How does nature deal with persistent pollutants?

Certain chemicals, both man-made and natural, 'biomagnify' up the food chain

By Kristin Pangallo

Why would I choose to spend my years in graduate school up to my elbows in foul-smelling whale blubber? To explore how some of the most notorious man-made pollutants reach dangerous concentrations in large predators, even when concentrations of these pollutants in seawater are low and considered "safe."

When I entered graduate school, I knew that some man-made pollutants could be concentrated in large predators. I had heard how DDT caused the collapse of eagle populations, and I was aware that eating a lot of swordfish was a bad idea because of mercury contamination. But I was surprised and intrigued when my Ph.D advisor, WHOI marine chemist Christopher Reddy, explained that researchers have recently discovered a few naturally produced chemicals that also accumulate with each link in the food chain—a process called biomagnification.

These natural biomagnifying compounds have existed for eons, far longer than their man-made counterparts, with no apparent harm to the environment. Ecosystems have evolved with these compounds and seem to be able to deal with their presence. So, if we can better understand how naturally produced biomagnifying compounds travel through—and eventually exit—ecosystems, we can better predict the pathways and fates of man-made biomagnifying pollutants now littering the oceans.

When I explained my research to my father, he had his own take on it: "Very interesting theory," he said, "Learning from Mother Nature to help clean up the kids' messes."

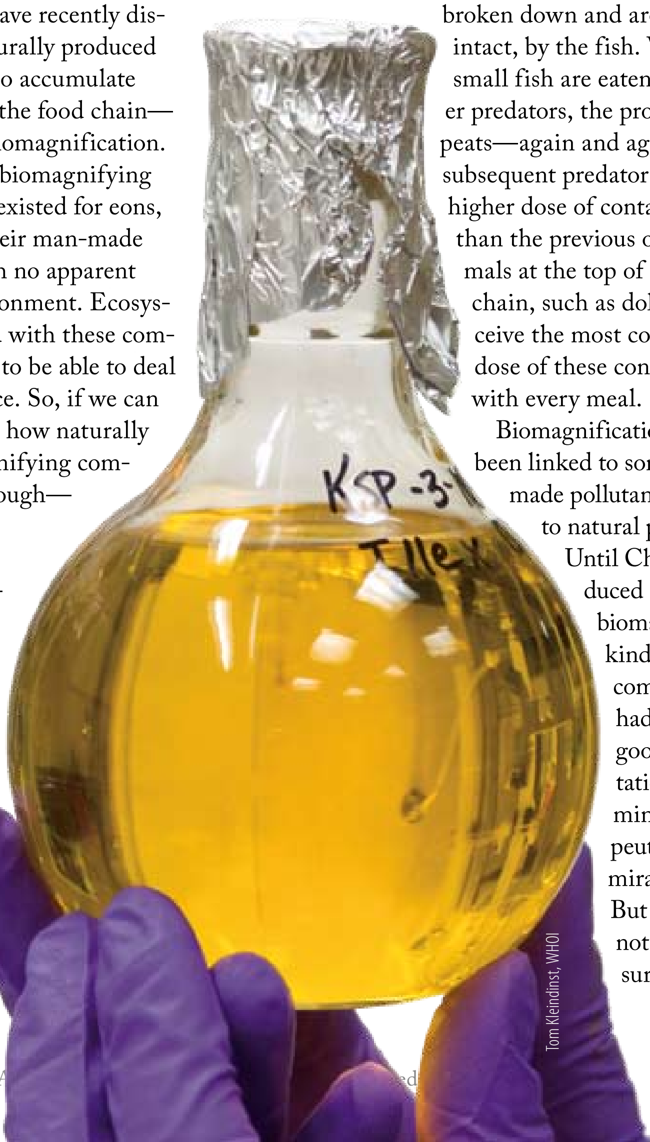
The ins and outs of ecosystems

Biomagnification occurs when contaminants that don't easily degrade increase with each link in the food chain. And they don't go away—they can stick around for decades, and maybe even centuries. That is why most of the world has banned or restricted their use.

Here is what happens. In seawater, these persistent molecules stick to small particles and phytoplankton. Small fish eat the phytoplankton, but the contaminants can't be broken down and are absorbed, intact, by the fish. When small fish are eaten by larger predators, the process repeats—again and again. Each subsequent predator receives a higher dose of contaminants than the previous one. Animals at the top of the food chain, such as dolphins, receive the most concentrated dose of these contaminants with every meal.

Biomagnification has long been linked to some man-made pollutants, but not to natural products. Until Chris introduced me to the biomagnifying kinds, natural compounds had all sorts of good connotations in my mind: therapeutic, gentle, miracle drugs. But I should not have been surprised to have this worldview overturned. After all, brevetoxin, the naturally produced red tide poison, graces the cover of my college organic chemistry textbook.

But even after grappling with the concept of potentially harmful natural products, I was still captivated by the idea that some natural products could biomagnify. Why? Basically, because nature usually balances its checkbook. Whatever enters an ecosystem eventually gets processed back out. Over time, the incoming and outgoing amounts should be equal.



Does this flask of oil extracted from squid contain biomagnified chemicals?

Tom Kleindinst, WHOI

The Cape Cod Stranding Network

Studying these long-lived natural products requires analyzing marine animals. To make my job easier, I start with samples rich in biomagnified contaminants—blubber!

But how do you get your hands on pounds and pounds of blubber? Whales, dolphins and seals are protected; we can't hunt them or take their lives in the name of science. As a child, I was enthralled by these magnificent animals, and I still am. I wouldn't want to harm them for any purpose, scientific or otherwise.

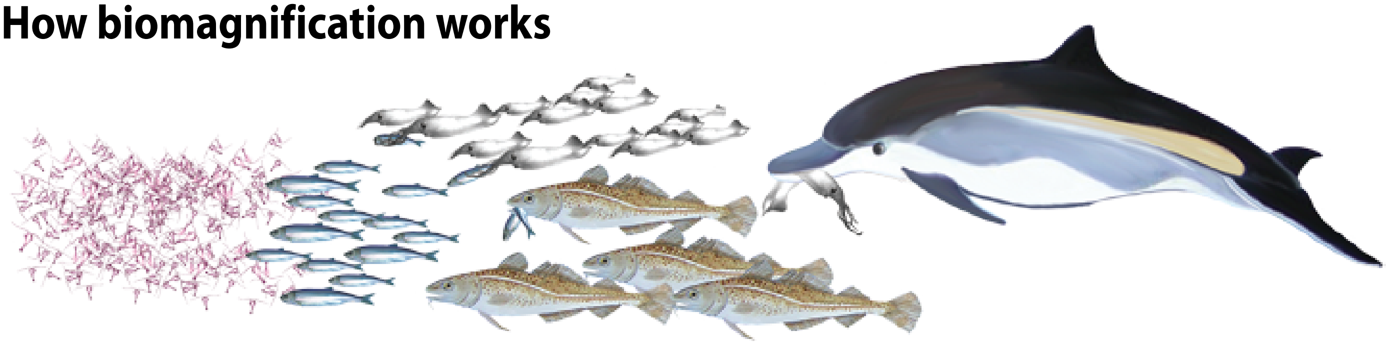
Fortunately, my lab works with the Cape Cod Stranding Network (CCSN), which strives to help the hundreds of animals stranded each year on the beaches of Cape Cod. Rescuers push some back out to sea and bring others into aquariums for rehabilitation and release. But, unfortunately, some animals just don't make it.

The CCSN ensures that these losses benefit living animals by performing necropsies (the animal equivalent of autopsies) and distributing tissues to researchers for studies on diseases, boat/motor-collisions, and, for me, chemical analyses.

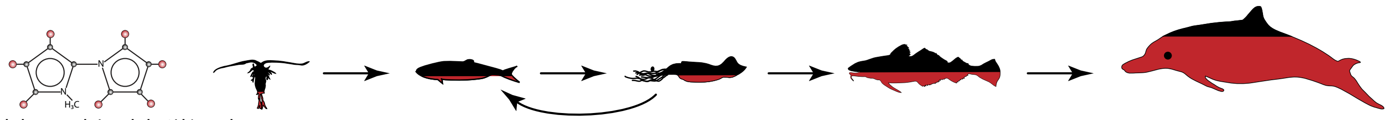
Make mine a whale smoothie

From the large slabs of frozen blubber that I receive from the CCSN, I make a viscous, brilliantly yellow, and very "fragrant" oil. Unlike the whalers of previous generations, I do not "cook" the oil out of the blubber, because that might alter its chemical signature. Instead, I use a blender

How biomagnification works



From left to right: Contaminants that don't easily degrade stick to small particles and phytoplankton, which are eaten by small fish. The contaminants don't break down and are absorbed, intact, by the fish. The process repeats as larger predators eat smaller fish and squid.



halogenated 1'-methyl-1,2'-bipyrrole

Each subsequent predator receives a higher dose of contaminants than the previous one. Animals at the top of the food chain, such as dolphins, receive the most concentrated doses.

E. Paul Oberlander, WHOI

to make a blubber "smoothie."

It is really quite gross. However, simply by filtering this pungent "smoothie," I end up with clear, banana-yellow oil that those long-ago whalers would envy.

All the compounds that I analyze are floating around in this oil. To separate them, I take advantage of the size difference between the very large oil molecules and the very small compounds.

I pass the oil through a long glass column packed with particles that have tiny cavities. The small molecules go in and out of these cavities. They take their time and pass through every nook and cranny. The larger oil molecules can't fit in the crevices, so the bright yellow oil rushes straight through. I discard the oil and collect the interesting molecules all by themselves.

I still need to purify my extract further. I repeat the process, using different columns that separate molecules by their different properties, such as volatility (how easily they escape into the air) or polarity (how electrons are arranged in a molecule). As molecules emerge from the final column, I can determine their identities and how much of each was present in the original blubber.

Natural cousins of pollutants

In my four years as a graduate student, I've established that a new class of natural compounds is widespread in the blubber and livers of marine mammals in the North Atlantic. The impossible-to-pronounce name for these chemicals is the halogenated 1'methyl-1,2'-bipyrroles, commonly abbreviated MBPs.

We don't yet know where MBPs come from, what function they might perform, or why they accumulate in marine mammals. But we can tell that MBPs are remarkably similar to many man-made pollutants that biomagnify. Both turn up in similar amounts in my blubber and liver samples. This suggests that MBPs biomagnify as well.

To confirm that MBPs biomagnify, my next step is to analyze lots of fish, squid, crustaceans, and plankton from the Northwestern Atlantic—creatures representing other links within this food chain. By measuring MBP concentrations in these samples, I'll see if MBPs really do magnify at each level.

Now, I just have to get my hands on lots of fish. As far as I know, there is no "Fish Stranding Network." But the National Marine Fisheries is just down the road from my lab, and I hear they take requests.

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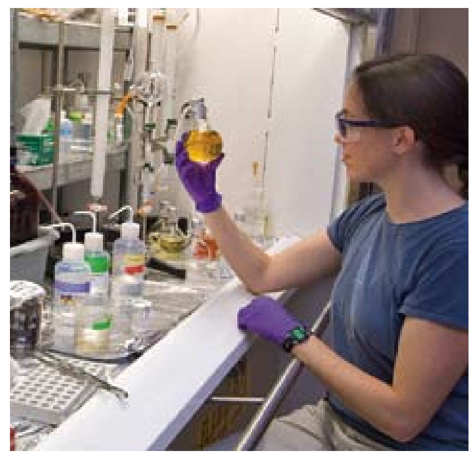

Tom Kleindinst, WHOI

Kristin Pangallo has dreamed about working with dolphins and whales since she was a little girl in Plattsburgh, N.Y. Her interest in marine science brought her to WHOI as a research technician after she earned a bachelor's degree in chemistry from Bates College in 2002. Working at WHOI convinced her that her future lay in chemical oceanography, and in 2004, Pangallo started in the MIT/WHOI Joint Program. Now in her fifth year, she continues to be fascinated with the marine world and thrilled that her research benefits the amazing creatures that initially inspired her. Outside of science, Pangallo's passion is dance, and she can't wait to get back in the studio once she's completed her Ph.D. She is a proud alum of Up with People, Cast B '97, the performing troupe that also assists communities.