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The practical significance of mud

Mandy Joye sees the world in a spoonful of sediment

By Rahilla Shatto

Samantha B. Joye
Profile

Born
August 16, 1965
Laurinburg, North Carolina

Family
Father, Benton, farmed soybeans, other vegetables, and tobaccco.
Mother, Vernie, is a retired finance banker.
Sister, Jennifer, is a geochemist with the United States Geological Survey in Menlo Park, California and specializes in groundwater research.

Hobbies
Dressage and three-day events on horseback, rock climbing, running, and ultimate frisbee.

Best book read lately
High Tide in Tuscon by Barbara Kingsolver

Experience
1995-present:
Assistant Professor
Oceanography, Texas A&M University
1993-1995:
Research Associate
Center for Environmental Studies
San Francisco State University

Education
Ph.D. 1993
Marine Sciences, University of North Carolina
M.S. 1989
Marine Sciences, University of North Carolina
B.S. 1987
Biology, University of North Carolina

Research Interests

- Biogeochemistry of nitrogen, carbon, sulfur, and trace metals in coastal environments
- Microbial physiology and ecology
- Geochemical modeling

Joye escapes the pressure of tenure-track faculty life with her horse, April, and with her chocolate labrador retrievers. APril is the latest in a series of horses Joye has ridden competitively since her childhood on a North Carolina farm. (Photo by Donald P. Shatto)

In an article for *The New Yorker* magazine Malcolm Gladwell wrote that some researchers can commit their lives to science because "they are able to imagine a certain dignity and meaning in the narrow, microscopic worlds they study." Samantha (Mandy) Joye, one of the newest additions to the Texas A&M oceanography faculty, is just such a scientist.

Joye studies biogeochemistry of estuaries; the relationships between mud, water, and microscopic life that keep estuaries alive. The subjects of her investigations are dense, dark mats made by legions of tiny bacteria, and in them she sees no less than a mirror of the past-the "early earth in action."

Estuaries as primordial soup

You may have known for a long time that wetlands are valuable economic and natural resources, but when was the last time you were inspired by a mudflat? That smelly, desolate-looking, black-green goo left by the retreating tide is actually millions upon millions of microorganisms breathing sulfate instead of oxygen and gorging themselves on a smorgasbord of raw nitrogen, phosphorus, and carbon. In doing so the bacteria convert elements into compounds that are edible to other organisms. When Joye explains this system, she transforms the mudflat from a contemptible assault on the senses to a living machine designed to produce the building blocks of life on Earth with awe-inspiring efficiency.

True to her mother's prediction that she would somehow find a way to keep her hands dirty, Joye spends a considerable amount of time trompiong through intertidal mudflats to find choice sedimnets samples for laboratory experiments. Here Joye collects mud and grass from Tomales Vay in Califrnia where she was a postdoctoral scholar before she came to Texas A&M. (Photo by Hans Paerl)

"You've never had the pleasure of going to a marsh with me," Joye said to me, "but people always laugh because I look for the stinkiest, most disgusting spot. That's where you're going to find these incredible mats of photosynthetic bacteria. In the deep ocean you'd have to go meters into the sediment to see what you see in one centimeter in [the marsh] environment. There are the same basic processes, but they're just squashed into a very thin, narrow zone that you can walk out and examine in your Tevas!"

Joye is so taken with marshes, that when she is driving along mudflats of Trinity River on the way to Galveston Bay she finds it hard to keep her eyes on the road. "It's because of those fluffy green carpets!" she exclaims. "You just know there are photosynthetic bacteria there and you know that they are as productive as a water column of phytoplankton! They're in a film that is maybe two millimeters thick. It's the action zoneI think of it as a mirror back into the past. You can look at the processes going on in those [bacterial] mats and imagine what it must have been like when the earth was forming and oxygen was being introduced into the atmosphere. These are the descendants of the organisms that did that."

Messing with Mother Nature-on purpose

Joye takes an innovative approach to studying the chemical reactions taking place in coastal ecosystems. Bacteria live longer and produce more under favorable conditions, which include specific amounts of certain elements, chemicals, light, and water. To find out how environmental conditions affect estuarine bacteria, Joye collects samples from the marsh, exposes them to different chemicals under controlled laboratory conditions, then measures the resulting changes.

If this sounds simple, it is. "A lot of those types of experiments are very intuitive," Joye told me. "Sometimes you tend to write off your intuition [and] think, 'Oh well, if I thought of it then a million other people have thought of it and they've probably already done it.'" On the contrary, Joye noted that the oceanographic community has been focused on observation of ocean environments as the primary research tool. Today, more oceanographers are taking a manipulative approach. Joye describes herself as an experimenter and credits her method as the difference that allows her to pin down the most important chemical regulators in estuaries.

In a 1995 paper for the journal Science, Joye and a colleague, Tim Ho

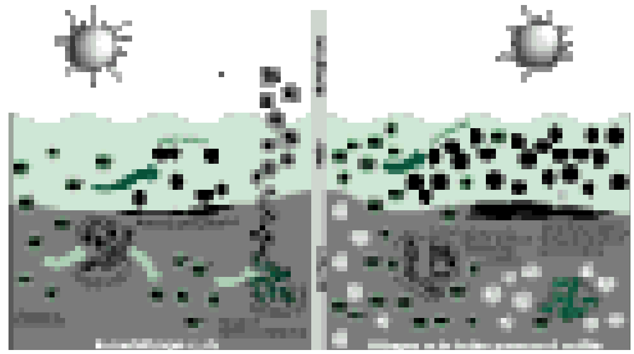

Diagram of the estuary nitrogen cycle [~35K]

llibaugh, described how sulfide in estuarine sediments regulates the way nitrogen cycles through the ecosystem. Sulfide prevents a certain group of bacteria from converting nitrogen in ammonia ions to nitrate and nitrite ions, or nitrifying it. Once nitrified, nitrogen can be consumed by another type of estuarine bacteria that denitrify it, or convert it to nitrogen gas, which then bubbles out of the estuary. The two bacteria working in concert constitute the primary mechanism for removing nitrogen from an ecosystem. If the nitrifying bacteria do not function, then too much nitrogen in ammonia ions accumulates in the system. This imbalance favors the life cycle of another type of organism, phytoplankton, which can then overpopulate the estuary. As more phytoplankton grow and die, their microscopic corpses accumulate in layers of fine organic material in the sediment. The increase in organic material creates favorable conditions for more sulfide to be formed by-you guessed it-more bacteria.

Oceanographers knew that nitrogen cycles in freshwater and seawater are different, but they did not understand why. Knowing that sulfide levels in each environment also differ, Joye put nitrifying bacteria and sulfide together in a beaker and watched what happened. The rate at which the bacteria did their job fell by 50 to 100%, clearly indicating that sulfide in the estuary disrupts the removal of nitrogen from the system.

As long as the source of the sulfide is a natural one, then the ecosystem will eventually check itself. The period of imbalance will end when the increased numbers of phytoplankton finish off one of the other staples in their diet and starve. Since phytoplankton form the entire menu of small fish, shrimp, and mollusks, local fisheries suffer. Gradually, however, less organic matter accumulates in the sediment. Consequently, sulfide production decreases and the nitrifying and denitrifying bacteria regain a fighting chance. But if humans add organic material from farm run-off, fertilizer plants, and sewage treatment facilities, then conditions will continue to favor sulfide. The system remains out of balance and phytoplankton cannot fully recover, leaving other estuarine life with a greatly reduced food supply.

There is another way estuary inhabitants can end up without enough phytoplankton to eat-if too much nitrogen is converted to gas and released from the system. In Galveston Bay the availability of nitrogen is affected by trace metals in the environment that influence the chemical reactions that can take place.

"Nitrogen is the element closest to my heart but manganese is running a close second right now," Joye says. Manganese oxides in the sediment can reduce the concentration of toxic sulfide that is present. This, in turn, allows nitrogen-gas producing bacteria to thrive uninhibited and remove huge amounts of nitrogen from the system. Remove too much nitrogen, and the phytoplankton and their predators are no better off than they were when sulfide was over-abundant.

Galveston Bay contains high levels of manganese that wash into it from the surrounding watershed. Joye is currently investigating biogeochemical reactions in the bay to find out just how big a role manganese plays and what that means for Gulf Coast residents. Knowing what influences the unique balance of critical inorganic nitrogen compounds in our estuaries will help scientists develop strategies for protecting their health.

It looks like pollution and smells like pollution-but is it?

More amazing than Joye's love for smelly mudflats is her gift for making other people feel the same way toward them. She gets so excited about biogeochemistry that her voice grows considerably louder in describing how to find a rainbow in estuary mud: "Take your finger and draw a line in the sediment and look along the little path made by your finger. You'll see green, pink, orange, and yellow, [made by] different groups of photosynthetic bacteria that use different light sources and have different pigments. You can see it! With your eye! And the trail is tiny, a half centimeter, but yet they're cycling [chemicals] so fast in that little centimeter. It blows my mind when I think about how fast they cycle things."

It's not hard to imagine how Joye feels about teaching. Her biggest challenge is talking slowly enough for her students to follow. "I'm very enthusiastic about what I do," she says, "and I think that comes across to people, but sometimes I get carried away.

"I love watching people learn. I guess that's the greatest reward when I teach-seeing the light bulbs come on and watching people develop an understanding of a process or pattern in the distribution of an element. It's an amazing amount of work. Maybe I put too much into it." She paused for a moment, then continued, "but I don't think you can put too much into teaching. It's too important. Especially with undergraduates. It's your chance to make an impression, hopefully one that will last a long time. They'll look at an intertidal mudflat differently. They'll think about the ocean differently. When they're out on a boat they'll think twice before they dump that can over the side. Any little thing you can do to make them think twice about something, and just develop in them an appreciation of how it works-if you can do that then you've done a good job."

When I asked Joye what she would do if she had unlimited resources, she replied the she would like to build a coastal ecology center with a public education focus. "It would be a place for people to come look around and say 'Wow, so this is what those little stinky things are in the marsh!'

"A lot of people think that when they see the white film over sediment, they think it's some sort of a pollutant. You also sometimes see what looks like an oily film in marshes. And people think 'Oh, that's a nasty polluted environment.' A lot of that's natural. The white is Beggiatoa, sulfide oxidizing bacteria, and the shimmering film is pyrite that's being formed. It's a metallic looking substance. The film that it makes is confusing if you don't know what it is. A lot of people think that it's some disgusting man-made pollutantbut it's natural. You can watch it in the bay, disappear and reappear as the organisms do their little daily thing."

Thinking globally

Joye traces her interest in biochemistry back to a gift from her parents when she was nine years old, a microscope to play with between chores on their North Carolina farm. It was nothing fancy, she recalls, "but I could see little green things in pond water! I was just fascinated by that. I collected everything-I had samples from all over." Thus began a lifelong interest in small things and their amazing productivity.

With this in mind, I was surprised when Joye told me that global change is the most compelling issue facing oceanographers today. Then again, she is one of those people for whom the microscopic and the universal are never far apart. Joye explains: "A lot of the global change research is focused in the middle of the ocean, and many coastal ecologists believe that an important component of the global carbon budget is not receiving enough attention. That component is the coastal ocean. Unlike the open ocean, a lot of coastal environments are heterotrophic; they produce carbon dioxide and send it to the atmosphere. The open ocean sequesters carbon dioxide from the atmosphere. So there is a net sink for carbon dioxide in the open ocean and a net source in the coastal ocean. If you look at some of the numbers, they suggest that the coastal ocean is a very important source, which means we may need to reevaluate the way we think about carbon cycling in the ocean as a whole. As we're gaining more of an understanding of what happens in coastal environments we see that they are functioning as little grinding mills, recycling a lot of the materials that come in from the rivers and sending them back to the atmosphere pretty quickly."

Joye says she would like to work with some of Texas A&M's climate scientists in the future. In fact, two things she really likes about Texas A&M oceanography are the opportunities to collaborate with so many other scientists and the way people work together. Commenting on what it is like to be a young member of the faculty, she observed that in spite of the bureaucracy that exists at all large institutions people at Texas A&M are caring and sincere. "They go out of their way to help you if they can," she said. "It makes everybody work together more efficiently and the attitude is a lot more positive than it might otherwise be."

The collaboration that becomes possible with this kind of atmosphere is an important prerequisite to tackling complicated problems like global change. Joye feels she can contribute significantly to the study of global phenomena using her experimental approach, which is well-suited to teasing out cause-and-effect relationships in estuarine environments.

Another young professor in our department, Ben Giese, employs similar tactics. Giese uses computer models of the ocean and atmosphere as a virtual laboratory in which he exposes the global climate to extreme conditions, such as an 18-month year or a sun that never sets, then watches what happens. Giese and Joye are trying to quantify the importance of each ingredient in extremely complex systems by changing variables one at a time and measuring the results. It is the scientific method in its purest form, applied to Earth's environment on molecular and global scales. If their techniques continue to reveal useful information, we could be witnessing the birth of a new and productive trend in ocean research.

Global change is "a can of worms, like most big problems," Joye says, "but I think that in the years to come when we start talking about carbon dioxide, global warming, global change, sea-level rise-you name it-the coastal zone is going to be one of the places that people start looking for some of the answers to these questions."

Joye observes that since human populations concentrate along the coasts, we have disturbed the ecosystems there to a greater degree than we have altered the middle of the ocean. "In the years to come," she says, "particularly when we consider sea-level rise, [the coastal zone] is where the action is going to beand that's where I want to be."