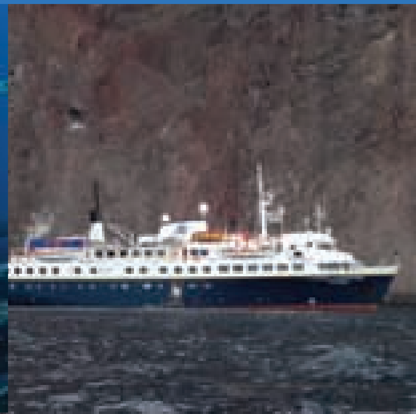
livingwiththesea

local efforts buffer effects of global change

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Learning how to live with the sea

Establishment of marine managed areas (MMAs) is a long-term investment in secure and sustainable ecosystems—secure for the people that depend on them for sustenance and livelihoods, sustainable in terms of the long-term persistence of habitats and species present. The goal of MMAs is to operate over timescales of multiple generations and deliver returns of increased diversity and abundance of native organisms and ecosystem resilience, as the expected return of ecosystem health and robustness can take decades.

Creating MMAs in many different places throughout the world provides discovery of both local knowledge and global generalizations. This knowledge forms a powerful management tool that can be tailored to specific locations.

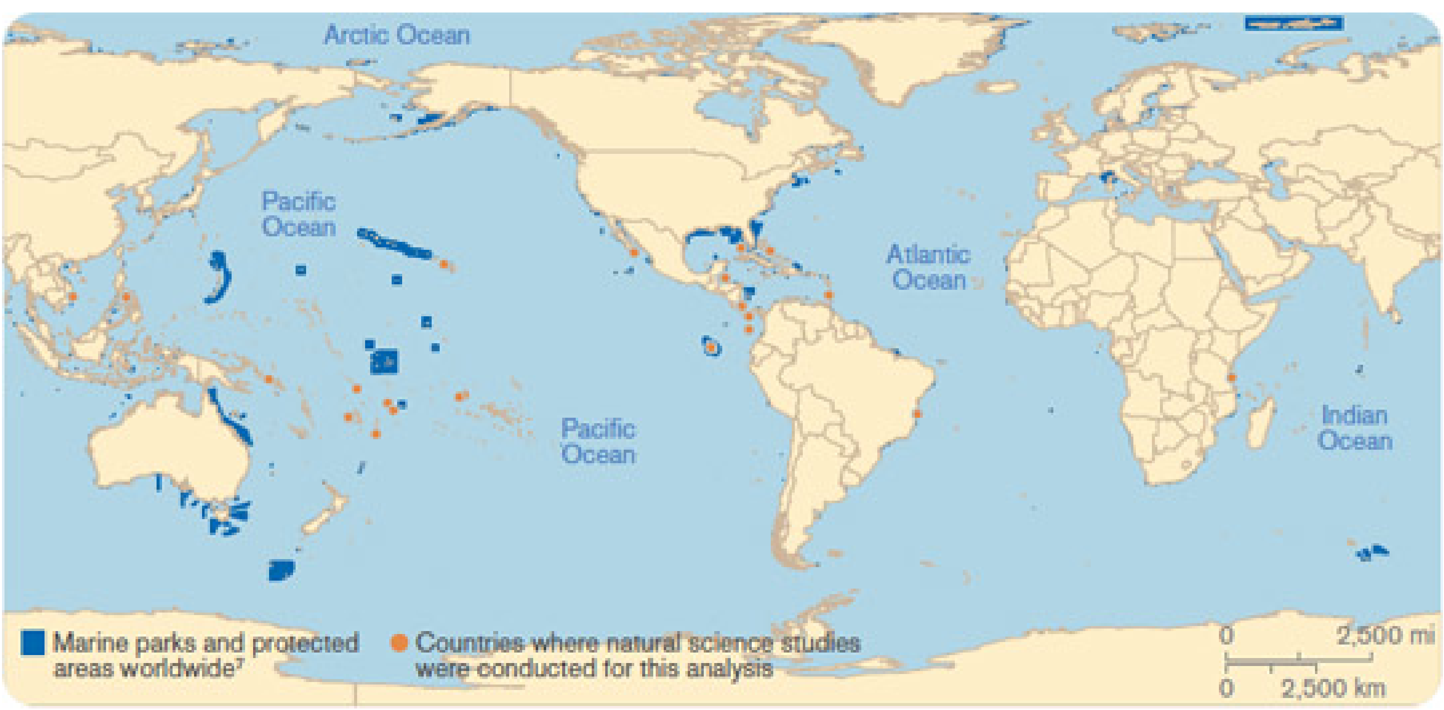
This document draws on MMA experiences worldwide by synthesizing results from over 25 natural science studies conducted over the past five years in 18 tropical countries in 48 MMAs (see References and www.science2action.org). The analysis focuses on the role of MMAs in maintaining healthy oceans, showing that MMAs can be used to enhance fisheries outside their borders and safeguard threatened species. Conserving multiple habitats using MMAs can also protect diverse livelihoods[1] and increase fisheries yields.[2] Local protection of marine resources through the MMA process can provide strong local benefits to species, habitats, and people. Local protection buffers against global climate change impacts while maintaining the richness of marine life. Finally, MMAs benefit by using new scientific approaches[3,4,5] and engaging citizen scientists.[6]

What are marine managed areas?

MMAs, as defined for this booklet, are multiuse, ocean zoning schemes that typically encompass several types of subareas, such as no-take areas (e.g., no fishing, mining), buffer zones with particular restrictions (e.g., no oil drilling), or areas dedicated to specific uses (e.g., fishing, diving).

MMAs can take many forms, addressing different issues and objectives. Some MMAs involve areas where multiple uses (e.g., fishing, tourism) are allowed under specific circumstances. Others involve areas where no extractive human uses (e.g., fishing, mining, drilling) at all are allowed. Still others restrict certain areas to one specific use (e.g., local fishing) that is judged to be the most beneficial use of that area to the exclusion of others.

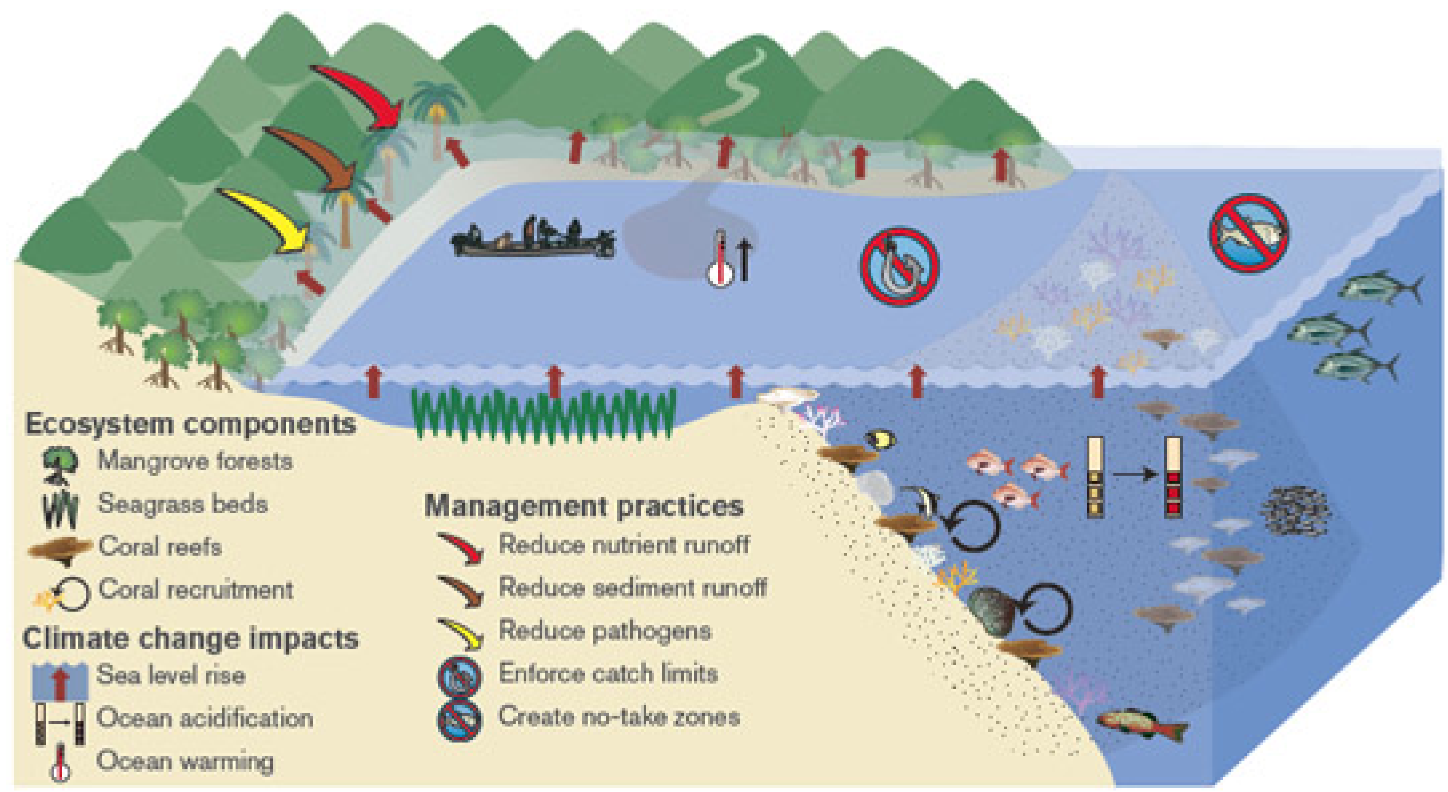
The term 'marine managed areas' is often used interchangeably with 'marine protected areas' (MPAs) as an inclusive way of describing different types of MPAs ranging from those with multiple-use to areas of complete protection. For more information on MMAs, see *Marine Managed Areas: What, Why and Where* available at www.science2action.org.



A healthy ocean has many benefits

Functioning ecosystems

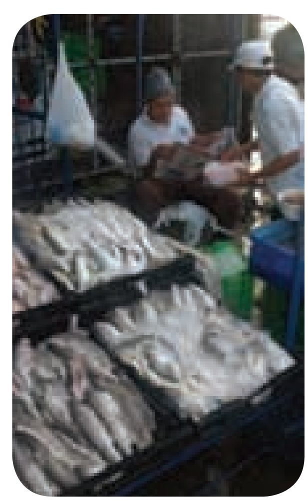
A healthy ocean has many benefits—it increases food supply, preserves ecosystem resilience, and buffers against global climate change. To provide for healthy oceans, negative human impacts should be limited. This can be accomplished by ensuring that watersheds are managed vigilantly with sustainable land use practices that reduce the flow of sediments, nutrients, and pathogens into coastal waters; catch limits and gear restrictions for fisheries are implemented; and non-extraction zones are established to maximize the well-being of selected marine habitats and to allow them to provide valuable ecosystem services.[8]



Sustainable fisheries

More than half the world's people live along tropical coastlines. Many of these people's lives revolve around extracting resources from the sea, eating them, and then trading the rest for their other needs. Fish makes up the major source of protein in their diets. Over a billion people rely on fish as their main source of animal protein globally.[9] The proteins derived from fish and shellfish account for 13.8% to 16.5% of the animal protein intake of the human population.[9]

A healthy ocean that provides a stable food supply is dependent on properly managed fisheries and a mosaic of healthy connected habitats. It requires that there be sufficient breeding adults of fish to populate the next generation, ensuring a continual supply and sustainable fishery.[10] As finfish and shellfish are dependent upon mangroves, seagrass, and coral reefs, it is critical that these pieces of the ecosystem are left intact, so as to eventually provide more food resources.



A sustained fishery is an important ecosystem service of a healthy ocean.

Ecological resilience

Ecosystems have evolved to recover from physical disturbance. Ecological resilience is the ability to return to a desirable state following disturbance. For example, mangrove forests devastated by a hurricane use their ecological resilience to return to a pre-storm stability and function.[11] There is considerable uncertainty today of what natural ecosystems will become following a disturbance, given the other threats they face. High levels of ecological resilience are desired so the ecosystem can repair itself and return to a state that is most valuable to itself and for people that depend on it.

Coral reef communities can be more resilient to acute local and global scale impacts if they have a healthy complement of microbes, corals and other invertebrates, and herbivorous and predatory fishes.

Ecological resilience exists on many different scales.[12] The first level is *individual resilience*—an individual is damaged and can heal itself. For example, when corals are broken after a physical disturbance, the remaining coral colony must resist invasion by disease, overgrowth by competitors, and consumption by predators, especially since the predators are now focused on a smaller remaining area of coral. *Population resilience* refers to when a population can rebuild itself after a very high mortality event. MMAs are critical in preserving population resilience, because MMAs consist of varying degrees of protection from people, providing refugia for fish and shellfish to repopulate areas where they are harvested. *Community resilience* occurs when the key species remain in the system after a disturbance. For example, after coral bleaching, the survival of a very high population of herbivorous fishes and other key functional members of the community can maintain an environment conducive to coral regeneration, leading the community back to health.

Climate change buffer

Organisms have adapted to disturbance for millennia.[13] Global climate change, however, presents a major challenge.[14,15] Climate change has many different components—ocean acidification, sea level rise, ocean warming, violent storms—that combine to form a set of stressors unlike anything these communities have evolved to endure. The best option available is to provide conditions that foster maximum possible ecological resilience.

Coral reefs in Belize bleach during an extreme high sea surface temperature event.

Presently, the changing ocean conditions continue to produce mass coral bleaching and mortality. Corals must maintain their essential functions (obtaining energy to reproduce, to maintain healthy immune systems, and to perform competitive behaviors) in a robust manner to boost their resilience. Well-managed MMAs reduce the severity of human impacts on coastal ecosystems and can therefore help corals cope with the acute stresses associated with global climate change.

MMAs maintain healthy oceans

Benefits of MMAs

The benefits of well-managed MMAs are many and varied.[16,17] Where MMAs exist, there can be increased abundance of fish and larvae both within and outside the MMAs, and ecosystem resilience is increased because biodiversity is less disrupted. These ecological services contribute to more varied and sustainable coastal livelihoods by increasing fish catch and marine tourism. Such demonstration of the wealth provided by marine habitats can be connected to land use improvements and effective MMA management. However, to be successful and provide the maximum benefit for local communities, the appropriate geographic scale of MMA planning and management must be considered.

Managing at appropriate scales

Gulf of Honduras

Juvenile fish swim in a shallow reef in the Gulf of Honduras.

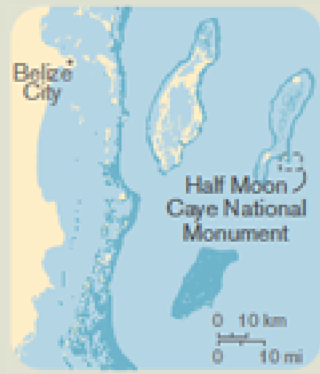
In order to maximize the success and benefits of MMAs, management efforts must consider threats on all scales. For example, the terrestrial inputs to the Gulf of Honduras from Guatemala, Honduras, and Belize all become entrained in the currents that bathe the Meso-American Barrier Reef (MAR), a World Heritage Site. The southern portion of the MAR suffers most acutely with a higher occurrence of disease due its close proximity to poor water quality. MAR-related conservation strategies must include a multinational component in order to improve conditions along the entire Meso-American Reef.

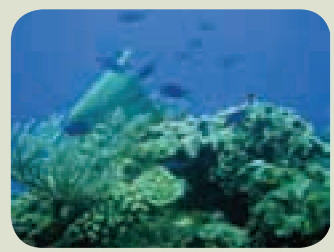
Fisheries

Many MMAs encompass critical breeding and nursery areas for fish and invertebrates.[8] As animals mature, many migrate outside of the protected areas and into parts of the ocean where they can be fished. Better management of nursery areas can result in more fisheries export beyond the limits of the MMA. By maximizing export of animals from MMAs, fisheries can be resupplied and potentially enhanced beyond the borders.

Increased fish

Half Moon Caye, Belize





Blue chromis swim over a mix of hard and soft corals along the Belizean Barrier Reef, the largest barrier reef in the Caribbean and the second largest in the world. This reef is part of the Southwater Caye Marine Reserve, a World Heritage Site.

Half Moon Caye on Lighthouse Atoll is one of the oldest reserves in Belize. Most famous for its thriving colony of red-footed boobies and the nearby Blue Hole, Half Moon and Blue Hole together are managed by the Belize Audubon Society. As part of Lighthouse Atoll, Half Moon Caye is about 70 km from the mainland and is part of the Mesoamerican Reef furthest removed from regional human impacts. Lighthouse is still heavily fished, but ecological monitoring results recently showed a positive effect of the no-take area at Half Moon, within the larger MMA of the Lighthouse and Turneffe Atolls. Inside the no-take area there was greater abundance and size of fishes, including large parrotfishes, which are critical to coral reef health. These positive effects are attributed to the age of the reserve, the investment in its management, and the distance from the mainland. Half Moon is also noteworthy for its balance of human values, including commercial fishing, recreational fishing, ecotourism, and cultural value (as a World Heritage site). Studies of Half Moon Caye indicate that similar ecological repair can occur elsewhere in the Meso-American Reef, but only with vigilant enforcement and support of the resident user community.[18]

Threatened species

Large and abundant animals, particularly fish and shellfish species, are usually targeted for fishing harvest. Without the existence of refuges of time and space and gear restrictions, even the most plentiful species can be diminished to levels of commercial or ecological extinction. This is especially the case when large productive females are removed and natural habitats damaged. This leads to a compromised ecosystem no longer able to provide food and sustenance, with little or no ability to adapt to environmental perturbations.

Adaptive management cycle

In true adaptive management, a feedback relationship exists in which scientific results inform daily MMA management practices in order to maintain a healthy ecosystem.[12] Monitoring programs must be in place in MMAs to quantify ecosystem response to different management regimes. Data collection, analysis, and discussion are critical to inform managers and other stakeholders regarding success or failure of management strategies. This knowledge enables managers to adapt management strategies to minimize adverse effects and maximize benefits. Trained personnel and flow of information are also critical to ensure adaptive management.

Supporting biodiversity

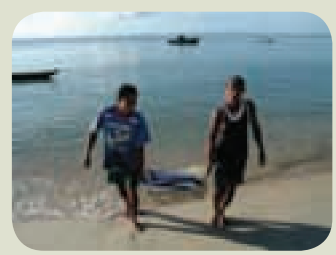
Cabo Pulmo, Mexico

*The leopard, or golden, grouper (*Mycteroperca rosacea*), listed as Vulnerable by the IUCN, is found within Cabo Pulmo National Marine Park.*

The Cabo Pulmo National Marine Park, established in 1995, is located in Baja California between La Paz and Cabo San Lucas. Although only 30% of the Park was originally designated as a no-fishing zone, the local community has treated the entire park as such.[19] The Park supports rich biodiversity[20] which has increased dramatically in the 15 years since the Park's establishment. In particular, the diversity and biomass of predatory fishes, such as snappers, groupers, jacks, and sharks, has increased so that Cabo Pulmo supports up to 20 times more biomass of these important top predators than any other area of equal size in the Gulf of California. Endangered Gulf grouper (*Mycteroperca jordani*) are in severe decline throughout the rest of the Gulf of California. However, Cabo Pulmo is proving a critical refuge for this species, with surveys in the Park's waters accounting for 30% of Gulf grouper sightings within the Sea of Cortez. The Park provides economic benefits resulting from ecotourism and sport fishing, which are also tied to the high fish biomass. The local community in Cabo Pulmo is very supportive of the Park, encouraging low-impact development in the area, and opposing the Mexican government's recent approval of a large development to be constructed just north of Cabo Pulmo.

Using science for improved resource management

Corumbau Marine Extractive Reserve, Brazil



A sustainable harvest of fish is enjoyed by fishermen who are part of the Corumbau Extractive Reserve in Bahia, Brazil.

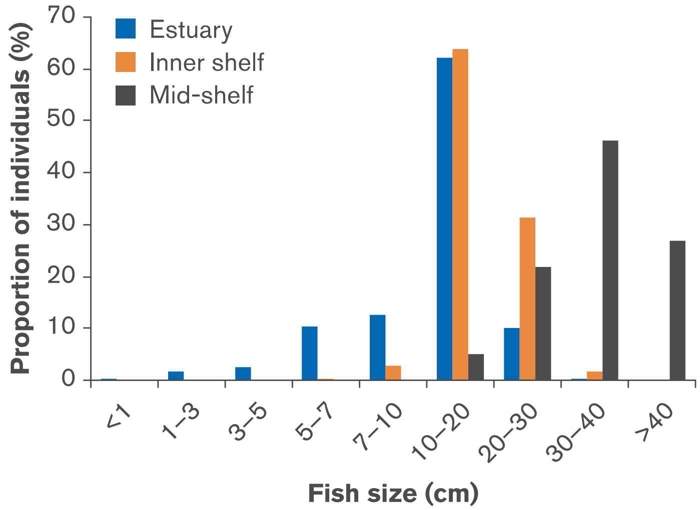
The Corumbau Marine Extractive Reserve (CMER) was created along the coast of Southern Bahia to assist neighboring fishing communities in securing a reliable and sustainable catch of finfish and shrimp, thereby maintaining their traditional and preferred livelihood. The shallow-water habitats found along the Abrolhos Bank were historically rich in commercially important species and these were heavily fished. Soon after the establishment of the CMER, which includes no-take areas, marine scientists conducted a fisheries assessment and initiated a regular ecological monitoring program. Within several years of monitoring, it was determined that no-take areas were successful in restoring the biomass (increased size and abundance) of targeted fish. Given this success, managers decided to ease restrictions on types of gear and areas closed to extraction. Scientists and fishers both quantitatively documented a precipitous and significant decline in target species and reinstated the fishing regulations. Biomass of target species subsequently returned to high levels.[21] Spillover of these target species from the no-take zones to the open-access areas has also been recorded, and the local fishers are supporting the creation of new MMAs in the region.[22]

Conservation of multiple habitats protects livelihoods

Near and far

Animals that are important food resources often have complex life cycles. They spawn in one place, young develop in another, adults live in another, and then the adults may move yet someplace else to spawn. Many species also move among habitats over the course of a day. The growth of many snapper species, for example, is dependent upon their ability to move amongst connected habitats of mangroves, seagrass, and coral reefs. A greater abundance of snapper can result from mangrove forest protection as mangroves function as refuge and feeding areas for early life stages before young move away as adults.[23]

As well as benefits to the species, habitats benefit each other in other ways. For example, intact mangrove forests physically protect coastlines and reefs from the effects of storm surge, tsunamis, and rising sea level, while providing nutrients to adjacent systems. The connection among habitats is critical, with intact mangroves, seagrass, and coral reefs each dependent upon the other.

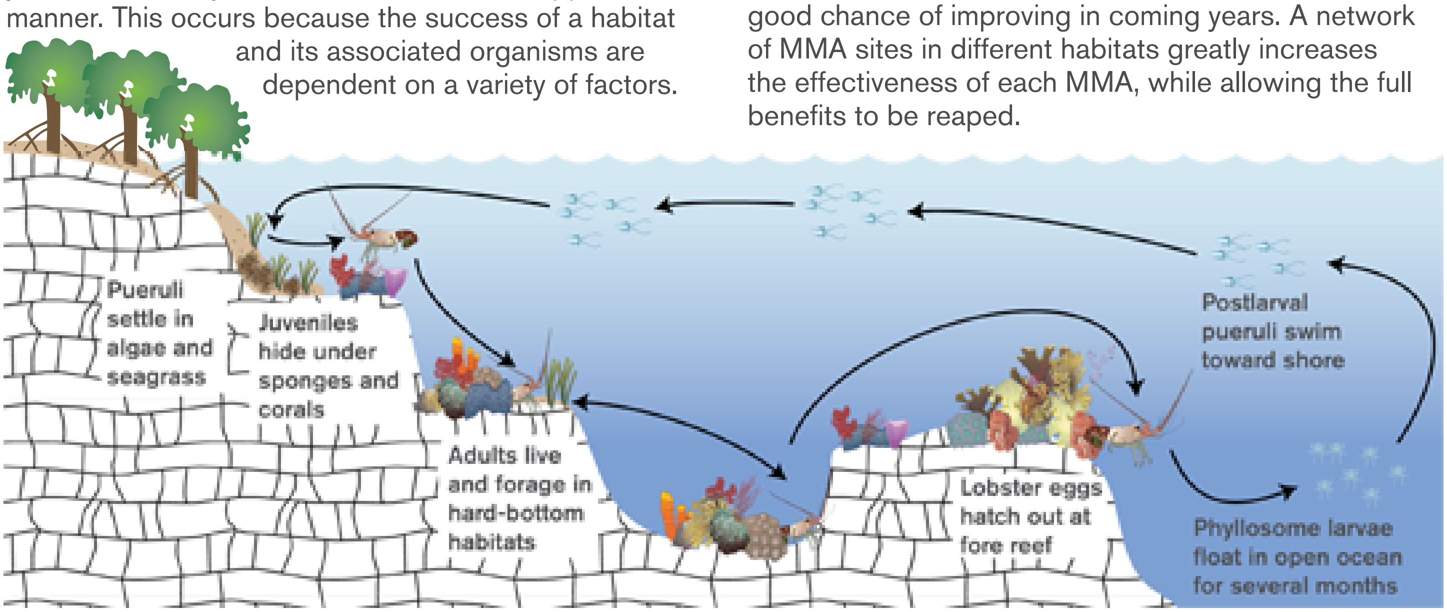


Early life cycle stages of dog snapper in Brazil typically occur inshore (estuary and inner shelf), while later stage adults are more abundant offshore (mid-shelf).[24]

Habitat patchwork

Ideal conditions required for growth of any particular organism vary over scales of both time and space.[24] For example, a particular mangrove forest that is very productive one year might perform very poorly the next year, while an adjacent forest reacts in the opposite manner. This occurs because the success of a habitat and its associated organisms are dependent on a variety of factors.

By protecting several replicates of similar habitats in the system, along an environmental gradient, the likelihood increases that at least one habitat will be healthy in any particular year. Healthy patches of habitat export plants and animals to the other patches, so that they have a good chance of improving in coming years. A network of MMA sites in different habitats greatly increases the effectiveness of each MMA, while allowing the full benefits to be reaped.



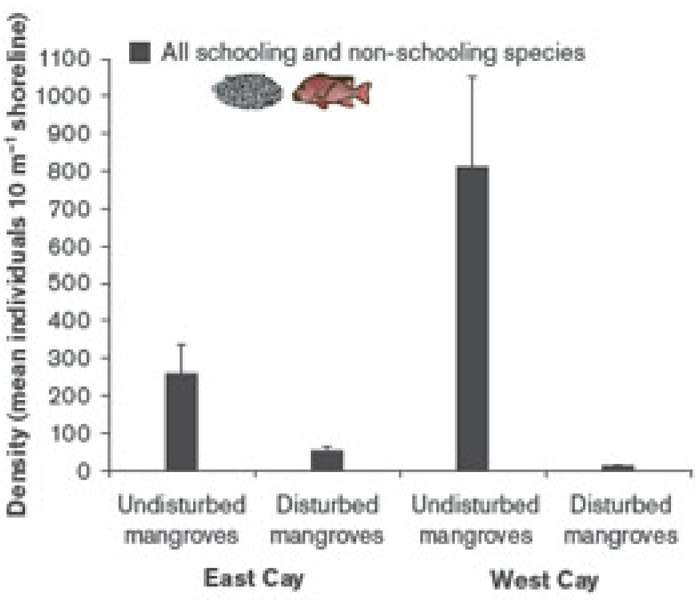
The life cycle of lobsters shows that just one species needs many connected habitats to survive and reproduce successfully.

Increased fisheries

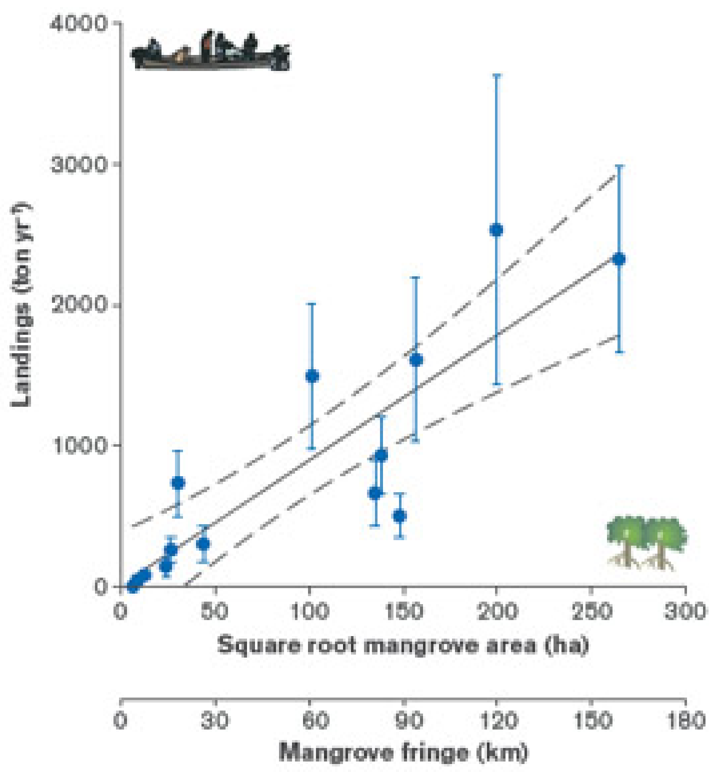
It is increasingly common for MMAs to be managed in ways that lead to increased abundance and size (i.e., biomass) of commercially important shellfish and finfish species. To ensure the sustainability of these populations, MMAs often focus on protecting habitats utilized by these species throughout their life history, particularly spawning and nursery grounds.

Mangroves play a particularly critical role as nursery grounds. The areal extent of mangrove forests has been closely correlated with fish and invertebrate landings.[25] Shrimp and fish productivity in intact (undisturbed) mangrove forests is 50% greater than in converted (disturbed) mangroves.[26,27] In order for mangrove forests to maintain high levels of productivity, they must remain intact and undisturbed.

Mangroves are particularly critical ecosystems to protect because of their role as nursery grounds for many marine species.



Fish density is far greater in undisturbed mangroves as compared with disturbed mangroves in the Twin Cays of Belize.[26]



As mangrove area increases, landings for fish and crabs in the Gulf of California increase as well, demonstrating the importance of these ecosystems (data are average ± SE [2001–2005]; solid line, model; dashed line, 95% confidence intervals).[25]

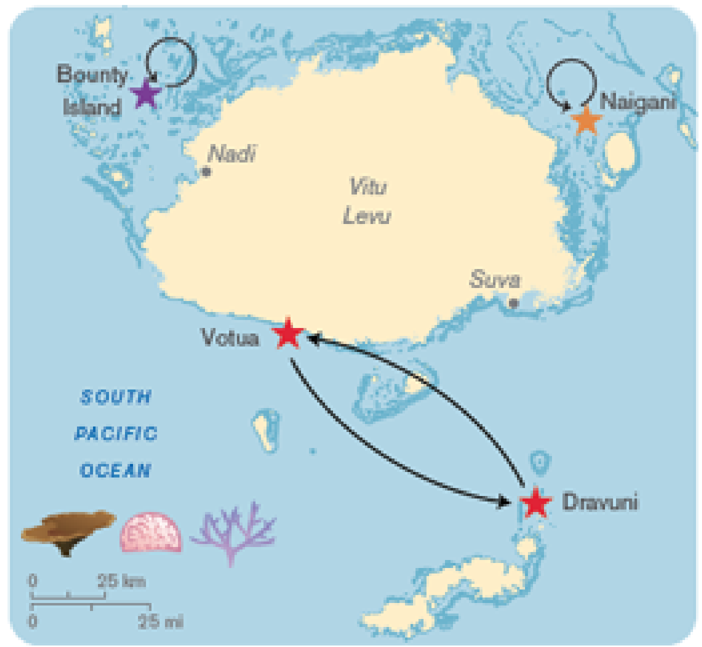
Local protection provides strong local benefits

Localized replenishment

Historically, there has been an assumption that marine species populations were replenished by distant populations, with the implication that localized management efforts were not critical. Recent analyses, however, have shown that many organisms are more localized in their dispersal ability than previously realized, and stakeholders cannot rely on distant populations to replenish local populations. Consequently, local management efforts are critical for long-term sustainability of these populations.

As larvae, most marine organisms have the ability to travel vast distances over the ocean, but this does not mean that they do. Most have evolved the behavior of catching currents that return them close to their birthplace. This mechanism of dispersal is imprecise: some distant populations remain connected, but the distance animals actually stray from their birthplace is much less than previously thought—on the order of a few tens of miles, not hundreds or thousands.[28,29,30]

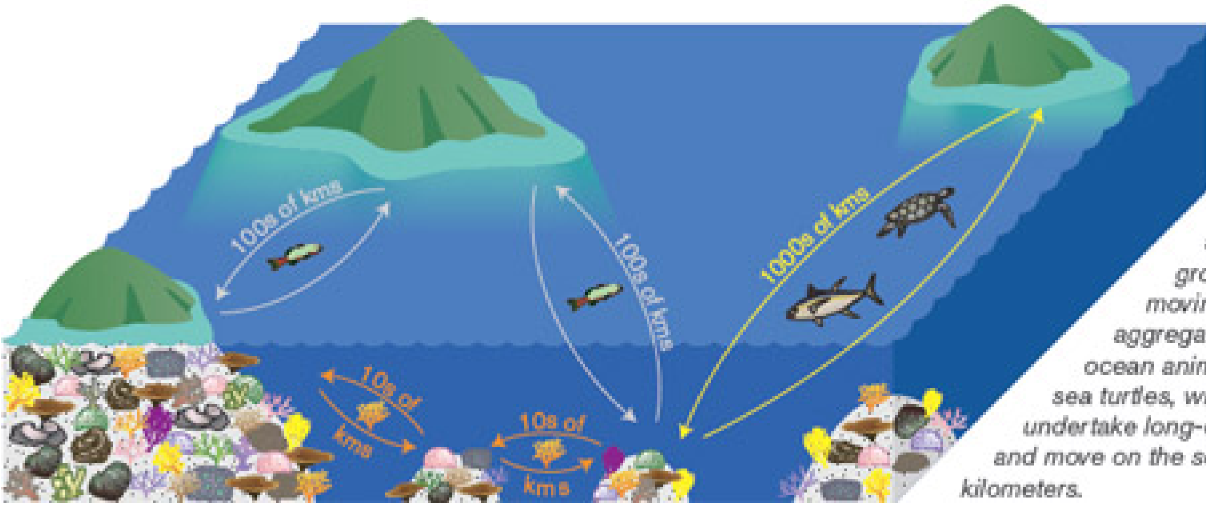
Past the phase in which pelagic larvae can disperse on ocean currents, connectivity occurs on a hierarchical scale with newly settled individuals and juveniles moving on a small scale and adult animals moving on a larger scale.[31] Generally, most mobile organisms are fairly local, as they move only tens of kilometers. This includes the vast majority of organisms inhabiting coral reefs, mangroves, and seagrass habitats.



Within the Fijian archipelago, corals, sea cucumbers, and fishes disperse surprisingly little—only a few tens of kilometers per generation. There are genetically distinct populations of coral species that exist geographically close to each other but do not exchange larvae often enough to remain genetically similar.[30]

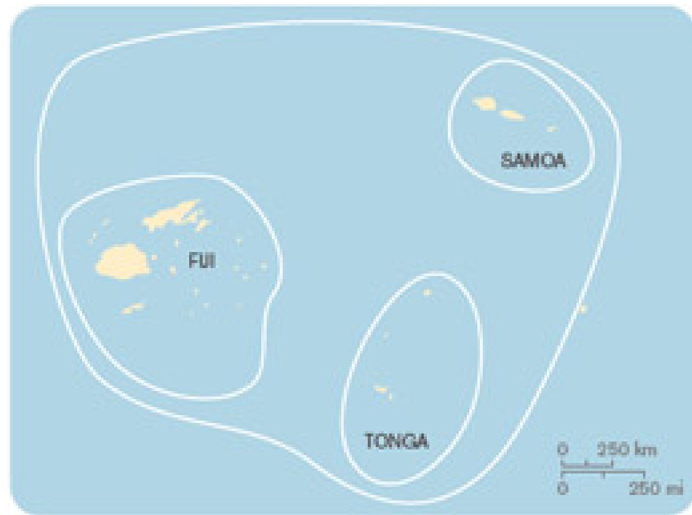
Cinnamon clownfish (*Amphiprion melanopus*) | Talbot's damselfish (*Chrysiptera talboti*) | Dotted wrasse (*Cirrhilabrus punctatus*) | Cleaner wrasse (*Labroides dimidiatus*) | Lemon damsel (*Pomacentrus moluccensis*)

Scientists originally thought that Fijian fish populations (top panel), which look similar to populations in the rest of the Indo-West Pacific (bottom panel), were closely connected. It was thought that these "neighbors" replenished Fiji's fish stocks thousands of miles apart. However, genetic analysis has proven that belief incorrect, with much lower levels of connectivity than expected. This is strong evidence of the need of MMAs to protect local habitats to ensure species' continued existence.[28]



Examples of animals that move on the scale of hundreds of kilometers are pelagic fishes, sometimes including groupers and snappers moving to spawning aggregations. Large open-ocean animals, such as sea turtles, whales, and tuna, undertake long-distance migrations and move on the scale of thousands of kilometers.

These levels of connectivity have important management implications. On the smaller scale, if stakeholders want these animals tomorrow, they have to take care of them today. If local populations are depleted it will take a long time for the animals to return since a limited adult population will be available for replenishment. On the larger scale, the implication of animals undertaking great migrations is that they are extremely vulnerable both in aggregation and on nesting grounds, as reproduction is usually the reason for such migrations. Consequently, it is particularly important to protect nursery and spawning aggregation sites.



Graphic representation of biogeographic affinities of Southwest Pacific, showing the unit as a whole as well as slight differences among Fiji, Tonga, and Samoa.[32]

Long-scale migrations vs. local populations

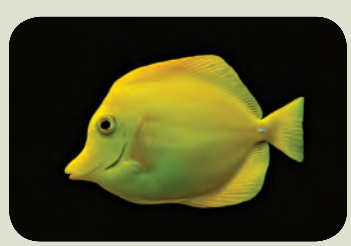
Large ocean-going animals like bluefin tuna, sea turtles, and whales are famous for their great migrations. When scientists found that even small fishes can potentially move very far across the ocean as eggs and larvae, naturally they assumed this was the rule and that fish populations were connected over large distances. As it turns out, this often is not the case. But even limited dispersal potential is sufficient to keep from being completely eliminated by natural disasters (e.g. earthquakes, volcanoes, and hurricanes) that can destroy entire populations. Most of the time, it is a good strategy for the young to return to where they were born. Previous generations did well there and low dispersal from one generation to the next can be advantageous. This strategy serves like an insurance policy against future disasters, as well as a way to keep the local population sufficiently large.

Humpback whales migrate great distances between their summer feeding grounds in the polar region and winter calving and breeding areas in warmer regions. These animals need protection at both ends of their migrations.

MMA spillover benefits fishery

Hawaii

Some young yellow tang (*Zebrasoma flavescens*) hatched in no-take 'Fish Replenishment Areas' (FRAs) along the Kona coast of the Big Island in Hawaii ultimately settle and develop along the same coastline. Extensive enforcement of these FRAs and public communication has resulted in abundant populations of this exploited species. The spillover of these populations to the surrounding areas has supplemented the surrounding populations, which are eagerly harvested for the aquarium industry.[33]

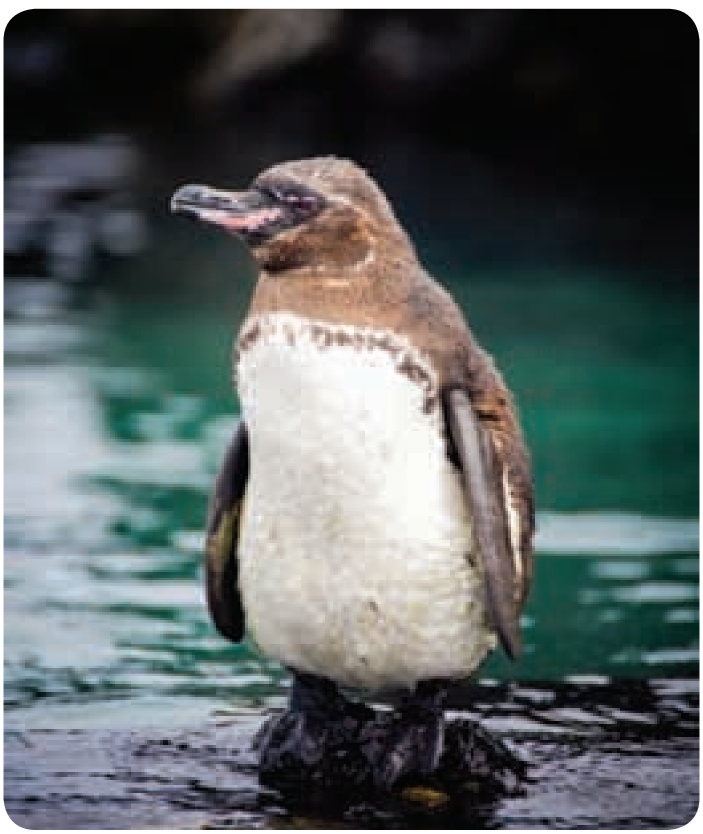


Yellow tang populations are supported by FRAs.

Local protection buffers global climate change

Local impacts can reduce resilience

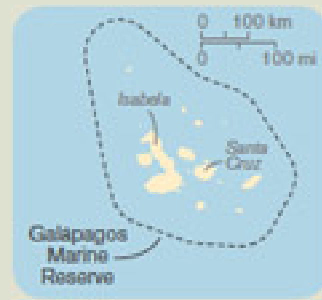
Coastal ecosystems are affected by local and global impacts. Unsustainable fishing pressure, pollution, and climatic changes can reduce the resilience of the ecosystem to handle the additional effects of global climate change. MMAs can protect coastal ecosystems from local impacts and thereby restore the abundance and diversity of marine life and overall ecosystem health. The case studies on these pages demonstrate that if a system is intact to begin with, it can respond and recover more quickly from the negative effects of global climate change. However, it is necessary for these systems to possess that resilience if they are to survive these new and large-scale global challenges. The systems that appear to be most resilient—the most capable of coping effectively—are systems that are geographically remote from human beings.

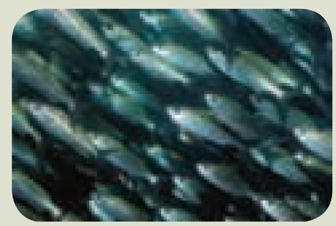


*The Galápagos penguin (*Spheniscus mendiculus*) is endemic to the Galápagos Islands. It is the only penguin that lives north of the equator in the wild. The penguin is endangered, and the rarest of penguin species, with a population size estimated in 2004 to include around 1,500 individuals. Its survival is directly linked to the presence of cool water temperatures.*

Resilience to El Niño

Galápagos Islands





*A school of black-striped salema (*Xenocys jessiae*) in Galápagos. This Galápagos endemic species was assessed as Vulnerable by the Global Marine Species Assessment, and will likely be included as such on the IUCN Red List.*

Research results from the Galápagos Islands provide some indication of how resilience is influenced by MMAs.[34] The Galápagos Islands are subject to periodic climate shifts every few years when an El Niño event occurs. These events provide a large-scale laboratory that replicates impacts of global climate change on marine ecosystems. The Galápagos archipelago is comprised of two opposing systems—cold water and warm water. Nowhere else do penguins swim over reef-building corals. During an El Niño cycle, a warm water regime dominates. This is similar to what the region will experience over a longer period of time with global climate change impacts. Research results have found that the systems within MMAs are potentially better positioned to cope with El Niño episodes than those outside MMAs. Across the Galápagos Marine Reserve, islands located at greatest distance from fishing communities were found to possess higher densities of fishes, lower densities of grazing sea urchins, and higher coral cover, suggesting that predation by large fishes and lobsters controls numbers of grazing animals that inhibit coral growth. These patterns likely arose as a consequence of stresses associated with fishing and ocean warming acting together. Thus, coral reefs in lightly fished areas are less affected by El Niño periods of extreme warming than corals in fished areas because numbers of coral predators such as pencil urchins are controlled by high predator populations. Newly created conservation zones in Galápagos Marine Reserve where fishing is excluded should therefore assist coral habitat in resisting impacts of future El Niños and climate change. Overall, existing monitoring studies need to be extended over longer time periods to determine the full extent to which effective governance and strict protection from fishing generate benefits beyond increased fish biomass.

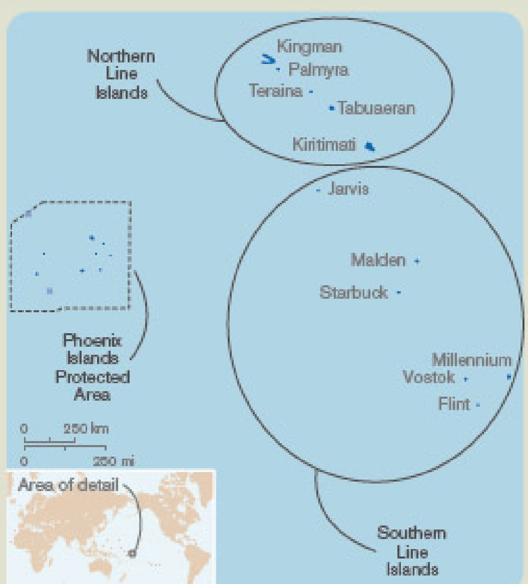
A natural experiment in resilience

Southern Line Islands

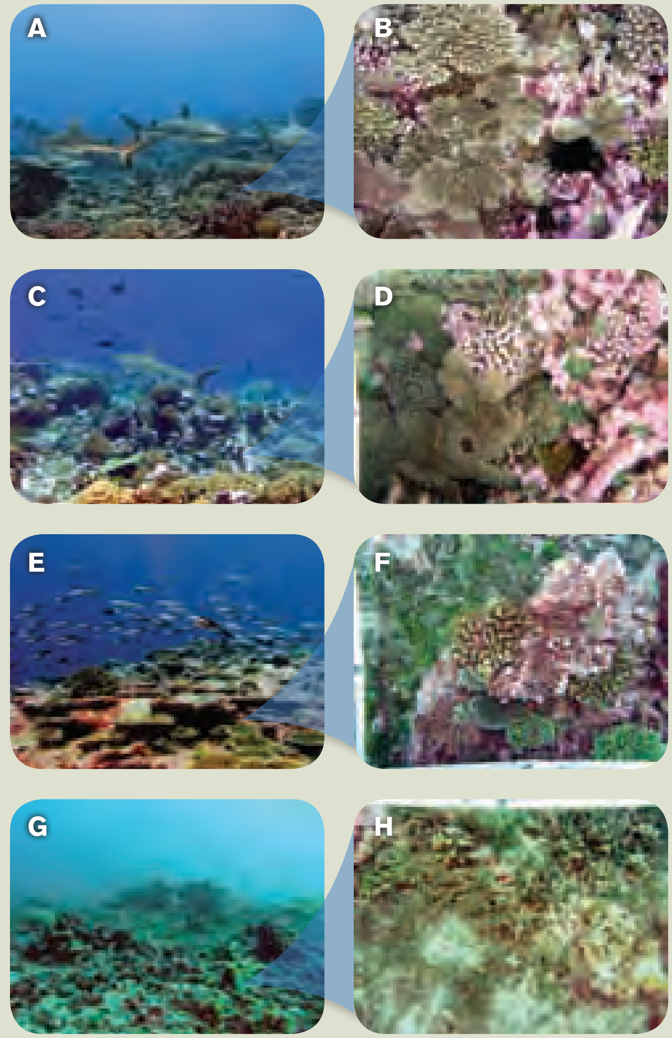
The Southern Line Islands and Phoenix Islands make up a chain of atolls and reefs in the central Pacific Ocean. Prior to 2002, the Southern Line Islands and Phoenix Islands had the same marine communities, the same endemic species, and were considered among the most remote and pristine coral reef systems on earth. In 2002, a mass bleaching event entirely bleached all of the Phoenix Islands but left the Southern Line Islands unscathed. This gave us a natural experiment to help us understand how reefs might recover from bleaching in the absence of all local human impacts that would otherwise compromise coral community health.

Surveys in 2009 provided evidence that the coral reefs of the Phoenix Islands are regenerating with extraordinary vigor. Not only that, but they are regenerating mostly by gradually accumulating more coral from the small percentage of coral that survived bleaching. These reefs are self-healing. In the few places in the Phoenix Islands where there were very modest local impacts due to nutrient inputs, reef recovery did not occur. This lack of recovery was demonstrated by low coral cover and cyanobacterial mats preventing coral recruitment.

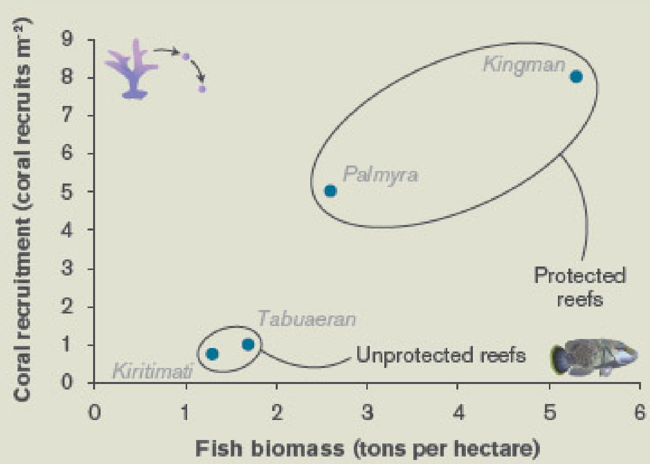
This natural experiment provides insights into how very resilient coral reefs can be against global climate change if local human impacts can be minimized through appropriate and effective management.



The Phoenix and Line Islands were chosen as a case study because of their remoteness and because they encompass a gradient of human disturbance, from inhabited islands with intensive fishing (Northern Line Islands) to uninhabited islands with pristine coral reefs (Phoenix and Southern Line Islands). The islands were affected by the warming event of El Niño in 1997–98 and many corals died from bleaching. The islands with better protection, less human impacts, and greater fish biomass recovered more completely. This natural experiment suggests that the better protected the local ecosystem is, the more likely it is to recover from the impacts of global climate change.



General aspect of fore-reef habitats (left column) and representative shallow benthic habitats (right column) at Kingman (A–B), Palmyra (C–D), Tabuaeran (E–F), and Kiritimati (G–H). As population and human impacts increase from Kingman (uninhabited) to Kiritimati (population 5100), fish biomass, coral cover, and coral recruitment decrease.[35]



Coral recruitment and fish biomass on four reefs in the Line Islands, showing reefs with better protection recovered better after an El Niño-related bleaching event in 1997–98.[35]

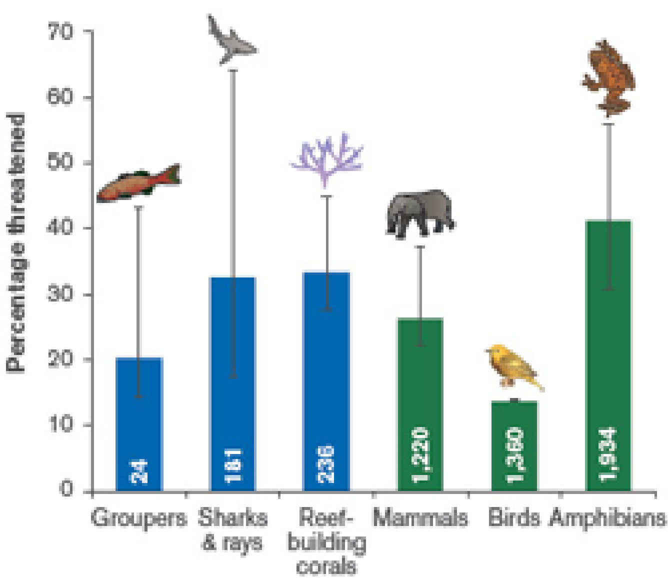
Local protection maintains the richness of life

Extinction matters

Species extinction deprives humanity of resources for food, genetic stock, tourism, cultural identity, and options for the future. In addition, extinction is wholly irreversible—once a species is lost, it can never be brought back. On land, human impacts have accelerated species extinction rates to a thousand times higher than rates normal throughout Earth's history. In the sea, though, a popular belief has been that marine species are somehow immune to extinction. Recent research proves that this is not the case.[36]

Worldwide, one in five grouper species, one in three species of sharks and rays, and one in three species of reef-building corals face extinction. These threat levels are comparable to those known for terrestrial species groups of mammals, birds, and amphibians.[37] In the Galápagos alone, human impacts have driven the likely extinction of nine species of fish, seastar, and seaweed over the last quarter-century. No less than 74 shorefish and 15 seaweed species found only in the Eastern Tropical Pacific Seascape (ETPS) have now been documented to face a high danger of extinction.

*The Galápagos stringweed (*Bifurcaria galapagensis*), an alga unique to the Galápagos, was historically abundant, but has not been recorded since 1983 and is now assessed as Critically Endangered (Possibly Extinct), likely due to extreme ocean warming during El Niño and local threats. As a result, marine iguanas (*Amblyrhynchus cristatus*) now rarely feed subtidally. The iguanas are now listed as Vulnerable on the IUCN Red List.*[37]



Threat rates for marine species groups are comparable to terrestrial species. Bars indicate percentages of species listed as threatened on the 2009 IUCN Red List (excluding Data Deficient species; maximum error bars show percentages if all Data Deficient species are threatened, minimum error bars percentages if no Data Deficient species are threatened). Numbers within the bars are the total numbers of threatened species in each group.

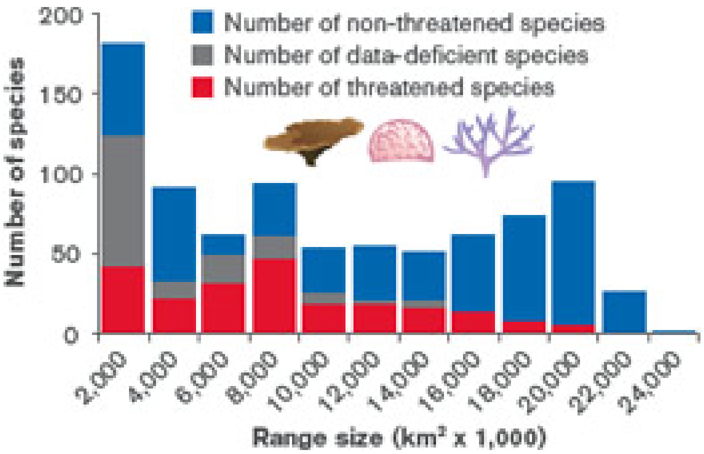
Important shallow-water species are still being discovered

Brazil

The Brazilian snapper (*Lutjanus alexandrei*) was discovered during implementation of the MMAS Program and described as new to science in 2007. It is endemic and has a small range on a global scale, as it is restricted to shallow-water habitats off northeastern Brazil.

The Brazilian snapper is a newly documented species of snapper.

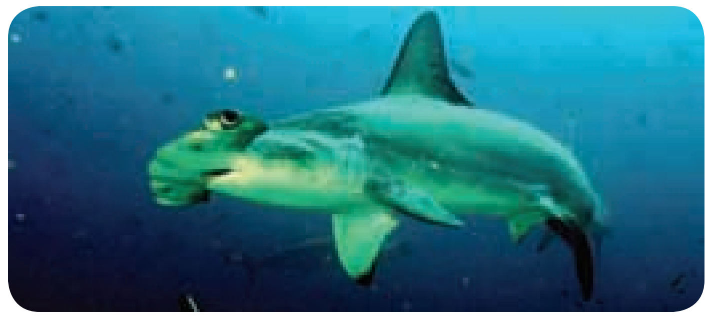
Local actions, however, can stop this loss of global diversity of marine life. Many threatened marine species inhabit small geographic ranges, as the following chart shows for corals.



Many marine species, particularly threatened and poorly known species, have small ranges. For reef-building corals, shown here, more species fall into the smallest range size class than any other, and most threatened and data-deficient species have small ranges. Data from 2009 IUCN Red List, courtesy Beth Polidoro and Kent Carpenter.

Moreover, while 63% of the 231 threatened coral species are particularly sensitive to global pressures such as bleaching and disease, 52% are especially vulnerable to local pressures including community disruption and harvesting.[38]

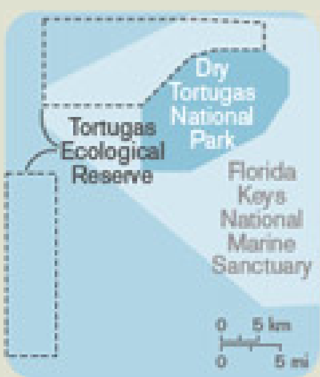
Local protection is already helping to prevent this extinction crisis in the sea. In Samoa, for example, five threatened marine species are known to live in marine protected areas.[39] When surveys are completed, it is likely that many other threatened species will be found. In the Florida Keys National Marine Sanctuary, investigations show reduced abundance of two exploited and threatened species in fully fished areas, intermediate abundance in the national park where limited recreational fishing is allowed, and increased abundance in the no-take marine reserve.[40] Long-term monitoring efforts are needed to continue to assess the effectiveness of MMAs under different management regimes.



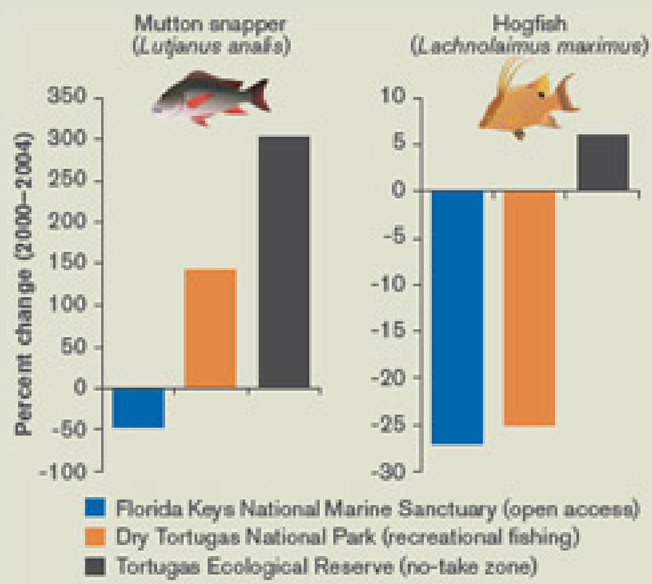
*The scalloped hammerhead shark (*Sphyrna lewini*) plays an important ecological role at aggregation sites, including at Cocos Island (Costa Rica) and the Galápagos in the Eastern Tropical Pacific Seascape. It is classified as Endangered by the IUCN Red List.*[37]

Protection benefits threatened fish populations

Tortugas Ecological Reserve, Florida



In the Florida Keys, increased fishing pressure from both commercial and recreational interests raised concerns about overall fisheries sustainability. Previous research has documented unsustainable exploitation of 70% of the species representing the "snapper-grouper" fish complex. Since the Dry Tortugas area is an important source of recruitment for coral reef fishes, no-take marine reserves (NTMR) (566 km^2) were established in 2001 as zones within the Florida Keys National Marine Sanctuary. Reef fish populations were assessed before and three years after NTMR establishment using fisheries-independent surveys. The researchers analyzed population and community metrics, which included frequency of occurrence, abundance, size compositions, and species richness. Significant signs of recovery of reef fish populations were seen over relatively short time periods since NTMR implementation, providing evidence that no-take reserves can lead to the recovery of threatened species populations.[40]



Percent change in abundance over three years of protection. Strictest protection in Tortugas Ecological Reserve yielded the largest population increases of mutton snapper and hogfish (both assessed as Vulnerable on the IUCN Red List).[40]

Habitat conservation uses new tools and people

New scientific approaches provide global insights

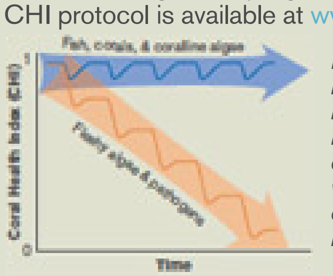
The role of science in MMAs is to help people understand how these areas respond to changes in the environment and to management. The results of science-based assessments and long-term monitoring become the insights for finding solutions needed to improve ocean health. However, limitations presently exist as more precise methodologies are needed to connect observed stress in the ocean and its organisms to specific sources. These methods should be efficient in both cost and labor.

Recent achievements in understanding the complex working of genomes of coral reef organisms are presenting many possibilities for understanding the agents that stress corals, and how these organisms may adapt accordingly. Likewise, with years of experience gained through studying and monitoring coral reef conditions, scientists agree on the most important metrics to be used in developing indices of coral reef community health.

The approaches in doing this work can be streamlined, but the costs will remain. However, the effectiveness of management cannot be evaluated without data collection and analysis. Recognizing this, costs can be justified as an investment in the future health of our natural systems by providing accountability.

Coral Health Index measures reef health from local to global scales

The Coral Health Index (CHI) was developed to provide a simple method of quantifying the gradient from healthy to degraded reef. The resulting index, based on combining metrics used to measure key benthos, fishes, and microbes, is an accepted diagnostic measure to understand the difference between healthy and degraded coral reefs. Using this index informs scientists and managers of basic reef processes and when used globally will establish a global baseline for measuring and monitoring future progress in conservation actions. CHI protocol is available at www.science2action.org.



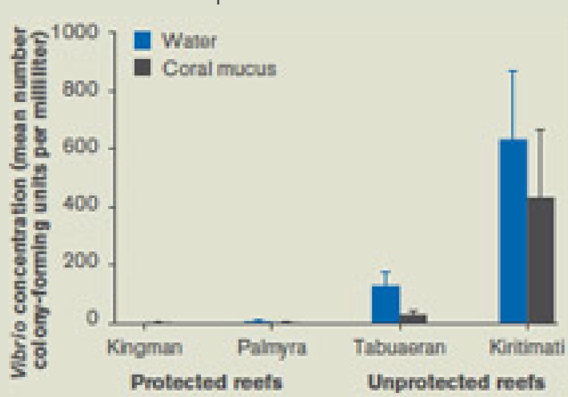
Natural services from coral reefs to human society are maximized when reefs are healthy (CHI = 1.0). The choices people make today will determine the state, and continued existence, of coral reefs now and into the future.

New molecular approaches enhance conservation science

Research at the genetic level can help in understanding and improving coral health rather than merely documenting declines.[41] Some genes are expressed ("turned on") specifically to defend against stressors in their environment. The expression of genes in resilient individuals differs from susceptible individuals. Therefore, an understanding of the genetic basis of such differences could allow an estimation of vulnerabilities of populations. By testing for genotypes in different populations, vulnerability to particular stressors at key locations can be determined and this knowledge used for creating marine managed areas and tracking the sources of threats.[42]

Corals also have genes used to defend against disease and heal damaged tissue; these genes and the chemicals that they produce are often termed the 'defensome'. Methods are currently being developed to measure the patterns of defensome activity to provide the ability to predict when corals are at greatest risk from threats caused by local and global stressors.

The role of microbes is increasingly recognized for contributing to both healthy and degraded coral reefs. A healthy microbial community is essential for productive and resilient reefs, as the proliferation of unhealthy microbes (e.g., *Vibrio*) results in degraded reefs due to increased incidence of disease. Recent developments in assaying the distribution, relative abundance, and diversity of microbes in and around coral reef habitats will lead to advances in detecting threats and their sources in order to prevent them.



Microbes are key to both healthy and degraded coral reefs. Concentrations of Vibrio*, a pathogenic bacteria, in the Line Islands indicate that protected, healthy reefs like Kingman and Palmyra have low levels of toxic microbes while degraded reefs have higher concentrations.*[43]

Citizen science provides an early warning system

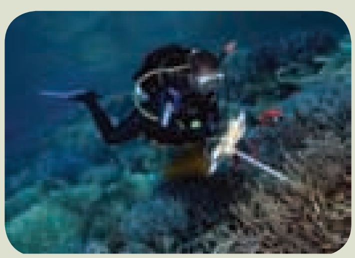
Monitoring different management regimes within a MMA serves as an antenna to assess the effectiveness of human stewardship. This tool allows scientists to look at different management efforts in different places to see what works and what does not. As doctors diagnose patients, scientists can "take the temperature" of an ecosystem by using the correct diagnostic tools. Science provides better diagnostics, better flow of information, and a way of integrating information and drawing conclusions about investments in ecosystem management.

Scientific surveys of marine habitats are expensive but provide the best opportunity to accurately track the global ecological state of the marine environment over the long term. Interested non-scientists that assist in the collection of data are called citizen scientists. As new tools are developed for gathering basic scientific data, citizens can economically employ those tools in an effective manner.[44]

In effect, citizen science programs involving networks of recreational divers allow scientists to "remotely sense" patterns at scales otherwise impossible to cover. Invaluable information on reef ecosystems at regional to global scales has been provided by programs run by the Reef Environmental Education Foundation (REEF, *www.reef.org*), Reefcheck (*www.reefcheck.org*) and Reef Life Survey (RLS; *www.reeflifesurvey.com*).

Since 2004, the Gulf and Caribbean Fisheries Institute (GCFI), with support from the United Nations Environment Programme (UNEP) and other partners, has presented the Gladding Memorial Award to recognize leading fishers committed to sustainable use and conservation of marine resources. The award empowers these leaders to learn more about management issues and to promote sustainable fishing practices in their countries and beyond. To date, 13 fishers have received the award, representing 11 diverse countries throughout the Caribbean. More information is available at: www.gcfi.org/PGMA/PeterGladdingMemorialAward.html

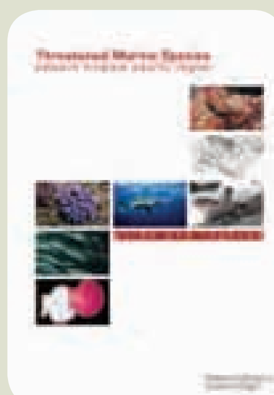
Reef Life Survey assesses marine communities



Volunteer RLS diver reeling in transect tape after censusing coral reef fishes and invertebrates.

Reef Life Survey (RLS) produces data used by scientists to measure the human footprint on marine ecosystems. It aims to provide high-quality information to better manage inshore marine habitats for conservation, recreation, and resource utilization. RLS does this through development of a small network of skilled recreational divers trained to quantitatively survey marine communities, producing technically rigorous, species-level data on the abundance and size of fishes, corals, sea urchins and other invertebrates, and marine plants. RLS places particular emphasis on data quality, which is achieved by limiting the program to the most capable divers, by providing immediate feedback when divers complete surveys or have queries, and by collaboratively involving divers on scientific research cruises. *www.reeflifesurvey.com*

Recreational divers track threatened species



The guide booklet also includes a log, which divers electronically forward after completing dives with their records of abundances and locations to a central Galápagos database managed by the Charles Darwin Foundation.

Most threatened marine species are rarely observed or highly localized in distribution—a challenge for scientists trying to accurately determine changes in population numbers of these species. Managers also need information on population trends when assessing if local conservation strategies are successful. Recreational divers provide the needed eyes for an innovative program aimed at tracking population changes of threatened marine species across the Eastern Tropical Pacific Seascape (ETPS). Divers identify any threatened species observed on dives using an illustrated guide. Through this cost-effective process, over a thousand records of threatened marine species have now been compiled (Threatened Marine Species: ETPS available at www.science2action.org).

Recommendations

The following are recommendations stemming from the natural science analyses highlighted in this publication and from the social science analyses highlighted in *People and Oceans* (both available at www.science2action.org).

Government Agencies:

- ***Regulate*** with appropriate penalties to enable managers to effectively police their MMAs.
- ***Enforce*** MMAs by surveillance and detection, interception and arrest, prosecution, and sanctions.
- ***Invest*** in MMAs by providing funding, personnel, and infrastructure support.
- ***Plan*** for sustainable regional development, while recognizing global issues such as climate change.
- ***Integrate*** ocean management with land management.
- ***Coordinate*** scientific discovery and citizen scientist efforts to support MMAs.

Local Community:

- ***Participate*** in the design and establishment of MMAs so that stakeholders are vested in the success of the MMA.
- ***Learn*** and ***adapt*** to the changing conditions and use MMAs as social learning experiments.
- ***Celebrate*** ocean resources through cultural events and engage broader groups of people in MMAs.
- ***Engage*** in alternative livelihoods to sustain marine resources, as well as engage life-long learning activities afforded through MMAs.
- ***Respect*** the limits of the ocean and the patchwork of MMAs to maintain diversity of habitats.
- ***Wait*** long enough for MMAs to have desired effects; impatience with natural ecosystems is not often rewarded.

Marine Scientists:

- ***Monitor*** the effectiveness of MMAs, both in terms of natural resources and management practices such as economic incentives.
- ***Develop*** targeted research to help to decide between trade-offs and capture the links between natural and cultural knowledge.
- ***Disseminate*** scientific knowledge to MMA managers and stakeholders for effective management and success of MMAs.
- ***Establish*** monitoring and research relevant to MMA issues and draw on local community knowledge.
- ***Investigate*** the relationship between spatial size and arrangement of MMAs and their effectiveness for fisheries and for other ecosystem features.
- ***Create*** new scientific tools for professional scientists and well as citizen scientists to better monitor and interpret MMA effectiveness.

Marine Managers

- ***Seek*** economic support for MMAs by matching fees to the willingness to pay (value) of the MMA and engage in fundraising activities.
- ***Educate*** visitors and stakeholders on how people depend on oceans (ecosystem services) and promote awareness of sustainable resource use for long-term benefits.
- ***Maintain*** compliance of the local community for MMAs using incentives and enforcement.
- ***Manage*** MMAs in an integrated fashion, encompassing the watershed and adjacent marine ecosystem beyond MMA boundaries.
- ***Connect*** MMA management to local community initiatives.
- ***Facilitate*** communication between MMAs and stakeholders to acheive climate adaptation, biodiversity maintenance, and habitat protection.

Private Businesses:

- ***Allocate*** a portion of profits to the establishment and operation of MMAs to assist in long-term conservation.
- ***Educate*** staff and visitors about conservation practices and improve environmental literacy.
- ***Promote*** sustainable use of resources and good conservation practices.
- ***Develop*** experiences in which a healthy ocean is the feature that attracts sustainable development.
- ***Balance*** the seemingly contradictory demands of protecting natural resources to be able to reliably obtain these same resources.
- ***Focus*** on biodiversity and locally unique (endemic) species or habitats to foster ecotourism.

Non-Government Organizations:

- ***Foster*** long-term partnerships between natural resource agencies, conservation managers, and communities.
- ***Inform*** policy and influence decision-makers through environmental and conservation education, interpretation, and media outreach programs.
- ***Develop*** sustainable financing mechanisms including economic incentives and payments for marine ecosystem services.
- ***Build*** capacity in the local community to manage MMAs through training programs and investments in conservation support.
- ***Adopt*** a systems-wide perspective to manage MMAs within the context of the landscape and seascape.
- ***Educate*** government officials, scientists, and resource managers about conservation values and economic values of MMAs.

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This is a publication of the **Science-to-Action** partnership, which includes more than 75 organizations led by Conservation International's Marine Management Area Science Program. **Science-to-Action** is dedicated to sustaining the health of coastal and marine ecosystems, and the well-being of people who depend on them.

Our global network puts science into action so that the ocean can provide the multiple benefits needed by people today and tomorrow. Since 2005, we have conducted more than 50 studies in over 70 MMAs in 23 countries, using an integrated approach of natural and social sciences. Based on the scientific results, we develop conservation and management recommendations, and we engage directly with people at local to international scales to implement science-based solutions.

The following **Science-to-Action** publications present global research findings and lessons learned.

Marine Managed Areas: What, Why, and Where defines MMAs and discusses the challenges of implementation.

People and Oceans examines the role of people in MMAs, including the human well-being benefits and challenges of MMAs, and how socioeconomic conditions affect success.

Living with the Sea examines the role of marine managed areas in restoring and sustaining healthy oceans, particularly the importance of local management efforts.

Science-to-Action provides practical guidance for scientists and decision-makers on using science to inform ocean policy and management.

Economic Incentives for Marine Conservation provides guidance on how to select and implement incentive-based solutions: buy-outs, conservation agreements, and alternative livelihoods.

Coral Health Index provides a comprehensive methodology for monitoring the condition of coral reef ecosystems.

Economic Values of Coral Reefs, Seagrasses and Mangroves: A Global Compilation provides statistics on the economic value of tropical marine resources organized by type of use and by region.

Socioeconomic Conditions Along Tropical Coasts: 2008 demonstrates people's dependence on marine resources for livelihoods, discusses people's perceptions of resource conditions, and highlights governance status worldwide organized by region.

Four-page policy briefs summarize these longer booklets and guidebooks.

These publications and information about the Science-to-Action global learning network are available at science2action.org.

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