H2O: Nature's Barometer

Water flows through a variety of research at JMU

HIGH ALONG THE RIDGES OF THE BLUE RIDGE MOUNTAINS, trout are making a comeback after suffering from the effects of acid rain. In streams winding through mountain forests, scientists gather evidence on the bacteria polluting our fresh water to determine where they're coming from and their resistance to antibiotics. Meanwhile, on the shores of the Great Lakes, rising and falling water levels help scientists to reconstruct the history of the Great Lakes and climate change.

Like the key piece of evidence in a great detective drama, water flows through the research of JMU scientists on seemingly disparate courses. It is in the water, the lifeblood of our environmental system, that these researchers find answers to their questions. It is the water that provides a barometer on fish populations, climate change, pollution, antibiotic effectiveness and ultimately the health of the planet. *By Donna Dunn ('94)*

BRUCE A. WIGGINS
JMU biology professor and microbiologist
Determining the source of fecal pollution in fresh waters

JMU biology professor Bruce A. Wiggins began studying water pollution about 10 years ago while he was conducting microbiology tests at the North River for indicator bacteria. "I was measuring all this pollution - knowing it was there - but not knowing where it was coming from," says the microbiologist, whose Friends of the Shenandoah River Academic Award adorns his office wall in Burruss Hall.

At the same time, the Environmental Protection Agency began demanding that states clean up tributaries deemed impaired by pollution. Those tasked with the job of clean up and meeting Total Maximum Daily Load standards faced the same conumdrum Wiggins faced - first finding the source of the pollution.

While it is no surprise that one of the big offenders of water pollution is fecal contamination, the mystery was determining specifically where along the thousands of miles of streams and rivers it was entering the water.

Then Wiggins made a distinction. If he could differentiate among the kinds of fecal contamination - human, livestock or wildlife - he was finding, environmentalists and agencies could come that much closer to finding the physical location of the pollution sources.

Today Wiggins' work is gaining national attention.

It capitalizes on bacteria's resistance to antibiotics. Because humans and animals do not consume the same antibiotics, the bacteria in their intestinal tracts, *enterococci,* develop different resistances. So Wiggins has developed microbiology tests based on how pollution samples react to the antibiotics commonly consumed by humans and livestock.

Throughout the semester, Wiggins takes his students into several sub-watersheds of the Middle River to collect water samples from streams. Back in the lab, students pass the samples through filter paper in order to concentrate the contamination on the paper filter. They transfer the bacteria to petri dishes of antibiotics and cultivate them overnight in a refrigerator.

"If it grows or not is the indication of what kind of fecal contamination it is," says graduating senior Jacqueline McCarty, who plans to go to graduate school to study infectious diseases. "Until working with Dr. Wiggins, I didn't realize how much microbiology applies to the environment and how it relates to humans. Water quality is important to correct. I saw firsthand how cows were just walking in streams. That water is used in the irrigation of the crops we eat and then runs back into streams. It's just a big cycle."

By collecting samples and generating data on the antibiotic resistance of the array of bacteria found in fecal matter, Wiggins is creating a bacterial reference library that he can use in tandem with lab and computer analysis to determine the source of pollution in future stream samples.

While measuring bacteria's resistance to antibiotics had been done before, Wiggins has expanded on it with new statistical methods.

While there is still no standard for determining contamination sources, research is ongoing. There are still many questions to answer, such as whether patterns of resistance stay the same over time as bacteria become more and more resistant to antibiotics.

"Dr. Wiggins has been on the forefront of developing methods to differentiate the sources of fecal pollution," says Bill Keeling, TMDL project coordinator for the Virginia Department of Conservation and Recreation. For now, Keeling says that antibiotic resistance analysis (ARA) remains one of the best methods.

There are currently three methods of analyzing fecal contaminants: molecular (looking at DNA), biochemical (what Wiggins is doing) and chemical (looking for chemicals - the presence or absence of). Keeling says biochemical and molecular analysis provide the best data, but the biochemical method is by far the most economical.

Wiggins has been receiving steady grant funding for his work. Just this year he received $50,524 from the U.S. Department of Agriculture and another $73,000 from the Virginia Department of Conservation and Recreation.

JAMES HERRICK
Environmental microbiologist and JMU biology professor
Antibiotic resistance genes among native stream and soil bacteria.

James Herrick, an environmental microbiologist and biology professor, has also been looking at the resistance of bacteria to antibiotics. However, he is using the waterways to help determine whether antibiotics are getting into the natural environment through contamination, thereby furthering bacteria's resistance to antibiotics.

Herrick's concern over antibiotic resistance is in step with other scientists who are alarmed that overuse of antibiotics by humans and in agriculture might create virulent resistant superbugs that will render current antibiotics useless for treatment.

Herrick is closing in on antibiotic resistance in nature and its human causes.

How do bacteria become resistant? Bacteria have the ability to conduct horizontal gene transfer, Herrick explains. They transfer tiny plasmids from one organism to another. Each plasmid is a self-replicating piece of DNA that may or may not tell a bacterium how to react to certain antibiotics. Bacteria are among the only organisms in the world with this ability.

"It's as if you were to bump up against someone on the street and you woke up the next day with blond hair," Herrick explains to a brunette.

Like Wiggins, Herricks knows that fecal matter in fresh waters contain bacteria with different resistances to antibiotics. Herrick wants to know if those bacteria that come from people and animals transfer plasmids to bacteria found in the natural environment. If that is the case, and Herrick has found evidence that it is, then overuse of antibiotics in people and animals may be transferring to native bacteria that do not normally come into contact with people and animals.

Herrick is concerned especially with the effects of agricultural use of antibiotics. According to Herrick, 40 to 70 percent of antibiotics used in the United States are not used on humans. Instead, they are used in animals and crops to promote growth. He believes that his work might show that this overuse in agriculture is contributing to an increase in resistant native bacteria.

The process for research has not been easy. Bacteria in the environment, which are found in soils, streams and oceans, are tough to study because most are not culturable on standard lab media. Herrick developed his own process for analyzing these bacteria using a capture method created in Wales.

He captures bacteria in nature, in this case in streams, and applies them to plates treated with different antibiotics. By using this method, Herrick has found that tetracycline-resistant genes in fecal matter do move into native bacteria through plasmids.

DANIEL M. DOWNEY

Analytical chemist and JMU chemistry professor
Mitigating acidity in streams and lakes to protect and enhance fisheries and other aquatic life

Chemistry professor Daniel M. Downey knows first-hand the consequences of pollution in fresh water. An avid fisherman and outdoorsman, he sees the connections between his research into acid rain and the declining fish populations at some of his favorite haunts.

In his Miller Hall office, decorated with fishing lures and a fish-themed carpet, he recalls the growing concern in the 1980s over acid rain and the creation of the National Acid Precipitation Analysis Program (NAPAP). After returning to JMU in 1985 (he is a Madison College undergraduate), Downey was called upon to conduct research on acid rain as JMU began a cooperative effort with the Virginia Department of Game and Inland Fisheries and the U.S. Forest Service. Downey was among the first to introduce analytic chemistry to JMU's department and soon had undergraduates busy at work on research.

George Washington National Forest's St. Mary's Wilderness, which encompasses 10,090 acres in southern Augusta County, has been referred to as one of Virginia's finest fisheries. But in the 1980s, that began to change.

"It became painfully apparent that the fish population in St. Mary's was in decline," Downey says. Through testing, it was found that acid rain had increased the pH level in the lake to a level intolerable to some of the lake's wildlife.

Downey began to work with a method for adding limestone to the feeder streams to reduce acidity from acid rain. It was not the first time such a method had been tried, but it was a first for Virginia.

Lime is a naturally occurring base element (low pH level). Mountain water sources above 1,400 feet sea level are especially susceptible to acid rain because the low-soluable materials, like granite, that constitute mountains weather at a slower pace than the rate of acid rain deposition. When this acid-neutralizing rock does not break down quickly enough, there is nothing to offset the effects of the rain's acidity.

But how do you add lime to water sources high in the mountains where roads may be nonexistent? The answer for St. Mary's in 1999 was helicopters, which deposited 140 tons of limestone in six locations. The limestone was brought in from closely related areas of Virginia, so the solution to the acid rain was as natural as possible.

"The key feature of our work has been ecosystem restoration," Downey says. The water chemistry at St. Mary's has been restored, and the Forest Service keeps check on it by conducting weekly water samples. The solution is not permanent; another liming will probably need to be done in 2004, but the results are well worth the effort, Downey says.

For 15 years, sampling of St. Mary's has continued. Some of Downey's former students come back as alumni for his quarterly forays to sample the entire watershed. In between, the forest service takes weekly samples at the boundaries of the territory. All of those samples pass through Downey's lab at JMU, where he supervises undergraduates who run tests using a variety of lab techniques and equipment to track the water quality.

Graduating senior Colleen Norman, one of Downey's recent field assistants, says her experience has opened her eyes. "I didn't really know acid rain was such a problem. By doing field research, I understand how much geology makes an impact on an aquatic ecosystem and am learning more about the geology and chemistry of the streams within the mountains and valleys of Virginia," says Norman, who begins teaching chemistry this fall on Long Island. "It is personally rewarding for me to know that I've had a positive impact on the environment and can pass that appreciation for the environment and the methodology I've learned with Dr. Downey along to my future high school students."

STEVEN J. BAEDKE
Geologist and JMU geology professor
Reconstructing the record of Great Lakes water levels

Water levels in the Great Lakes are being used as a different kind of barometer - one that is producing interesting new information about the history of our earth's climate. For more than a decade, geology professor Steve J. Baedke has been immersed in research that studies the lake levels and shoreline history of the Great Lakes.

The Great Lakes and Coastal Susceptibility Study began after the 1986 flood, when the lakes reached record all-time highs and damaged coastal property around Chicago. The Department of Interior offered money for scientists to find out more about the history of the Great Lakes' levels in order to predict future flooding. In 1988 as a master's student in hydrogeology at Indiana University, Baedke was a field assistant for Todd A. Thompson, an Indiana Geological Survey geologist. This relationship continued until in 1991 Baedke was hired as a research associate by the Indiana Geological Survey to work with

Thompson full-time.

"Past research has had difficulty establishing detailed lake level changes before historical records were kept. Our work has been able to extend our knowledge of lake level changes that have occurred during, roughly, the past 4,200 years. What we have found is that water levels in the Great Lakes have been significantly higher and lower than historical records suggest. We've also found a cyclic signature," Baedke explains.

The key is finding beach ridges along the coasts that indicate where the water levels were hundreds and even thousands of years ago. Each time the lake level changed, a new ridge formed. (Follow the links **http://geollab.jmu.edu/baedke/fieldwork/sum2003.html** to aerial photos that show these distinct beach ridges.)

Between ridges, wetlands form and the organic material they preserve can be used to interpret the age of the wetlands and beach ridges around them through radiocarbon dating techniques. Thompson and Baedke are finding that the ridges seem to form in response to lake-level changes approximately every 30- to 35-years - something that Native American lore indicates they observed centuries ago.

Thompson says he began studying the ridges because he was not satisfied with the existing data collection processes. "I knew I could use the relict shorelines (beach ridges) to provide information on the elevation of the lake when each ridge formed," Thompson says. "I decided to use the wetlands between ridges to date them. So with elevation and age, a hydrograph could be constructed."

In order to establish whether climate might be controlling lake levels in more than one place on any of the Great Lakes, and also might be controlling each of the Great Lakes differently, research continues. So far, the team has looked at six sites on Lake Michigan and four on Lake Superior, and they have been funded for more research through 2004.

"Our research is being used by aeolian and coastal geomorphologists and sedimentologists; archaeologists; paleobotanists, plant ecologists, synoptic climatologists, local and regional planners, and federal agencies," Thompson says. "I receive e-mails and phone calls from scientists in many disciplines to citizens with real estate on the lakes. I am always amazed at how far-afield our study reaches."

One breakthrough in the research came from the discovery that some areas are behaving differently than others. The cause, after a bit more investigation, was identified as isostatic rebounding. "Thousands of years ago when glaciers were laid over the lake, they depressed the land surface," Baedke says. "Since then, the ground surface has been rising." So different areas are rebounding - or rising - at different rates, and Baedke and Thompson have been able to construct lake-level curves that explain the differences.

However, it still takes four or five years to collect enough data from enough sites around any one of the Great Lakes to ensure that they are getting all of the data they need. Most of the data collection has done by Baedke and Thompson during the summer months, but during the school year a full-time employee at Indiana Geological Survey has been hired to process what was collected during the summer.

Each summer these researchers can be found around the Great Lakes, and Baedke can be found wading up to his chest through wetlands carrying some pretty heavy-duty equipment. To gather data from the sites, the research team takes core from the ground using a cement vibrator that inserts a long tube into the ground and pulls up layers of soil that are 15-feet deep and about 10-pounds per foot.

"There's something very rewarding about looking at the end of the day after we collect 700 pounds of core," Baedke says. "It is invigorating work. I really enjoy it. To be able to do this kind of hard work is one of the reasons I became a geologist."

Sites for coring and sampling come from geologic maps and digital photos that show spots where embayments in the lake help create "beautifully distinct" ridges.

Ironically, while the research began to help prevent future flood damage, the lakes are now at all-time lows due to a lack of rain. Yet the data and research are revealing far more telling information than just new boundaries for a 100-year flood plain. The use of water levels as a barometer for climate change is especially garnering a lot of attention.

"Our work is being used to help assess whether this is only a Great Lakes phenomenon or whether it is part of a global climate change phenomena," Baedke says.