

Climate Change and the Occurrence of Harmful Microorganisms in Florida's Ocean and Coastal Waters ¹

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Summary

Climate change is expected to result in increased temperatures of nearshore ocean water, and this could lead to increased growth of harmful microorganisms. These include algae that form noxious or toxic blooms, including red tides, and bacteria and other pathogens. This situation could have negative consequences in regard to human health and also Florida's ocean-related economy.

Introduction

Climate change is the process whereby greenhouse gases like CO₂, CO, nitrogen oxides, and methane trap heat in the biosphere, much like the glass in a greenhouse traps heat from the sun. This causes warming of the air, land, and water. The warming of coastal waters around Florida could result in increased occurrence of harmful microorganisms in the water.

The fact sheet: (a) introduces the concept of increased ocean temperatures, (b) identifies projections of future ocean temperatures, (c) provides a brief description of microorganisms that live in the ocean and that may be harmful to people, (d) considers how those microorganisms might respond to changes in temperature and how this might affect people, and (e) identifies actions that could be taken to reduce these impacts.

Climate change is a serious issue for Florida in many ways beyond stimulating the growth of harmful microorganisms in ocean and coastal waters. For a more comprehensive review of effects that climate change is projected to have on Florida, see the 2009 and 2010 reports of the Florida Oceans and Coastal Council: <http://www.floridaoceans-council.org/reports/>.

How much have ocean temperatures increased?

The temperatures of land, water, and air have increased at an unnaturally rapid rate in the last century due to the greenhouse effect (IPCC 2014). The greenhouse effect is exacerbated by burning of massive amounts of coal, oil, and gas and activities such as deforestation. Since 1900, the average temperature of ocean surface waters has increased by about 1 degree Celsius (Doney et al. 2012). Although some locations have experienced greater or lesser warming, there have been documented symptoms of ocean warming, including bleaching of corals and outbreaks of harmful microorganisms in ocean and coastal waters (Burge et al. 2014).

How much more will ocean temperatures increase?

In its 2014 synthesis report, the Intergovernmental Panel on Climate Change (IPCC 2014) presented results that used

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the average of many different climate models to project future conditions. Models were used to evaluate three *representative concentration pathways* for future greenhouse gas emissions—a pathway with lowered emissions, a pathway with an intermediate increase in future carbon emissions, and a pathway with a large increase in future carbon emissions.

In regard to ocean surface temperatures, the IPCC projected ocean temperature increases for the end of this century, with plots that have depth on the vertical axis and latitude on the horizontal axis (Figure 1). For context, the state of Florida is at approximately 25 degrees north latitude at its southern end near Key Largo, and at approximately 30 degrees north latitude at its northern border with Georgia.

The three IPCC projections to the end of this century indicate that under all future climate scenarios, there will be warming of ocean surface waters at our latitude, ranging from 1 to 3 degrees Celsius. This amount of warming, on top of what already has occurred, could affect the geographic occurrence, growth rates, and effects (such as toxicity) of marine organisms (Burge et al. 2014).

What kinds of microorganisms might be affected in the ocean?

Before considering the responses of microorganisms to changes in water temperature, it is important to know something about what kinds of microorganisms occur in the water of our oceans and coasts. The water may look clear, yet it is teeming with a complex food web of

microorganisms that collectively take the energy of sunlight and convert it into the food that supports crustacean zooplankton and larval fish. These, in turn, are eaten by larger fish, sharks, dolphins and other marine animals, and humans. In addition, microorganisms recycle organic and inorganic materials and wastes, thereby enhancing the self-cleansing activities of the ocean.

Which microorganisms in ocean and coastal waters are harmful to people?

Among the many species of microorganisms that make up the ocean food web, there are some that are harmful to fish and other animals that live in the ocean, and also to people—in particular those who are at-risk due to suppressed immune systems.

These include, but are not limited to:

- **Toxic dinoflagellates** – a kind of phytoplankton (single-cell algae) that live in the ocean. These organisms periodically become highly abundant, causing *harmful algal blooms*. Harmful algal blooms are dense proliferations of algae cells near the water surface that cause problems ranging from odor and fish kills to skin irritation and respiratory distress (Fleming et al. 2011).

One species of dinoflagellates is *Karenia brevis*, which naturally occurs in the Gulf of Mexico and periodically forms blooms called *red tides* that stain the water an orange-red color. These algae release chemical toxins into

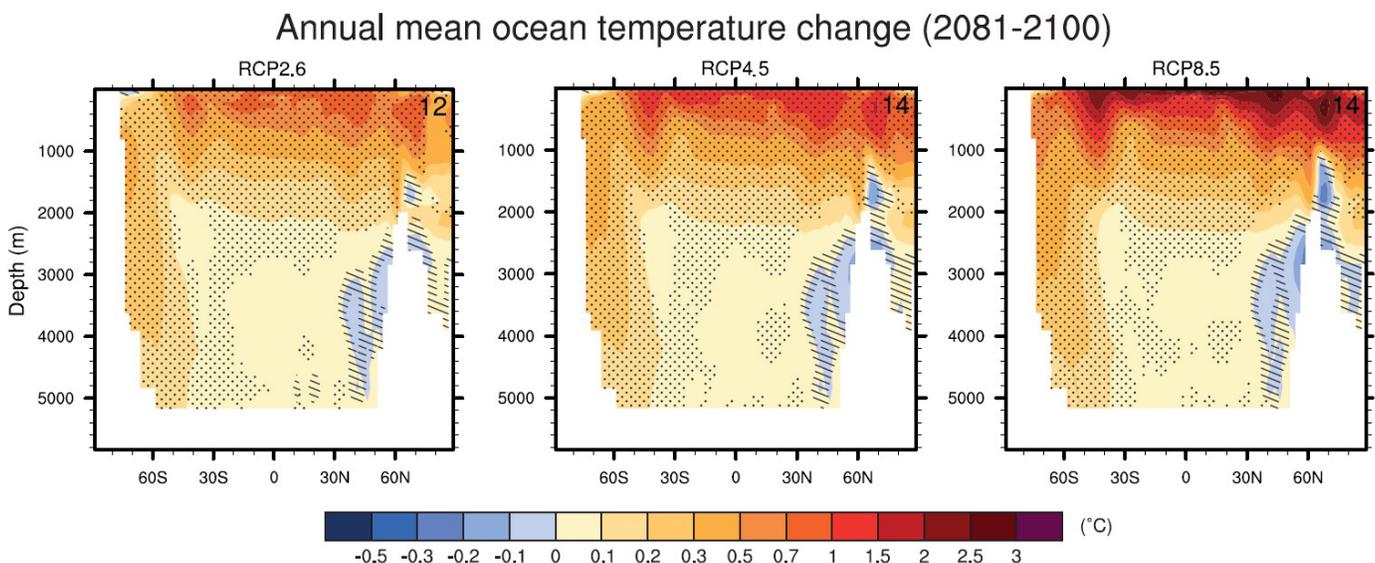


Figure 1. Projected increases in ocean temperatures towards the end of this century under a scenario of low (left panel), intermediate (middle panel), and high (right panel) human-caused greenhouse gas emissions as defined by the IPCC. In each case, water depth is on the vertical axis and latitude is on the horizontal axis. Colors correspond to predicted changes in temperature.

Credits: IPCC 2014

the water that can cause fish kills. The toxins can also become aerosolized by wave energy and cause respiratory problems for beach-goers, particularly those with pre-existing conditions such as asthma. Even healthy people who have visited a Florida beach during a red tide event can experience sore throat, coughing, and itchy, watering eyes from just a few minutes of exposure. Such exposure makes it nearly impossible to continue to enjoy time at the beach.

- **Toxic cyanobacteria** – a different kind of phytoplankton that occurs in fresh to brackish water including lakes, ponds, rivers, estuaries, and some coastal waters. Cyanobacteria are the most common kind of algae in these types of Florida waters, even under natural conditions. However, increased nitrogen and phosphorus inputs to lakes, rivers, and estuaries can cause dense blooms of cyanobacteria that have harmful or undesirable effects (Havens 2007). The blooms can affect aesthetics, causing the surface of the water to look like fluorescent paint or pea soup. When the blooms die, their decomposition can cause odor and may use up oxygen in the water. One of the most common bloom-forming species, *Microcystis aeruginosa*, can produce toxins that affect liver function in certain aquatic organisms. Domestic animals and humans that drink impacted waters can similarly be affected.
- **Pathogenic microorganisms** – can cause disease in fish, shellfish, and even humans. An example of a species that harms shellfish is *Perkinsus marinus*. It is not harmful to people, but it can cause disease in oysters, resulting in reduced growth if it occurs at a high density in their tissues.

Another example is *Vibrio vulnificus*, a naturally occurring marine bacterium that can infect shellfish. Eating shellfish with a high level of *Vibrio* can cause gastrointestinal illness in people. Serious effects are almost entirely restricted to people who are immune-compromised. *Vibrio* also occurs naturally in the ocean and coastal water. When it is abundant, the state issues a health advisory about swimming with open wounds. Again, the highest risk is to people with an immune-compromised condition, although there is a low risk that healthy people can develop serious infections.

Many human-derived pathogens occur in our coastal waters, and periodically beaches are closed because of higher than safe levels of bacteria such as *Escherichia coli*, which comes from fecal material. Coastal waters also contain varying levels of other human-derived bacteria, as well as viruses and protozoa such as *Giardia*. Florida

has monitoring programs for the common pathogens and issues public health advisories when their levels are high.

How will harmful microorganisms be affected by ocean warming?

Temperature is one of the most important environmental variables affecting the rates of feeding, metabolism, growth, and even life span of fish and other aquatic biota. Because these organisms cannot regulate their body temperatures, their entire metabolism speeds up or slows down with changes in temperature. Most fish and other aquatic biota have some optimal temperature range for growth and reproduction and cannot survive at extremely high or low temperatures. Some species living at the edge of their temperature tolerance can suffer high mortality with just a small increase in temperature. We see this with aquaculture clams in Florida, for example, where the high water temperature during the hot summer months kills many clams. On the other hand, certain organisms benefit from temperature increases. Scientists have found, in particular, that the kinds of algae and bacteria that can produce toxins or cause disease proliferate greatly compared to other less harmful species when there is an increase in water temperature, even above levels typically seen in mid-summer in Florida.

We can predict, therefore, that with a warmer ocean, the abundance of microorganisms will increase. It may be the case that the harmful species will grow at a faster rate than other species; it is known that this happens with cyanobacteria (Paerl and Huisman 2008, Moss et al. 2011). It also has been documented that nutrients and temperature act synergistically in the ocean to stimulate the growth of harmful phytoplankton blooms (Hallegraeff 2010). Increased water temperatures have been documented to stimulate the growth and even the virulence (the ability to cause disease) in pathogenic bacteria (Burge et al. 2014). Thus, if the ocean waters around Florida become warmer, it is reasonable to expect more frequent problems with the harmful microorganisms mentioned above (Figure 2).

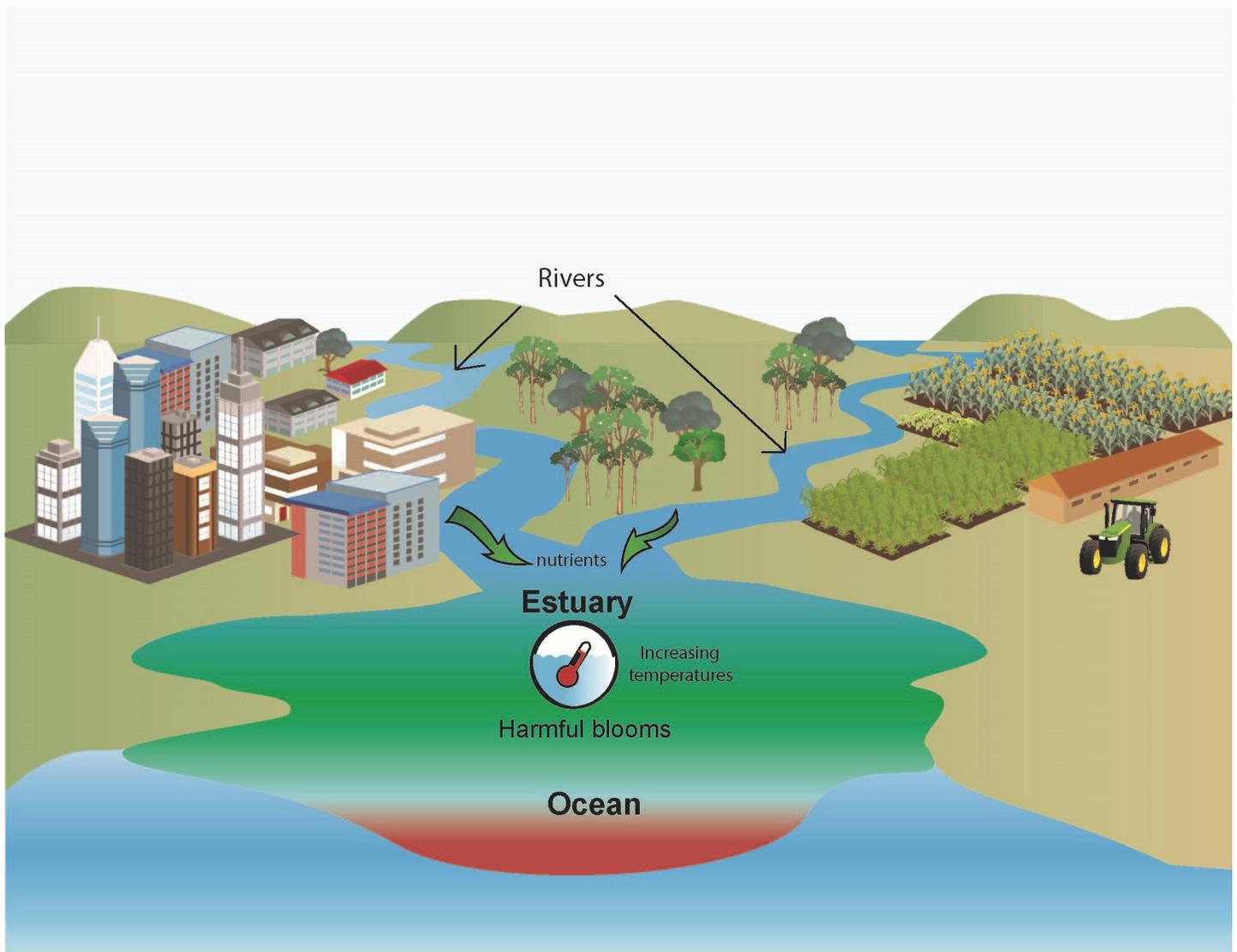


Figure 2. Nutrients and temperature act synergistically to stimulate blooms of harmful microorganisms in estuaries and nearshore ocean waters. Warming ocean waters caused by climate change are predicted to increase problems with blooms.
Credits: Florida Sea Grant

We already are seeing signs of what the future could look like in Florida. In 2014, when water temperatures in the Gulf of Mexico were at record highs, the Florida Fish and Wildlife Conservation Commission (FWC) recorded one of the largest red tide blooms ever, just northwest of Tampa (Figures 3, 4, and 5). It threatened beaches from Clearwater to Sarasota, yet remained largely offshore due to prevailing winds. According to the FWC, the red tide may have killed more than 10,000 fish.



Figure 3. A photograph of an area in the Gulf of Mexico covered with a dense bloom of the red tide phytoplankton *Karenia brevis*.
Credits: Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida



Figure 4. A map showing the large area off Florida's Gulf coast where in summer 2014 a red tide developed in a year with record-high ocean water temperature.

Credits: Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida

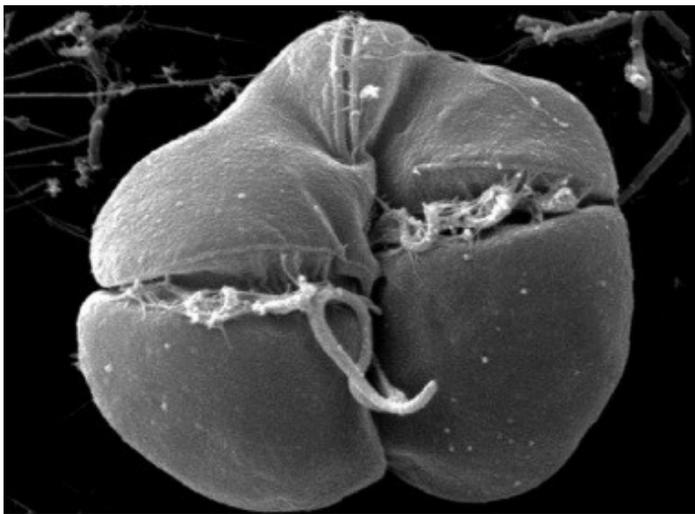


Figure 5. An electron microscope photograph of a single cell of *Karenia brevis*, the toxic dinoflagellate that causes red tides. For reference, one of these dinoflagellate cells measures about 30 microns (1/30,000 of a meter) in diameter and is too small to be visible to the naked eye.

Credits: Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida

At the same time that this was occurring, the warm water stimulated the growth of pathogenic bacteria in the Gulf. Of particular note, *Vibrio* reached high levels in the water. People from the Florida Panhandle to Sarasota were warned by state and county health departments about eating raw shellfish caught or raised in coastal waters of Florida, and about swimming at the beach with open wounds. Several people became ill and one person died. As noted earlier, the risk was particularly high for immune-compromised individuals, although a low risk existed for the general public.

What are the implications for Florida, and what can be done to minimize them?

Nearly 80 percent of the 20 million people in Florida live and work in counties bordering the ocean, and over 90 million tourists visit the state each year. Many of these people go to the beach, or they fish, boat, and swim in coastal waters. The economy associated with these activities is huge and accounts for a large part of the state's revenue.

If climate change results in the projected rises in ocean temperatures and stimulates increased occurrence of toxic and pathogenic microorganisms, it could threaten fish, marine life, shellfish, and human health.

A worst-case scenario is one where in the future, swimming at our beaches becomes more regularly associated with respiratory irritation; our coastal waters and shorelines often are covered with a scum of blue-green algae; and there more frequently are warnings about eating shellfish and about swimming at our beaches with open wounds. This could substantially affect the tourism industry, and people may go elsewhere. Yet, it is not certain if and when these events will happen. The underlying relationships are valid based on the science cited above. The ocean is warming, harmful microorganisms *do* have enhanced growth in warmer water, and these organisms are harmful to people and marine life when optimal environmental and exposure conditions prevail.

Floridians alone cannot stop climate change, yet we can make lifestyle decisions that reduce our use of energy and therefore contribute less to greenhouse gas emissions. We can also make choices as simple as applying proper amounts of fertilizer to our lawns and gardens so that excess fertilizer is not wasted and carried by rain and runoff to the coastal ocean. Ultimately, the well-established synergy between nutrients and temperature (Moss et al. 2011) could result in the federal and state governments needing to place even more stringent controls on nutrient runoff from cities, agriculture, and other human sources.

Today our beaches are generally as safe and clean as any in the world, and people from Florida and around the world enjoy their beauty without much concern. For those who plan to visit Florida beaches, it is possible to get timely information on red tides and public health warnings about coastal waters and beaches at these websites:

Red tides: <http://myfwc.com/research/redtide/statewide/>

Public health advisories: <http://www.floridahealth.gov/environmental-health/beach-water-quality/>

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