MPA news

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Climate Change and Ocean Warming: Preparing MPAs for It

Earth's climate and ocean systems are in a continual state of change. Such variability occurs on different scales of space and time, from daily weather to decades-long patterns in regional sea surface temperatures. Although much of this fluctuation is natural, it is now believed that change can be induced by human activity as well. Greenhouse gases from the burning of fossil fuels, for example, can cause warming of the planet's surface, including its oceans.

Average ocean temperature, from sea surface down to 10,000 feet (3050 meters), has risen by 0.05°C since the 1950s, according to researchers. Whether or not this is a result of human greenhouse gas emissions, the warming presents potential long-term challenges for MPA management, including coral bleaching, shifting habitats, and even disappearing species. *MPA News* covered the science of ocean warming and the challenges it poses for MPAs in July 2001 (*MPA News* 3:1). In light of the Kyoto Protocol taking effect last month, we revisit the subject of ocean warming, examining how managers might prepare for it.

Coral bleaching and the future of the Great Barrier Reef

Of the impacts of ocean warming on marine ecosystems, the one that is perhaps most easily visible is coral bleaching. A condition in which reef corals turn white, bleaching occurs when corals experience stress. Any number of stressors — siltation, pollution, destructive fishing practices, exposure to freshwater, and increased temperatures — can result in the loss of corals' symbiotic algae (zooxanthellae), whose photosynthetic pigments give coral reefs their color. Loss of the zooxanthellae removes a source of energy for the corals. Although bleached corals can survive for some time, they can die if conditions do not return to normal. In 1997-98, a massive worldwide bleaching event triggered by elevated sea surface temperatures resulted in widespread coral mortality.

The Great Barrier Reef Marine Park in Australia escaped the worst of that event, but has faced the challenge of bleaching in ensuing years, including a major bleaching event in 2002. "While the Great Barrier Reef was fortunate in that it did not experience catastrophic coral mortality in 1998, bleaching has caused widespread stress to many reefs in our park's ecosystem, particularly in shallower areas," says Paul Marshall, manager of the Climate Change Response Program for the Great Barrier Reef Marine Park Authority (GBRMPA). "Bleaching-related stress was evident on 60-95% of our reefs in 2002."

Marshall says monitoring studies suggest recovery of these reefs may take years, if not decades. Further warming of the sea surface could delay or even halt that process. "Repeated bleaching events, even if they are no more severe, have the potential to cause significant declines in the condition of the Great Barrier Reef over coming decades," says Marshall.

The marine park received media attention in February 2005 when a prominent Australian reef biologist — Ove Hoegh-Guldberg of Queensland University — told journalists that much of the park's shallower reefs could die off within 20 years due to increasingly frequent bleaching events. He warned of "a complete devastation of coral communities on the reef". (This echoed a 2004 report by Hoegh-Guldberg, released by WWF Australia and the Queensland Tourism Industry Council [*MPA News* 5:8].)

Marshall says GBRMPA is "certainly concerned" about the implications of climate change for the future of the Great Barrier Reef. The question becomes, how do you manage for it? "The ultimate cause of mass coral bleaching is anomalously warm sea temperatures in combination with UV light, and neither of these factors is amenable to management intervention over ecological spatial scales," he says. "However, an emerging understanding of the interactions between stressors, and about the factors that confer resilience to reef ecosystems, is proving an important basis for management actions in response to coral bleaching."

In particular, he says, it is becoming clear that good water quality, abundant and diverse herbivores, high biodiversity, and well-protected refugia are critical to optimizing the productivity and natural values of reef ecosystems. GBRMPA has launched several major initiatives aimed at restoring and maintaining these ecosystem qualities, thus moderating the effects of warmer waters on the Great Barrier Reef. These initiatives include a reef water quality action plan (*MPA News* 3:7),

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a substantial expansion of no-take zones (*MPA News* 5:10), and a partnership with the Florida Keys National Marine Sanctuary in the US to explore the science and management of reef resilience (*MPA News* 6:7).

Climate change may be impacting more than just the corals of the Great Barrier Reef, says Marshall. "There is research underway that suggests that high sea temperatures during warm years are impacting the ability of some seabirds to provide enough food for their chicks, leading to mass mortalities of fledglings on some islands," he says. "Other work is examining the effect of increased sand temperatures on sex ratios in sea turtle hatchlings." Over the next four years, he says, a major goal of the GBRMPA Climate Change Response Program is to complete an assessment of risk from climate change for key species and habitats.

Other effects of ocean warming

With persistent warming of the world's oceans, sea level would continue to rise as it has over the past century: as a result, coastal regions could be subject to increased wind, flood, and erosion damage, and low-lying islands would be submerged. Many researchers predict that warmer sea surface temperatures could also spur an increase in the frequency and severity of storms, particularly in tropical regions. And there is speculation that, if allowed to progress unchecked, the rising of ocean temperatures could even cause changes in major ocean circulation patterns, leading to abrupt shifts in climate.

For more information on the potential impacts of climate change, including on the marine environment:

Intergovernmental Panel on Climate Change (IPCC)
Climate Change 2001: Impacts, Adaptation and Vulnerability
http://www.grida.no/climate/ipcc_tar/

US National Research Council
Climate Change Science: An Analysis of Some Key Questions
http://www.nap.edu/catalog/10139.html?srchtop

Pew Center on Global Climate Change
Coral Reefs and Global Climate Change: Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems
http://www.pewclimate.org/global-warming-in-depth/all_reports/coral_reefs/index.cfm

Shifting of habitats

Fluctuations in ocean temperature — even as part of natural cycles like El Niño, the rapid warming trend in the Pacific Ocean — can cause shifts in the spatial distribution of species. When the waters of a particular site warm up, the site generally becomes more hospitable to warmer water species. When the waters cool down again, colder water species return.

The 4,292-km^2 Channel Islands National Marine Sanctuary (CINMS) stretches along the Pacific coast of the US state of California. Comprising a "mixing zone" where cool and warm ocean currents intersect, CINMS features a diverse array of temperate and sub-tropical species and habitats. The temperate ones are concentrated more northward in the sanctuary, while sub-tropical ones are predominantly southward. During El Niño cycles, the boundary between the temperate and sub-tropical portions of the sanctuary may shift tens of kilometers northward, resulting in local increases or decreases of some species. In essence, during these periods, the sanctuary becomes more sub-tropical and less temperate. (During La Niña cycles, the opposite is observed.)

In 2001-2002, when the multiple-use CINMS underwent a process to create a network of no-take marine reserves within its boundaries (*MPA News* 4:6), connectivity of habitats was a consideration in the planning. That is, to help ensure that species of interest would be protected throughout their life history, reserves were placed at distances that did not exceed larval and adult dispersal distances for these species. However, should ocean warming cause sanctuary habitats to move consistently northward over, say, the next 50-100 years, species dispersal could change and the reserves could conceivably lose some of their effectiveness.

Satie Airame, who served as CINMS liaison to a science advisory panel for the reserve-planning process, says the reserve design accounts for some of the natural variability in ocean temperature, but may not be enough to handle persistent habitat shifts. "The distribution of the reserves spans the entire island chain and the full range of habitats and species in the region," she says. "But if the region becomes completely sub-tropical as ocean warming proceeds, those species currently protected in cooler waters may persist only at northerly latitudes." Such latitudes could, perhaps, be only outside the sanctuary.

To protect the species of the region over the long term, Airame says, it may be necessary to establish reserves along the coast northward of CINMS. Indeed, the state of California is working to build a network of marine reserves throughout its waters, a process that could yield a functioning network by 2011, according to officials. "Because the scale of global warming is much larger than the Channel Islands region, complementary regulations that cover a much larger area — the entire state of California — are likely necessary," says Airame.

David Obura is East Africa regional coordinator of CORDIO, an international research program to respond to coral reef degradation in the Indian Ocean. He agrees with Airame that in the context of climate change, management of habitats and species must follow those habitats and species as they shift over the long term. But creating new MPAs to do it, or expanding the boundaries of existing ones, could face challenges from stakeholders, he says. Specifically, accusations of governmental "land grabs" could make such policies difficult to carry out. Instead, he would prefer to see comprehensive marine zoning, with up- or downgrading of protective measures in various zones as needed over time.

"If done cleverly, the boundaries of zones within such a system may not need to be changed — just the management regime," says Obura. "A reserve area within a buffer zone might be better protected if the activities in the buffer zone are more stringently licensed during a recovery period, such as after a coral bleaching event. Conversely, in an instance of total reef mortality in an area with 'reserve' status, this site would be reclassified as a fishery area; in exchange, a healthy area would be reclassified as a reserve."

Obura continues, "Viewed from a larger scale, the important thing is that proportional cover of different zones is maintained or altered according to specified guidelines. At a smaller scale, it amounts to trading areas. In fact, if the ability to do this is encoded in management and legislation, it could become a trading system along the lines of individual transferable quotas in fisheries."

Disappearing habitat of freshwater species

With ocean warming, colder water fish species face the challenge of shrinking habitat. As their preferred waters shift farther from the equator, these species must move as well. Many marine and anadromous species have the mobility to respond to such change, at least until it hypothetically becomes so extreme that there are no longer any suitable habitats available to them. (Anadromous species are those that spend all or part of their adult life in saltwater and return to freshwater streams and rivers to spawn.)

Peter Maitland, a biologist at Scotland's Fish Conservation Centre, says such migration has occurred in the past, as ice ages have come and gone. "Indeed, we know that it is happening at present as salmonid fish move into virgin waters in Alaska, opened up by glacier retreat," he says.

But for populations of freshwater fish species, climate change offers real potential for extinction as species become trapped in lakes and river catchments, unable to migrate to colder climes. "We can expect that southern populations of northern freshwater species, especially those at low altitudes, will steadily be eliminated as global warming proceeds," he says. "From a conservation perspective, protection for any one species should probably be given preferentially to sites at higher altitudes and those in the north, as being the most likely to survive." He points out that conservation organizations in Scotland are protecting populations of certain rare species not only through appropriate site management but also by creating "safeguard" populations in new waters, preferably at high altitudes.

Maitland says a major challenge to colder water species from global warming is outcompetition by warmer water species that move into their habitat. "This is one of the greatest threats to more sensitive northern fish species in Scotland and the rest of northern Europe, and is something we are battling," he says. "Not only do many southern species find waters in the north very suitable as they become warmer, but many of the species concerned are much more tolerant of the other anthropogenic changes that are affecting many waters, such as eutrophication and siltation. Thus, an important part of the management of waters with important populations of northern fish species is the prevention of alien species ever reaching them."

Maitland acknowledges that the phenomenon of alien species — along with changes in climate over history — are partly responsible for the "native" species assemblages we have today. "The majority of our northern freshwater fish species originated from anadromous stocks, as these were the only fish able to access most fresh waters after the ice retreat from Europe," he says. "These have eventually become isolated as the climate warmed up or barriers to migration appeared."

Asked whether it is a fruitless effort by humans to protect northern fish species in the face of global warming, he says, "It may be. But that should not prevent us from trying, and believing that today's conservation efforts will prevent tomorrow's extinctions — or at least some of them."

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Advice for coral MPA managers on managing for climate change

David Obura is East Africa regional coordinator of CORDIO, an international research program to respond to coral reef degradation in the Indian Ocean. He offers the following advice to coral MPA managers on protecting their resources from the effects of climate change:

1. Educate local stakeholders about the threat of climate change so that when a bleaching event occurs, there is greater opportunity for a considered response.

2. Prepare response options for bleaching events that include press releases, alerting stakeholders of what is happening, calling scientists to track the event, and planning potential closures or "additional care" measures that divers/fishers can take during and after a bleaching event. Discuss these openly (#1 above) so that there is prior acceptance.

3. Minimize the ecosystem stressors that can be minimized, particularly those that affect individual coral health (pollution) and ecological resilience/recovery processes (water quality, herbivory).

4. Establish basic monitoring programs involving rangers and frequent visitors so that the manager knows what is happening in real time; the network can serve to channel information to stakeholders as well. Bring in scientists to conduct more detailed monitoring programs to assess reef health, and link this with the less formal monitoring.

5. Promote sound management and protection of reefs outside the MPA to maximize the overall health of the system; this way, healthy patches of reef may survive somewhere to facilitate recovery. Focus particularly on water quality issues and fishing/extraction.

6. Join national and regional processes that publicize what is happening to reefs (*i.e.*, MPA and conservation networks, tourism marketing initiatives, artisanal fisheries advocacy programs) in order to pressure governments to consider the problem and advocate internationally for greenhouse gas reductions.

Project Is Underway to Create Global MPA Database

For more information

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Planning a network of marine protected areas requires knowledge of where MPAs currently exist, so that gaps in habitat protection can be addressed. Amid recent calls by governmental and conservation leaders for a worldwide network of MPAs by 2012 (*MPA News* 4:3 and 5:4), a project is underway to build an enhanced global database of MPAs, including each site's location, regulations, and habitats. The goals of the project are to use the database to help design scenarios for a worldwide network of MPAs, and to track progress toward building such a network.

Louisa Wood — a Ph.D. candidate with the *Sea Around Us* project at the Fisheries Centre of the University of British Columbia (Canada) — is heading the initiative, a collaboration with the UNEP-World Conservation Monitoring Centre (UNEP-WCMC), IUCN World Commission on Protected Areas-Marine, and World Wildlife Fund.

In short, the project is enhancing the marine portion of an existing inventory of terrestrial and marine protected areas: the World Database on Protected Areas, maintained by UNEP-WCMC. This enhanced version, nicknamed MPA Global, focuses only on marine protected areas, lists some sites not included in the original inventory, and contains more detail on each site. When complete, MPA Global is to be re-incorporated in the World Database on Protected Areas. During and beyond this project, UNEP-WCMC will retain its international responsibility for collating protected area data as reported by national and regional agencies and other organizations.

Submissions welcomed

Wood points out that MPA Global is a work in progress. More sites — as well as details on sites already in the database — are being added, and edits by the public are welcomed following registration at the project website (http://www.mpaglobal.org). Such edits are necessary to fill gaps remaining in the information. The descriptions of many sites offer only basic data — location, size, date of designation, and legal authority — with little on habitat or regulations.

"Registration is open to anyone, and edits are attributed to the person who submits them," says Wood. She reviews each edit submission and decides whether to incorporate it in the database, based on the information provided. All suggested edits are retained for comparative purposes.

The database allows visitors to search for MPAs by country, international convention, or site name. Approximately 5000 sites — including international, national, and state-level MPAs — are listed. Wood aims to conduct a thorough verification of the database in summer of 2005; until then, she cautions against using the data for analytical purposes. "The data at this point give a broad overview and, to be honest, the overall numbers might not change dramatically in the coming months," she says. "But I don't think they should be considered reliable yet."

The MPA Global project generally follows the IUCN definition of *marine protected area* ("an area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" [IUCN 1992]). Wood says the project does not rule

Defining "MPA" for an inventory

How many marine protected areas are there worldwide? The answer lies, to some extent, in how you define "marine protected area". Should seasonal fishing closures be included? Gear closures? No-anchor areas around pipelines? The more inclusive the definition, the larger an inventory will be.

Since 2001, in partnership with other federal, state, and territorial programs, the US National MPA Center has been creating an inventory of what it terms *marine managed areas* (MMAs) in the nation's federal and state waters. An interagency team determined that using the term MMA encompassed a potentially broader spectrum of management purposes than *marine protected area*, which is defined under US law as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources within them". That definition includes words that have not yet been strictly defined by the government — among them "lasting", leaving open the question of whether seasonal fishing closures are MPAs under US law.

Such sites can be included in the inventory as MMAs, however. "To include a site, what we look for at the minimum is a legally defined area that exists for some period of time in the same location each year, with at least the potential for permanence," says Jonathan Kelsey of the National MPA Center, adding that resource protection must also be part of the site's purpose. Of the sites in the inventory to date, there are 17 MMAs with protective regulations that do not apply throughout the entire year. In addition, there are 6 MMAs with protective regulations scheduled to expire in the future but which have some sort of renewal mechanism in place, or a history of renewals.

Not included in the inventory are sites such as gear closures designated solely to resolve gear conflicts, and closures around military, aerospace, and petroleum installations with no explicit purpose of protecting natural or cultural resources.

Officials expect to finish the draft MMA inventory (*http://mpa.gov/inventory/inventory.html*) by the end of 2005, and to define terms in the US MPA definition over the next two years. Staffers have also begun work on a list of *de facto* marine protected sites, including ones such as those above that have been excluded from the present inventory.

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out the possibility of adding other types of spatial management tools that fall along the marine protection continuum, such as various kinds of fishery closures. By using this relatively broad concept of an MPA, the database will be useful to an array of parties, she says. Analysts who later want to examine a subset of the database — such as trawl closures or sites with subtidal habitat — will be able to do so using the additional information included on regulations or habitat.

MPA Global is the second project of its kind to inventory MPAs worldwide. IUCN produced the four-volume *A Global Representative System of Marine Protected Areas* in 1995, which divided the world's marine waters into 18 large biogeographic zones and listed existing MPAs in each (http://www.deh.gov.au/coasts/mpa/nrsmpa/global/). An update of that seminal work has not yet been done, so information on sites designated over the past decade is incomplete. In the meantime, efforts to assemble national and regional inventories of MPAs have been undertaken, including in the US and Canada (*MPA News* 2:9 and 3:2).

UNEP-WCMC last updated the World Database on Protected Areas (WDPA, http://sea.unep-wcmc.org/wdbpa) in 2004, in partnership with the IUCN World Commission on Protected Areas and the WDPA Consortium, an advisory group of international conservation organizations.

Tsunami Aftermath: Pulau Weh, Indonesia

Last month, *MPA News* reported on efforts to assess impacts of the Indian Ocean tsunami on MPAs and marine resources (*MPA News* 6:7). Resource managers, scientists, and volunteers throughout the region continue their work to document the damage and, in some cases, begin repair of natural structures, such as coral reefs.

Marjan van der Burg operates the Lumba Lumba Diving Centre on the island of Pulau Weh, in the Indonesian province of Aceh. Pulau Weh has a 2.8-km^2, no-take marine nature park, Taman Wisata Pulau Weh Sabang, managed by a governmental nature conservation agency, KSDA. *MPA News* spoke with Van der Burg about the impact of the tsunami on the island's marine ecosystem, located so near to mainland areas devastated by the disaster.

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MPA News: Have you been able yet to view the underwater impact of the tsunami around Pulau Weh?

Marjan van der Burg: From what we have seen ourselves and heard so far, it seems that the deeper reefs were unaffected by the earthquake and tsunami. However, some shallower areas were damaged. During snorkeling and a shore dive off Gapang Beach — a kilometer south of the marine nature park — I saw a few places with heavily damaged patches of about 2 m across: table corals turned over and broken staghorn coral.

The next beach area to the north, Tepe Layeu, is part of the nature park. I understand that 1/2-m to 1-m sized boulders with *porites* coral were thrown ashore there. I haven't had the opportunity to dive or snorkel there yet.

A group of marine biologists from Singapore is planning to come the first or second week of March for a reef survey. Another group submitted a project proposal to replant mangroves on the island. We will have to do some clean-up dives once our compressor is repaired [it was flooded by the tsunami] and we can fill our tanks again. I saw jeans, roof material, a cupboard, branches, and other debris lying on the reef, including part of a huge tree trunk stuck under a rock-coral formation.

MPA News: What challenges does the marine nature park face at this point?

Van der Burg: We have heard that one or two small fishing boats from the island have restarted fishing with nets and possibly more destructive methods in the marine park, as a result of our not being able to dive or check the area since the tsunami. The fishermen snorkel and use big stones to bang on the corals to chase fish into their nets. We saw them do the same during the martial law period from May 2003 to May 2004, when no foreign visitors were allowed in Aceh and there were consequently few dive trips going out. At that time, we organized an action with the head of local fishermen from the nearby village, the KSDA, and a local policeman. Otherwise, there has never been regular, official patrolling in the park.

We would like to stimulate some patrolling again, so we are sponsoring the repair of the wooden boat of the KSDA, which was damaged in the tsunami. When the boat is available, KSDA can borrow one of our outboard engines for the next patrol action. But apart from what we are doing ourselves, there is no official project or donation fund available for the patrolling yet.

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Notes & News

MPA newsletter available for Western Indian Ocean

MPA practitioners in the Western Indian Ocean — consisting of Comoros, Kenya, Madagascar, Mauritius, Mozambique, Reunion, Seychelles, South Africa, and Tanzania — have a new resource to help share their ideas and knowledge. The *WIO-MPA Newsletter*, to be produced quarterly, will provide readers with news on MPAs in the region and notices of events. It was launched this past January, with the second issue set for release in April.

Keith Spencer, manager of De Hoop Nature Reserve in South Africa, is coordinating the project. "We hope the newsletter will contribute to raising awareness and informing key stakeholders on how MPAs in the region are doing," he says. Spencer is relying on contributed articles and notices from fellow managers to comprise the publication.

To receive the *WIO-MPA Newsletter*, you must join a listserv called *E-wiompaf* (Western Indian Ocean Marine Protected Area Forum). The newsletter is distributed via the listserv. For instructions, go to *http://www.crc.uri.edu/mailman/listinfo/e-wiompaf*.

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Fishery managers vote to close 950,000 km² of North Pacific to bottom trawling

Managers of US fisheries in the North Pacific voted in February to prohibit bottom trawling in nearly one million square kilometers of water in an effort to minimize the effects of fishing on sensitive coral and sponge habitat.

The North Pacific Fishery Management Council, which recommends management actions to the federal fisheries agency (NOAA Fisheries), voted to close 950,000 km² of its Aleutian Islands management area within the US Exclusive Economic Zone to bottom trawling. This would leave 4% of that management area, or 43,000 km², open to such gear. Additionally, six areas with especially high-density coral and sponge habitat would be closed to all bottom-contact fishing gear, including longlines and pots. The recommended measures await NOAA Fisheries approval, and would be permanent if approved.

The region's trawling industry has voiced its support for the closures, which would not significantly impact the sector in the near term. Most current and historic trawling activity has occurred in the 4% of areas slated to remain open. David Witherell, deputy director of the council, says the proposed closures have jagged topography on which trawls are easily snagged. "There isn't much incentive to fish there, given the abundance of fish elsewhere," he says. Still, in the future, should trawl vessels have difficulty finding fish schools on traditional grounds, the closures would prevent vessels from spreading out to new grounds. If approved, the closures would be required to be implemented by 13 August 2006.

The council also recommended that vessel monitoring systems (VMS) be required on all fishing vessels in the Aleutian Islands management area, to aid enforcement of the closures. Pending NOAA Fisheries approval, this would take effect concurrently with the closures.

The 950,000-km² closure would be nearly three times the size of Australia's Great Barrier Reef Marine Park, widely considered the world's largest MPA at roughly 350,000 km².

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Report: Using protected areas to reduce poverty

A new report examines how protected areas can be used to help reduce poverty in surrounding communities while still meeting the primary goal of biodiversity protection. A collaborative effort among IUCN, WWF, CARE, and the World Bank, the publication points out practical measures for resource managers and other stakeholders to apply, while cautioning against the potential pitfalls of integrated conservation and development projects.

"Protected areas are seldom designed specifically to alleviate poverty, but this does not mean that they are therefore isolated from sustainable development and the alleviation of poverty," writes IUCN Chief Scientist Jeffrey McNeely in the report's foreword. "This paper suggests many possible approaches that can be taken to deliver a greater share of the benefits of conservation to the rural poor, and thereby strengthen public support for protected areas."

The 60-page report features several very brief case examples from around the world, including MPAs. *Can Protected Areas Contribute to Poverty Reduction?: Opportunities and Limitations* is available for GBP 10.50 (US $20) from the IUCN bookstore. For directions on how to order, go to http://www.iucn.org/bookstore/pro-areas-1.htm.

Ship owner fined US $500K for coral damage in MPA

A ship owner has agreed to pay more than US $500,000 in fines related to a 2002 incident in which its freighter — the *MSC Diego* — dropped anchor in a no-anchor zone of the Florida Keys National Marine Sanctuary (US). The anchor and its chain caused damage to 1175 m² of coral, an area slightly smaller than an Olympic-size swimming pool. While admitting no fault, Mediterranean Shipping Company and its insurer will pay to reimburse the federal government for the costs of damage assessment and response ($100,000) and future monitoring and compensatory restoration ($465,796).

Attorney Sharon Shutler of the National Oceanic and Atmospheric Administration (NOAA) suggests the assessment would have been greater had the responsible party not responded as it did. Through a contractor and under FKNMS supervision, the shipping company and its insurer reattached more than 1000 overturned corals, paying for the effort out of pocket. "This was an expensive proposition entailing rental of large boats and expert divers," says Shutler.

Anne McCarthy, a sanctuary biologist who helped assess the cost of the damage, says the reattached corals could recover to their previous functional state in approximately five years, provided environmental conditions are good. NOAA will use the compensatory funds to restore crushed parts of the site or to undertake grounding prevention efforts, such as encouraging the use of various navigational aids.

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