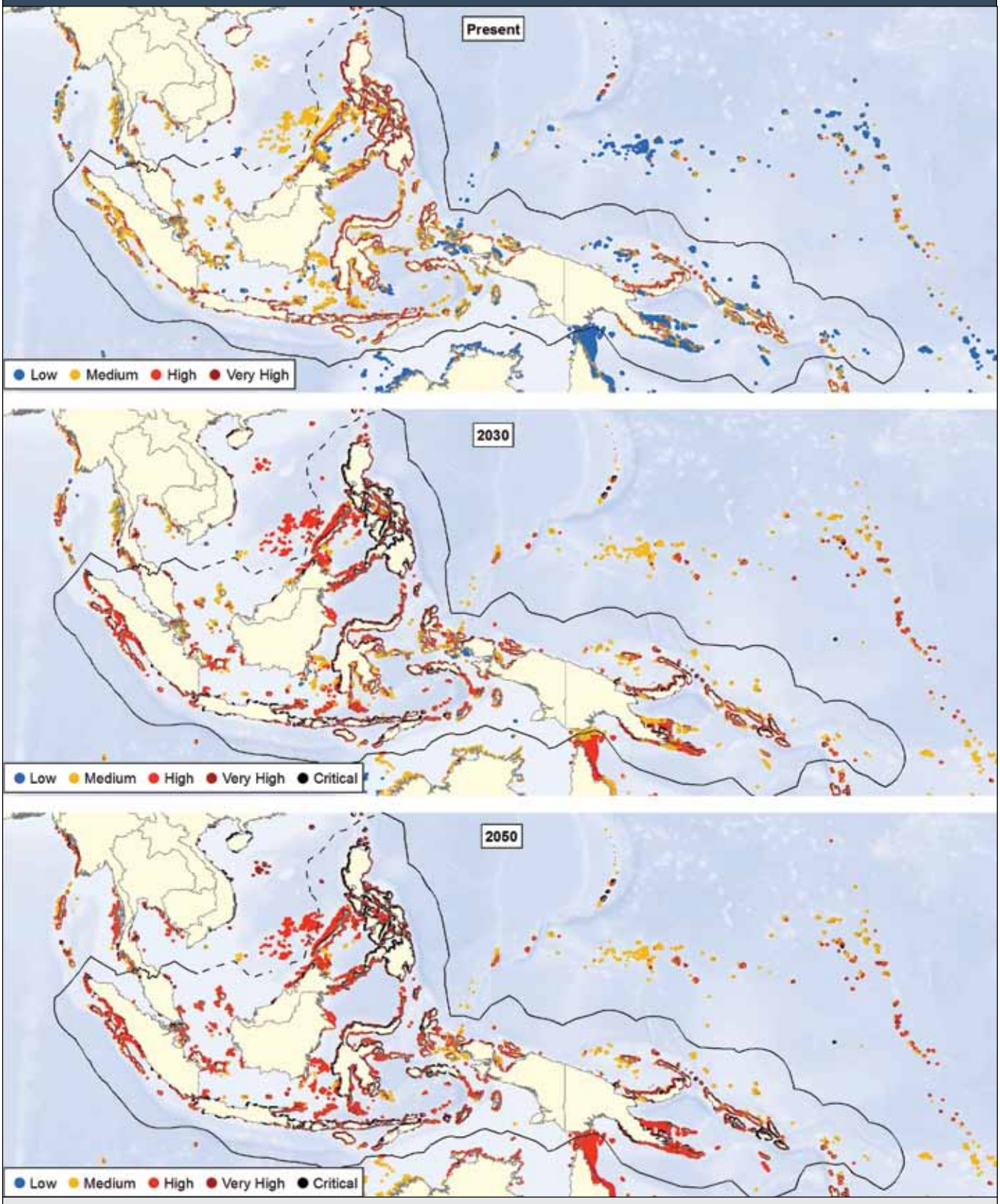
Philippines: Effective Management Promotes Coral Reef Resilience at Tubbataha Reefs Natural Park


PHOTO: CIEMON CABALLES

In the middle of the Sulu Sea, 150 kilometers off the coast of Palawan in the southwestern Philippines, lie the Tubbataha reefs. The magnitude of marine diversity at these reefs makes them both an important ecological asset and a popular diving destination. The reefs support at least 360 species of corals—representing more than 70 percent of all known coral genera in the world—and 600 species of fish. Despite their remoteness, the reefs of Tubbataha were badly damaged by the destructive fishing practices of local and migrant fishers in the 1970s. In order to prevent further degradation of the reefs, the Philippine government declared Tubbataha a national marine park in 1988; in 1993 the park became a UNESCO World Heritage Site. At 970 sq km, the Tubbataha Reefs Natural Park (TRNP) is among the largest effectively-enforced no-take marine reserves in Southeast Asia.

When the 1998 global mass coral bleaching event damaged reefs at Tubbataha—causing live coral cover to decline by about 22 percent—the reefs in the TRNP were better able to recover from the damage because of their protection inside the reserve. By 2008, live coral cover on the reefs had even exceeded that of pre-bleaching levels and fish density has gradually increased since 2000. TRNP is a successful model of effective MPA management largely because of its use of regular patrolling activities combined with financial and governance incentives: dive tourism generates revenue for the park, which is shared with local municipalities in exchange for not fishing in the area.[72,73]

MAPS 2.10.A, B, AND C. REEFS AT RISK IN THE PRESENT, 2030, AND 2050 IN THE CORAL TRIANGLE REGION



Note: Map 2.10a shows reefs classified by present integrated threat from local activities. Maps 2.10b and 2.10c show reefs classified by integrated local threat combined with projections of thermal stress and ocean acidification for 2030 and 2050, respectively. Method: Reefs are assigned their threat category from the integrated local threat index as a starting point. Threat is raised one level if reefs are at high threat from either thermal stress or ocean acidification, or if they are at medium threat for both. If reefs are at high threat for both thermal stress and acidification, the threat classification is increased by two levels. The analysis assumes no increase in future local pressure on reefs, and no reduction in local threats due to improvements in management.

Section 3. COUNTRY SUMMARIES

PHOTO: WOLCOTT HENRY

At a global scale, the threats facing the world's coral reefs present a considerable challenge to human society. However, it is only by understanding the root causes and impacts of these threats in specific locations that we can begin to develop effective responses. The key drivers of threats, the current condition and future risk to reefs, and the management measures used to protect reefs are highly variable from place to place. This section explores reef distribution, status, and threats in each country in the Coral Triangle Region.

INDONESIA

The country. Indonesia is the largest archipelagic country in the world, spanning 5,000 km from the Indian to Pacific Oceans and consisting of nearly 13,500 islands. Most of these islands are of volcanic origin and rise up from deep oceanic waters. Sixteen percent of the world's coral reefs—more than 39,500 sq km—are located in Indonesia.[74] Only Australia has a larger area of coral reefs (42,000 sq km). The major regions with regard to coral reefs are western Indonesia, including Sumatra and Java; central Indonesia, notably Sulawesi and the Lesser Sunda Islands (Nusa Tenggara); and eastern Indonesia around the Maluku Islands and West Papua (Irian Jaya). Most reefs are located in the eastern and central areas of the country. It is these reefs that lie within the Coral Triangle Core.

Biodiversity. Indonesia's complex geology, including tectonic and volcanic activity, coupled with climate and ocean circulation patterns, have resulted in a highly diverse and dynamic marine environment.[75] Indonesia's coral reefs are the most biologically rich in the world, with approximately 590 recorded species of hard coral,[76] which represents more than 95 percent of the total number of species recorded throughout the Coral Triangle Core.[1] Among Indonesia's reefs reside a rich and diverse population of fish and other marine species, with at least 2,200 reef fish species recorded in Indonesian waters.[77] Despite this great diversity, a relatively small number of species are unique to Indonesia. Of the 2,200 reef fish species, just 197 are considered endemic, thus showing that most species have wide ranges and that connectivity exists across the Coral Triangle Region.[77] Indonesia is also the center of global diversity for mangroves and seagrasses, hosting one fifth of the world's mangrove forests and extensive seagrass ecosystems.[49]

All types of coral reefs exist in Indonesian waters, including fringing, barrier, atoll, and patch reefs.. Fringing reefs are the most common type throughout Indonesia, located adjacent to many islands. The biodiversity of reefs tends to increase from west to east. The world's highest concentration of coral species is located around the Bird's Head

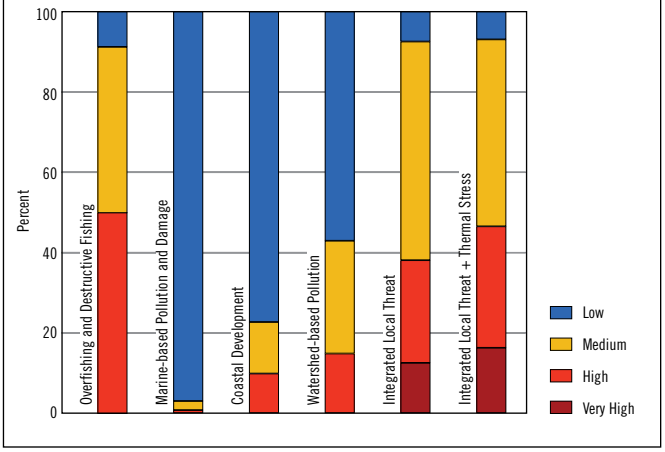
Peninsula, which makes up the northwest portion of West Papua. This area has 574 species of hard coral, with individual reefs hosting up to 280 coral species per hectare—more than four times the total number of hard coral species in the Atlantic Ocean.[1] Just offshore of the Bird's Head Peninsula, the Raja Ampat Islands are considered the "center of the center" of the world's coral reef biodiversity.[1] Reefs are less abundant on the southern shores of West Papua due to the large amounts of freshwater runoff, but some of the world's most extensive mangrove forests occur there.

People and reefs. Nearly 60 million people in Indonesia live on the coast within 30 km of a coral reef, which is the largest reef-associated population of any country in the world.[78] Java and Sumatra have the country's largest population centers, yet practically all of the country's coastlines are now populated. Currently, there is no sewage treatment in place for any major coastal city in Indonesia, which particularly affects reefs around Java and in the more heavily populated western and central regions of the archipelago.[79]

Indonesia has the highest total fish and seafood consumption of any country in Southeast Asia, and the fifth highest in the world.[80] The high-value trade in live reef fish for food markets in the Asia-Pacific region has greatly increased the income and attractiveness of fishing as employment, but it has also caused a proliferation of cheap, efficient, and often destructive fishing practices such as blast and poison fishing.[81] Indonesia is rated as having very high social and economic vulnerability to coral degradation and loss due to high dependence on coral reefs and low capacity to adapt to such loss (see section 4).

Status. According to 2007 survey data from the Coral Reef Rehabilitation and Management Program (COREMAP), 3 percent of surveyed reefs in Indonesia were rated very healthy; 21 percent were healthy; 42 percent were fair; and 34 percent were poor or very poor based on thresholds for live hard coral cover. The proportion of both healthy and very healthy reefs had decreased since surveys were conducted in 2003.[82] A report summarizing a decade of Reef Check surveys in Indonesia (1997–2006) corroborates these results, finding that overall hard coral cover is declining, with most coral cover considered average (26 to 50 percent live coral cover).[83] In 2010, unusually warm sea

FIGURE 3.1. REEFS AT RISK IN INDONESIA



temperatures caused a mass coral bleaching event throughout Southeast Asia that affected many reefs in Indonesia. The most severely affected areas were around Sumatra and Sulawesi, with 80 to 90 percent of reefs bleached around Aceh on the northern tip of Sumatra. Mild to moderate bleaching was also observed in Java, Bali, Lombok, West Papua, and the Malukus.[84]

Results.

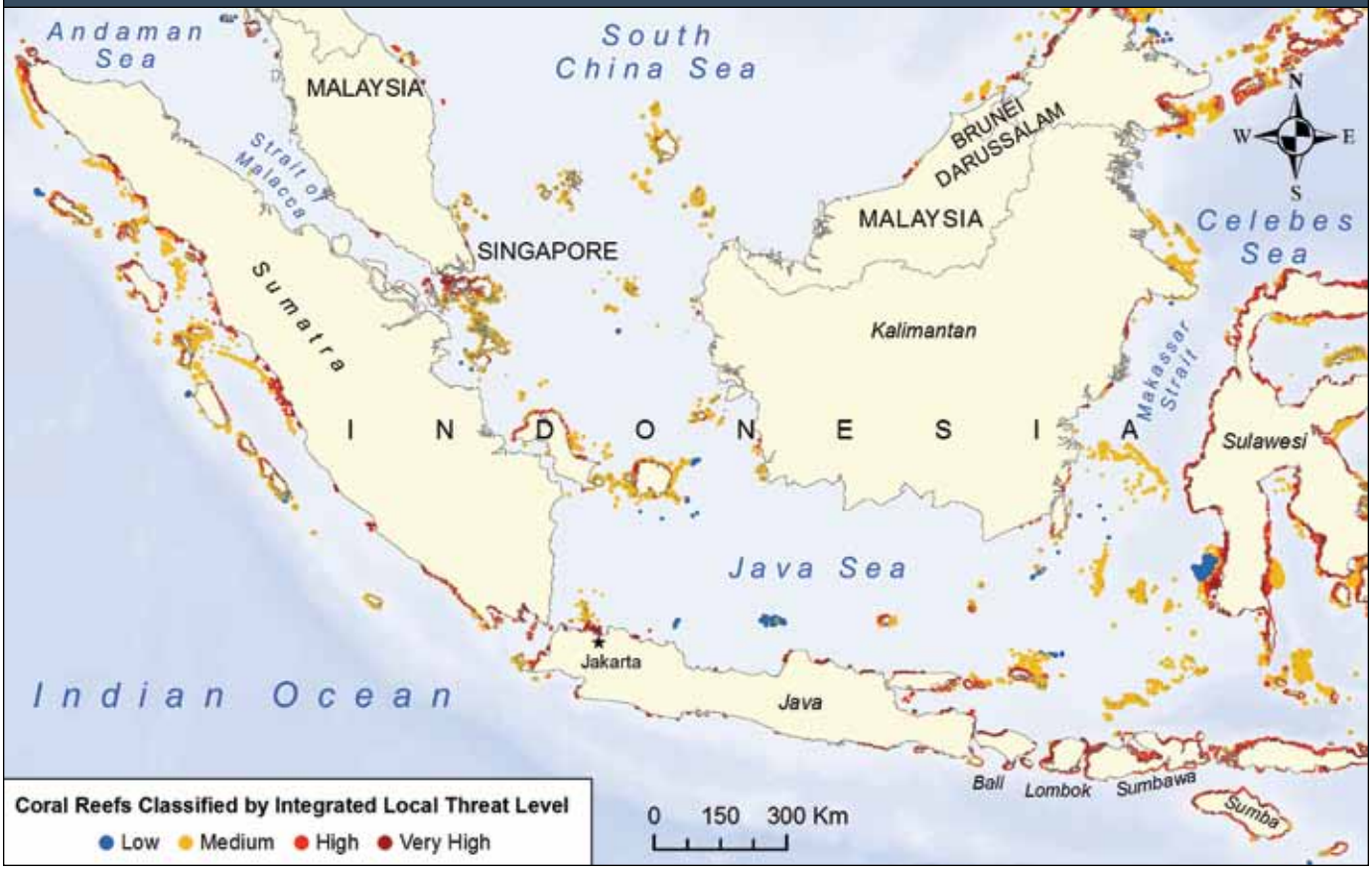
- Nearly 95 percent of coral reefs in Indonesia are threatened by local human activities, with more than 35 percent in the high or very high threat categories.
- *Overfishing and destructive fishing* are the greatest threats, affecting more than 90 percent of reefs. Fishing pressure is highest on nearshore fringing reefs and in areas of high population density, but our analysis suggests that pressure from fishing activities is found on almost all reefs, including those in remote areas. Destructive fishing (blast or poison fishing) is widespread and threatens nearly 80 percent of Indonesia's reefs (about 31,000 sq km). This practice occurs throughout much of the archipelago and the intensity tends to vary with local cultural values and practices (map 2.1).
- *Watershed-based pollution*, including sediment and nutrient runoff from deforestation and agriculture, threatens more than 40 percent of the country's reefs. This threat is more concentrated in central Indonesia and West Papua, where deforestation has been more widespread in recent years.

- *Coastal development*, including runoff from construction and waste from coastal communities, threatens about 20 percent of reefs.
- Compared to the other countries in the Coral Triangle Region, *marine-based pollution* is not as significant a threat in Indonesia, and affects less than five percent of reefs.
- When the influence of recent *thermal stress and coral bleaching* is combined with local threats, the area of reefs rated at high or very high threat increases to more than 45 percent.

The combined pressures leave few reefs in Indonesia unthreatened, with high to very high threats predominating, especially around Java and the Lesser Sunda Islands. However, there remains room for hope, because most reefs have not been significantly impacted by bleaching. Thus, while diversity and live coral cover have declined, many reefs still have a good complement of species and could be resilient in the face of future change if local threats can be reduced.

Conservation. As part of its commitment to the Coral Triangle Initiative, the government of Indonesia pledged to conserve 100,000 sq km of its marine area in MPAs by 2010, and exceeded this aim with the declaration of the Savu Sea Marine National Park in 2009 (35,000 sq km).[85] In 2011, the Ministry of Marine Affairs and Fisheries formally established the Anambas National Marine Park, which covers an area of about 12,600 sq km in western Indonesia. As of 2011, Indonesia had a total of 139,000 sq km of protected marine area and has pledged to expand protection to 200,000 sq km by 2020.[85] However, enforcing MPA regulations and effectively managing threats in these vast areas is an ongoing challenge throughout the country, and is just beginning to be addressed. At present, approximately 40 percent of Indonesia's MPA area is currently managed under the Ministry of Forestry, while 60 percent is managed under the Ministry of Marine Affairs and Fisheries (MMAF), local governments, or communities. This latter group is expected to increase their share of the management distribution as more MPAs are transferred to MMAF authority and more local MPAs are established.[85]

MAP 3.1.A. REEFS AT RISK IN WESTERN INDONESIA



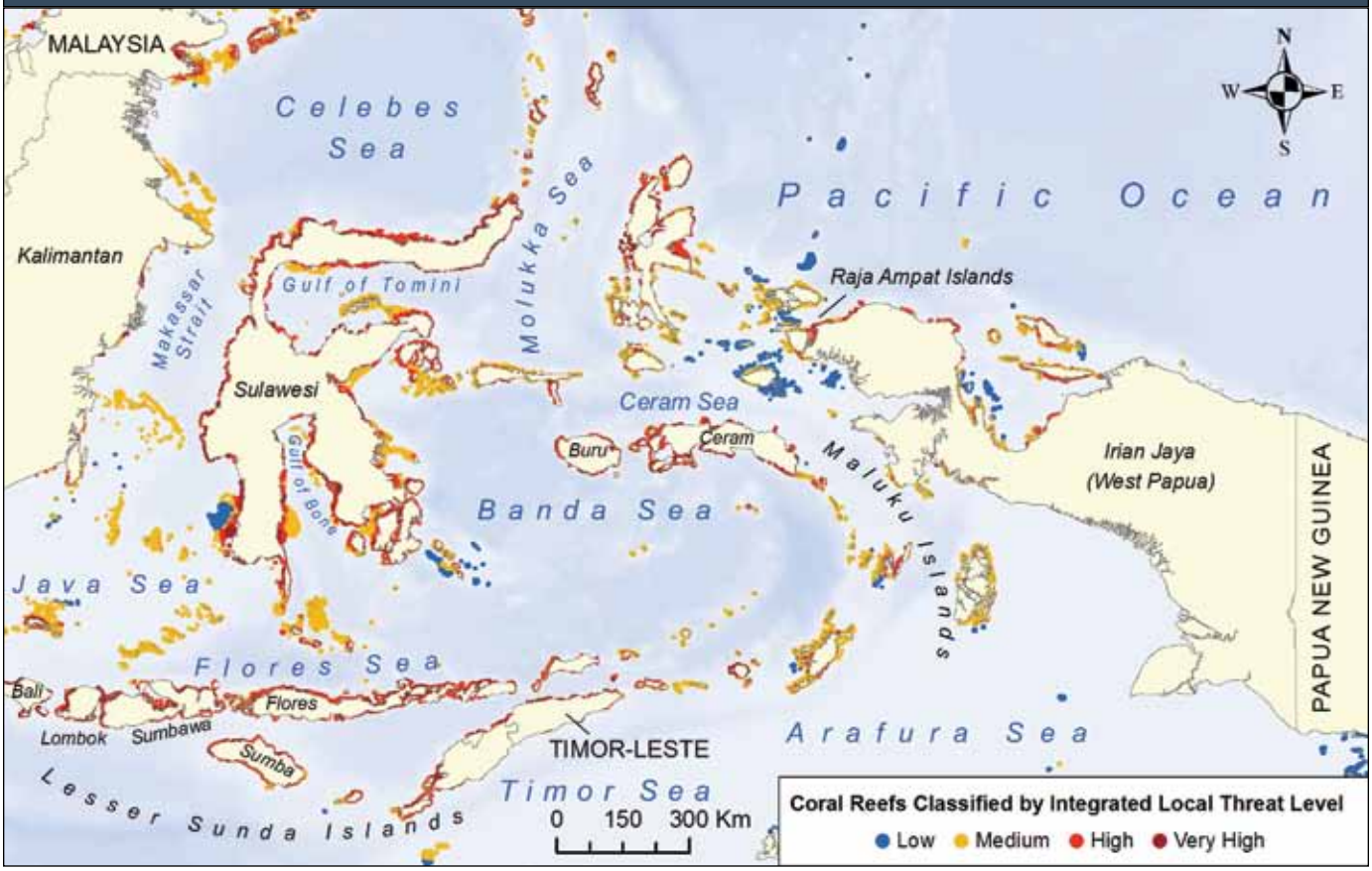
The analysis of MPAs conducted for the *Reefs at Risk Revisited in the Coral Triangle* report found that Indonesia has the highest proportion of coral reefs inside MPAs of any country in the Coral Triangle Region (29 percent); however, only 3 of the 175 mapped MPAs were rated as being fully effective at managing fishing pressure. These three MPAs (West Waigeo National MPA, Kofiau and Boo Islands Marine Conservation Area, and the Teluk Mayalibit Marine Conservation Area) are all located in the Raja Ampat Islands, and together protect less than 1 percent of Indonesia's reef area. About 9 percent of Indonesia's reefs are inside MPAs rated as partially effective, 14 percent are in MPAs rated as not effective, and the remaining 5 percent are in MPAs for which ratings were unavailable (see section 5 for additional management information). In an effort to improve the effectiveness of MPAs, the USAID Coral Triangle Support Partnership and the Ministry of Marine Affairs and Fisheries are developing a protocol to strengthen MPA management in Indonesia and across all six countries of the Coral Triangle Initiative.

BOX 3.1 REEF STORY

Indonesia: Maps Help Communities Manage Resources in the Kei Islands

In Indonesia's Kei Islands, located in the southeastern part of the Maluku Island chain, natural resources are managed within the jurisdiction of a *ratschaap*—a customary designation of territory (or kingdom) that has been in place in the Kei Islands for centuries. In West Kei Kecil, there are three *ratschaap* jurisdictions—Danar, Nu Fit, and Jab-Faan. Although they have lived side-by-side for centuries, recent disputes over the boundaries of each *ratschaap* have led to conflicts over access rights to natural resources. As part of the Coral Triangle Support Partnership, WWF initiated a mapping project to clarify *ratschaap* boundaries and assess the status of marine resources within these boundaries. The maps were presented to the communities of each *ratschaap* as part of a series of meetings to help resolve differences and clarify boundaries. These efforts facilitated initial agreements to establish a marine protected area through which government and communities could jointly manage marine resources in West Kei Kecil district. The maps represent an important tool for building upon traditional management practices, and have helped communities to visualize and plan for the long-term sustainability of their resources.[86]

MAP 3.1.B. REEFS AT RISK IN EASTERN INDONESIA



MALAYSIA

The country. Malaysia is governed as a federation made up of 13 states, 11 of which are located in Peninsular Malaysia. The remaining two, Sabah and Sarawak, are on the island of Borneo and are sometimes collectively referred to as East Malaysia. Peninsular and East Malaysia are separated by the South China Sea and the underlying Sunda Shelf. Malaysia's coral reefs cover nearly 3,000 sq km, with the majority located around the northern and eastern coasts of Sabah on the margins of the Sulu Sea.[87]

Biodiversity. In total, about 540 species of hard corals have been identified in Malaysian waters to date.[1] More than 90 percent of the country's reefs are located off the coast of Sabah and consist mainly of fringing and barrier reefs. These reefs are part of the biogeographic Coral Triangle Core and support a far greater diversity of corals and fish than elsewhere in the country. Reefs are sparse along the mainland coasts of both Sarawak and Peninsular Malaysia, although island groups further offshore support many fringing reefs. Across Malaysia, at least 925 different species of fish inhabit coral reefs.[88] Many of these reef fish benefit from close proximity to coastal mangroves, which provide habitat and protection from predators, especially during juvenile stages. Of the 73 known species of mangroves in the world, 40 can be found in Malaysia.[49]

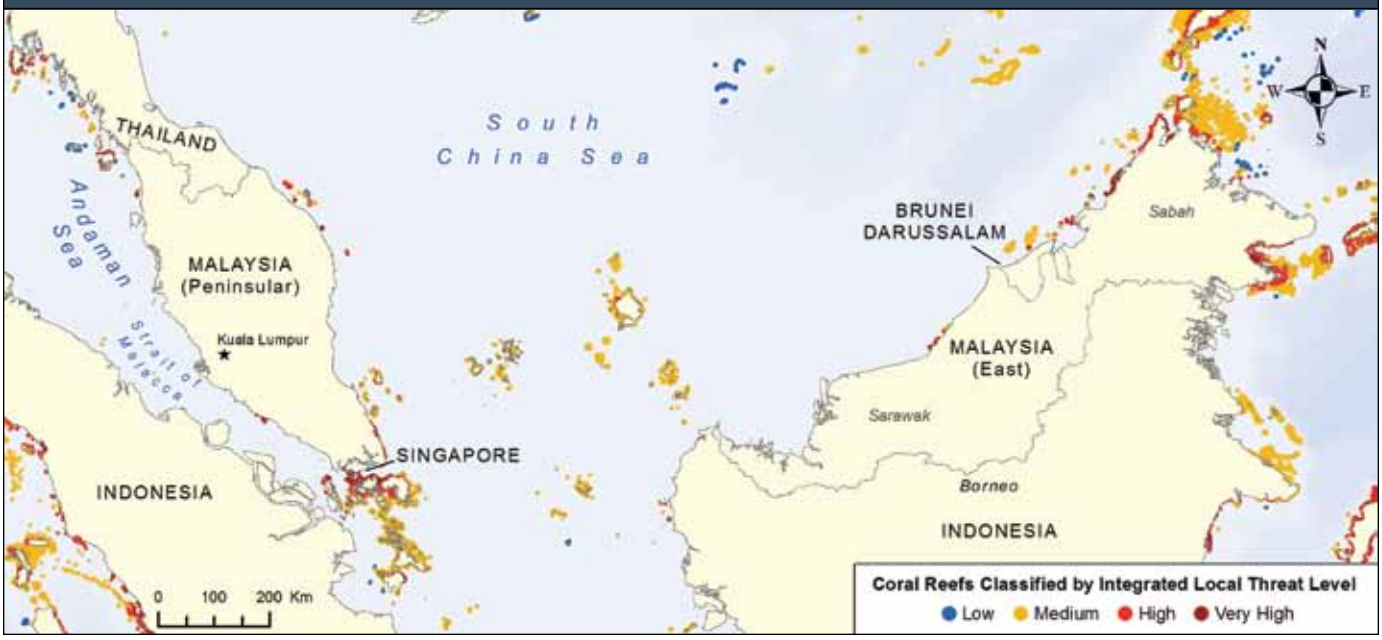
Mangrove forests cover more than 7,000 sq km across the country, some of which are inside reserves and are successfully managed for sustainable timber harvest.[49]

People and reefs. Approximately five million people in Malaysia live on the coast within 30 km of a coral reef. This number includes 3.2 million people in Peninsular Malaysia and 1.8 million in East Malaysia.[89] While Malaysia as a country continues to grow and develop its economy, rates of development are not occurring uniformly in both regions.[90] Since the mid-1990s, Peninsular Malaysia has become increasingly industrialized, with an economy supported by manufacturing, while the economy of East Malaysia has remained largely agricultural and resource-based.[91] Poverty rates in rural areas have also diverged, with 23 percent of the population living in poverty in East Malaysia compared to 6 percent in Peninsular Malaysia.[90]

While fish is an important food staple throughout the country, with an annual consumption rate of about 52 kg per person,[92] people in East Malaysia are more dependent on fisheries for income and food security than those in Peninsular Malaysia.

Tourism is one of the fastest growing sectors of the country's economy; tourist arrivals grew fourfold between 1998 and 2009, from 5.5 million to 23.6 million.[93] Tourism has also been identified as an important sector for development

MAP 3.2. REEFS AT RISK IN MALAYSIA



in East Malaysia, to help close the gap in economic growth between the two regions.[90]

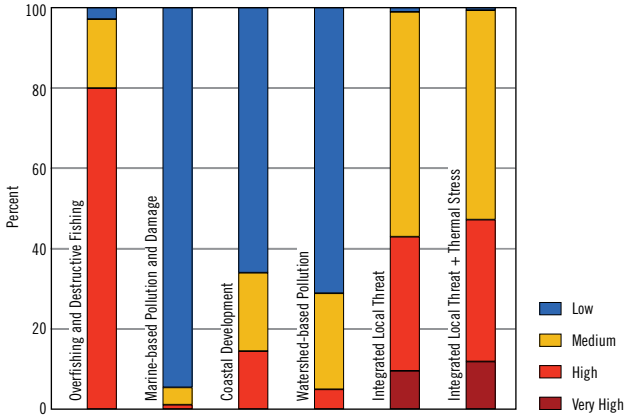
Status. According to surveys of reef condition conducted by Reef Check Malaysia in early 2010 for 67 sites across the country, coral reefs in Peninsular Malaysia averaged 48 percent live hard coral cover and reefs in East Malaysia (Sabah and Sarawak) averaged 35 percent.[94] Higher algal cover was recorded in Peninsular Malaysia (7 percent) than in East Malaysia (4 percent).[94] This is likely due to higher nutrient levels in the waters around Peninsular Malaysia—driven by intense agriculture, coastal urbanization, and the growth of coastal tourism—but may also be related to the decline of herbivorous fish due to overfishing as well as variation in reef types between the two regions. High percentages of coral rubble—signs of blast fishing—were recorded at many survey sites in East Malaysia. In both regions, low diversity and density of key "indicator" reef fish species (i.e., valuable species such as Humphead wrasse and Barramundi cod) are indicative of heavy fishing pressure.[94]

It is important to note that these surveys were conducted prior to a mass coral bleaching event triggered by unusually warm sea temperatures across the region in mid-2010.[94] Severe bleaching occurred along the east coast of Peninsular Malaysia, affecting 75 to 90 percent of reefs.[84] The severity of this bleaching prompted Malaysia's Department of Marine Parks to take the unprecedented action of closing twelve dive sites inside three marine parks for several months to help bleached reefs recover. Reefs in Sabah and along the west coast of Peninsular Malaysia were also affected by bleaching, but to a lesser extent and severity.[84]

Results.

- Nearly all reefs in Malaysia (99 percent) are threatened by local human activities, with more than 40 percent under high or very high threat.
- *Overfishing, including destructive fishing,* is the most widespread threat, affecting approximately 97 percent of reefs in Malaysia, including nearly all reefs in Sabah and Sarawak. Destructive fishing (blast and poison fishing) alone threatens 85 percent of Malaysia's reefs. The highest threat is concentrated along the nearshore reefs of Sabah.

FIGURE 3.2. REEFS AT RISK IN MALAYSIA



- About 30 percent of reefs are threatened by *watershed-based pollution*. This threat is largely concentrated around Peninsular Malaysia (55 percent of reefs threatened) and Sarawak (75 percent) due to the substantial contribution of sediment and pollutants from major river outfalls. In Sabah, many reefs are located farther from shore and are thus less affected.
- *Coastal development* threatens nearly 35 percent of Malaysian reefs. Reefs in Sabah and Sarawak are most at risk from coastal development pressure, which threatens 35 percent and 45 percent of reefs in each state, respectively. About one-quarter of reefs in Peninsular Malaysia are at risk from coastal development.
- *Marine-based pollution* threatens approximately 5 percent of reefs. This threat is concentrated almost entirely around Peninsular Malaysia, where 35 percent of reefs are threatened by the presence of ports and busy shipping lanes.
- When the influence of recent *thermal stress and coral bleaching* is combined with local threats, the area of reefs rated at high or very high threat increases to about 50 percent.

Conservation. Although Malaysia has an extensive network of protected areas, certain types of coverage are underrepresented, particularly coverage of mangroves and coastal areas that link land and sea ecosystems.[95] The Tun Mustapha Park, proposed to be located off the north coast

BOX 3.2 REEF STORY

Malaysia: Pilot MPAs in Sabah's Tun Mustapha Park Set Stage for Malaysia's Largest MPA

In Sabah, Malaysia, the state government, local communities, and the private sector are working with the Coral Triangle Support Partnership (CTSP) and WWF-Malaysia to create one of the largest marine protected areas (MPAs) in the region. At over 1 million hectares, the proposed Tun Mustapha Park (TMP) will be Malaysia's largest MPA. While planning of the TMP is under way, a series of smaller pilot MPAs are being established to serve as models of how the larger TMP network will operate. Critical to the success of these pilot sites is the development of local management capacity alongside the creation of alternative livelihoods that reduce dependence on marine resources.

One of the first of these pilot sites is Maliangin Sanctuary, just off the northern tip of Sabah. In this area, overfishing and destructive fishing are among the most significant threats to coral reefs, fisheries, and the long-term economic security of residents of Maliangin Island. Together with WWF-Malaysia and the CTSP, the Maliangin Island Community Association, which co-manages the sanctuary with the Sabah Parks and Fisheries Departments, hosted a week-long handicraft workshop to provide residents with new skills to develop and market traditional handicrafts as an alternative source of income to fishing. As a pilot site, the Maliangin Sanctuary seeks to demonstrate how effective MPA management, which includes social and economic considerations, benefits both the biodiversity and the people of the islands.[99]

PHOTO: ANGELA LIM/CTSP

of Sabah, comprises 10,000 sq km and will dramatically increase Malaysia's MPA coverage (box 3.2).[96] MPA management falls under a number of national and regional institutions. Fisheries management, as well as provisions for establishing federal MPAs, are regulated under the Fisheries Act of 1985.[97] At present, the Department of Marine Parks manages 42 MPAs in Peninsular Malaysia, which includes the marine area surrounding 38 offshore islands. Four MPAs are established in Sabah, of which three are managed by the Sabah state government (Sabah Parks) and one is privately managed. Sarawak state has five national marine parks. Local agencies in each state are responsible for management and enforcement; however, a lack of capacity and overlapping jurisdictions among agencies has hindered effective management of coastal resources.[98]

The analysis of MPAs conducted for the *Reefs at Risk Revisited in the Coral Triangle* report found that Malaysia has a total of 93 MPAs, which encompass 7 percent of Malaysia's coral reef area. Of the 93 MPAs, 5 were rated as effective at reducing fishing pressure, 41 rated as partially effective, and 30 rated as ineffective. The effective MPAs encompass just a fraction of 1 percent of the country's reefs, and the partially effective MPAs encompass about 5 percent. The remaining 2 percent of reefs are inside MPAs that are rated as ineffective or under an unknown level of management (see section 5 for additional management information).

PAPUA NEW GUINEA

The country. Papua New Guinea (PNG) consists of the eastern half of the island of New Guinea and numerous smaller islands mainly to the north and east. The Indonesian province of Papua occupies the western half of New Guinea, while Australia lies immediately to the south. North of the mainland, the smaller islands of PNG include Manus, New Britain, New Ireland, and Bougainville. Due to the historical isolation of many parts of the country, the people of

MAP 3.3. REEFS AT RISK IN PAPUA NEW GUINEA

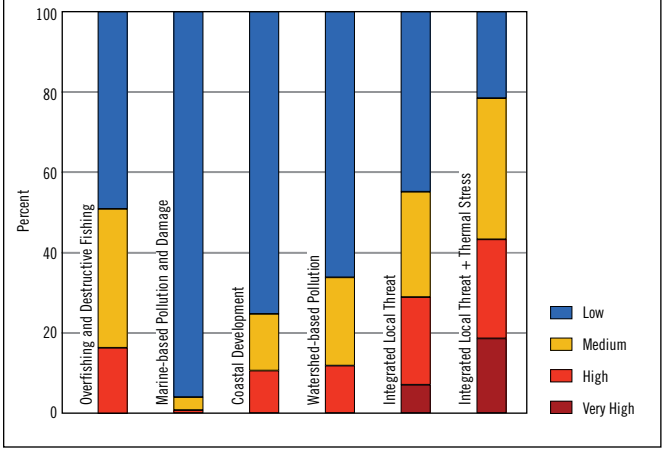
PNG speak more than 800 languages, illustrating the country's considerable diversity of people and cultures.[100]

Biodiversity. PNG has a unique array of both terrestrial and marine ecosystems. The mainland is exceptionally diverse, with ecosystems that vary from high alpine ranges and plateaus to rainforests and swamps. Approximately 78 percent of the mainland is covered in natural forest.[101] Coastal and marine ecosystems include seagrass beds, mangrove forests, and more than 14,500 sq km of coral reefs (6 percent of the world total).[87] The coral reefs located south of the mainland are largely an extension of the Great Barrier Reef, while reefs along the northern coast of PNG and around the northern islands are more similar to those found throughout the Coral Triangle Region.[102] Fringing and patch reefs make up the majority of reef types in PNG, with barrier reefs south and east of the mainland.[101] At least 514 species of hard corals have been recorded in northern Papua New Guinea, including the offshore islands.[1] In Kimbe Bay, on the north coast of New Britain, more than 860 species of reef fish have been recorded.[6] Milne Bay, on the eastern tip of the mainland, has similarly high biodiversity, with at least 511 species of hard corals[1] and over 1,100 species of reef fish.[103]

People and reefs. Much of mainland PNG is made up of rugged and largely inaccessible terrain, such that many areas are sparsely populated and undeveloped.[101] The total population of PNG is about 5.7 million, and population density averages 12 persons per sq km for the entire country.[100] However, because of the rugged interior, much of the population lives in the more accessible coastal areas. Some coastal villages, such as those surrounding Kimbe Bay, have population densities as high as 130 persons per sq km.[104] Resources in these areas are under increasing pressure to support a population that is growing at about 2.7 percent per year.[105]

Eighty-five percent of Papua New Guineans live in rural villages and support themselves with subsistence agriculture

FIGURE 3.3. REEFS AT RISK IN PAPUA NEW GUINEA



or fishing, occasionally selling a portion of their yields at markets when cash income is needed. [100,105,106] Fishing tends to be more intensive in areas near large market centers, such as Port Moresby, where high demand commands high prices for fish. Conversely, fishing intensity tends to decrease with distance from markets due to the lower demand and prices, and thus lower profit margins.[106] Of all the Coral Triangle countries, PNG's fisheries are the least exploited, and fishing activities on reefs are almost exclusively artisanal.[107] The primary commercial fisheries target tuna and prawns, further offshore. Although reef fisheries are less exploited on the whole, the areas that are close to larger population centers and cash markets are fished beyond sustainable levels.[107] Other major sources of income and employment in PNG include large-scale commercial agriculture, such as palm oil plantations, mining, petroleum extraction, and forestry.[101] All of these activities have the potential to contribute large volumes of sediment and pollutants to coastal waters when not managed properly.

Status. The coral reefs in PNG have not been widely surveyed and particularly few data are available from long-term monitoring reports. However, the available data suggest that average hard coral cover often exceeds 40 percent, though this varies widely with location, reef type, and depth.[102]

The best-studied reefs are located in Kimbe Bay (New Britain) and Milne Bay (southeast mainland). James Cook University and The Nature Conservancy started monitoring reefs in Kimbe Bay in 1996, and found that coral cover declined from about 66 percent in 1996 to a low of 7 percent in 2002, with a recovery to about 15 percent by 2003.[108] The factors identified as likely causes of the decline were a combination of coral bleaching (observed in 1997, 1998, 2000, and 2001), an increase in sediment runoff from the land, and outbreaks of crown-of-thorns starfish, which feed on corals. As part of this same study, surveys of reef fish indicated a 75-percent decline in abundance between 1996 and 2003, with some species declining to less than half their original number, thus indicating a highly co-dependent relationship between fish populations and the condition of reef habitat.[108] Reef condition improved between 2003 and 2007, with branching coral cover reaching 26 percent. Populations of most reef fish species also recovered over this time period.[6]

In Milne Bay, a rapid assessment of reefs at several sites led by Conservation International in 2000 found that coral condition was generally good overall.[103] Live hard coral cover ranged from 13 to 85 percent, with cover at most sites between 30 and 50 percent. Coral bleaching was observed at survey sites in the northernmost areas of the bay, which correlated with higher sea temperatures recorded there than in the southern areas. Sedimentation was observed on a few coastal fringing reefs. Fishing pressure appeared relatively low, given the observed abundance of most target fish species and high overall fish biomass compared to other parts of the Coral Triangle Region where prior rapid reef assessments had been conducted (e.g., Indonesia and Philippines).[103] However, smaller sized fish were much more abundant than large fish among all target species, which may indicate overexploitation.

Results.

- Approximately 55 percent of reefs in PNG are rated as threatened by local human activities. Of all the Coral Triangle countries, PNG's reefs are the least threatened, due largely to the relatively sparse population density across much of the country.
- *Overfishing* is the most pervasive threat, affecting about 50 percent of reefs. Overfished reefs are largely found in areas near coastal population centers, especially around

New Britain, New Ireland, and Madang in the north and Port Moresby in the south.

- *Destructive fishing* (blast and poison fishing) is less common in PNG than other countries in the region, affecting only about 1 percent of reefs.
- *Watershed-based pollution*, including runoff from deforestation and agriculture, threatens nearly 35 percent of reefs, and is most widespread around New Britain.
- *Coastal development* affects about one-quarter of PNG's reefs in areas scattered widely around the country, though concentrated more highly around the smaller islands of New Britain, New Ireland, Manus, and Bougainville.
- *Marine-based pollution* is the least pervasive threat, affecting less than 5 percent of reefs.
- When the influence of recent *thermal stress and coral bleaching* is combined with local threats, the area of threatened reefs increases to nearly 80 percent, with more than 40 percent rated at high or very high threat.

Conservation. In PNG, several national laws govern the management and protection of coastal resources. For instance, the Fisheries Management Act (1998) grants a central governing body the authority to set policies and guidance, such as restrictions on fishing gear, catch sizes, and access to fishing grounds.[109] However, most management occurs at the local level, particularly for subsistence and nearshore fisheries through customary marine tenure, a traditional practice where communities have ownership of their coastal resources with the right to exclude others.[110] As stated in the country's constitution, national and provincial governments legally recognize customary tenure; however, the actual implementation of tenure is as varied across different communities as the cultures, traditions, and socioeconomic conditions.[85] More than 90 percent of the coastal and nearshore resources in PNG are under customary tenure.[85,111] Thus, while higher levels of government can set policies, their implementation relies primarily on local communities, and the national government lacks both the funding and capacity to enforce most environmental regulations.[100,107] For these reasons, developing capacity for resource management at the local level is particularly critical to the overall health of

BOX 3.3 REEF STORY

Papua New Guinea: In Milne Bay Province, Community Sets Benchmark for Local Marine Management

The Nuakata Iabam Pahalele Community (NIPC) Marine Managed Area, located in Milne Bay Province on the southeastern tip of Papua New Guinea, is setting a standard for community conservation that is reverberating throughout the province and the country. Communities throughout Milne Bay are taking the lead in managing and monitoring their MPAs and engaging local and provincial governments to formalize their MPA ownership rights—with the ultimate goal of self-sufficiency in managing their marine resources. With support from the Coral Triangle Support Partnership, Conservation International has worked with communities throughout Milne Bay, including the NIPC, to provide training on biological monitoring and MPA management.

In 2012, the communities' efforts paid off when the Milne Bay Provincial Assembly adopted the new Local Government Law recognizing the role and rights of communities as managers of their local natural resources. This law gives NIPC and other communities across the province the legal authority to develop and implement their own resource management plans, designate protected areas, and monitor fishing activities. The law represents an important step forward in formally designating decision-making authority regarding resource management directly to the people most dependent on these resources. Moreover, the government's recognition of communities as environmental stewards sends an important message of empowerment—not only to the people of Milne Bay, but also to other communities in Papua New Guinea and beyond.[114]

PHOTO: JAMES MORGAN

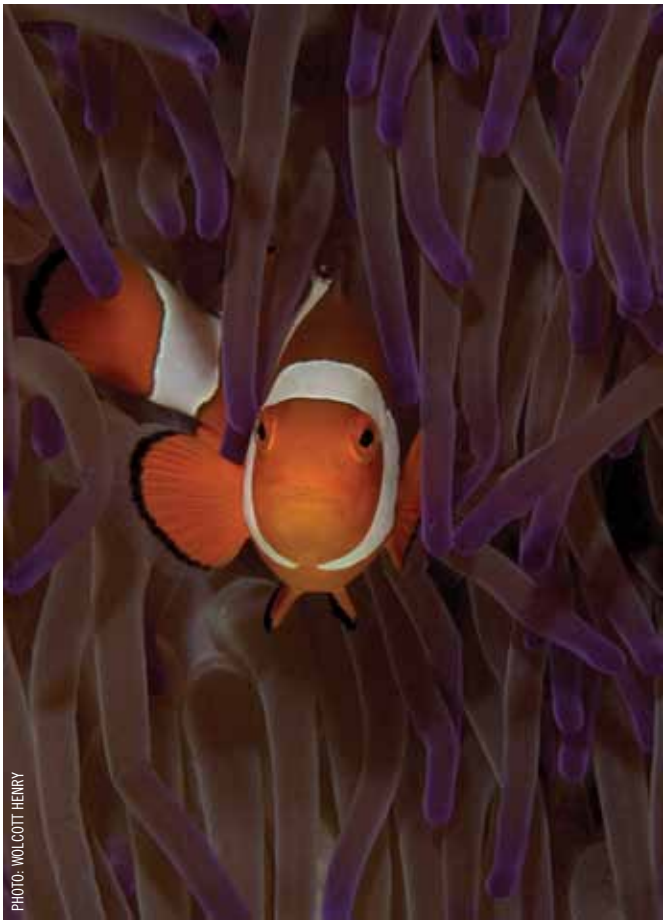


PHOTO: WOLCOTT HENRY

PNG's natural resources. Locally managed marine areas (LMMAs) are gaining traction throughout the country with PNG's participation in the Pacific-wide LMMA Network since 2003. A newly founded NGO, the PNG Centre for Locally Managed Areas, was established in 2009 to facilitate and expand LMMA activities.[112]

The analysis of MPAs conducted for this report found that Papua New Guinea has 96 established MPAs, which protect 5 percent of the country's coral reefs. Data on the effectiveness of these MPAs in reducing fish pressure were unavailable for the vast majority of MPAs. Three MPAs were rated as partially effective, ten as ineffective, and the remainder were unknown. A fraction of one percent of the country's total reef area is inside the partially effective MPAs, while about 3 percent are in ineffective MPAs. (See Section 5 for additional management information). However, progress in establishing MPAs has been swift, considering that the country's first MPAs were established in 2000.[113]

PHILIPPINES

The country. Making up the northern tip of the Coral Triangle, the Philippines consists of about 7,100 islands[115] and more than 33,000 km of coastline.[116] The three main island groups, from north to south, include Luzon, the Visayas, and Mindanao. Among these island groups are 17 regions, 80 provinces, 138 cities, 1,496 municipalities, and more than 42,000 barangays (village districts that are the smallest political unit). The Philippines is a culturally diverse country; more than 150 languages are spoken across the many islands.

Biodiversity. The Philippines has 22,500 sq km of coral reef area, which represents 9 percent of the global total, making it the country with the third-largest reef area in the world (after Australia and Indonesia).[87] All major reef types are present in the Philippines; most are fringing reefs along the coastlines, as well as some areas of barrier, atoll, and patch reefs.[117] With such an extensive and diverse array of reefs, together with its location within the biogeographic core of the Coral Triangle, the country's marine biodiversity is remarkable, most notably in the center of the country within the Verde Island Passage between Mindoro and Luzon, as well as in the Visayas region to the south.[118] In total, 464 species of hard corals,[115] 1,770 species of reef fish,[119] and 42 species of mangroves[49] have been recorded in the Philippines to date.

People and reefs. More than 40 million people live on the coast within 30 km of a coral reef, which represents about 45 percent of the country's population.[120] Approximately 2 million people in the Philippines depend on fisheries for employment,[121] with about 1 million small-scale fishers directly dependent on reef fisheries.[122]The country's reefs yield 5 to 37 tonnes of fish per sq km, making them very important to the productivity of fisheries.[122] The Philippines is a major supplier of fish to the live reef food fish trade (LRFFT), a billion-dollar industry in the Asia-Pacific region.[123] In 2007, the Philippines exported at least 1,370 tons of coral trout (*Plectropomus leopardus),* one of the trade's most important species in terms of volume,[124]which fetched an estimated retail value of about $140 million, though this is likely an underestimate due to the high incidence of illegal and unreported trafficking in live fish.[125] Additionally, the Philippines

MAP 3.4. REEFS AT RISK IN THE PHILIPPINES

BOX 3.4 REEF STORY

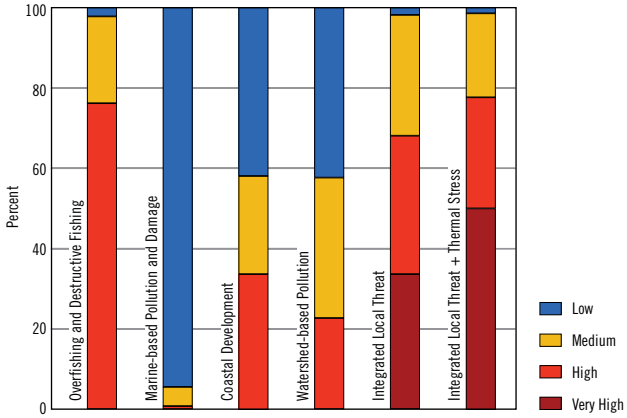
Philippines: Small MPA Provides Big Returns on Apo Island

Apo Island is a small volcanic island (<1 sq km) in the central Philippines that is home to more than 700 residents, most of whom depend on fishing for their food and livelihoods. The near-collapse of fish stocks around the island in the late 1970s led to a municipal ordinance establishing the Apo Island Marine Reserve in 1986. Gaining national protection in 1994, the MPA is currently co-managed by the national government and elected community members. While the marine reserve is small in area, its effect on the island community is substantial. Fisheries yields on the perimeter of the no-take reserve have improved significantly, both in terms of total catches and catch per unit effort (CPUE). Surveys have estimated a two-fold increase in yields and a 50-percent increase in CPUE for the period 1998 to 2001, as compared to the mid-1980s.

Meanwhile, the reserve has become an internationally renowned dive site for tourists seeking healthy coral reefs. The community generates revenue by charging tourists a fee to enter the MPA, and many former fishers (as many as 50 percent) have converted their primary employment from fishing to tourism-related activities. The continued success of the Apo Island Marine Reserve over the past 25 years illustrates that rapid and sustained ecological and socio-economic benefits are possible with a strong community commitment to MPA management.[136,137]

PHOTO: ALAN WHITE

FIGURE 3.4. REEFS AT RISK IN THE PHILIPPINES



exported nearly 1,000 tons of other species of live reef fish[126] with a retail value of more than $35 million. The high market price for live reef fish has attracted a growing number of small-scale fishers over the past decade, but at the expense of increasing overharvesting of these valuable species. This is exacerbated by the incidence of destructive fishing methods, including poison fishing, targeting spawning aggregations, and capture of immature fish. All of the Philippines' main target reef fisheries species are showing signs of overfishing.[127]Overall, the harvest rate of Philippine fisheries is approximately 30 percent higher than the maximum sustainable yield, which will likely trigger stock collapses in the absence of increased management.[121]

Status. The coral reefs of the Philippines have been studied fairly extensively relative to other countries in the region, with surveys for some areas dating back to the late 1970s.[128] Many of these surveys document a progressive decline in coral reef condition over the past few decades. A 2004 study found that reefs considered to be in excellent condition had declined from 5 percent in 1981 to 1 percent in 2004, and reefs in good condition decreased from 25 percent in 1981 to 5 percent in 2004.[115] Surveys of coral reefs conducted at 424 sites across the Philippines between 2000 and 2004 found that the vast majority of the sites (94 percent) had average live coral cover (hard and soft corals) in the fair or poor categories (50 percent living coral cover), while 24 sites had good coral cover and one had excellent coral cover.[115] It is important to note

that reefs with the highest and most stable levels of coral cover are most often found in protected areas, as are higher densities of fish and other reef species.[129-132]

Widespread development of the coastline has also led to degradation of nearshore ecosystems such as mangroves and seagrass beds. Mangrove cover across the Philippines has declined by 75 percent since the early 1900s, largely to clear areas for fishponds to support a growing aquaculture industry, but also due to logging for construction materials and fuelwood.[133]

Results.

- Almost all reefs in the Philippines are threatened by local activities. Two-thirds are rated in the high or very high threat categories.
- *Overfishing and destructive fishing* are the greatest threats, affecting 98 percent of reefs, with the exception of those within effectively managed MPAs. Destructive fishing alone (i.e., blast or poison fishing) threatens nearly 70 percent of reefs.
- *Coastal development* along crowded shorelines threatens nearly 60 percent of reefs.
- *Watershed-based pollution*, primarily from agricultural runoff and erosion of deforested slopes, also threatens nearly 60 percent of reefs.
- *Marine-based pollution* is a relatively minor threat, affecting about six percent of reefs.
- When the influence of recent *thermal stress and coral bleaching* is combined with local threats, nearly 80 percent of reefs are rated at high or very high threat, with over half in the very high threat category.

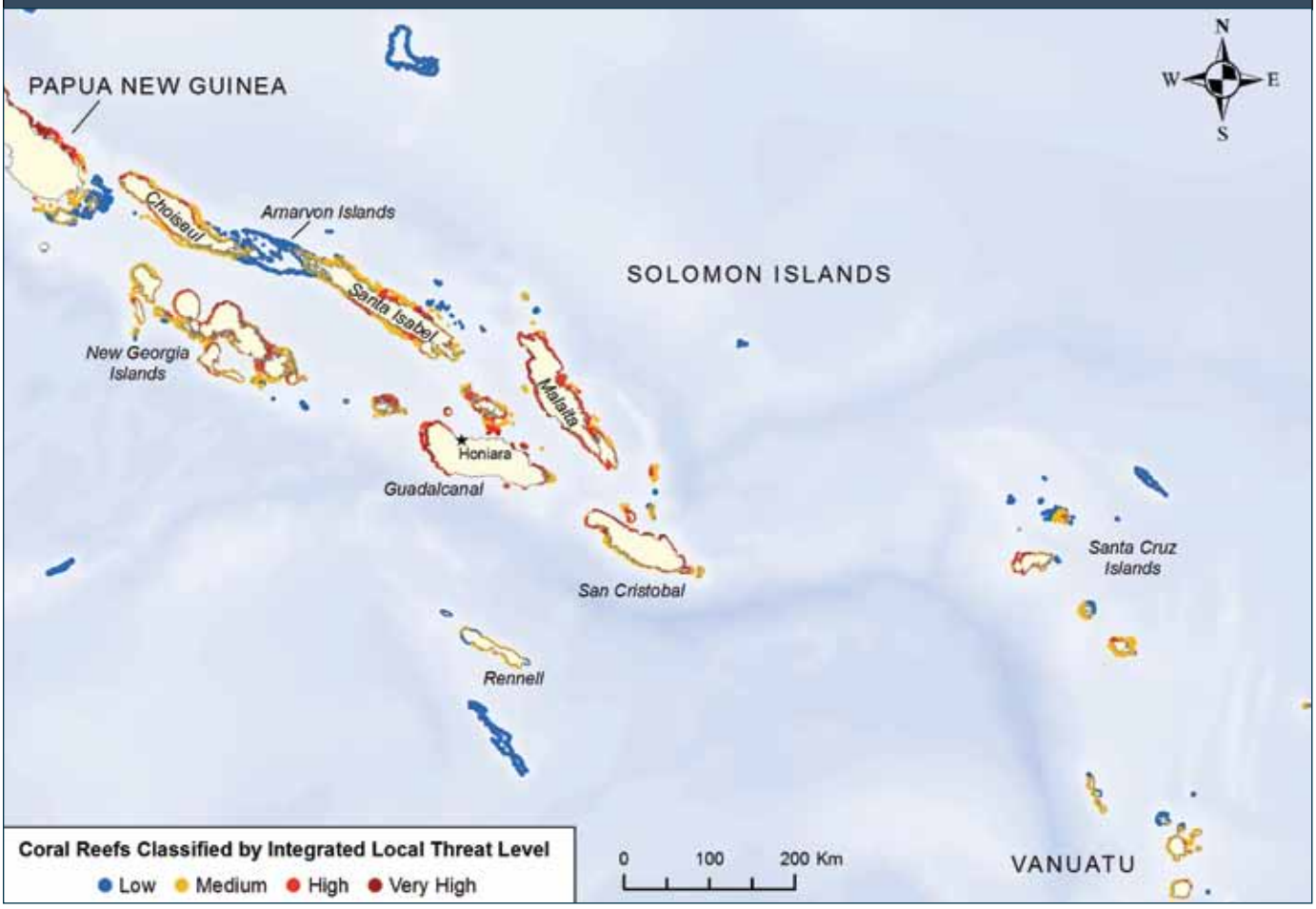
Conservation. Management of marine resources and marine protected areas (MPAs) in the Philippines is largely decentralized. Local government units manage the vast majority of MPAs located in municipal waters (defined as 15 km from the shoreline). This delegation of authority to the local level has contributed to an increase in the numbers of municipal MPAs, which can be established entirely through a municipal ordinance without national government approval.[132]At the national level, the National Integrated Protected Areas System Act grants authority to the Department of Environment and Natural Resources to establish and manage ecologically and nationally significant MPAs in partnership with local government through a Protected Area Management Board composed of national and local agencies and stakeholders.

National targets for MPA coverage were declared in the 1998 Fisheries Code, which calls for protection of 15 percent of municipal waters within no-take MPAs, and the Philippine Marine Sanctuary Strategy of 2004, which calls for 10 percent of coral reefs within no-take MPAs by 2020.[85,134] A 2010 evaluation of progress toward these goals found that about 5 percent of municipal waters were within MPAs, of which 0.5 percent was no-take area. [134]

As of 2011, the Philippines had 28 MPAs supported at the national level and more than 1,000 small MPAs supported by local governments.[85] Many of these local MPAs are still unmapped. The MPA analysis conducted for this report was able to include 232 mapped MPAs, which comprises all 28 national MPAs and about 200 local MPAs. Surveys on the effectiveness of these MPAs rated 25 MPAs as fully effective at reducing fishing pressure, 112 as partially effective, and 61 as ineffective. Of the fully effective MPAs, two are national MPAs—Tubbataha Reefs and Apo Island—and 23 are local. In total, 7 percent of Philippine reefs are inside MPAs, with less than 1 percent in effectively managed MPAs, 2 percent in partially effective MPAs, 2 percent in ineffective MPAs, and the remaining 3 percent in unrated MPAs.

The benefits of MPAs to fisheries are largely dependent on effective enforcement and compliance, which remains a challenge in the Philippines but is showing encouraging signs of improvement. The MPA Support Network, a local collaboration of government and nongovernmental organizations formed to build capacity for MPA management, performed a survey of MPAs in 2007 and found that the enforcement of fishing regulations at MPAs had improved since a previous survey was conducted in 2000.[113,135]

MAP 3.5. REEFS AT RISK IN SOLOMON ISLANDS



SOLOMON ISLANDS

The country. The Solomon Islands archipelago is located due east of Papua New Guinea in the Pacific Ocean and comprises the eastern boundary of the Coral Triangle Core. The archipelago is made up of six main islands (Choiseul, Santa Isabel, New Georgia, Guadalcanal, Malaita, and Makira) and more than 986 smaller islands.[138] A former British colony, Solomon Islands gained independence from the United Kingdom in 1978. The country has a parliamentary system of government and is divided into nine provinces that are governed at the local level by provincial assemblies.

Biodiversity. Marine biodiversity and species richness in Solomon Islands are among the highest in the world. Coral reef types include fringing, patch, barrier, lagoon, and atoll reefs,[138] which make up nearly 6,750 sq km of total coral reef area.[87] The Nature Conservancy conducted the first in-depth scientific survey of the country's marine biodiversity in 2004,[139] and identified 494 coral species, including nine potentially new species and extended the known range of 122 coral species.[140] The survey also recorded 1,019 species of reef fish, of which 47 were species range extensions.[141] Much of this diversity can be explained by the wide variety of habitat types and environmental conditions found throughout the archipelago, which range from sheltered embayments, enclosed lagoons, and barrier reefs to mangrove forests and seagrass meadows.[140] At least 24 species of mangroves cover approximately 600 sq km of coastal area in Solomon Islands.[49]

People and reefs. Approximately 540,000 people, 97 percent of the total population of Solomon Islands, live on the coast within 30 km of a coral reef.[142] The annual population growth rate is 2.8 percent, which is among the world's highest. Eighty-five percent of people live in rural villages, and most are dependent on marine resources for their livelihoods.[139] Approximately 83 percent of households engage in

fishing and, on average, Solomon Islanders consume nearly 46 kg of fish per person annually.[143] In coastal fishing communities, a socioeconomic study estimated annual fish consumption at an average of 118 kg per person.[144]

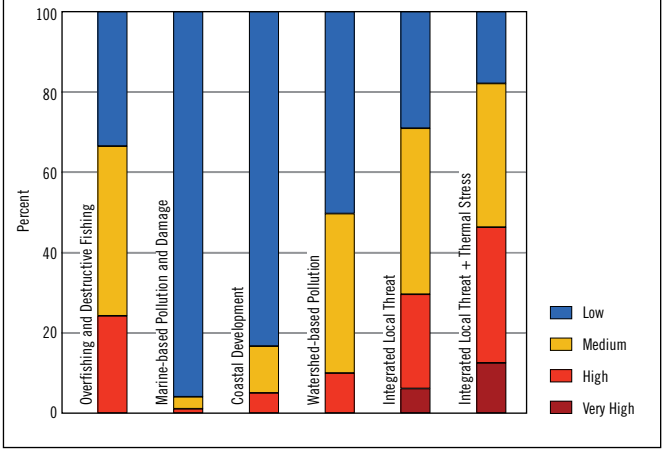
Fisheries in Solomon Islands are composed of two main sectors: industrial, which focuses on off-shore species such as tuna, and artisanal, which focuses on reef species. While the industrial sector generates more revenue for the national economy, the artisanal sector is vital for the employment and food security it provides for much of the population.[145]

The live reef food fish trade (LRFFT), which began operating in Solomon Islands in 1994, has always been a much smaller industry in the country than elsewhere in the Coral Triangle Region for several reasons. These reasons include its greater distance from the primary marketplace (Hong Kong), and thus higher mortality of fish during transport; and the relatively slim profit margin that fishers receive for live fish as compared to the local market price for dead fish.[146,147] In 1999, the Fisheries Department imposed a moratorium on LRFFT export licenses, primarily to curb heavy fishing of spawning aggregations. Even though the moratorium was lifted in 2000, no operators have resumed the business.[146,147]

Logging for the timber trade is a major industrial activity in Solomon Islands, generating more than half of all export revenue for the country. Mining is an expanding industry. Both of these industries are known to contribute significant pollution to coastal waters.[138]

Status. Compared to other parts of the Coral Triangle Region, the corals and marine resources of Solomon Islands are in relatively good condition.[148] The Nature Conservancy's 2004 marine assessment found that live hard coral cover ranged from 29 to 47 percent across the archipelago, with a decreasing trend from west to east.[149] The highest hard coral cover was surveyed in the Western, Isabel, and Choiseul provinces, which make up the western half of the country. The provinces around Makira and Malaita in the east had the lowest coral cover. Areas of high and low coral cover were strongly related to proximity to population centers and areas of industrial activities such as logging. Although fish diversity is high, a low number of target species indicates that fishing pressure also is high.[141] Species that are highly sought-after for the live reef food fish trade, particularly humphead wrasse, groupers, and large emperors, were rare throughout the Islands, with the highest populations found in the northwestern provinces. Aquarium fishes were found at low densities around Guadalcanal and Malaita, and the most popular species such as anemone fishes and angelfishes were rare throughout the Islands.

FIGURE 3.5. REEFS AT RISK IN SOLOMON ISLANDS



In 2007, a major earthquake and tsunami hit the western Solomon Islands. A rapid impact assessment of 29 locations in Western Province led by the WorldFish Center and WWF-Solomon Islands found varying levels of damage to reefs ranging from unaffected to significant.[150] The worst-affected areas had corals that were broken, rolled, cracked, or smothered with sediment. At some sites, underwater landslides had removed corals from reef slopes, and at other sites, reefs, seagrasses, and mangroves that were previously submerged had been uplifted and exposed to the air.

Results.

- About 70 percent of reefs in Solomon Islands are at risk from local human activities.
- *Overfishing and destructive fishing* are the most widespread threats, affecting more than 65 percent of reefs, especially around the more heavily populated central and eastern portions of the archipelago. Blast and poison fishing practices are relatively localized in Solomon Islands, affecting about 5 percent of reefs, mainly in the central

BOX 3.5 REEF STORY

Solomon Islands: Arnavon Islands MPA Improves Quality of Life in Local Villages

The Arnavon Community Marine Conservation Area, located between the main islands of Choiseul and Santa Isabel in the western Solomon Islands, is a 158-sq-km MPA that includes the three small Arnavon Islands and more than 18 sq km of coral reefs. It is co-managed by three local communities—Kia, Wagina, and Katupika—and the provincial government, with support from The Nature Conservancy. Approximately 2,200 people live within the three communities that manage the MPA.

In the nearly 15 years since its establishment, the MPA has dramatically improved the lives of residents of the three managing communities compared to communities elsewhere in Solomon Islands. A recent survey of community members found that household incomes are more than double that of other communities, due largely to the diversification of employment opportunities beyond fishing, which include MPA patrols, vegetable farming, and custom handcrafts. Trade and communication between the three culturally diverse communities have increased as village leaders work together on the MPA management committee. Moreover, the committee framework has empowered more villagers, especially women, to have an active role in community meetings and a more direct dialogue with the provincial government, which has strengthened government support for fisheries and local health care. While the MPA has not completely eliminated poverty among these communities and there have been challenges in sustaining consistent incomes from alternative livelihoods, villagers have noticed a clear improvement in their quality of life over the past 15 years because of the MPA.[137,154]

PHOTO: JAMES MORGAN

archipelago around Malaita and the Russell and Florida Islands near Guadalcanal.

- *Watershed-based pollution* is also a significant threat, affecting about 50 percent of reefs, especially due to run-off of sediment and nutrients from large-scale agriculture, logging, and mining.
- Population growth and urbanization are contributing to *coastal development* pressure, which threatens more than 15 percent of reefs, especially around Guadalcanal.
- The threat from *marine-based pollution* is relatively minor, affecting about 4 percent of reefs.
- When the influence of recent *thermal stress and coral bleaching* is combined with local threats, the area of threatened reefs increases beyond 80 percent, with about 45 percent rated at high or very high threat.

Conservation. The management of coastal resources in Solomon Islands is largely decentralized; several national laws assign responsibility to the provincial and local levels.[151,152] In particular, the country's constitution recognizes customary laws and the traditional rights of landowners to exercise control over their land and resources. This is significant for conservation strategies, given that Solomon Islanders have customary tenure rights to 87 percent of the country's land and adjacent marine resources. [152] The Fisheries Act (1998) recognizes customary fishing rights and also grants overall management responsibility for coastal and inshore fisheries to the nine provincial governments.

However, the provincial governments have largely not exercised this power and thus management of fisheries and other resources is mainly organized at the community level.[152] The Solomon Islands Locally Managed Marine Area (SILMMA) Network, a national branch of the region-wide grass-roots LMMA Network, has played a large role in proliferating the establishment of community-based MPAs and building capacity for resource management in Solomon Islands since 2003.[151,152] Most recently, the Protected Areas Act (2010) makes provisions for communities to acquire legal recognition for local management plans.[138,153] This legislation illustrates progress toward an integrated management approach that includes more coordination among the national, provincial, and local levels, which has been identi-

fied as a means of strengthening the existing practices and closing gaps in the current management system.[153]

The analysis of MPAs conducted for this report identified 127 MPAs in Solomon Islands, of which 18 were rated as partially effective at reducing fishing pressure and 109 had an unknown level of effectiveness. The vast majority of these MPAs (more than 100) are LMMAs. In total, 6 percent of the country's total reef area is inside MPAs, of which about 1 percent is inside MPAs rated as partially effective.

TIMOR-LESTE

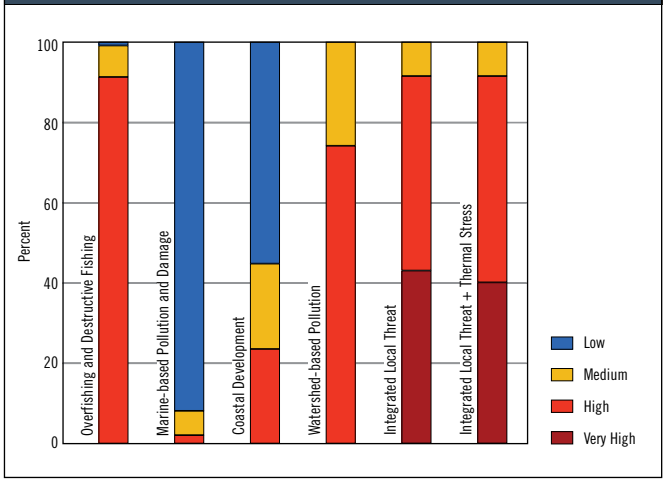
The country. Timor-Leste (also known as East Timor) is small country located on the southern boundary of the Coral Triangle Core. It lies within the Lesser Sunda Islands, and is made up of the eastern half of the island of Timor, the small islands of Atauro and Jaco, and the enclave of Oecussi, which is surrounded by the Indonesian province of West Timor. Indonesia occupies the remaining western portion of Timor. The total land area of Timor-Leste is 14,500 sq km,[155] and the population is about 1.1 million, 80 percent of which is rural.[156] Timor-Leste is a young democratic nation, having only gained its independence from Indonesia in 2002.[157] Following its recent emergence from a long period of conflict, Timor-Leste is one of the world's poorest countries, with a strong reliance on foreign aid, and more than 90 percent of the population dependent on subsistence livelihoods.[157,158] However, over the past few years, Timor-Leste has improved its standard of living, and the poverty rate has decreased from 50 percent in 2007 to an estimated 41 percent in 2009.[159]

Biodiversity. Approximately 146 sq km of fringing coral reef are located in the coastal waters of Timor-Leste, mostly along the northern coast and around the two offshore islands.[87] Timor-Leste is a mountainous country and parts of the coastline are dominated by steep cliffs. The country has little shelf area—the water drops steeply to depths of over 3,000 meters within just a few kilometers of the coastline.[160] For this reason, the area of nearshore coral reefs is small. Timor-Leste's reefs are not well-studied, thus there is little documentation of their biodiversity.[161] However, given its location within the Coral Triangle Core, reefs and other coastal ecosystems such as mangroves likely have rich biodiversity similar to that of the other countries in the region. Mangroves can be found primarily along the northern coastline, but Timor-Leste lost 80 percent of its mangrove area over the past 70 years, declining from 90 sq km in 1940 to 30 sq km in 2000 and to 18 sq km in 2008.[161]

People and reefs. More than half of Timor-Leste's total population lives on the coast within 30 km of a coral reef.[162] The Timorese are highly dependent on natural resources for food and livelihoods.[157] About one-third of households rely on subsistence farming, but production is

MAP 3.6. REEFS AT RISK IN TIMOR-LESTE

FIGURE 3.6. REEFS AT RISK IN TIMOR-LESTE



BOX 3.6 REEF STORY

Timor-Leste: Aquaculture Development has Potential to Generate Income and Food Security in Coastal Communities

As a young nation emerging from a history of conflict, Timor-Leste is still in the process of developing government institutions and building their capacity to meet the needs of the people. Two of the most pressing issues that the country must address are increasing the availability of food, which is chronically insufficient to feed a rapidly growing population, and cultivating sustainable economic growth. Given that more than 70 percent of the population currently depends on subsistence agriculture or fisheries, natural resource management is an integral part of addressing both of these issues.

To help increase food security and generate new income opportunities for coastal citizens while also reducing the pressure on nearshore fisheries, the Coral Triangle Support Partnership is supporting Conservation International's work with the government and citizens of Timor-Leste to develop a sustainable aquaculture industry. Seaweed farming is the most viable aquaculture opportunity and has had the most success in the country to date, particularly on the island of Atauro, located 25 km north of the capital of Dili. However, the lack of a legal framework for aquaculture businesses, such as designated farming areas and access regulations, has led to conflicts over competing uses of coastal resources. Furthermore, the limited number of local seaweed buyers has led to friction between buyers and sellers over fair market prices.

Conservation International is helping to further develop the industry by mediating between resource users, expanding the selling opportunities for farmers, and providing input to the government on its National Aquaculture Strategy. This strategy, including the development of necessary laws and institutional capacity, is crucial for the long-term sustainability of the industry, which in turn is critical to achieving the greater goal of poverty alleviation and food security in Timor-Leste.[166,167]

PHOTO: JHARENDU PANT (WORLDFISH)

low, and food shortages are common.[159] Despite the high employment in agriculture, it generates only about 2 percent of the country's wealth, while 85 percent is generated by large offshore petroleum reserves.[163] The rocky and steep terrain contributes to the food production difficulties; moreover, poor farming practices, such as clearing of forest and cultivation on steep slopes have caused significant erosion. The country's fishing industry is relatively small—the area of shallow, productive waters is limited and artisanal fishing is highly concentrated on the country's small reef area.[156] The Timor-Leste government estimates that about 5,000 fishers operate along the country's coastline, mainly using small canoes in coastal and intertidal areas.[158] The combination of low supply and high demand for fish causes high market prices, thus making fish a luxury food item that many Timorese people cannot afford.[158] Tourist visitation is currently low, with an estimated 1,500 tourists per year, but eco-tourism is a potential sector for growth and development.[163]

Status. There are few known surveys on the condition of Timor-Leste's reefs. One survey conducted in 2004 assessed the fringing reefs around the northeastern portion of the island of Atauro.[164] The survey recorded live coral cover ranging from 18 to 46 percent, which is considered fair condition. Reef fish diversity was high, but abundance of most commercially valuable species such as groupers, sweetlips, and snappers was very low. A number of absent species included those targeted by the live fish trade such as Barramundi cod and Bumphead parrotfish.[164] A 2009 survey of the reefs on the eastern tip of Timor-Leste and the island of Jaco revealed low coral cover (about 18 percent on average) likely due to recent outbreaks of crown-of-thorns starfish. Positively, there was little evidence of disease, bleaching, or blast-related damage. Hard coral diversity was found to be relatively low (124 species) compared to other areas of the Indo-Pacific; however, overall fish diversity was high (432 species), although densities of large predators and commercially valuable species were low.[165]

Results.

- All of the reefs in Timor-Leste are rated as threatened by local activities, with 92 percent at high or very high threat.

- *Overfishing* affects nearly every reef, although destructive fishing (blast and poison fishing) appears to be less common in Timor-Leste than in other Coral Triangle countries, affecting about 10 percent of reefs.
- *Watershed-based pollution* also threatens nearly every reef, driven by the steep, deforested slopes that contribute large volumes of sediment and pollution to the island's rivers and streams.
- *Coastal development* is not as widespread a threat as elsewhere in the region, affecting about 45 percent of reefs, although this may become a greater threat as the economy develops.
- About 8 percent of reefs are threatened by *marine-based pollution* from such activities as shipping and oil and gas extraction.

Conservation. In 2007, the government proposed the country's first national park, the Nino Konis Santana National Park on the far eastern tip of Timor-Leste. The park covers approximately 1,240 sq km in total, of which about 680 sq km is terrestrial and 560 sq km is marine area.[165] The management plan for the marine area is under development,[165] and the park is awaiting full legal establishment, though it is already operating as a protected area. The government of Timor-Leste is collaborating with CTSP to strengthen capacity for the management of the marine component of the national park. Thus far the collaboration has included work with local government and communities to generate a series of community-based zoning maps to facilitate establishment of a network of Locally Managed Marine Areas (LMMAs). These LMMAs will enable communities to better manage threats that require collective community action.

BRUNEI DARUSSALAM AND SINGAPORE

Brunei Darussalam and Singapore are both small countries adjacent to Malaysia with coastlines along the South China Sea (map 3.2). Brunei Darussalam, on the island of Borneo, has more than 185 species of hard corals among its 109 sq km of fringing, patch, and atoll reefs.[168] The primary threats to Brunei Darussalam's reefs are overfishing and destructive fishing, though these threats are less severe than in neighboring countries.

Singapore is made up of 63 islands at the tip of the Malay Peninsula. Despite its small area of coral reefs (13 sq km), diversity is relatively high; as many as 255 species of hard coral have been recorded there.[169] However, as a major industrial port and densely populated country, the reefs of Singapore are severely at risk from activities associated with land reclamation, sedimentation, and shipping, especially the reefs nearest to the shoreline.[169]

PHOTO: DANIEL AND ROBBIE WISDOM

Section 4. SOCIAL AND ECONOMIC IMPLICATIONS OF REEF LOSS

PHOTO: REBECCA WEEKS/MPB

In many nations, coral reef ecosystem services—including fisheries, tourism, and shoreline protection—are critically important to people's livelihoods, food security, and well-being. As a result, threats to reefs not only endanger ecosystems and marine species, but also directly threaten the communities and nations that depend on them. The relative social and economic importance of reefs is further increased by the fact that many reef-dependent people live in poverty, and have limited capacity to adapt to the effects of reef degradation. For many reef nations, a shift toward more effective conservation and sustainable use of coral reef resources may offer valuable opportunities for poverty reduction and economic development.

This section builds on the findings of the threat analysis by examining where identified threats to reefs may have the most serious social and economic consequences for reef nations. We represent a country's vulnerability to reef degradation and loss as the combination of three components: exposure to reef threats, dependence on reef ecosystem services (that is, social and economic sensitivity to reef loss), and the capacity to adapt to the potential impacts of reef loss.[170-172]

REEF DEPENDENCE

Hundreds of millions of people worldwide rely on reef resources.[173-175] Global estimates of the economic values attributed to reef ecosystem services range from tens to hundreds of billions of dollars annually (box 4.3). Yet these numbers provide only a broad overview of the importance of reefs to economies, livelihoods, and cultures. To capture the multidimensional nature of people's reliance on reefs, we break down reef dependence into six indicators that are important at the national scale:

- *Reef-associated population.* Globally, more than 275 million people reside in the direct vicinity of coral reefs (within 30 km of reefs and 10 km of the coast), where livelihoods are most likely to depend on reefs and related resources. Within the Coral Triangle Region alone, 114 million people (31 percent of the total population) live in the direct vicinity of reefs.[176] In Solomon Islands, 97 percent of people are in this category.

- *Fisheries employment.* Fisheries are one of most direct forms of human dependence on reefs, providing vital food, income, and employment. They also play an important role in poverty alleviation.[174] In absolute numbers, the three countries with the greatest numbers of people who fish on reefs are found in the Coral Triangle –

BOX 4.1. ASSESSING VULNERABILITY: ANALYTICAL APPROACH

The three components of vulnerability to degradation and loss of reefs are outlined in table 4.1, with the national-level indicators used to assess them in the global *Reefs at Risk Revisited* assessment completed in 2011. We focused mainly at the national level, and included 108 countries, territories, and subnational regions (e.g., states) in the global study. Where data were unavailable, we interpolated values based on countries or territories within the same region that were culturally and economically similar. Results are presented as quartiles, with countries and territories classified in each of four categories (low, medium, high, and very high).

TABLE 4.1 VULNERABILITY ANALYSIS COMPONENTS, INDICATORS, AND VARIABLES

Component	Indicator	Variable
Exposure	Local threats to coral reefs	• *Reefs at Risk* integrated local threat index weighted by ratio of reef area to land area
Reef dependence	Reef-associated population	• Number of coastal people within 30 km of reefs • Coastal people within 30 km of reefs as a proportion of national population
	Reef fisheries employment	• Number of reef fishers • Reef fishers as a proportion of national population
	Reef-associated exports	• Value of reef-associated exports as a proportion of total export value
	Nutritional dependence on fish and seafood	• Per capita annual consumption of fish and seafood
	Reef-associated tourism	• Ratio of registered dive shops to annual tourist arrivals, scaled by annual tourist receipts as a proportion of GDP
	Shoreline protection	• Index of coastal protection by reefs (combining coastline within proximity of reefs, and reef distance from shore)
Adaptive Capacity	Economic resources	• Gross domestic product (GDP) + remittances (payments received from migrant workers abroad) per capita
	Education	• Adult literacy rate • Combined ratio of enrollment in primary, secondary, and tertiary education
	Health	• Average life expectancy
	Governance	• Average of worldwide governance indicators (World Bank) • Fisheries subsidies that encourage resource conservation and management, as a proportion of fisheries value
	Access to markets	• Proportion of population within 25 km of market centers (> 5,000 people)
	Agricultural resources	• Agricultural land area per agricultural worker

Indonesia, the Philippines, and Papua New Guinea. In both Indonesia and the Philippines, more than one million fishers are dependent on reef fisheries for their livelihood.[177] In Solomon Islands, more than 80 percent of households engage in fishing.[143]

- *Nutritional dependence.* Healthy reefs provide an abundant variety of foods, many of which are inexpensive sources of high-quality animal protein. In some places—particularly small, isolated islands with limited resources and trade—reefs may be the only such source. Across all reef nations and territories globally, people consume an average of 29 kg of fish and seafood per capita each year.[178] Of the countries in the Coral Triangle Region, fish consumption is higher than the global average in Malaysia, Singapore, the Philippines, Brunei Darussalam, and Solomon Islands. In Solomon Islands, fish provide more than 90 percent of total dietary animal protein.[144]
- *Export value.* Exports of reef-derived species and products represent important sources of revenue for tropical economies. Exports include many species and products from live and dead fish and invertebrates, as well as seaweeds. In 21 countries and territories globally, reef-associated exports are valued at more than 1 percent of total exports. Of the Coral Triangle countries, Solomon Islands has the highest relative value of reef-associated exports at about 3 percent of total exports.[87] In absolute terms, Indonesia and Philippines are among the top five exporters of reef products globally, with exports valued at more than US $115 million.[87]

- *Tourism.* About 100 countries and territories benefit from reef tourism globally.[179] In 23 reef countries and territories, tourism accounts for more than 15 percent of the country's GDP.[180] Spending by divers, snorkelers, beachgoers, and recreational fishers supports a range of businesses, including dive shops, hotels, restaurants, and transportation, and in some places, directly contributes to the management costs of marine parks and other types of marine protected areas (MPAs). Tourism in the Coral Triangle Region is a burgeoning segment of national economies. Malaysia receives the fourth-highest number of tourists globally, with an average of more than 17 million visitors each year.[28] Malaysia and Solomon Islands generated the highest income from tourism in the region in 2009 as a proportion of total GDP. In each of these countries, tourism accounted for about 9 percent of GDP.[30] Indonesia also has a rapidly growing tourism industry. Between 2006 and 2010, the number of tourists visiting the country grew by more than 40 percent, from about 4.9 million to 7 million tourists annually.[29]
- *Shoreline protection.* Coral reefs play a valuable role in buffering coastal settlements and infrastructure from the physical impacts of wave action and storms, thereby reducing coastal erosion and lessening wave-induced flooding. More than 150,000 km of shoreline in 106 countries and territories benefit from protection provided by reefs.[181] In the countries of the Coral Triangle Region, an estimated 45 percent of the coastline is protected by reefs, with higher proportions protected in Solomon Islands (about 70 percent) and the Philippines (about 65 percent).

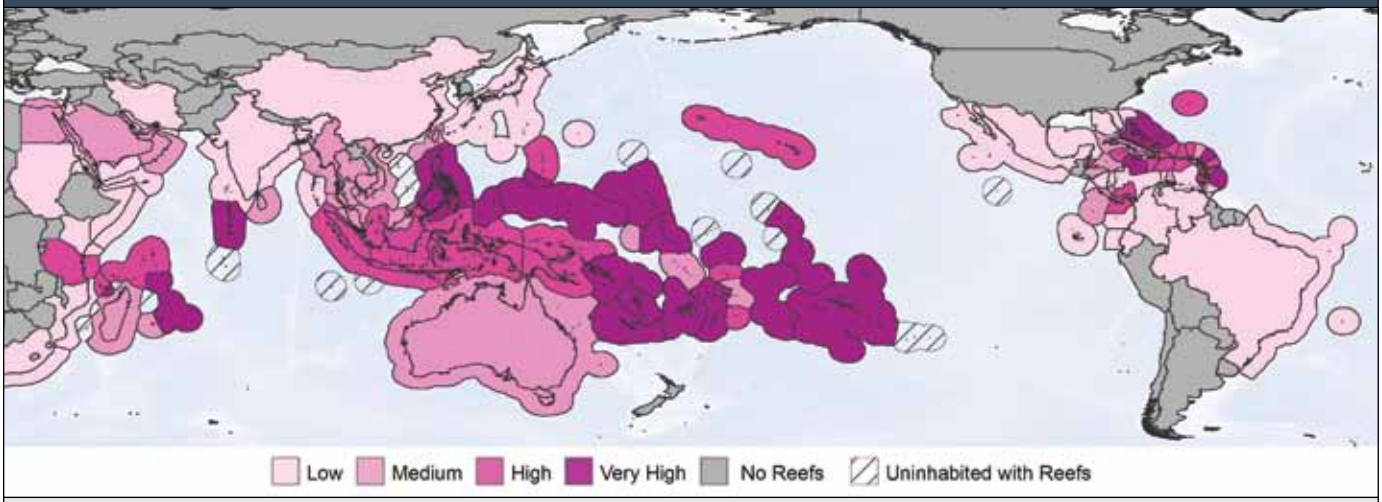
Combining all six indicators reveals several geographic clusters of particularly strong dependence on reefs (map 4.1). Globally, nearly all of the most strongly reef-dependent nations are small-island states.

Within the Coral Triangle Region, the Philippines and Solomon Islands are the most heavily dependent on reefs, with both rated as having very high reef dependence. Indonesia, Papua New Guinea, and Sabah (Malaysia) are considered to have high dependence on reefs.

ADAPTIVE CAPACITY

Adaptive capacity is the ability to cope with, adapt to, or recover from the effects of changes.[184] For nations faced with reef degradation and loss, adaptive capacity includes the resources, skills, and tools available for planning and responding to the effects of the resulting losses of reef ecosystem services. Like reef dependence, adaptive capacity is complex and cannot be directly measured. We therefore separate adaptive capacity into six national-scale indicators that are relevant to reef-dependent regions. We use two types of indicators: (1) those that describe general aspects of human and economic development, including economic resources, education,

MAP 4.1. 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. Eighty-one countries, 21 island territories, and six subnational regions (Florida, Hawaii, Hong Kong SAR, Peninsular Malaysia, Sabah, and Sarawak) were assessed, and are categorized according to quartiles. Reef territories that are only inhabited by military or scientific personnel are not included.

BOX 4.2 REEF STORY

Philippines: Multidisciplinary Approach Reduces Pressure on Culion Island's Reefs

Culion Island, part of the Palawan province in the southwestern Philippines, is surrounded by rich and diverse reefs. Yet in coastal villages, rapid population growth, heavy dependence on coastal resources, and destructive fishing practices have resulted in the near collapse of reef habitat and fisheries. To address these concerns, PATH Foundation Philippines started the Integrated Population and Coastal Resource Management initiative. The PATH approach helps communities address the relationships among population, environment, and the economy in a holistic fashion. This includes improved access to family planning, better community-led coastal conservation, and more options for alternative livelihoods that are less dependent on reefs. Women and young people are actively encouraged to participate. So far this initiative has increased community well-being, food security, and the health of Culion's reefs. Surveys conducted between 2001 and 2007 found that over this period the number of families reliant on subsistence fishing had decreased, as did the use of destructive fishing methods. Furthermore, both average live coral cover and biomass of reef fish had increased.[182,183]

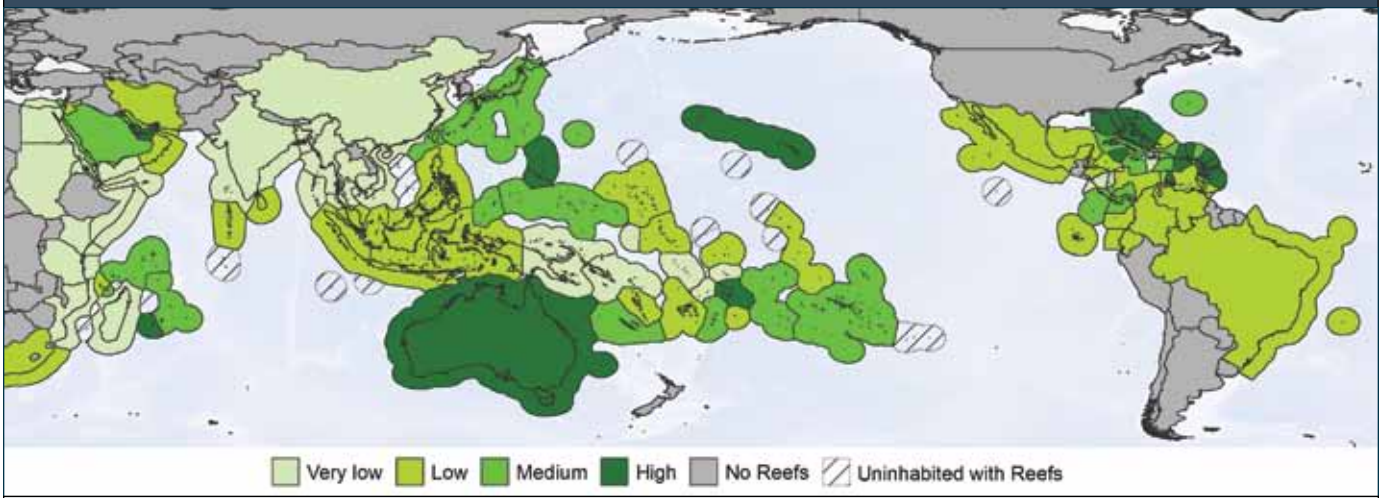
PHOTO: PATH FOUNDATION

See full story online at http://www.wri.org/reefs/stories.

health and governance; and (2) those that are more specific to the case of potential reef loss, including access to markets (for trading food and goods not derived from reefs) and agricultural land area (a proxy for the availability of non-reef natural resources to provide food and livelihoods).

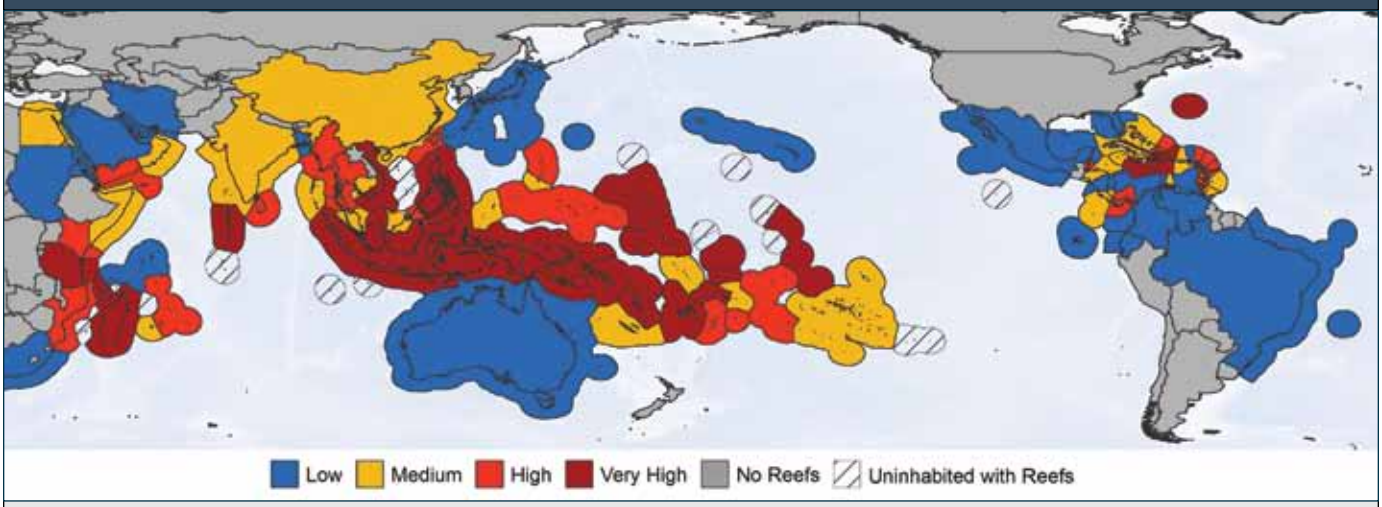
When these six indicators are combined, we find three countries in the Coral Triangle Region are characterized by having very low adaptive capacity—Timor-Leste, Papua New Guinea and Solomon Islands. Adaptive capacity is low in three other countries—Indonesia, Malaysia, and the Philippines. Not surprisingly, adaptive capacity is typically greatest among countries characterized by high levels of economic development and resources (such as Singapore) and oil-producing nations (such as Brunei Darussalam) (see map 4.2 and table 4.2).

MAP 4.2. CAPACITY OF REEF COUNTRIES AND TERRITORIES TO ADAPT TO REEF DEGRADATION AND LOSS



Notes: Adaptive capacity is based on economic resources, education, health, governance, access to markets, and agricultural resources. Eighty-one countries, 21 island territories, and six subnational regions (Florida, Hawaii, Hong Kong SAR, Peninsular Malaysia, Sabah, and Sarawak) were assessed, and are categorized according to quartiles.

MAP 4.3. SOCIAL AND ECONOMIC VULNERABILITY OF COUNTRIES AND TERRITORIES TO REEF LOSS



Notes: Vulnerability is based on exposure to reef threats, reef-dependence, and adaptive capacity. Eighty-one countries, 21 island territories, and six subnational regions (Florida, Hawaii, Hong Kong SAR, Peninsular Malaysia, Sabah, and Sarawak) were assessed, and are categorized according to quartiles.

TABLE 4.2 THREAT, REEF DEPENDENCE, ADAPTIVE CAPACITY, AND SOCIAL AND ECONOMIC VULNERABILITY RATINGS BY COUNTRY OR SUBNATIONAL REGION FOR THE CORAL TRIANGLE REGION

Countries and Territories	Exposure to Threat of Degradation	Dependence on Reefs	Adaptive Capacity	Social and Economic Vulnerability
Brunei Darussalam	Medium	Medium	High	Low
Indonesia	High	High	Low	Very High
Malaysia—Peninsular	Medium	Medium	Low	Medium
Malaysia—Sabah	High	High	Low	High
Malaysia—Sarawak	Low	Medium	Low	Medium
Papua New Guinea	Medium	High	Very Low	Very High
Philippines	Very High	Very High	Low	Very High
Singapore	High	Medium	High	Low
Solomon Islands	Medium	Very High	Very Low	Very High
Timor-Leste	High	Medium	Very Low	Very High

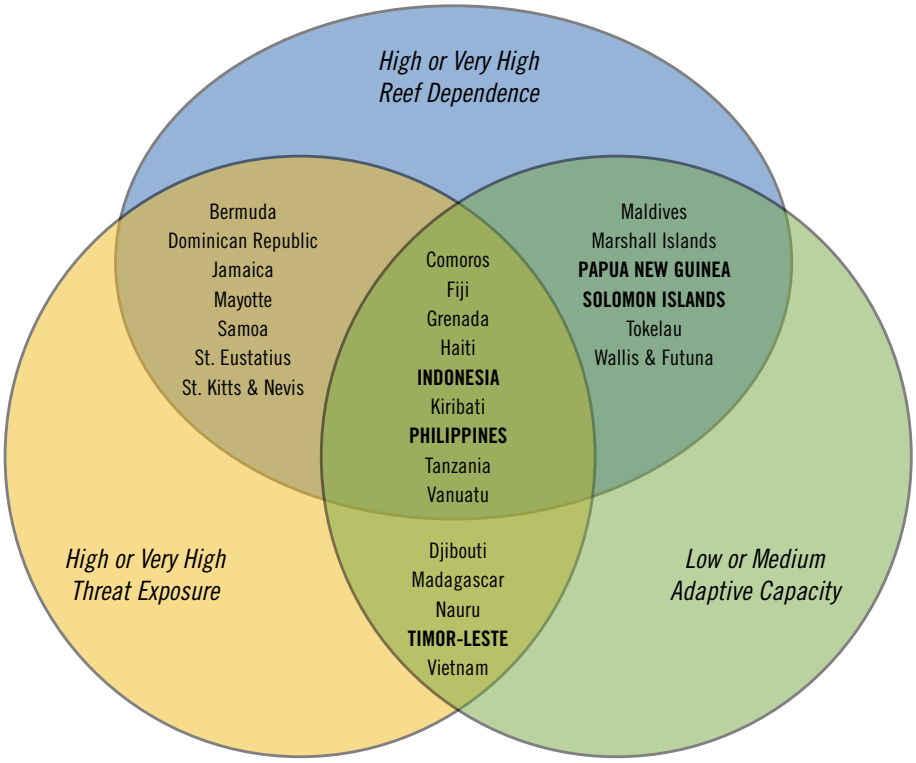
Notes: Most countries were evaluated at the national level within this global analysis. For a few countries, such as the discontiguous nation of Malaysia, sufficient information was available to permit a subnational assessment.

SOCIAL AND ECONOMIC VULNERABILITY

Combining the three components of vulnerability (exposure to reef threats, dependence on reef ecosystem services, and adaptive capacity) reveals that the countries and territories that are most vulnerable to the degradation and loss of reefs are spread throughout the world's tropical regions (map 4.3). Within the Coral Triangle Region, vulnerability is extremely high. Five countries—the Philippines, Solomon Islands, Indonesia, Timor-Leste and Papua New Guinea—are among the most highly vulnerable to coral reef degradation and loss (table 4.2). In the case of Malaysia (for which subnational data were available), Sabah was rated as highly vulnerable to reef degradation and loss, while Sarawak and Peninsular Malaysia were rated at medium vulnerability. Vulnerability is low for Singapore and Brunei Darussalam, owing to a combination of medium reef dependence and high adaptive capacity.

The most vulnerable countries and territories reflect different underlying combinations of the three components (figure 4.1). Each of these types of vulnerability has different implications for the likely consequences of reef loss; identifying them provides a useful starting point for setting priorities for resource management and development action to minimize potential impacts. It may also provide an

FIGURE 4.1. DRIVERS OF VULNERABILITY IN VERY HIGHLY VULNERABLE NATIONS AND TERRITORIES



Note: Only the 27 very highly vulnerable countries and territories are shown. Five of the six countries of the Coral Triangle Initiative are rated as having very high vulnerability to reef loss. Malaysia is the exception—vulnerability is high in the state of Sabah, but medium in Sarawak and Peninsular Malaysia.

opportunity for countries that are not considered highly vulnerable to plan how best to avoid future potential pitfalls.

Of the Coral Triangle countries, Indonesia and Philippines are in a position of most serious immediate social and economic vulnerability, with high to very high exposure and reef dependence, and low to medium adaptive capacity. These nations require concerted national and local efforts to reduce reef dependence and build adaptive capacity, alongside reducing immediate threats to reefs. These efforts should ideally be integrated within the broader national development context. Recognizing the needs of reef-dependent communities within other ongoing development initiatives may bring opportunities for reducing their vulnerability to future reef loss, as well as identifying the role that sustainable use of reef resources can play in poverty reduction and economic development. Accordingly, both countries have enacted proactive policies to support local stewardship of coral reef resources in an effort to address reef destruction and dependence through programs that engage coastal communities in resource management, marine protected areas, livelihood projects, and education.

In Papua New Guinea and Solomon Islands, exposure to reef threats is rated as medium, and is not yet extreme at the national scale. However, their strong reliance on reefs and limited capacity to adapt suggest that if pressures on reefs increase, serious social and economic impacts may result. This situation may offer a window of opportunity to build secure management frameworks to protect reefs, shift some human dependence away from reefs, and strengthen local and national capacity for reef management. Customary tenure and an expanding network of LMMAs are important aspects of management in both countries, offering the potential for such actions that may reduce vulnerability. The window may be limited, however, given that large-scale threats such as climate change and natural disasters, which are not included within the exposure index, may also have serious consequences on reefs. For example, reefs in the western Solomon Islands were affected by an earthquake

and tsunami in 2007, with resulting impacts on coastal communities and fisheries.[150]

In Timor-Leste, very high vulnerability stems from high threats to reefs and limited adaptive capacity, despite only moderate national-scale dependence on reefs. This combination of drivers suggests that while social and economic impacts of reef loss may be serious for some local areas, these effects are likely to be less significant on a national scale. Vulnerability may be reduced most effectively by targeting efforts to reduce threats to reefs and build capacity at local scales, raising government awareness about locations where reef dependence is particularly high, and paying attention to others where this dependence may increase. A primary objective within the government of Timor-Leste is to identify and encourage economic development opportunities that both employ people and lessen dependence on natural resources, including coral reefs.

BOX 4.3. ECONOMIC VALUE OF CORAL REEFS

Valuation

Economic valuation is a tool that can aid decision making by quantifying ecosystem services, such as those provided by coral reefs, in monetary terms. In traditional markets, ecosystem services are often overlooked or unaccounted for, an omission that regularly leads to decisions favoring short-term economic gains at the expense of longer-term benefits; for example, clearing mangroves to make room for aquaculture versus the longer-term benefits of leaving mangroves in place, which include nutrient filtering, shoreline protection, and habitat for fisheries species. Economic valuation provides more complete information on the economic consequences of decisions that lead to degradation and loss of natural resources, as well as the short- and long-term costs and benefits of environmental protection.

Coral reef values

Many studies have quantified the value of one or more ecosystem services provided by coral reefs. These studies vary widely in terms of spatial scale (from global to local), method used, and type of value estimated. Some assessments focus on the annual benefits coming from reefs, and some estimate total value over a number of years. Still others focus on the change in value as an ecosystem is altered.

Of the many ecosystem services provided by coral reefs, reef-related fisheries, tourism, and shoreline protection are among the most widely studied because their prices are traceable in markets and are thus relatively easy to calculate. We provide examples of values in table 4.3. The economic benefits derived from coral reefs vary considerably by site, depending on the size of tourism markets, the importance and productivity of fisheries, level of coastal development, and the distance to major population centers.

TABLE 4.3 SAMPLE VALUES: ANNUAL NET BENEFITS FROM CORAL REEF-RELATED GOODS AND SERVICES* (US$, 2010)

Extent of Study	Tourism	Coral-reef Fisheries	Shoreline Protection
Global[a]	$11.5 billion	$6.8 billion	$10.7 billion
Indonesia (National)[b]	$127 million	$1.5 billion	$387 million
Philippines (National)[c]	$133 million	$750 million	$400 million
Raja Ampat, Indonesia (local)[d]	$1.7 million	$7.7 million	$62 thousand
Tubbataha, Philippines (local)[e]	$3.7 million	$1.5 million	Not evaluated

* All estimates are net benefits (which take costs into account) and have been converted to US$ 2010.

Sources:

a. Cesar, H., L. Burke, and L. Pet-Soede. 2003. *The Economics of Worldwide Coral Reef Degradation.* Zeist, Netherlands: Cesar Environmental Economics Consulting (CEEC).

b. Burke, L., E. Selig, and M. Spalding. 2002. *Reefs at Risk in Southeast Asia.* Washington, DC: World Resources Institute. Adapted from H.S.J. Cesar. 1996. "Economic Analysis of Indonesian Coral Reefs." Working Paper Series 'Work in Progress.' Washington, DC: World Bank.

c. Burke, L., E. Selig, and M. Spalding. 2002. *Reefs at Risk in Southeast Asia.* Washington, DC: World Resources Institute. Adapted from A.T. White, H.P. Vogt, and T. Arin. 2000. "Philippine Coral Reefs under Threat: The Economic Losses Caused by Reef Destruction." *Marine Pollution Bulletin* 40, 7 (2000): 598-605; and A.T. White and A. Cruz-Trinidad. 1998. *The Values of Philippine Coastal Resources: Why Protection and Management are Critical.* Cebu City: Coastal Resource Management Project.

d. Emerton, L. 2009. "Investing in Natural Infrastructure: The Economic Value of Indonesia's Marine & Coastal Ecosystems." Denpasar, Indonesia: Indonesian Marine Program, The Nature Conservancy. Based on work presented in Dohar, A. and D. Anggraeni. 2006. *Economic Valuation of Natural Resources and Ecosystem Services, Raja Ampat.* Jakarta: Universitas Negeri Papua (UNIPA) and Conservation International Indonesia; and Sumaila, U.R. and M. Bailey. 2007. *Towards Ecosystem-Based Management in the Birds Head Functional Seascape of Papua, Indonesia: The Economic Sub-Project.* Jakarta: The Nature Conservancy, Conservation International, and WorldWide Fund for Nature Indonesia.

e. Subade, R.F. 2006. "Mechanisms to Capture Economic Values of Marine Biodiversity: The Case of Tubbataha Reefs UNESCO World Heritage Site, Philippines." *Marine Policy* 31, 2 (2006): 135-142. Adapted from Arquiza, Y., and A. White. 1994. "Tales from Tubbataha: Natural History, Resource Use, and Conservation of the Tubbataha Reefs, Palawan, Philippines." Mandaluyong City, Philippines: Rainee Trading and Publishing, Inc.

BOX 4.3. *continued*

Valuation of losses due to degradation

Although many economic valuation studies have focused on estimating the benefits of coral reef ecosystem services, some studies have also focused on changes in value—that is, what an economy stands to lose if a reef is degraded. Examples include:

- The 2004 *Reefs at Risk in the Caribbean* study estimated that, by 2015, the projected degradation of Caribbean reefs from human activities such as overfishing and pollution could result in annual losses of US$95 million to US$140 million in net revenues from coral reef-associated fisheries, and US$100 million to US$300 million in reduced tourism revenue. In addition, degradation of reefs could lead to annual losses of US$140 million to US$420 million from reduced coastal protection within the next 50 years.[187]
- Pervasive overfishing in Indonesia and the Philippines could result in massive societal losses, estimated at US$1.9 billion over 20 years in Indonesia and $1.2 billion over 20 years in the Philippines.[35]
- Another study estimated that Australia's economy could lose US$2.2 billion to US$5.3 billion over the next 19 years due to global climate change degrading the Great Barrier Reef.[188]

Moving in the other direction, improved management can increase the sustainable benefits provided by coral reefs. A valuation of coral reefs surrounding Olango Island in the Philippines compared current economic benefits (net revenues) with those that would be possible under improved coastal and fisheries management within an MPA, and projected a 55 to 60 percent increase in benefits, which vastly exceeds management costs. For the Giluntungan Marine Reserve at Olango, estimates of incremental annual revenues from tourism and fisheries under improved management were estimated at US$176,000 and $24,000, respectively, while estimated management costs were only US$21,000.[189]

Policy and Management Applications

The goal of economic valuation is to influence decisions that will promote the conservation and sustainable management of reefs. By quantifying the economic benefits or losses likely to occur due to degradation of reefs, it is possible to tap public and private funding for coastal management, gain access to new markets, initiate payments for ecosystem services, and charge polluters for damages. The results of coral reef valuation studies have helped to establish user fees at MPAs, improve fisheries management regulations, and inform damage claims assessments. Despite the usefulness of economic valuation, there are still many challenges to its practical application. In particular, although global-scale valuation studies are frequently cited, they are often misleading due to the difficulty of aggregating values and constraints on data at the global level. Furthermore, economic valuation can produce only a partial estimate of total ecosystem value, as humankind's limited technical, economic, and ecological knowledge prevents us from ever truly identifying, calculating, and ranking all of an ecosystem's services, benefits, and values. Valuation studies also contain a range of assumptions and limitations, which must be taken into account during the decision-making process. Economic valuation can inform policy decisions, but valuations tend to be most useful when developed with a particular policy application in mind, such as evaluating the benefits of a no-take reserve, and at a scale that national or local policy makers can relate to from their own experience.

PHOTO: BRUCE BOWEN

Reducing reef dependence is extremely challenging. In many areas, a lack of information about dependence on specific reef ecosystem services—for example, dietary consumption, or numbers of subsistence fishers—has hindered planning and prioritization at local scales. Even where reef dependence is well-understood, past efforts to develop alternative livelihoods in coastal areas have frequently proven unsuccessful.[185] Such initiatives have typically been carried out on a very limited scale and as stand-alone efforts, rather than within the framework of broader development programs. Furthermore, many such initiatives have failed to identify or adequately consider the reasons why individuals choose to engage in reef-dependent livelihood activities. In some cases, activities such as agriculture, aquaculture, tourism, or trade may represent viable alternatives, but these will only be sustainable where their development takes into account local aspirations, needs, perceptions, and cultural ties to coral reefs.[186] For millions of reef-dependent people in the Coral Triangle and around the world, it is critical that such efforts succeed.

Section 5. SUSTAINING AND MANAGING CORAL REEFS FOR THE FUTURE

PHOTO: MOHD YUSUF BIN BURAL/WWF

Despite an overall picture of rising levels of stress and of failing reef health and productivity, people *can* live sustainably alongside reefs. The Coral Triangle Region offers a number of examples of places where people have derived considerable benefits from reefs, sustainably, over decades or centuries. The challenges, as societies grow and technologies change, are to understand the limits to sustainability and to manage human activities to remain within these limits.

This section focuses on the role of marine managed areas—notably marine protected areas (MPAs) and locally managed marine areas (LMMAs)—in protecting coral reefs. Such areas are the most widely used tools in coral reef management and conservation, and are the only tools for which sufficient data were available to conduct a global analysis. The section first briefly discusses the role of MPAs and LMMAs in reef management, and then presents the results of an assessment of reef coverage in managed areas, including the level of effectiveness of these managed areas, for both the world and the Coral Triangle Region. Section 3 provides additional details on reef conservation and management in each country of the Coral Triangle Region.

REEF PROTECTION APPROACHES

In addition to marine managed areas, a broad range of other management approaches can support reef health and resilience. Numerous fisheries management tools—regarding fishing grounds, catch limits, gears, fishing seasons, or the capture of individual species—are often applied independently of individual MPAs and at a broader geographic scale. Other management measures deal with marine-based threats; for example, through controls on discharge from ships, shipping lanes, and anchoring in sensitive areas. Land-based sources of sediment and pollution are managed through coastal zone planning and enforcement, sewage treatment, and integrated watershed management to reduce erosion and nutrient runoff from agriculture. A number of these approaches are visited again in section 6, which presents overall recommendations for reef conservation.

Communications, education, outreach, and training are all critical elements of reef protection, conservation, and sustainable use, both for improving people's understanding of risks, and for ensuring sustained application of management measures. In many cases, simply informing communities of alternative management approaches can lead to rapid changes. Incentives can also play an important role. Examples of alternative management approaches include training reef users to

BOX 5.1. MANAGING FOR CLIMATE CHANGE

One of the greatest challenges to coral reef conservation comes from climate change. Unlike other threats, damage to reefs from climate change cannot be prevented by any direct management intervention. However, there is good evidence that the likelihood and severity of damage on particular reef ecosystems can be reduced by (1) identifying and protecting areas of reef that are naturally likely to suffer less damage from climate change (that is, promoting "reef resistance"), and (2) designing management interventions to reduce local threats and improve reef condition, so that rates of recovery can be improved (that is, promoting "reef resilience").[47,197]Reef resilience is the basis for a number of new tools designed to help managers deal with climate change.[46] It involves developing a management framework, centered on MPAs, but extending beyond them using approaches integrated with coastal zone, watershed, and fisheries management. Small, isolated MPAs are less likely to promote resilience than networks of MPAs, which would ideally include some large areas. MPA networks should include representation of all reef zones and habitats to reasonable extents. Furthermore, they must protect critical areas, such as fish spawning areas or bleaching-resistant areas. The networks should also be designed to utilize connectivity, so that replenishment following impacts can be maximized. Finally, it is critical to establish effective management to reduce or eliminate other threats that would otherwise hinder

PHOTO: FREDA PAVA, TNC

recovery.[198] Although the impacts of ocean acidification have still not been broadly shown *in situ,* it is possible that proposed measures for managing reefs in the context of warming seas may also provide better conditions for corals to survive early stages of ocean acidification. It is critical to note that, at best, such local-scale measures will only buy time for coral reefs—accelerating climate change will eventually and irreversibly affect all reef areas unless the ultimate cause of warming and ocean acidification, greenhouse gas emissions, is addressed by the global community.

ensure sustainable practices, provision of alternative livelihoods, or even direct financial interventions such as payment for ecosystem services where local communities—when recognized and empowered as owners or stewards of an ecosystem—are paid in cash or kind for the benefits provided by the ecosystem.

Marine Protected Areas

MPAs are one of the most widely used management tools in reef conservation. Simply defined, an MPA is any marine area that is actively managed for conservation.[190] Such a definition is broad and includes a range of possible management regimes, with different types of management practices and authorities. At one end of the scale, it includes areas with just a few restrictions on fishing or other potentially harmful activities, with a reliance on local enforcement of customary rules. At the other, it extends to sites with comprehensive protection based on formally adopted and strict legal frameworks targeting multiple activities such as recreational boating, fishing, pollution, and coastal development. The management authority for MPAs can be vested with the central or local government, and can include varying degrees of local participation and community empowerment. In this report, the term MPA includes LMMAs, which are described in greater detail in the next section.

MPAs are valuable for research, education, and raising awareness about the importance of an area. Where the boundaries of sites extend into adjacent terrestrial areas, they may provide additional benefits, such as limiting coastal development or other damaging types of land use. Even sites with limited enforcement of regulations offer a basis on which future, more effective, management can be built.

At their most effective, MPAs are able to maintain healthy coral reefs even if surrounding areas are degraded. They support recovery of areas that may have been overfished or

affected by other threats, and they build resilient reef communities that can recover more quickly than non-protected sites from a variety of threats, including diseases and coral bleaching.[58,59,191-193] Establishing MPAs in networks is an important strategy for building reef resilience, especially in the face of climate change. MPA networks consist of individual MPAs established in strategic locations to enhance benefits from connectivity (e.g., larval dispersal between sites), protect critical areas such as fish spawning sites, replicate protection of habitat types, and integrate different management approaches (box 5.1). Of course, reefs inside MPAs are not immune to impacts. In most cases, MPAs offer only a proportional reduction in impacts, and degradation of reefs within MPAs is still a major problem.[194-196]

Locally Managed Marine Areas

The trend toward local ownership or authority of marine space or resources has led to more comprehensive and community-based management strategies in many areas. LMMAs are marine areas that are "largely or wholly managed at a local level" by individuals or groups who are based nearby.[199] Such areas are typically managed for sustainable use rather than conservation, but most restrict resource use, and many contain permanent, temporary, or seasonal fishery closures. In this way, LMMAs in their entirety are similar to many MPAs with no-take zones or wider areas of restricted use. The primary benefits of LMMAs are that the community can tailor and adapt the management approach to the meet the immediate needs of the community and address specific resources and activities.

In the Coral Triangle Region and throughout the Pacific, there is growing legal recognition of community-based ownership in countries such as Fiji, Solomon Islands, the Philippines, Papua New Guinea, and Vanuatu, often strengthening traditional tenure practices that in some countries go back centuries[200-202] (box 3.3). Such local management also facilitates the rapid transmission of ideas between neighboring communities and islands; for example, there has been a significant increase in the establishment of LMMAs in recent years across much of Solomon Islands.[199,203]

Scaled-up across multiple locations and communities, LMMAs could prove as important for coral reef conservation as the designation and effective management of very large-scale MPAs in remote areas where local threats are minimal. For the sake of simplicity, references to MPAs for the remainder of this chapter also include LMMAs.

Coverage of MPAs Globally and in the Coral Triangle Region

There are an estimated 2,688 coral reef protected areas worldwide, encompassing approximately 28 percent of the world's coral reefs (table 5.1).[204] There is considerable geographic variation in this coverage: while more than three-quarters of Australia's coral reefs are within MPAs, outside of Australia the area of protected reefs drops to only 17 percent. In comparison, within the Coral Triangle Region, 16 percent of coral reefs are inside MPAs (table 5.2).

While these overall protection figures are high compared to most other marine or terrestrial habitats, there is still cause for concern.

- *First, most coral reefs lie outside any formal management framework* (72 percent globally, but 84 percent in the Coral Triangle Region).
- *Second, not all MPAs are effective in reducing human threats or impacts*. Some sites, often described as "paper parks," are ineffective simply because the management framework is ignored or not enforced. This has long been an issue across the Coral Triangle Region.[35] If the regulations as defined in the MPA management framework were enforced, they would make a large contribution toward protection of coral reefs. In other cases, the regulations, even if fully and effectively enforced, are insufficient to address the threats within the MPAs' borders. For example, many of the larger sites in the Coral Triangle Region appear to protect large expanses of marine space, but provide only limited regulation of threats. An ongoing issue in the region is that the cost of enforcement tools (e.g., staffing, boats, fuel, aerial surveillance) are not yet affordable or available at the scale needed to be effective, particularly for MPAs farther off shore. In many cases, enforcement of MPAs in the Coral Triangle Region is more effective when the MPA is within sight of villages and towns, or within easy traveling distance.

A further problem is that many reefs are affected by threats that originate far away. Across the Coral Triangle Region, for-

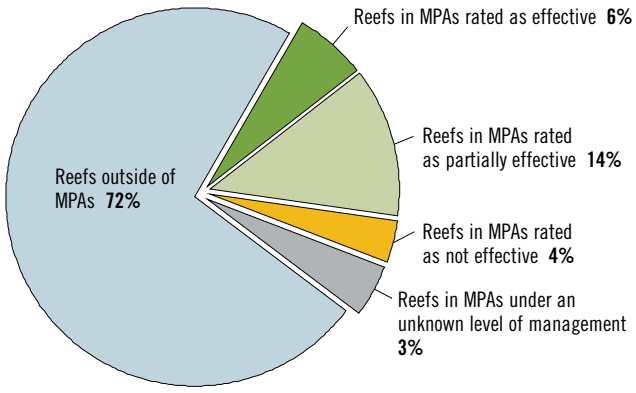
TABLE 5.1 GLOBAL COVERAGE OF CORAL REEFS BY MPAS AND MPA EFFECTIVENESS (BY REGION)

REGION	No. of MPAs	Reef Area in MPAs (sq km)	Total Reef Area (sq km)	Reefs in MPAs (%)	Sites rated	Number of Sites by Rating			
						Effective	Partial	Not effective	Unrated
Atlantic	617	7,630	25,850	30	310	38	82	190	307
Australia	171	31,650	42,310	75	27	12	14	1	144
Indian Ocean	323	6,090	31,540	19	192	56	88	48	131
Middle East	41	1,680	14,400	12	27	9	10	8	14
Pacific	944	8,790	65,970	13	252	46	144	62	692
Southeast Asia	592	13,180	69,640	19	389	32	187	170	203
Global Total	**2,688**	**69,020**	**249,710**	**28**	**1,197**	**193**	**525**	**479**	**1,491**

Notes: MPA counts only include those likely to contain coral reefs. Data are based on Reefs at Risk Revisited, supplemented with data from the CTSP, Coral Triangle Atlas, and Indonesian Ministry of Marine Affairs and Fisheries for Southeast Asia and the Pacific.

est clearance and agricultural intensification have led to increased pollutants and sediments in many coastal waters, and these cannot be kept outside of MPA boundaries. While healthy reefs within MPAs may be more resilient to such stresses, MPAs alone are unlikely to provide sufficient protection, and other management approaches may be required to deal with these issues. In a few cases, MPAs have made considerable progress by engaging with nearby communities to improve land management and reduce pollution and sediment runoff in adjacent areas.[205] Overall, more integrated forms of management are needed that include watersheds, coastal areas, and marine areas adjacent to MPAs, where threats exist that influence reef condition inside MPAs.

FIGURE 5.1. COVERAGE OF THE WORLD'S CORAL REEFS BY MPAS AND EFFECTIVENESS LEVEL

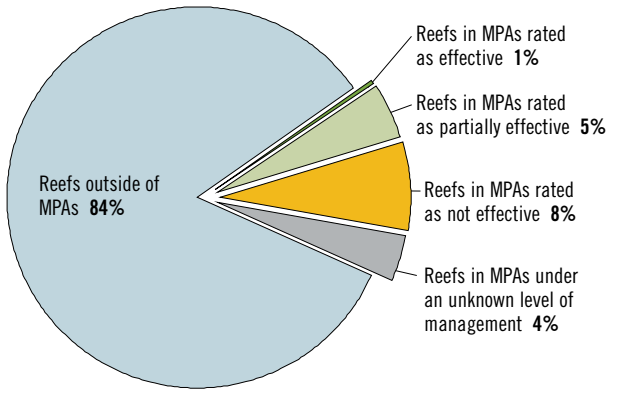


Note: The global area of coral reefs is 250,000 sq km (which represents 100% on this chart), including 69,020 sq km (28%) inside MPAs.

MANAGEMENT EFFECTIVENESS AND CORAL REEFS

There is no single agreed-upon framework to assess how well MPAs reduce threats, although considerable resources are now available to support such assessments.[206] For the global *Reefs at Risk Revisited* analysis and subsequent update for this report based on more recent and detailed information for the Coral Triangle Region, WRI and partners undertook a rapid review—with a limited scope—to try to assess the effectiveness of MPA sites at reducing the threat of overfishing.[207] Our interest was to capture the ecological effectiveness of MPA sites in as many places as possible. Sites might thus be classed as ineffective or partially effective either because of the failure of implementation *or* because the regulatory and management regime allowed for some ecological impacts. We obtained scores from regional experts

FIGURE 5.2. COVERAGE OF THE CORAL TRIANGLE REGION'S CORAL REEFS BY MPAS AND EFFECTIVENESS LEVEL



Notes: The area of coral reefs in the Coral Triangle Region is 86,500 sq km (which represents 100% on this chart), including 14,270 sq km (16%) inside MPAs.

Updated data on MPA coverage and effectiveness for the Coral Triangle Region supplemented the global analysis implemented under Reefs at Risk Revisited (WRI, 2011).

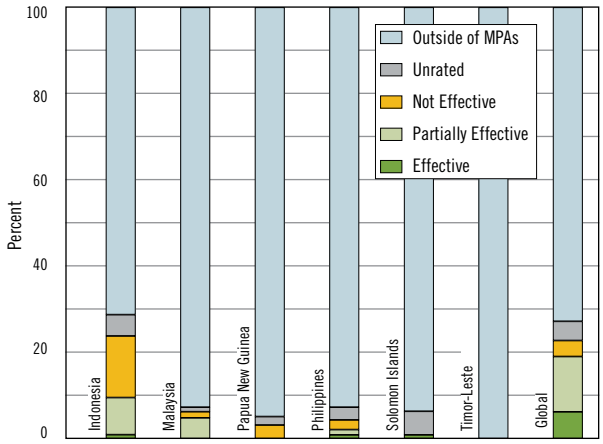
TABLE 5.2 COVERAGE OF CORAL REEFS BY MPAS AND MPA EFFECTIVENESS FOR COUNTRIES OF THE CORAL TRIANGLE REGION

Country	No. of Established MPAs	Reef Area in MPAs (sq km)	Total Reef Area (sq km)	Reefs in MPAs (%)	Number of Sites by Rating			
					Effective	Partial	Not effective	Unrated
Brunei Darussalam	7	<1	109	<1	0	3	0	4
Indonesia	175	11,383	39,538	29	3	24	59	89
Malaysia	93	205	2,935	7	5	41	30	17
Papua New Guinea	96	697	14,535	5	0	3	10	83
Philippines	232	1,572	22,484	7	25	112	61	34
Singapore	3	1	13	6	0	0	1	2
Solomon Islands	127	412	6,743	6	0	18	0	109
Timor-Leste	0	0	146	0	0	0	0	0
Total for Coral Triangle Region	**733**	**14,270**	**86,503**	**16**	**33**	**201**	**161**	**338**

Notes: MPA counts only include those likely to contain coral reefs. Based on Reefs at Risk Revisited, supplemented with updated data for the Coral Triangle Region. The table presents available ratings on management effectiveness, which are incomplete for many areas.

PHOTO: LAURETTA BURKE

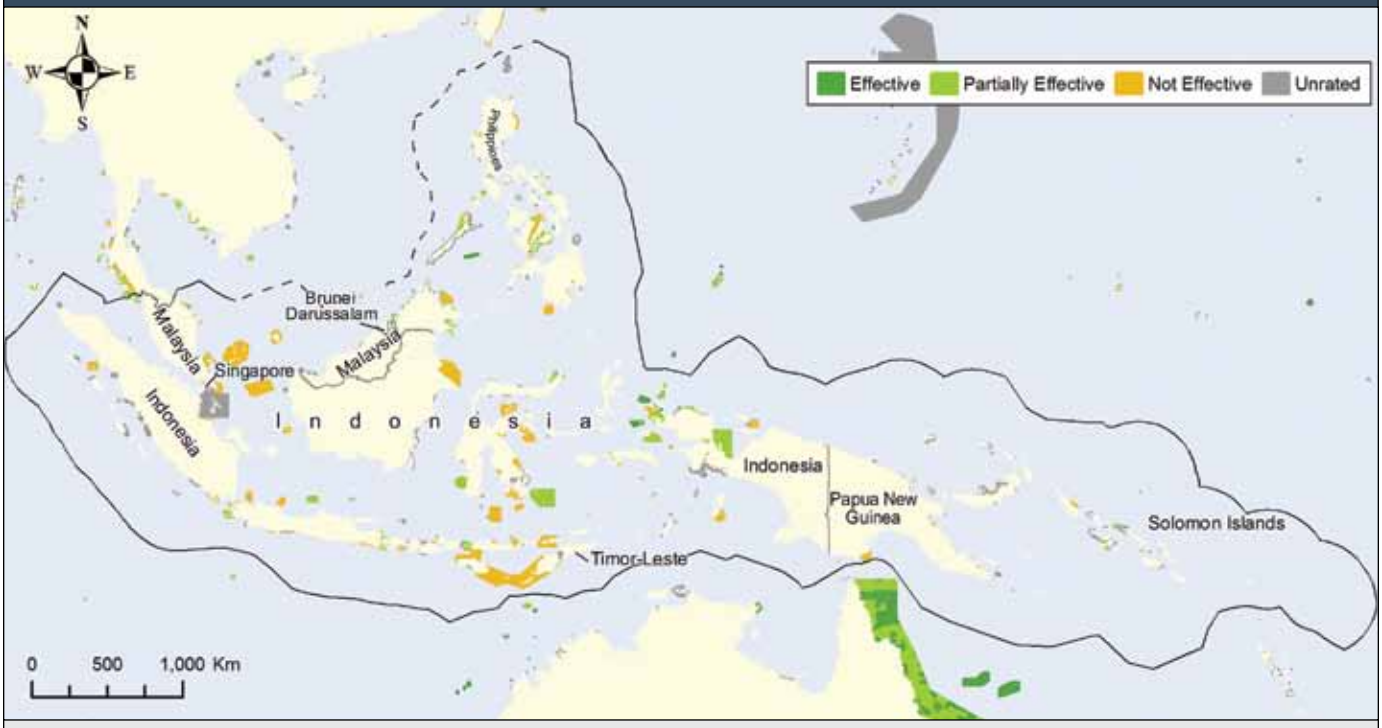
FIGURE 5.3. PROPORTION OF REEF AREA PROTECTED, BY MANAGEMENT EFFECTIVENESS



for 1,197 sites around the world, including 395 sites in the Coral Triangle Region (tables 5.1 and 5.2).

Globally, we find that 28 percent of the world's coral reefs are inside MPAs. However, only 6 percent of the world's reefs are located in MPAs rated as effectively managed, and 14 percent are located in areas rated as partially effective. About 4 percent are in areas rated as not effective (figure 5.1). Management of MPAs is even more of an issue in the Coral Triangle Region, due to the limited number of MPAs that are both effectively managed and large in size. In the Coral Triangle Region, we find that *less than 1 percent of coral reefs are in effectively managed MPAs* and only 5 percent of reefs are in partially effective MPAs (figures 5.2 and 5.3). Eight percent of the region's reefs are in MPAs rated as not effective, and 4 percent are in areas under an unknown level of management, though it is highly likely that MPAs for which management ratings were unavailable are not being managed effectively.

MAP 5.1. MARINE PROTECTED AREAS IN THE CORAL TRIANGLE REGION CLASSIFIED ACCORDING TO MANAGEMENT EFFECTIVENESS RATING



Notes: MPAs for coral reef regions were rated by regional experts according to their effectiveness level using a 3-category scheme. (1) MPAs rated as "effective" were managed sufficiently well that local threats were not undermining natural ecosystem function. (2) MPAs rated as "partially effective" were managed such that local threats were significantly lower than adjacent non-managed sites, but there may still be some detrimental effects on ecosystem function. (3) MPAs rated as "not effective" were unmanaged, or management was insufficient to reduce local threats in any meaningful way.

BOX 5.2 REEF STORY

Indonesia: Communities Protecting "Fish Banks" in Wakatobi National Park

Many larger reef fish such as groupers and snappers travel long distances to spawn in dense aggregations. Fishers often target such gatherings, rapidly decimating the adult population and simultaneously reducing the production of fish larvae that naturally restocks the reefs. Preventing fishing on these spawning aggregations is a considerable challenge, given the high market value of these species and the relative ease of catching fish at these sites.

With support from the Coral Triangle Support Partnership, communities living near Wakatobi National Park are working with The Nature Conservancy and World Wildlife Fund to address the decline in fish populations by increasing people's awareness of the reasons behind the decline. These efforts have fueled community-led initiatives, in collaboration with national park authorities, to close fishing on spawning aggregation sites. Some locals have begun referring to them as "fish banks," in recognition of their importance as investments in future food security. In areas of Wakatobi where the fishing closures have been effectively enforced, fish counts have shown a stabilizing of the numbers of groupers, snappers, and other reef fish, with the expectation that recovery of entire populations will follow. See full story online at **http://www.wri.org/reefs.**

PHOTO: ROBERT DELFS

Section 6. CONCLUSIONS AND RECOMMENDATIONS

PHOTO: JEFF YONOVER

This report presents a deeply troubling picture of the status of coral reefs in the Coral Triangle Region and around the world. Because of their high biodiversity and productivity, the Coral Triangle's reefs are arguably the most important in the world. Yet more than 85 percent are seriously threatened by a variety of local human pressures. Meanwhile, the accelerating impacts of global climate change are compounding these threats.

The extent and severity of local and global threats to the Coral Triangle's reefs point to an urgent need for action to preserve the critically important ecosystem services that the reefs provide. People's high dependence on reefs, in terms of providing food and livelihoods, means that the degradation of the region's reefs will be felt acutely by local populations, with implications for regional food security and globally important fish stocks.

But this report also highlights a path forward and, with appropriate action, a reason for hope: reefs around the world have shown capacity to rebound from damage. In the case of the Coral Triangle, historic exposure to wide variations in sea surface temperature in some areas may enable reef systems to be more resilient to warming seas associated with climate change.[208] Finally, active management and protection has already proven effective in aiding reef recovery and maintaining reef health, as shown in case studies from the Philippines' Tubbataha Reefs Natural Park (box 2.4) and Apo Island (box 3.4) and Indonesia's Wakatobi National Park (box 5.2), among others in the Coral Triangle Region.

However, to avoid irreversible damage and loss, we need to improve existing efforts to protect the Coral Triangle's reefs and the services they provide. Our collective ability and willingness to do so is becoming stronger—as evidenced by the region-wide Coral Triangle Initiative (box 6.1)—but we need to continue to expand the array of measures to deal with the many threats to reefs. National programs—such as those to design, implement, and enforce networks of MPAs—are critical to ensure efficient use of limited resources. At national and local scales, programs need to be integrated and coordinated across sectors so that marine resource management is reinforced by appropriate economic development actions. Local and national efforts also must continue to be linked within a regional framework, such as the six-nation Coral Triangle Initiative, to improve their efficiency and effectiveness. To support and facilitate more active engagement at and between the different scales, there is a continuing need to develop new management tools, improve communications, and increase public understanding.

BOX 6.1. THE CORAL TRIANGLE INITIATIVE

In May 2009, the governments of Indonesia, Malaysia, Papua New Guinea, the Philippines, Solomon Islands, and Timor-Leste signed the Coral Triangle Initiative Declaration on Coral Reefs, Fisheries, and Food Security (CTI-CFF). CTI-CFF is a multilateral partnership that aims to safeguard the marine and coastal resources of the Coral Triangle.
Under the CTI-CFF, the six Coral Triangle countries collectively adopted a Regional Plan of Action, which was soon followed by each country's adoption of a CTI-CFF National Plan of Action that aligns with the goals of the regional plan. The Regional Plan of Action is organized around five goals, each supported by a technical working group chaired by one of the six countries:

1. Priority seascapes designated and effectively managed (chair: Indonesia)
2. Ecosystem approach to management of fisheries and other marine resources fully applied (chair: Malaysia)
3. Marine protected areas established and effectively managed (chair: Philippines)
4. Climate change adaptation measures achieved (chairs: Indonesia and Solomon Islands)
5. Threatened species status improving (chair: Philippines).

The technical working groups include national representatives from each country and various partners that provide technical and financial assistance, including the United States Agency for International Development (USAID), the government of Australia, the Global Environment Facility, and the Asian Development Bank.
The Regional and National Plans of Action contain indicators and targets for each of the five goals at both the regional and national scales that are to be accomplished by 2020. For example, one strategy for protecting and enhancing the condition of the Coral Triangle's reefs—as part of achieving Goal 3 for MPAs—is to "establish and make fully functional by 2020 a Coral Triangle Marine Protected Area System (CTMPAS)." The MPA Technical Working Group is designing the CTMPAS framework, where each country will contribute qualified MPAs to a region-wide system of MPAs. Criteria under consideration for determining qualified MPAs include meeting minimum standards for effective management, addressing core biodiversity issues, fulfilling fisheries and climate adaptation needs, and, where appropriate, providing key connectivity linkages within the larger MPA system. A projected benefit of the CTMPAS is that it provides an incentive for each country to elevate its standards for MPA design and management so that its MPAs will qualify for inclusion in the system.

Regional and global 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. Current international efforts, even if wholly successful, are not likely to curb increases in atmospheric warming, sea surface temperatures, and ocean acidification, all of which will have dramatic impacts on reef systems around the world, including those in the Coral Triangle. However, by taking the appropriate actions now to protect reefs from local pressures, we may be able to "buy time" in the face of climate change through local-scale measures to increase reef health and resilience.

RECOMMENDATIONS

We hope this report will spur further action to save the globally important reef ecosystems of the Coral Triangle Region. Toward this aim, we recommend the following specific actions involving a broad range of people at the local, national, regional, and international scales. Most of these actions are addressed under the Coral Triangle Initiative (CTI) Regional and National Plans of Action, and can be implemented with combined national and international support.

- **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 inefficient subsidies that encourage overfishing; enforcing fishing regulations; halting destructive fishing; improving and expanding MPAs to maximize benefits; and involving stakeholders in resource management.
  - *Manage coastal development* by implementing coastal zone planning and enforcement to encourage sound land development; protecting coastal vegetation;


PHOTO: JUN LAO/CTSP

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 (plants along rivers and streams).
- *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.

- **Enhance reef resilience locally.** A growing body of evidence has shown that by reducing local threats (including overfishing and land-based pollution), reefs may be able to recover more quickly from coral bleaching. Strategic planning to enhance local-scale reef resilience should target critical areas, such as fish spawning locations and areas of reef that are naturally more resistant to bleaching. Networks of protected areas should include different parts of the reef system to support reproductive connectivity and future reef replenishment.[209] Such efforts may represent an opportunity to "buy time" for reefs until global greenhouse gas emissions can be curbed (box 6.2).
- **Develop integrated management efforts at ecosystem scales.** Agreements that involve impacted sectors and communities are more likely to avoid duplication of efforts and potential conflicts, as well as maximize potential benefits. These agreements also need to consider ecological relationships that exist across jurisdictional boundaries. For reefs, relevant approaches include integrated coastal management, ocean zoning, and watershed management. In addition, the development and implementation of climate-resilient MPAs and networks of MPAs designed to protect biodiversity and support sustainable fisheries are essential to such efforts.[209,210]
- **Scale up efforts through international collaboration.** At all scales, political will and economic commitment are needed to reduce local pressures on reefs and promote reef resilience in the face of a changing climate. International tools can help, 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 the International Convention on the Prevention of Pollution from Ships (MARPOL), which regulates marine pollution. The Coral Triangle Initiative represents a tremendous step forward for international collaboration, one that will lead to real and practical results as full-scale implementation proceeds.
- **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 393 ppm (in 2012) 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. Individuals and civil society, NGOs, scientists, engineers, economists, businesses, national governments, and the international community all have a role to play to address this enormous and unprecedented global threat.

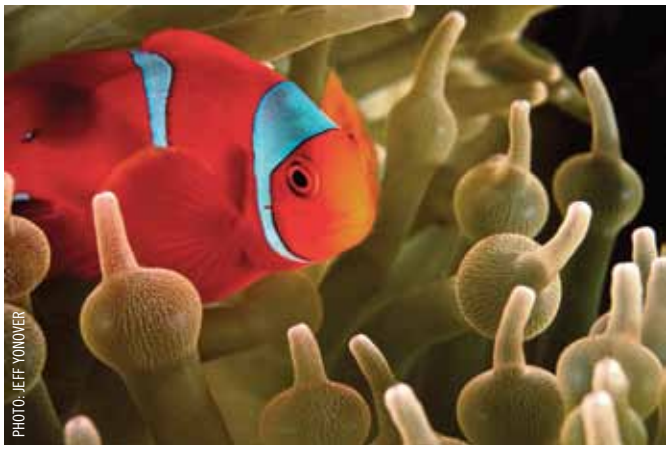
- **Build consensus and capacity.** Knowledge about reef species, threats, and management approaches has grown tremendously in recent years, allowing reef users and managers to better recognize problems, address threats, and gain political, financial, and public support for reef conservation. Nevertheless, a gap remains between our existing knowledge and results. Closing this gap depends on action within the following key areas:
  - *Involve local stakeholders* in the decision making and management of reef resources.
  - *Train and build capacity* of reef stakeholders to manage and protect reefs, understand and argue for their value, spread awareness, and reduce vulnerability in reef-dependent regions.
  - *Conduct 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.
  - *Conduct and publicize 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.
  - *Educate and communicate knowledge* to inform communities, government agencies, donors, businesses and the general public about how current activities threaten reefs and why action is needed to save them, to highlight examples of replicable conservation success, and to encourage greater collaboration across sectors. Raising awareness helps to build political will.
  - *Provide support to policy makers and planners* in making long-term decisions and implementing improved policies that will affect the survival of coral reefs, and that will help coastal communities to adapt to environmental changes and reef degradation.

- **Individual action.** Regardless of whether you live near or far from a coral reef, you can take action to help them:
  - *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. Do not use destructive methods (poison or blast fishing).
    - Avoid causing physical damage to reefs with boat anchors, or by walking on or touching reefs.
    - Choose sustainably caught seafood whenever possible, at a minimum avoiding rare species or juvenile fish.
    - Reduce household waste and pollution that reaches the marine environment.
    - Help protect coastal vegetation, such as mangroves and seagrass beds, that can buffer areas from natural disasters and protect coral reefs from land-based pollution.
    - 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.
    - Avoid buying souvenirs made from corals and other marine species.
    - Tell your political representatives why protecting coral reefs is important.

PHOTO: PERI PALERACIO

- *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 whenever possible.
  - 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.

Whichever of these you do, encourage others to do the same.



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BOX 6.2. BUILDING RESILIENCE IN THE FACE OF CLIMATE CHANGE IN THE CORAL TRIANGLE

In October 2011, the six countries of the Coral Triangle Initiative (CTI) adopted the "Region-Wide Early Action Plan for Climate Change Adaptation for the Nearshore Marine and Coastal Environment and Small Island Ecosystems" (REAP-CCA), which national representatives and partners developed during a series of regional exchange workshops. The REAP-CCA outlines the immediate actions that are needed across the Coral Triangle to build resilience to climate change among coastal communities and ecosystems. The goals of the REAP-CCA are to: (1) maintain marine and coastal ecosystem structure, function, and services critical to livelihoods and food security of coastal communities; and (2) support diversification strategies that build coastal community resilience to climate change. Each CTI country is currently developing detailed Local Early Action Plans (LEAPs) to help implement the region-wide plan. Typical strategies set forth in the LEAPs include performing vulnerability assessments; designing and implementing functional and climate-resilient MPA networks; ensuring that coastal areas of mangroves, reefs, seagrass beds, and beaches are protected and exempted from development; improving coastal governance monitoring and evaluation practices; and building capacity at the local level so that such actions and policies can be implemented. The REAP-CCA and LEAPs serve as important steps forward in realizing Goal 4 of the CTI Regional Plan of Action (climate change adaptation measures achieved).

CONCLUSION

Coral reefs are vitally important to the well-being of all of the countries of the Coral Triangle Region. They play a critical role in the lives of people through fisheries, tourism, and coastal protection, and provide inspiration to all who have seen a healthy coral reef. We are at a critical juncture in the conservation of reefs in the region. No other marine area in the world equals the Coral Triangle in terms of the diversity and productivity of reefs. This report highlights the most serious threats facing the region's reefs, and the steps that must be taken if these threats are to be addressed. Only immediate action can ensure that the Coral Triangle's reefs continue to provide food, livelihoods, and inspiration to the millions of people who depend on them now and for generations to come.

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204. For *Reefs at Risk Revisited*, we compiled a new global dataset of MPAs near coral reefs, which was updated for the *Reefs at Risk Revisited in the Coral Triangle* report based on more recent and detailed data for the region. Our definition of a coral reef MPA includes all sites that overlap with coral reefs on the maps, but also those that are known (from a variety of sources) to contain reefs. The primary source for this information is the World Database of Protected Areas (WDPA), which provided the majority of sites. In addition, ReefBase provided information on over 600 LMMAs for Pacific Islands and in the Phillipines. The Nature Conservancy, the Coral Triangle Atlas, and the Indonesian Ministry of Marine Affairs and Fisheries provided data for additional sites in the Coral Triangle, while reviewers provided about 50 additional sites globally.

205. Great Barrier Reef Marine Park Authority. 2009. *Great Barrier Reef Outlook Report 2009*. Townsville: Great Barrier Reef Marine Park Authority.

206. A number of studies have attempted to develop tools for assessing "management effectiveness," although to date such measures have only been applied to a small proportion of sites. These include: (a) Hocking. M., D. Stolton, and N. Dudley. 2000. *Evaluating Effectiveness: a Framework for Assessing the Management of Protected Areas*. Gland: IUCN; (b) Pomeroy, R.S., J.E. Parks, and L.M. Watson. 2004. *How is Your MPA Doing? A Guidebook of Natural and Social Indicators for Evaluating Marine Protected Areas Management Effectiveness*. Gland: IUCN, WWF and NOAA.

207. Unlike some broader measures of management effectiveness, our primary interest was in ecological effectiveness, and given the challenges in any such survey we reduced our focus simply to the influence of an MPA on reducing the threat of overfishing. Building on earlier work undertaken in the regional *Reefs at Risk* analyses for the Caribbean and Southeast Asia, as well as input from a number of other experts and a literature review, sites were scored using a 3-point scale: (1) Effective, where the site is managed sufficiently well that in situ threats are not undermining natural ecosystem function; (2) Partially effective, where the site is managed such that in situ threats are significantly lower than adjacent non-managed sites but there may still be some detrimental effects on ecosystem function; and (3) Ineffective, where the site is unmanaged, or management is insufficient to reduce in situ threats in any meaningful way. Given that the sampling drew on field knowledge by regional experts rather than field practitioners, there is likely to be a sampling bias toward better-known sites, with perhaps a higher proportion of effective sites than would be found overall.

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THE *REEFS AT RISK* SERIES

Reefs at Risk Revisited and *Reefs at Risk Revisited in the Coral Triangle* are part of a series that began in 1998 with the release of the first global analysis, *Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs*. Two region-specific publications followed with *Reefs at Risk in Southeast Asia* (2002) and *Reefs at Risk in the Caribbean* (2004). These regional studies incorporated more detailed data and refined the modeling approach for mapping the impact of human activities on reefs. *Reefs at Risk Revisited* — an updated global report — has drawn upon the enhanced methodology of the regional studies, improved global data sets, and new developments in mapping technology and coral reef science. *Reefs at Risk Revisited in the Coral Triangle* is based on the global report, supplemented with more recent and detailed data for the Coral Triangle Region. Both of these *Reefs at Risk Revisited* reports were collaborative efforts that involved more than 25 partner institutions (see inside front cover). The projects have compiled far more data, maps, and statistics than can be presented in the reports. Additional information and data are available at www.wri.org/reefs and on the accompanying data disk.

The World Resources Institute (WRI) is a global environmental and development think tank that goes beyond research to create practical ways to protect the Earth and improve people's lives. WRI's work in coastal ecosystems includes the *Reefs at Risk* series, as well as the Coastal Capital project, which supports sustainable management of coral reefs and mangroves by quantifying their economic value. (www.wri.org)

The Coral Triangle Support Partnership (CTSP) supports the governments of Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste in their regional commitment to ensure that the world's most precious marine areas are sustained into the future. Made up of a consortium of the world's leading conservation NGOs — World Wildlife Fund (WWF), Conservation International (CI) and The Nature Conservancy (TNC) — CTSP is a five-year, $32 million project supported by the United States Agency for International Development (USAID). This partnership encourages the development of transformational policies on natural resource management; strengthens the capacity of institutions and local communities; and builds decision support capacity. (www.usctsp.org)

The Nature Conservancy (TNC) is a leading conservation organization working around the world to protect ecologically important lands and waters for nature and people. The Conservancy and its more than one million members have protected more than 480,000 sq km of land and 8,000 km of rivers, and engage in more than 100 marine conservation projects. The Conservancy is actively working on coral reef conservation in 24 countries, including the Caribbean and the Coral Triangle regions. (www.nature.org)

WorldFish Center is an international, nonprofit, nongovernmental organization dedicated to reducing poverty and hunger by improving fisheries and aquaculture. Working in partnership with a wide range of agencies and research institutions, WorldFish carries out research to improve small-scale fisheries and aquaculture. Its work on coral reefs includes ReefBase, the global information system on coral reefs. (www.worldfishcenter.org)

United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC) is an internationally recognized center for the synthesis, analysis, and dissemination of global biodiversity knowledge. UNEP-WCMC provides authoritative, strategic, and timely information on critical marine and coastal habitats for conventions, countries, organizations, and companies to use in the development and implementation of their policies and decisions. (www.unep-wcmc.org)

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