A Global Challenge

Rising temperatures, which encourage algal blooms and the spread of human and other pathogens, may be creating a new agenda for microbiologists

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The main refuge for waterfowl in Europe—one of a series created across the continent to provide sanctuary for birds flying on their long migrations—is Donana National Park in southwest Spain. It receives continual expert attention from both ornithologists and biologists concerned with other aspects of conservation. Also designated as a World Heritage Site, Donana is home to representatives of more than 70% of all European bird species.

Paradoxically, it was here that thousands of waterfowl died recently in an incident considerably worse than the mass mortalities that occur from time to time along migratory routes. It began when blue-green scum, composed of dense patches of cyanobacteria, appeared on the Los Ansares lagoon and elsewhere in the park. Three days later, observers found thousands of fish floating on the lagoon and hundreds of dead herbivorous waterfowl nearby. Then other birds died, presumably as a result of eating the dead fish. Within two weeks, a total of at least 6,000 birds, including endangered species such as the white-headed duck and marbled teal, had succumbed.

When investigators from the Universidad Complutense de Madrid in Madrid, Spain, sampled the Los Ansares lagoon, they found that the main and extremely abundant phytoplankton species was a toxin-producing cyanobacterium, *Microcystis aeruginosa*. The water contained high concentrations of cyanotoxins, in particular a large quantity of microcystin. Clinical signs shown by the dying birds, together with post mortem findings, were all consistent with cyanotoxicosis.

“The severe cascade of deaths in the Donana National Park can be explained by the role of cyanotoxins in the food web,” write the investigators (V. Lopez-Rodas et al, Vet. Record 162: 317, 2008). “First, cyanotoxins affect bird species that consume the cyanobacterial scum. At the same time, cyanotoxins accumulate in zooplankton and aquatic invertebrates; hence the cyanotoxins affect fish that feed on plankton. Finally, piscivorous birds consume cyanotoxins in the contaminated fish.” The conclusion was that the levels of microcystin detected in the livers of the dead birds and fish were sufficient to explain the mass mortality.

This was not the first such incident to occur in a wildfowl reserve like Donana. Indeed, the gathering of huge numbers of birds at a specially created and protected wetland site is likely to heighten their vulnerability to disease. But researchers are beginning to wonder whether climatic change may be one factor responsible for events of this sort.

Recent years have certainly seen growing anxiety about cyanobacterial threats to aquatic ecosystems—ranging from Lake Taihu in China and Lake Victoria in Africa to Lake Erie in Canada and the Baltic Sea in Europe. In addition to the production of toxins by some cyanobacteria, which can not only harm wildlife but also cause liver, neurological, and other diseases in humans, algal blooms kill fish and invertebrates by depleting oxygen and by increasing the turbidity of water.

Rising temperatures favor cyanobacteria in several ways, as Hans Paerl and Jeff Huisman have pointed out (Science 320:57, 2008). They mostly thrive better at higher temperatures (often above 25°C) than other phytoplankton such as diatoms and green algae. Warming of surface waters also strengthens the vertical stratification of lakes, reducing vertical mixing.

“Furthermore, global warming causes lakes...
to stratify earlier in Spring and destratify later in Autumn, which lengthens optimal growth periods. Many cyanobacteria exploit these stratified conditions by forming intracellular gas vesicles, which make the cells buoyant,” Paerl and Huisman write. “Buoyant cyanobacteria float upwards when mixing is weak and accumulate in dense surface blooms. These surface blooms shade underlying nonbuoyant phytoplankton, thus suppressing their opponents through competition for light.”

There are even examples (as in the Baltic Sea) of cyanobacterial blooms raising water temperature directly, by absorbing light very intensely. All of their deleterious activities may be enhanced by alterations in the hydrological cycle, such as more intense precipitation, caused by global warming.

The scale of the dangers of cyanobacteria for human health is illustrated by the situation in Taihu, China’s third-largest lake. There, a vast bloom appeared at the beginning of June, 2007, and within a year had necessitated the removal of more than 6,000 tons of algal sludge. As with many other cyanobacterial blooms, the underlying cause was eutrophication, attributed to an accumulation of nutrient-rich sewage and runoff from agricultural land. But the trigger was unusually hot, dry conditions in the area. Normally, the lake not only serves as China’s most important fishery but also provides drinking water for over 2 million people.

Evidence that global warming is affecting cyanobacterial populations comes from the substantial extension of their geographical ranges. One example is Cylindrospermopsis raciborskii, which was responsible for a mysterious outbreak of severe hepatitis-like illness in Palm Island, Australia (W. W. Carmichael, Human Ecol. Risk Assess. 7:1393, 2001). Originally a tropical and subtropical species, it has moved into higher and higher latitudes and is now widespread in the lakes of northern Germany.

All of these developments point towards a new agenda and a new challenge for microbiologists in seeking to understand and where possible ameliorate some of the consequences of global warming. Another major component of that agenda is, of course, the direct impact of raised average temperature on human pathogens and their vectors. Whereas just a decade ago, discussion was largely restricted to speculations founded on computer modelling, there are now more tangible grounds for concern.

In its Fourth Assessment Report on Climatic Change Impacts, Adaptation and Vulnerability, published in 2007, the Intergovernmental Panel on Climate Change concluded that dengue fever was likely to become more common as a result of global warming. The Panel also mentioned malaria, which has attracted most attention in this context, but highlighted dengue, a more urban disease, since climatic change is likely to play an even more important role in its spatial and temporal distribution. One problem is that, while rises in temperature or rainfall can promote the disease, so can drought because household water storage may provide more breeding sites for mosquitoes.

Writing in The Lancet (367:863, 2006), Anthony McMichael and colleagues have argued that, while no one study is conclusive, several reports have already indicated effects of global warming on some infections. For example, in association with alterations in climate, the geographical range of ticks that transmit Lyme borreliosis and viral encephalitis has extended northwards in Sweden and increased in altitude in the Czech Republic. Also, changes in the intensity (amplitude) of the El Niño cycle since 1975, and more recently its frequency, have accompanied the strengthening of the relationship between the cycle and cholera outbreaks in Bangladesh.

Similar arguments apply to plant diseases. Neal Evans and coworkers at Rothamsted Research, Rothamsted, United Kingdom, have demonstrated that global warming will increase both the range and severity of phoma stem canker (Interface 10.1098/rsif.2007.1136). This could mean a corresponding rise in the worldwide losses of $900 million already caused by epidemics of this disease in oil seed rape and other brassicas.

In the media and popular books and articles, microbiology tends to be scarcely mentioned, alongside climatology, ecology, meteorology, and computer modelling, as a source of key questions—and answers—about global warming and its practical repercussions. Given the multifarious roles of microorganisms as drivers of some of the largest-scale phenomena on the planet, from photosynthesis and the cycling of nitrogen and other elements to pandemics of infectious disease (P. G. Falkowski et al., Science 320:1034, 2008), it could soon prove to be one of the most important. There is much microbiology yet to do.