How Climate Change Could Affect MPAs: What Practitioners Need to Know

Earth's climate is continually varying on a wide range of time scales, from seasons to the lifetime of the planet. Most of this variability is natural, such as the periodic rapid warming trend in the Pacific Ocean known as El Niño. Climate change can also be induced by humans, however, through activities causing the emission of greenhouse gases, including carbon dioxide.

Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities. Among climate scientists, there is general agreement that this build-up is likely the main cause of a rise in surface air temperatures and subsurface ocean temperatures in recent decades. The average ocean temperature, from sea surface down to 10,000 feet (3050 meters), has risen by 0.05 degrees C since the 1950s. Researchers have only just begun to determine the effects of such warming on marine ecosystems. This month, MPA News examines the scientific understanding of climate change in the marine environment, and what global ocean warming could entail for the planning and management of MPAs.

Scientific uncertainty

There are difficulties involved in adequately observing the diverse aspects of the climate system. A recent report by the US National Research Council (NRC) -- *Climate Change Science: An Analysis of Some Key Questions* -- states that accurate predictions of global climate change will require major advances in the modeling of factors that determine greenhouse gas concentrations and the various feedbacks in the climate system. The level and timing of natural variability inherent in the climate record is still uncertain.

Elbert (Joe) Friday, director of the Board on Atmospheric Sciences and Climate for the US National Academy of Sciences, says the complexities of marine ecosystems add further challenges to determining the impact of climate change on oceans. Friday, who addressed the Second Marine Conservation Biology Symposium (San Francisco, California, US) last month, said much more research is necessary on cause-and-effect relationships among physical and biological factors in the marine environment.

"Most of the 'climate' observations in the marine environment do not include measurements of the biological systems and vice versa," said Friday. "We are truly entering into an era when multidisciplinary research is a must for proper understanding of the ecosystem responses to climate variability and change."

That said, climate scientists are in general agreement over what some of the effects of global warming could be on physical ocean and coastal systems. Sea level, which rose over the past century, would continue to rise through the 21st century, mostly due to thermal expansion of seawater. With higher sea level, coastal regions could be subject to increased wind, flood, and erosion damage, as well as loss of wetlands and mangroves. Low-lying islands would be submerged. Some scientists predict that climate change could also increase the extent and severity of storm impacts, particularly in tropical regions.

On a longer time scale -- into the 22nd century and beyond -- the dynamics of large ice sheets would become increasingly relevant, according to the NRC report. If all polar ice were to melt, the sea level would rise by 200 feet (61 meters).

Such substantial melting of the polar ice sheets could take centuries to occur, however. Friday cautions MPA practitioners against focusing too much on the long-term threat of climate change and not enough on natural climate variability. "The time scale of climate change is such that its impacts on the contents of marine protected areas are small compared to the natural climate variability and the major changes caused by such events as hurricanes, floods and severe droughts, for example," he said. "Climate change may have a gradual impact over the long run, but the seasonal to interannual variabilities will probably predominate MPAs for some time to come."

Ocean warming and coral bleaching

Among MPA practitioners in tropical regions, discussions of climate change often center around the issue of coral bleaching. Coral bleaching, in which reefs turn white, occurs when corals experience stress. Any number of stressors -- including 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. Bleached corals can survive for some time, but if conditions do not return to normal they can die.

In 1997-98, a massive coral bleaching event -- in which reef systems around the world bleached and suffered widespread mortality -- caused many coral researchers to draw a link between climate change and bleaching. The timing was suggestive: 1998 was the warmest year recorded last century, which resulted in elevated sea surface temperatures in many areas. Many reports of bleaching coincided with these unusually high sea surface temperatures, which were often 3-5 degrees C higher than normal.

Although coral bleaching is not a new phenomenon, the extent of coral mortality in 1998 was the most severe and extensive ever documented. In response, the United Nations Convention on Biological Diversity in 1999 convened an expert group on coral bleaching; the group concluded that the geographic extent and increasing frequency of mass bleaching events since the mid-1970s were likely the result of rising sea surface temperatures caused by climate change.

If sea temperature is expected to continue to rise, and bleaching is a consequence of higher sea temperatures, coral reef communities inside and outside of MPAs could be significantly affected.

Janice Lough, principal research scientist with the Australian Institute of Marine Science, notes that bleaching response of corals has been shown to vary with location, depth, and taxa. "Certain species appear to be more susceptible to bleaching mortality," said Lough. "Thus, repeated severe bleaching events (in the absence of significant adaptation or acclimation) are likely to alter the make-up of present-day coral reef communities."

Coral species diversity might decrease, she said, as well as the diversity of habitats available for non-coral components of coral reef ecosystems. The composition and distribution of reef fish species would change in turn. "Coral reefs would not disappear but individual reefs would look different," said Lough.

Lough points out, however, that although climate change appears to be a real threat to coral reefs, there are many local stressors that make coral reefs more susceptible to the impacts of climate change, like pollution and destructive fishing practices. "Working to solve local stresses and human impacts on coral reef ecosystems can help coral reef ecosystems become more resilient to, and better able to cope with, climate change," she said.

Reducing local stresses

Indu Hewawasam agrees with Lough. A senior environmental specialist for environment and social development in Africa with the World Bank, Hewawasam says that although warming sea temperatures were the ultimate reason for the 1997-98 event, there were several chronic factors that had already served to weaken many of the reefs.

"This crisis offers an opportunity for policymakers to control some of those other factors," she said. Hewawasam is a leader of CORDIO, an international program created to respond to coral reef degradation in the Indian Ocean. Supported by several organizations, including the Swedish International Development Cooperation Agency and the World Bank, CORDIO is working to mitigate impacts of coral bleaching through, among other efforts, the development of alternative livelihoods for coral-dependent communities.

"One of the goals of the program is to move people away from reef-based activities in general," said Hewawasam. "It's a big challenge. You can't change people's behavior easily. We've been trying to take a participatory approach to learn what they are interested in doing." The program is not just for the good of the reefs, she said; it can also help human communities to avoid economic dislocation in the event of mass coral bleaching.

A new report from the University of Rhode Island Coastal Resources Center (US) offers suggestions to coral resource managers on how to prepare for bleaching events. Compiled from papers presented at the 2000 International Coral Reef Symposium in Bali, *Coral Bleaching: Causes, Consequences and Response* (see box at end of article) provides practitioners with a two-pronged strategic approach to coral management. The first strategy is to implement responses that generally promote coral health, under the assumption that healthier reefs are usually less vulnerable to mortality from bleaching. The second strategy is to identify and pursue responses specific to bleaching. This latter strategy could include management of fisheries on bleached reefs to protect species population composition and species that are useful in maintaining coral health during bleaching events (e.g., herbivores that scrape algae off dead coral, maintaining suitable surfaces for coral larvae recruitment).

David Obura of CORDIO-East Africa says fisheries management is critical. "Specifically for East Africa, there are two aspects of fishing that are damaging," said Obura. "First is plain overfishing, such that the ecological state of the reef shifts toward macroalgae and/or bioeroding grazers (sea urchins). In this situation the survival of coral recruits and juveniles is compromised, and this is quite easy to explain to fishermen. Without young corals, the reef as a whole degrades, and they understand well the concept of corals as 'fish homes'. Second is beach seining -- large nets with small mesh size, dragged over the bottom by teams of 10-25 men. Again, it's not hard to explain to fishermen that physical destruction of corals -- while they're obviously dying from bleaching -- is not good for the reef."

Obura says that through CORDIO's involvement of local fishermen in reef monitoring exercises around the Kiunga Marine Reserve in Kenya, they have seen first-hand the bleached coral as it is being explained to them. "The additional threat to their livelihoods from bleaching has strengthened their resolve to sort out issues they can deal with, like overfishing," he said.

Effects of climate change at higher latitudes

According to the NRC report, climate models predict global warming to be larger over high latitudes than over low latitudes. Nonetheless, marine scientists studying temperate and polar ocean systems have not had the attention-getting image of coral bleaching on which to focus. Perhaps as a result, research on the effects of ocean warming at higher latitudes has appeared to be somewhat more diffuse.

Extreme environmental variability and change has characterized northern high-latitude seas for the past two to three decades. Vera Alexander, dean of the School of Fisheries and Ocean Sciences at the University of Alaska Fairbanks (US), points out that ice cover, water temperature, salinity, and nutrient content have all changed in that time span, though not necessarily in concert.

In a presentation to the Marine Conservation Biology Symposium, Alexander suggested that for the lowest trophic levels over the southeast Bering Sea shelf, changes in the marine food chain were directly linked to major oceanic changes in the region. One of the main trophic changes has been a switch from fast-growing early spring blooms of diatoms to persistent but slower growing primary producers. Alexander said these changes are "probably not reversible." Nonetheless, although Alexander said that climate change could be a factor in the trophic changes, she added that other factors -- both natural and human-caused -- were probably playing a role as well.

The impact of climate change on ocean circulation is of growing concern to northern Europeans. For the past decade, scientists have speculated that should there be an increase in precipitation and ice melting at northern latitudes, the salt-heavy water that normally sinks quickly in the North Atlantic would be diluted, and would therefore sink more slowly. As a result, ocean and air currents that currently carry a significant amount of heat to Northern Europe would be weakened and temperatures would fall.

What effect would this have on marine living resources in the area? Bogi Hansen of the Faroese Fisheries Laboratory says that although detailed predictions are difficult, significant changes could be expected, especially for the Norwegian Sea and Barents Sea. Hansen co-authored a study with British and Norwegian researchers in the journal *Nature* (June 21, 2001) on how deep water flow from the Nordic seas into the Atlantic Ocean has decreased since 1950, consistent with models of anthropogenic climate change. The study concluded that if the decreased flow were not compensated by increased flow from other sources, the marine ecosystem in the Norwegian Sea and Barents Sea could change from warm to cold.

"These areas are exceptionally warm due to the inflow of warm Atlantic water, and the extent of the Atlantic water determines the living conditions to a large extent," said Hansen. "An example of [a species that would be affected] is herring in the Norwegian Sea, which depends on the Atlantic water distribution."

An assessment of how coastal parks will change

Parks Canada, the Canadian national parks agency, has conducted an assessment of how climate change could affect its holdings, including its coastal protected areas. The report *Climate Change and Canada's National Park System* (see box at end of article), published in May 2000, called the implications "considerable" for ecosystem change and conservation.

The report subdivided the agency's 38 national parks into six broad geographic regions where the range of anticipated climate change impacts would be relatively similar. Among its conclusions:

- Climate change-related sea-level rise on the Atlantic coast will be exacerbated by continental subsidence, and related coastal erosion and salinity changes will potentially degrade key marine, dune, tidal pool, salt marsh, and estuary habitats;
- An increase in sea surface temperatures in the Pacific coast parks should lead to an increase in the frequency and distribution of red tide blooms, and higher populations of southern fish species such as mackerel and albacore tuna, which prey on and compete heavily with salmon populations;
- The reduction of sea ice in the Arctic parks will have substantial impacts on marine mammals, including on polar bears, which use the ice to access prey; the population of bears at one park is expected to disappear.

"Climate change simultaneously represents a threat and opportunity to different species and ecological communities within the national parks system," states the report. "As individual species respond to climate change, current ecological communities will begin to disassemble and re-sort into new assemblages. The dynamic brought about by global climate change will effectively alter the 'rules' of ecological conservation. Accordingly, the strategic role of Parks Canada in an era of climate requires much analysis and deliberation."

The report provides several suggestions to Parks Canada site managers on how they might plan for climate change, including identifying sites and species at risk to climate change; examination of how climate change might affect the invasibility of park habitats; and how current management practices may influence evolutionary trajectories. It also suggests that Parks Canada take a leadership role in initiating a national roundtable on protected areas and climate change, to identify key research needs and examine the range of adaptation pathways, including park selection and design criteria.

In a changing world, why bother with MPAs?

As suggested by the Parks Canada report, if climate change is going to cause populations and habitats to shift or disperse, it stands to reason that some might migrate out of the protected areas originally established to protect them. This begs a question for marine resource managers: are MPAs a rational long-term tool to use if climate change is going to alter marine and coastal communities anyway?

Cristina Soto, a Ph.D. candidate in resource and environmental management at Simon Fraser University (British Columbia, Canada), has concluded that MPAs -- and particularly no-take areas -- will continue to play a critical role as scientific controls, perhaps now more than ever. "MPAs are key in attempting to distinguish effects such as fishing from environmental variability such as regime shifts and global warming," she said in a presentation to the Marine Conservation Biology Symposium. "We need to strengthen this message as a rationale for marine reserves."

Soto suggests that some research MPAs be established in areas that have undergone faunal shifts in the past, expressly to study those shifts. Other MPAs should be managed in an adaptive manner, she says, allowing for shifts in boundaries if necessary to follow populations and critical habitats.

Some researchers have speculated on whether MPAs could be established in areas not expected to experience significant effects from climate change. CORDIO-East Africa's Obura says, however, that it is hard to know which sites will end up being important in a climate-changed world.

"Coral reefs and other marine ecosystems are very highly connected with distant places: by the water in currents, by food and chemicals carried in the water, by genetic flow through larvae and adults, etc.," he said. Thus, while a particular coral reef that exhibits high susceptibility to bleaching may not be important in the immediate scale of a bleaching event, it could be critical as a stepping stone and available habitat for recovery of a larger regional reef system.

"If these sites are not included in protected area networks, they may degrade through many other influences and become unavailable as sites for recovery," said Obura. "The key thing is that we don't yet know very much, so the precautionary principle should be applied so that we don't lose sites that may be important for unknown reasons."

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Box: NRC climate report is online

The US National Research Council report *Climate Change Science: An Analysis of Some Key Questions* is available online at http://www.nap.edu/catalog/10139.html?srchtop.

Box: Two reports on coral bleaching

Two recent reports on management responses to coral bleaching are available online:

Schuttenberg, H.Z. (ed.). 2001. *Coral Bleaching: Causes, Consequences and Response*. University of Rhode Island Coastal Resources Center. 102 pp.http://www.crc.uri.edu/comm/htmlpubs/coral.html

Westmacott, S, K. Teleki, S. Wells, and J. West. 2000. *Management of Bleached and Severely Damaged Coral Reefs*. IUCN, Gland, Switzerland. 37 pp.http://iucn.org/places/usa/webdocs/documents/English.pdf

Box: Socioeconomic impact of coral bleaching

In addition to its impact on biological systems, coral bleaching can have socioeconomic effects, including potentially significant tourism-related losses. Several studies of reef-dependent tourism following the 1997-98 bleaching event found indirect losses equivalent to several million US dollars in each of multiple countries, including Tanzania, the Maldives, Sri Lanka, and the Philippines.

The abovementioned studies are included in the report *Coral Bleaching: Causes, Consequences and Response*, published by the University of Rhode Island Coastal Resources Center. It is available online (see box above)

Box: Report on Canadian parks

The report *Climate Change and Canada's National Park System* is available online at http://www.msc-smc.ec.gc.ca/airg/pubs/parks.htm

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