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An algal bloom in Stuart, Florida, in June led to a state of emergency.

Study role of climate change in extreme threats to water quality

Record-breaking harmful algal blooms and other severe impacts are becoming more frequent. We need to understand why, says **Anna M. Michalak**.

With concerns about climate 'extremes' growing[1], water is often the focus — either too much or too little. That is no coincidence: climate and the hydrological cycle are tightly coupled, and water is essential to ecosystems and societies. But it is not just the quantity of water that matters. So does its quality.

Last year, Lake Erie, one of the US Great Lakes (which contain one-fifth of the world's fresh surface water), experienced its biggest recorded harmful algal bloom. At its peak, the bloom spread some 200 kilometres across most of the lake[2]. Meanwhile, off the continent's west coast, another record harmful bloom stretched from Baja California in Mexico up to Alaska, probably triggered by unusually warm water in the Pacific Ocean[3]. Both blooms were dominated by species of phytoplankton that produce powerful toxins.

Such episodes can wreak havoc. During a previous bloom, in 2014, 500,000 people living near Lake Erie were ordered not to drink tap water, because it contained levels of hepatotoxins produced by the cyanobacterium *Microcystis* that were 2.5 times higher[4] than the World Health Organization's safe standard. The 2015 west-coast bloom of the diatom algae *Pseudo-nitzschia* shut down fisheries. The Dungeness crab fishery, one of the most valuable on the west coast, opened four months late owing to toxic levels of the neurotoxin domoic acid in the crabs. Brain damage in sea lions has also been documented as a result of exposure to this toxin[5].

Impaired water quality is a global and growing problem, limiting resources for drinking, domestic use, food production and recreation, as well as harming ecosystems. The types and causes range from excess nutrients feeding harmful algal blooms and hypoxic 'dead zones', to bacterial, viral and chemical contamination, to pollution by personal-care products and pharmaceuticals. Cases of extreme impairment often lead to disproportionate human and ecosystem impacts. The costs can be huge. More than US$4 billion are lost each year in the United States alone as a result of harmful algal blooms[6].

Because the most severe water-quality impacts are exacerbated by weather, climate plays a part. Runoff of nutrients from farmland spikes after heavy rains; warm temperatures accelerate the growth of bacteria and phytoplankton. As climate change alters weather patterns and variability, conditions conducive to severe water impairment are likely to become more frequent.

Yet there has been scant study of how climate will affect the occurrence of the extreme events that relate to water quality rather than quantity. We do not know how to relate water-quality extremes, their causes, their severity or their occurrence directly to changes in climate. It is time to plug this knowledge gap.

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Scientific understanding of extreme storms, droughts and rising sea levels has improved markedly over the past decade. The impacts of extreme weather events are integral to discussions about climate-change mitigation and adaptation. The expected rise in the frequency and severity of such events is well established, and even individual episodes have been linked probabilistically to climate change[1].

Not so for water quality. Researchers have explored trends in water quality with climate, but the science of projecting and attributing the occurrence of extremes is in its infancy. This is despite evidence of strong links with climate.

Regional studies reveal how multiple factors often conspire to create conditions ripe for dire water quality. For example, summer toxic blooms in Lake Taihu, the third-largest freshwater lake in China, are more intense after tropical cyclones, because the associated rains wash more nutrients into the lake, and the subsequent warmer temperatures and lower wind speeds further encourage the growth of blooms[7]. In 1999, a series of hurricanes triggered severe hypoxia in Pamlico Sound, North Carolina (part of the United States' second-largest estuarine system) by delivering huge amounts of nutrients, organic carbon and fresh water to the estuary[8]. In North American regions as diverse as the Great Lakes, the east coast's Chesapeake Bay