Defenders of Wildlife

Climate Change & Harmful Algal Blooms

Harmful Algal Blooms

Harmful algal blooms and red tides are emerging as widening conservation threats, with impacts to oceans, estuaries, and vulnerable species. Algal blooms harm marine ecosystems in two major ways: 1) their proliferation and decomposition causes dead zones by depleting oxygen levels; and 2) various species also produce an array of toxins that harm the liver, nervous system or other tissues of affected people and animals (Gilbert et al. 2005). Climate change is creating conditions that increase the likelihood and impacts of harmful algal blooms.

Pile of beached crabs that suffocated in a dead zone. Photo: National Science Foundation.

Dead Zones

Harmful algal blooms threaten aquatic and marine ecosystems and wildlife through the creation of hypoxic conditions, and also through the toxins they produce. Hypoxia refers to the severe reduction in the amount of oxygen dissolved in the water associated with blooms of any type of algae. Algal blooms produce oxygen when they are alive and photosynthesizing, but most of this oxygen stays in the warmer, well-lit surface waters. When the algae die, they sink to the bottom, where the water is colder, darker, and in coastal areas, saltier. As the algae decompose, the oxygen in this bottom layer gets used up by the bacteria breaking down the algae. Since there is very little photosynthesis going on in the darker bottom layer, and very little mixing between the upper and lower layers, oxygen levels quickly plunge to levels that cannot sustain fish, crabs and other organisms. Mobile animals like fish can escape, but more sessile creatures are killed outright, hence the term “dead zone.” Dead zones form in Lake Erie the Chesapeake Bay, Gulf of Mexico, and elsewhere.

Dinoflagellate Toxins

Usually referred to as red algae or brown algae, dinoflagellates are single-celled organisms that share characteristics of both plants and animals. Like plants, they possess cell walls and convert the sun’s energy into chemical energy via photosynthesis. But unlike plants, they can also move using a pair of whip-like flagellae. Some species produce toxic substances to deter predators (Adolf et al. 2006), while others are themselves predatory, and may use toxins to “stun” their prey. Through direct exposure, or via bioaccumulation by unaffected predators, these compounds can damage the nervous systems and livers of shellfish, fish and humans. Most “red tides” and “brown tides” are dinoflagellate blooms.

Photo: NOAA

Neurotoxic Shellfish Poisoning is caused by a compound called brevetoxin, which disrupts the function of electrical impulses between nerve cells. Brevetoxin accumulates on sea grasses and in fish, reaching concentrations sufficient to harm and even kill animals at the top of the food chain (Flewelling et al. 2005). Red tides of brevetoxin-containing organisms have killed hundreds of bottlenose dolphins; led to strandings and deaths of sea turtles, including two federally threatened species, the loggerhead turtle and the green turtle, and one federally endangered species, the Kemp's ridley turtle; and may be responsible for as much as 17 percent of the annual mortality in federally endangered manatees.

Paralytic Shellfish Poisoning is even more dangerous. The culprit, a compound called saxitoxin, can completely halt nerve transmissions and paralyze the respiratory system, leading to death by asphyxiation (Ahmed 1991). Fourteen federally endangered humpback whales stranded and died on Cape Cod over a six-week period in late 1987 after eating mackerel contaminated with saxitoxin. It has also affected several bird species, including shag, northern fulmar, great cormorant, herring gull, common tern, common murre, Pacific loon and sooty shearwater (USGS 1999). Sublethal saxitoxin exposure may also contribute to reproductive failure in endangered North Atlantic right whales, which number fewer than 400 individuals (Reeves et al. 2001, Doucette et al. 2006).

Dinoflagellates cause other problems as well. *Pfisteria piscicida* produces an organic compound containing copper, which induces free-radical damage in cells (Moeller et al. 2007). Other dinoflagellates have spines or other structures that cause irritation and lesions. And a 2007 mass stranding that killed over 300 fulmars, grebes, loons and surf scoters in Monterey Bay was caused by a bloom that produced a slimy yellow protein film that coated the birds' feathers, reducing buoyancy and insulation. (Jessup et al. 2009).

Toxic Diatoms

Diatoms are a separate group of single-celled algae, characterized by "pillbox" shells of silicon dioxide. Like dinoflagellates, they are a large and widespread group, with some members that produce toxins. The most important is domoic acid, which causes neurological problems, and has been linked to the stranding and death of over 400 sea lions on the California coast in 1998 and 184 animals in 2000 (Gulland et al. 2002). Domoic acid also causes heart inflammation in federally threatened sea otters. It was reported for the first time in 2003 as the cause of death in 5% of the deaths of southern sea otters recorded from 1998-2001 (Kreuder et al. 2003, 2005). The worst outbreak to date occurred in 2007, killing a wider than ever array of species than ever seen before: seals, sea otters, dolphins, a sperm whale, a minke whale, and large numbers of birds, including grebes, gulls, cormorants, American avocets, loons and endangered California brown pelicans, which literally fell out of the sky after suffering seizures during flight.

Photo: NOAA Ocean Service Education

The Climate Connection

Multiple factors are involved in the proliferation of harmful algal blooms. One key cause is excess fertilization. Nitrogen and phosphorous are key limiting nutrients in aquatic systems, inputs of these elements stimulate excess growth of many kinds of algae. Nitrogen and phosphorous are key components of human and animal wastes, and are important fertilizers on land as well. Thus, they enter rivers and estuaries from many sources: improperly treated sewage, fertilized lawns and golf courses, and agricultural runoff, both from fertilized fields and animal waste (Carpenter et al. 1998). Discharge of untreated ballast water provides a means for organisms to move into new areas. Overharvesting of fish and shellfish that would keep plankton populations in check also plays a role.

While all these factors are important in promoting algal blooms, climate change also exacerbates the problem in a number of ways:

Warmer waters

Long-term changes in water temperatures may allow tropical species of toxic algae to broaden the seasonality of their activity or to expand their ranges into temperate zones and beyond. Several species of dinoflagellates grow more quickly in warmer waters, and are predicted to expand their ranges northward as temperatures become favorable. Warmer water may also magnify the detrimental effects on organisms, especially those sensitive to oxygen depletion. Warmer waters are also more likely to experience anoxic conditions because 1) warm water holds less dissolved oxygen; and 2) oxygen demand increases under warm conditions as organisms' metabolism increase (Stanley & Nixon 1992, Buzzelli et al. 2002).

Photo: NOAA National Marine Fisheries Service

Severe weather events

Climate change is expected to increase the frequency of heavy precipitation events ("very likely") while also widening the area affected by drought ("likely") (IPCC 2007). Intense precipitation events are associated with large flows of runoff and associated pulse of nutrient input. In many municipalities combined sanitary and storm sewer systems are periodically overwhelmed by large precipitation events, resulting in release of raw sewage along with the rest of the runoff. Large pulses of nitrogen and phosphorus promote the growth of harmful algal blooms; however, the effect of large storms might be offset somewhat by the mixing effect and increased turbidity that result. Shifts in snowmelt timing might also send nutrients downstream earlier in the year, and the effects of these changes are not yet known (Moore et al. 2008).

Ocean acidification

Finally, the world's oceans function as an important carbon sink, absorbing carbon dioxide from the atmosphere. Carbon dioxide in solution forms an acid, and oceans have become 0.1 pH units more acidic since the beginning of the industrial revolution (IPCC 2007). Continued acidification of the ocean could inhibit the growth of phytoplankton species that have shells of calcium carbonate, which dissolve in acidic conditions. More acidic oceans would favor those organisms which do not have calcium carbonate shells, including the harmful dinoflagellates (Moore et. al. 2008).

Reducing the Impact of Climate Change and Harmful Algal Blooms

Reduce the nutrient load on coastal waters. The links between pollution and algal blooms are well established, and one of the best ways to halt harmful algal blooms is to reduce the amount of nitrogen and phosphorus that wash downstream into estuaries and coastal waters. Improvements are needed to municipal storm and sanitary sewage treatment. Better timing and targeting of fertilization of farm fields, golf courses and lawns will also help reduce nutrient loads, as will widespread adoption of best management practices to contain livestock waste.

Photo: NOAA

Reduce overharvest of fish and shellfish species.

Overfishing is one of the oldest and most pervasive human impacts on aquatic and marine ecosystems, and it may be an important driver of ecological change in these systems; specifically, removal of species at the top of the food chain leads to a population explosion lower down the food chain (Jackson et al. 2001). Since even the algae considered most toxic are tolerated and eaten by certain species of fish and shellfish, bringing overfishing and overharvest to a halt will moderate the impacts of algal blooms.

Enact Ballast Water Controls to halt the spread of harmful species.
Ballast water from cargo ships is an important vector for a wide array of aquatic invasive species; for instance, zebra mussels entered the Great Lakes ecosystem via ballast water. There is also evidence that ballast discharges have played a role in moving harmful bloom-forming dinoflagellates into new ranges (Bolsch & de Salas 2007). As climate changes create favorable conditions for harmful tropical species in temperate latitude, keeping those species out becomes even more important. Enactment of stringent, uniform performance standards for ballast water treatment will help protect aquatic and marine ecosystems from multiple invasive species.

Improve research, monitoring, coordination and veterinary techniques.
Harmful algal blooms affect wildlife health, public health, fisheries, tourism, recreation and local economies. Because of their wide range of impacts, a variety of state and federal agencies as well as private entities engage in research, monitoring and response to bloom events and wildlife mortalities. However, as climate change alters bloom dynamics and potentially exposes more wildlife species to toxin risk, more research, monitoring, and rapid response will be needed (Gaydos 2006). In particular, veterinary techniques and treatments to reduce wildlife mortality have been developed for certain species; their applicability to other species should be investigated, and rapid response protocols should be developed and disseminated.

Adopt a precautionary approach toward climate change mitigation proposals that involve promotion of algal blooms.
One proposal to help mitigate climate change involves promoting algal blooms by "fertilizing" stretches of open ocean with iron, mentioned above as an important limiting nutrient. Under this scenario, the resultant algal blooms would take up large amounts of carbon dioxide, before dying and sinking to the bottom, effectively locking up the carbon on the ocean floor (WHOI 2003). Other research has called into question the efficacy of this "geo-engineering" approach (Watson et al. 1994). Even more problematic, one of the species that responds best to this approach is the domoic acid-producing *Pseudo-nitzschia*. Any assessment of this geo-engineering technology would have to include potential impacts to wildlife and fisheries resources from elevated toxicity (Marchetti et al. 2008).

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