Defenders of Wildlife

Climate Change & Coral Reef Disease

Coral Reef Diseases

Coral reefs only account for about one-tenth of one percent of the world's area, but harbor at least five percent of its known species. These remarkable systems depend on a symbiotic relationship between a tiny animal and an even tinier alga. The coral itself is a primitive animal related to jellyfish, consisting mostly of a stomach topped with tentacles they use to sting and eat plankton. In addition, each coral polyp can ingest tiny photosynthetic algae called zooxanthellae and harbor them in its stomach cavity without digesting them. In this symbiotic relationship, the coral provides the algae with carbon dioxide, the essential building block of photosynthesis, important nutrients like nitrogen and phosphorus, as well as a protected place to live and reproduce. In turn, the photosynthetic action of the zooxanthellae provides the coral with up to 90% of its energetic requirements, as well as oxygen, a by-product of photosynthesis. Because of this unique relationship, coral reefs are tremendously productive even in nutrient-poor waters. In fact, in waters that are enriched with nitrogen and phosphorus—for instance, near river outlets—other types of algae quickly outcompete the coral. Coral reefs are found exclusively in warm, clear, shallow waters where enough light reaches the bottom to enable photosynthesis.

Protecting each coral is an external skeleton of calcium carbonate, and thousands of identical polyps live colonially together, and over long these skeletons build up to form the structure of the reef, around which vast numbers of organisms feed, shelter or live. Australia's Great Barrier Reef, for instance, contains 350 species of hard corals and 1500 species of fish; huge numbers of sponges, anemones and other invertebrates also live in association with reefs.

The structure, biodiversity and sheer beauty of coral reefs provide enormous ecological and economic benefits. By one estimate, the world's coral reefs provide annual economic benefits totaling $29.8 billion, through tourism and recreation ($9.6 billion), coastal protection ($9.0 billion), fisheries ($5.7 billion), and biodiversity ($5.5 billion) (Cesar et al. 2003). Unfortunately, 27% of the world's coral reefs have been destroyed by overexploitation, pollution, sedimentation and disease. Worse, another 30% may be lost in coming years (Cesar et al. 2003). And the loss of coral reefs has negative consequences for biodiversity: for instance, in the Caribbean, where coral cover has decreased by 80% since the 1970s, populations of reef fish have plummeted by 32 to 72% (Paddack et al. 2009). Evidence is mounting that climate change is exacerbating the threats to coral reefs, particularly the various diseases ravaging these unique environments.

A diseased Elkhorn coal. Photo: U.S. EPA

Coral diseases

The disease pathology of coral reefs is incredibly complicated, due to the huge array of coral species and the multiplicity of diseases affecting them. In the Caribbean alone, 20 different diseases have been described, affecting 45 species of hard and soft corals, sponges, and other reef organisms (Harvell et al. 2007). The causative agents have been definitively identified for only a small subset of the diseases, so most are described according to their symptoms. Some of the more important and widespread coral diseases include:

Coral bleaching is the most serious global disease threat to corals (Harvell et al. 2007). Bleaching occurs when the zooxanthellae algae vacate their places within the coral structure. The coral animals themselves are transparent, so the loss of the brightly colored algae leaves the "bleached" skeletal calcium carbonate structure visible. The coral can survive for short periods without their algae, but they will eventually die if they do not re-establish their dinoflagellate flora. High water temperatures can directly induce bleaching, and in other instances it is caused a bacteria related to cholera.

Photo: U.S. Geological Survey.

Black Band Disease is one of the most common and widespread coral diseases, affecting reefs in the Caribbean, Australia, Philippines and East Africa. Infection takes the form of a narrow black band encroaching on living tissue, with the dead white coral skeletons above. The band's color comes from concentrations of bacteria that produce sulfur compounds and low-oxygen conditions, which kill the coral (Viehman et al. 2006).

White plague, white pox and *white band* are the names given to a set of diseases characterized by a spreading lesion of white skeleton. The various types are distinguished by which species they infect, how quickly they spread, and the pattern of spread exhibited (Bythell et al. 2004). Several different species of bacteria are involved in these and similar diseases called yellow blotch and band.

Other disease. A few coral diseases are attributable to protozoa, including skeletal eroding band and brown band syndrome, which are found in Australia (Ulstrup et al. 2007). Fungi also cause coral reef disease: *Aspergillosis*, which causes purple blotches on several species of sea fans, is caused by *Aspergillus sydowii*, a member of a large group of terrestrial fungi that also trigger mold allergies and other infections in humans (Geisner et al. 1998). Finally, emerging research indicates that viruses may also play a role in coral reef disease, but their extent and pathology remain uncertain (Davy et al. 2006).

The Climate Connection

The loss of coral reefs is a complicated phenomenon and involves a host of factors. Pollution from onshore, including sewage effluent, agricultural runoff, and sediments promote the growth of algae that suffocates corals, and pollutants like PCBs, pesticide residues, heavy metals and other chemicals are also damaging to corals (Pastorak & Bilyard 1985). Overfishing is also a problem, since the main mechanism to keep algae in check is grazing, and reduced fish stocks allow algae to proliferate even further. Aquaculture and discharge of ballast water are also hastening the pace at which exotic and potentially damaging species enter new marine environments.

While all these factors are important, mounting evidence suggests that climate change is exacerbating the disease threat to corals. The Fourth Assessment IPCC states that "recent warming is strongly evident at all latitudes in sea surface temperatures over the oceans" (IPCC 2007). Sea temperatures have already risen by 0.7^{o}C, and are currently the warmest they have been at any time in the past 420,000 years (Hoegh-Guldburg et al. 2007). Other important effects of climate change include increased incidence of high temperature anomalies, changes in wind patterns, and an increase in extreme events, and ocean acidification.

Thermal stress to corals

Corals have a fairly narrow water temperature tolerance range, about 18^{o}C to 30^{o}C (Harvell et al. 2007), and water temperatures are important in disease dynamics. Disease prevalence increases when approaching the equator, and also shows seasonal trends, with increased disease progression in the warmer months. Warm sea temperatures stress corals and increase their vulnerability to disease, possibly because warmer water holds less oxygen. Coral bleaching, characterized by the loss of photosynthetic algae, intensifies under warm sea surface temperatures, even in the absence of a pathogen (Brown 1997). In particular, warm sea surface water temperature anomalies associated with the El Niño Southern Oscillation (El Niño) produced coral bleaching events in 1982, 1997-8, and 2005.

Advantages to pathogen

High water temperatures also directly benefit the disease organisms. The bacterium that causes white plague II shows optimal growth between 30 and 35^{o}C. Furthermore, higher temperatures also allow the bacteria to thrive in more acidic conditions, which are key to overcoming the coral's main defense mechanism, an outer protective coating with acidic properties. In many cases both factors above may be at work, with warm temperatures simultaneously enhancing the disease and stressing the coral.

Wind and storms

Aspergillosis disease of Caribbean fan corals is caused by a terrestrial fungus found in North Africa. Transatlantic dust deposition has been on the increase over the past thirty years as drought conditions have intensified in the Sahara and Sahel regions (Prospero and Lamb 2003); therefore it seems the purple blotches on Caribbean fan corals may be yet one more fingerprint of climate change. Climate change models also forecast an increase in the intensity of hurricanes, however their impact on coral reefs is unclear: they do physical damage to reef systems, but on the other hand wind-driven mixing of water layers reduces sea temperatures, which may actually alleviate some of the thermal stress behind bleaching and other disease outbreaks (Manzello et al. 2007).

Ocean Acidification

As carbon dioxide emissions have risen, a significant proportion of the carbon dioxide—roughly 25%-- has been taken up by the oceans (Canadell et al. 2007). The fraction taken up by the ocean dissolves to form carbonic acid, which, in sufficient quantity, decreases the pH of the ocean water. The pH of the oceans has already dropped by 0.1 pH units, to the lowest level of the past 420,000 years (Hough-Guldberg et al. 2007). Acidification reduces availability of carbonate to living systems, inhibiting the ability of reef-forming organisms to lay down their aragonite crystal skeletons. Corals exposed to lower pH conditions exhibit decreased growth rates and lowered density of their skeletons (Hough-Guldberg et al. 2007). It is not yet known whether acidification leads to greater disease susceptibility or interacts with thermal stress in other ways (Eakin et al 2007), but this important consequence of increasing carbon dioxide emissions should not be ignored.

Reducing the Impact of Climate Change and Coral Reef Disease

Improve water quality in tropical oceans

As discussed throughout this document, the dynamics of coral reef disease are very complicated and affected by a wide variety of factors including, but not limited to, climate change. Pollution from onshore sources has been long recognized as a destructive force to coral reefs. Steps should be taken to limit this stress on these ecosystems as an important means of implementing climate change adaptation for corals.

Photo: NOAA

Reduce overfishing

As with many marine systems, overfishing has harmed coral reef ecosystems by removing fish that would graze upon algae that threaten to overgrow corals. But coral reefs are critically important nursery areas for the young of many commercially fished species. Thus, the loss of coral reefs will potentially exacerbate the effects of over-fishing, since recruitment depends on these nursery habitats. Fishing-free, fishing-reduction zones or other management measures may help corals adapt to climate change.

Manage ballast water to prevent spread of exotic organisms, invasive species or pathogens

Given the uncertainty about the origins of many coral diseases, and the potential for these organisms to be spread to new regions in the ballast water of ships, enactment of stringent, uniform performance standards for ballast water treatment is as important for the protection of coral reefs as it is for reducing the spread of harmful algal blooms. Measures should also be put in place to halt the release of exotic aquarium species into waterways where they could transmit pathogens to corals or to other reef species. This is particularly prudent given the uncertainties regarding the nature and origins of many coral pathogens.

Expand research into the origins of coral disease and potential treatments

Coral diseases are largely uncharted scientific territory: for all but a handful of the disease syndromes, the causative organism or set of organisms have not even been definitively identified. We are only beginning to understand the dynamics of infection and resistance. The possibility remains that some coral diseases might be treatable, for instance by inoculation with viruses that can help the corals combat invading microbes (Efrony et al. 2007). Given the tremendous biodiversity and economic benefits provided by coral reefs, a greater societal investment in basic research and protection of these systems is warranted.

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