First Heavy Rains Nourish Dangerous Algae in Monterey Bay
by Mairi Wood

You may have heard to wait a few days after a heavy rain before you go into the ocean. An ongoing science project shows that's much more than an old wives' tale: major storms wash the land of oil, fertilizers and human waste, and it all drains into Monterey Bay.

So, it's appropriate that the first heavy rain of the year is called "first flush." Nutrients and pollution build up on land over the dry season, and septic tanks in the region's rural areas often fail. Rain washes it all into streams, rivers and then the bay, making the water less than inviting to the informed. Toxic algae thrive in this watery stew.

"The rule of thumb if you're a surfer… is you wait three days after it rains," says Raphael Kudela, an oceanographer at UC Santa Cruz. "So we wanted to know, what's it like [in Monterey Bay] three days after it rains." His lab led the first flush research—the first time anyone has looked at how this annual event affects harmful algae in Monterey Bay.

Kudela's team, along with researchers from the National Oceanic and Atmospheric Administration (NOAA) and the Monterey Bay Aquarium Research Institute (MBARI), measured bacteria, toxins, nutrients and phytoplankton levels before and after the first flushes in 2009 and 2010.

The first rain in 2009 was heavy, but in 2010 it rained over and over in smaller spurts. "[2009] is a real first flush and [2010] is sort of like jiggling the toilet handle," Kudela jokes. This allowed the team to compare the results of a classic huge flush and the smaller, more pulsing flush of 2010.

Satellite images give Kudela's team a visual picture of how much algae is in the bay. The team also takes water samples from many places in the bay. They test these samples for bacteria and nutrients that come from human activities, as well as algae and the toxins they produce.

In both years the scientists saw a large increase in all of these things, but more dramatically in 2009. One of the hazardous substances they measure is domoic acid, a neurotoxin produced by algae. "We have the [domoic acid] concentrations before and after it rained… and the toxin concentrations increased by a factor of four," says Kudela. And that, he adds, can pose health risks—both to wildlife and to people.

Some of these nasty items usually aren't even detectable in the bay before it rains, such as the bacteria associated with our guts and waste. "When we first got those bacteria data back and saw that essentially you're swimming in sewage during that really intense first flush event, [we started to] think twice about how we were sampling and sticking our hands in the water," Kudela says.

Additional concerns come from the explosive growth of phytoplankton following first flush. Phytoplankton are tiny algae—most too small to see with the naked eye. These algae are the base of the food web, providing most of the energy that fuels life in the ocean.

When the phytoplankton grow so much that they discolor the water, it's called an algal bloom or a "red tide." These blooms can be harmful to people, because some algae release toxins or have spiky shells. Almost one-fourth of the species of algae that aggregate in large enough numbers to cause a bloom are considered harmful to humans.

In Monterey Bay, algae blooms are fueled naturally by upwelling. Upwelling occurs when cold, nutrient-rich water forces its way to the surface, replacing warm water depleted of its nutrients. This upwelling provides lots of new "food" for the algae to consume and grow.

Generally, a lack of nitrogen in seawater prevents algal populations from exploding. The upwelling provides a natural source of nitrogen, in the form of nitrate. However, an unnatural source of nitrogen also enters our bay: ammonium and urea. "The ammonium and urea are coming from things like septic tanks and runoff from the roads and people's front yards," says Kudela.

"The rivers are generally really high in nitrates and pretty low in ammonium and urea, because they're mostly draining the agricultural fields" of industrial fertilizers, Kudela explains. During first flush, "We're getting this switch to the ammonium and urea that we know really promotes harmful algal blooms." These sources come from humans—and they are dangerous to us, because harmful phytoplankton prefer them.

One such phytoplankton is *Pseudo-nitzschia*. *Pseudo-nitzschia* releases domoic acid, a neurotoxin that puts the brains of people and other mammals at risk.

Marine animals such as anchovies and shellfish eat *Pseudo-nitzschia*—along with domoic acid. This allows the toxin to work its way onto people's plates.

Consuming shellfish with large amounts of domoic acid causes amnesic shellfish poisoning in humans. Mild levels cause normal food poisoning, but higher levels can lead to permanent short-term memory loss and brain damage, and in extreme circumstances can even kill people. Careful shellfish monitoring has prevented this from becoming an issue in Monterey Bay.

"If you give *Pseudo-nitzschia* urea, you're going to produce more domoic acid," says Kudela. Changing their nutrient source not only helps them 'bloom,' but also makes each algal cell release more of the toxin, he notes. "We are… feeding the bloom, and it's cranking out the toxin."

Another concern comes from cyanobacteria, a freshwater algae that produces the toxin microcystin. These toxins can harm humans as well, and they are the culprits behind many recent sea otter deaths. But how does this freshwater toxin get into the ocean in the first place?

"We don't detect microcystins in the ocean unless it's been raining," says Kudela. His team helped show that rain washes these microcytins out of contaminated ponds and lakes and into Monterey Bay. Otters get liver damage from eating shellfish that build up these toxins in their tissues.

Until recently, microcystin was not considered a risk to marine shellfish because it's typically an inland, freshwater toxin. The many sea otter deaths, along with the first flush data, have begun to make scientists reconsider whether this toxin merits monitoring along our coast.

But there's more than toxins to worry about. "For a long time we just assumed that if the bloom isn't producing a toxin… and it doesn't have big spikes of silica sticking out of it, it's probably harmless and just a naturally occurring thing," says Kudela. "What we are learning now is that a big increase of organic material… [is] a food source for all bacteria, including ones that are potentially harmful to humans."

The algal blooms provide organic material and feed bacteria in the ocean. "We're discovering… it's a more complicated problem than we thought," says Kudela. "You can't just simply look at the phytoplankton and say, 'Well, there's no toxin, therefore it's not dangerous.'"

For example, in September 2009 a local woman went to the emergency room for a painful ear infection. She was given treatment, but the infection went into her brain. She is a diver and went into the bay during a non-harmful algal bloom.

Bacteria associated with the bloom probably caused this unfortunate infection. This is the first documented case of this, but it's still a scary thought that you can get a brain infection from swimming in the ocean at the wrong time.

Many other infections have been linked to swimming in coastal waters, including skin, eye, and ear infections. "The more I talk to surfers and people around the water, the more convinced I am that people get sick with some frequency and just don't report it," says Kudela.

So after that first flush, the picture of Monterey Bay begins to look like a sewage-filled toxin bath.

Are we improving the quality of our freshwater inputs to the ocean? Sadly, it looks like we may be heading in the opposite direction. "If you look at the nutrient loading from things like rivers and first flush and you compare it to other places in the world… [they] are all getting better, but central California, along with China, is getting worse," Kudela warns. "Under almost any scenario, if we don't do anything, we would expect to see more and more of these problems."

Santa Cruz County public health officials monitor fecal indicator bacteria levels at beaches and river mouths each week. State law requires local agencies to post warning signs at popular beaches when levels are dangerous. Beachgoers should heed these signs, but other less-trafficked beach areas—where signs aren't posted—also may have hazardous water conditions.

Kudela and his team, along with NOAA and MBARI, continue to look at the dynamics of Monterey Bay and hope to catch the first flush data again in fall 2011. They also hope to make a website about water and toxin conditions in Monterey Bay that is easy for the public to understand. This research may help us fully appreciate the dangers that come from dumping our waste into the ocean.

But don't be scared. You can still go in the water. Just think twice about frolicking in Monterey Bay after a big heavy rain.

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Mairi Wood, a senior majoring in ecology and evolutionary biology, wrote this article in spring 2011 for SCIC 160: Introduction to Science Writing.