

Zebra mussels reroute contaminant flow through food chain

Conventional wisdom holds that contaminants such as PCBs accumulate up the aquatic food web, reaching the highest concentrations in the predatory fish at the top of the food chain. But not in Lake Michigan's Calumet Harbor—new research reveals that some smaller fish have higher PCB concentrations than the predators that eat them. The findings, presented at the Ecological Society of America meeting in Montréal in August, could mean that resource managers will have to revise fish advisories and sampling protocols for monitoring cleanups, experts say.

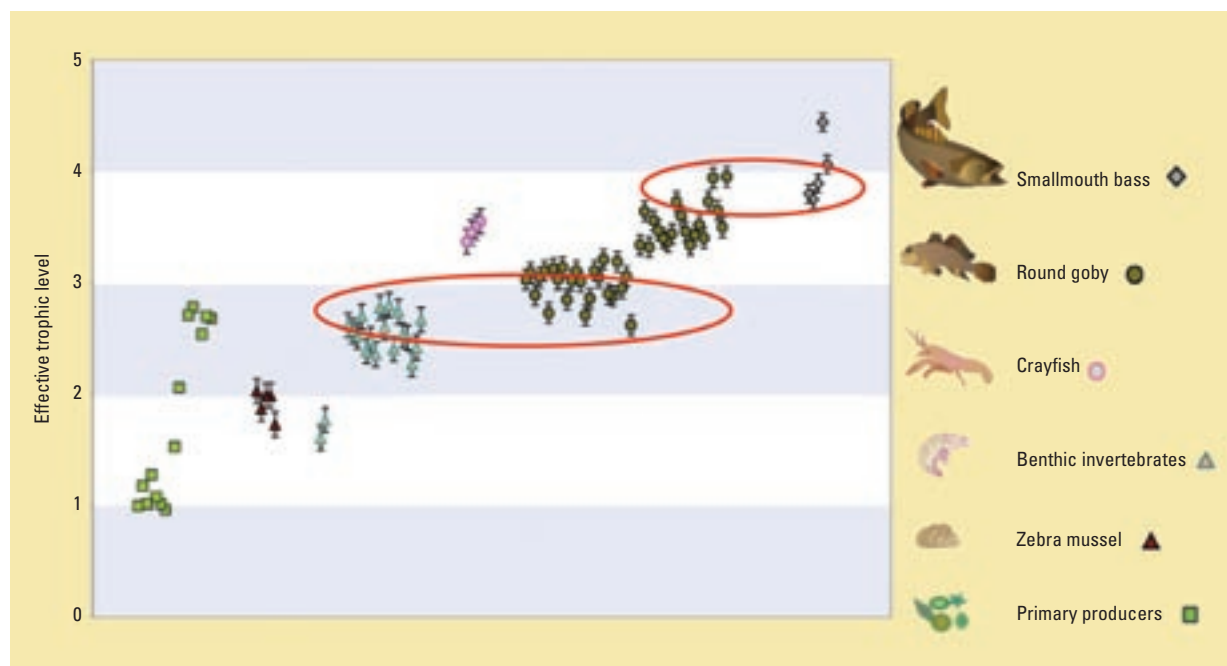
Calumet Harbor, which runs from Chicago, Ill., into northern Indiana, is heavily polluted as a result of industrial and shipping

activity. The harbor has a simple food web dominated by two invasive species, the zebra mussel and the round goby, says Carla Ng, a chemical engineer at Northwestern University and lead author of the study. Because of the food web's simplicity, Ng thought the harbor was a perfect location to test a new bioaccumulation model for PCBs that is based on nitrogen-15 (^{15}N) measurements. She and her colleagues, for the first time, applied a bioaccumulation model for PCBs to the stable ^{15}N isotope study of food web structure in the harbor.

The ratio of heavy to light isotopes of nitrogen generally increases by 3.4% with each consumer up the food chain because of the selective loss of the light isotope as organisms grow, and thus the

ratio is used to measure the position of each species in a food web, Ng says. But when the data were collected, the isotope analysis unexpectedly revealed that juvenile round gobies have a greater isotope signature and thus occupy a higher food web position than their predators, the smallmouth bass, she says. The researchers then calculated PCB concentrations and found that the juvenile round gobies, not the smallmouth bass, do indeed have the greater contamination levels. "The smallest round goby is as much as five times more contaminated with PCBs than the smallmouth bass," Ng says.

The switch in food web positions is due in part to the often-ignored role of detritus, such as fish carcasses, zebra mussels' feces, and



Isotopic profiles of ^{15}N in Calumet Harbor, which is located in and around Chicago, show that contaminant levels don't always increase smoothly up the food chain.

CARLA NG

the particles of undigested food wrapped in mucus that they excrete, which are known as pseudo feces, Ng says. When sediment-dwelling organisms such as insects and tiny crustaceans eat this detritus, they accumulate contaminant burdens linked to organisms at higher positions in the food web. Juvenile round gobies eat the sediment dwellers as well as the PCB-rich eggs of smallmouth bass and the eggs of other adult gobies. As a result, they receive a larger dose of PCBs than the adult gobies that mainly consume zebra mussels, which are lower on the food web, Ng says.

The lack of biomagnification of PCBs from gobies to bass can be explained by the bass's slower growth rate and consumption of other species lower in PCBs than the gobies, Ng says. The scientists who develop bioaccumulation models assume a food web structure based on average diets of adult species; hence, they expect the bass to have higher PCB levels than the gobies. They have overlooked that young gobies are eating bass eggs and that the zebra mussel has added a positive feedback loop in the food web, Ng says.

Federal and state resource managers will have to rethink their fish advisories, which currently rec-

ommend that people eat smaller fish to minimize exposure to contaminants, says Marty Berg, an aquatic ecologist at Loyola University and a coauthor of the study. "When we did the PCB analysis for the U.S. EPA's Great Lakes National Program Office, we interviewed anglers, and they said the round gobies were easy to catch and cooked up nicely," he says. Now, in addition to sampling large fish, resource managers will have to sample smaller fish for both fish advisories and monitoring cleanups, Berg warns.

"The research shows that if you're going to explain bioaccumulation of contaminants, you have to have a good understanding of the food chain and seasonal and year-to-year differences in diet," adds Anders Andren, an environmental chemist at the University of Wisconsin. The findings are not unique to Calumet Harbor, and similar bioaccumulation patterns may occur in many other water bodies, he says. Although other studies of nitrogen isotope ratios have found the complexities uncovered by Ng, her study was unique as the first to combine nitrogen isotope analysis with biocontamination models.

—JANET PELLEY

Electricity from cellulose

By using bacteria and fungi from the stomachs of cows, researchers from the Ohio State University have created one of the first microbial fuel cells (MFCs) to generate electricity by digesting cellulose, the primary constituent of plants. The development is notable because although cellulose is widely available as a potential substrate for powering MFCs, it is remarkably hard to break down.

A team of students and faculty capitalized on the ability of rumi-

nants to break down cellulose in their rumens, the first of several stomachs. The bacteria and fungi in rumen fluid are a key source of cellulolytic enzymes. In these experiments, the organisms were able to generate electricity without requiring exogenously added redox mediators. The need to replenish used-up redox mediators is a major limitation of many prototype MFCs.

The researchers have not yet identified any of the organisms

News Briefs

Study finds U.S. laws protect species

A recently published study concludes that federal programs directed at protecting endangered species in the U.S. are having a great effect (*Ecol. Lett.* **2005**, *8*, 986–992). Authors Tim Male and Michael Bean, both with the nonprofit group Environmental Defense, used data generated from 1998 to 2002 by the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration to develop a single measure of each species' recovery progress. They found that 52% of species listed as endangered or threatened before 2000 and almost two-thirds of species listed for 13 or more years have stabilized or are improving. They find that a key factor in a species' recovery is government funding through the 1973 Endangered Species Act, a law designed to protect U.S. biodiversity.



PHOTO/ISC

From mountain to tap

Common but misguided views about water management, particularly the myth that trees always improve water availability, have encouraged major investments in national and international water resource projects that are either ineffective or counterproductive, according to a new report from the U.K.'s Forestry Research Programme. *From the Mountain to the Tap: How Land and Water Management Can Work for the Rural Poor* is a summary of a series of research projects conducted over the past four years in India, Costa Rica, South Africa, and Tanzania. Although trees can provide many positive environmental benefits, the researchers' data show that mountain forests, often known as "cloud forests" don't really collect more rain than pasture lands.



USDA

This grazing cow has a permanent, surgically constructed fistula that allows scientists to access its first stomach, or rumen. A removable plug allows researchers to take samples.

in the microbial consortium that powered their MFC, but Hamid Rismani-Yazdi, one of the students involved in the project, says that maximum energy generation apparently involved cooperation among several species of bacteria and, possibly, fungi. When they inhibited the growth of many species of bacteria by adding broad-spectrum antibacterials, the researchers found that electricity production was reduced but not eliminated. This suggests that either antibiotic-sensitive and -resistant bacterial species cooperate or that fungi play a role, says Ann Christy, associate

professor of food, agricultural, and biological engineering and a coauthor on a paper about the MFC presented at the American Chemical Society meeting held in Washington, D.C., in August.

The researchers hope to determine whether rumen fungi are electrochemically active and whether they produce soluble redox mediators. To date, Christy says that no researchers have shown that anaerobic fungi can power MFCs. The development could lead to a whole new class of microorganisms with unique abilities for use in the fuel cells, she adds. —BARBARA BOOTH

More sources of mercury in the environment

Talk about tradeoffs! In the course of investigating how much mercury is emitted when so-called stabilized dredge material made from contaminated sediments is used as landfill, a team of researchers led by John Reinfelder of Rutgers University found that even after the material is mixed with cement, it can emit more of the toxic element than some scientists expected. But the research, published in this issue of *ES&T* (pp 8185–8190), also suggests that leaving mercury-laden sediments in place may result in significant emissions.

In order to maintain the shipping channels leading into the harbors in New Jersey and New York, the states must regularly dredge them. The result is 4 million cubic yards of sediments, says W. Scott Douglas, a coauthor on the paper and the dredging program manager for the N.J. Department of Transportation's Office of Maritime Resources. Up to half of that material is unsuitable for placement in the ocean because of unacceptable levels of mercury—as well as dioxins, PCBs, chlorinated pesticides, cadmium, and arsenic—and must somehow be stabilized, he explains.

Since 2000, a growing percentage of these sediments have been

stabilized with cement by one of two New Jersey facilities. Donjon Marine Co. operates an in-barge mixing facility in Port Newark, and Clean Earth Dredging Technologies, Inc., runs one in Jersey City, Douglas says, adding that other projects are in the pipeline. “We add 8–10% Portland cement to the dredged sediments in order to return the sediment to a soil-like consistency that has the engineering properties needed for transportation, spreading, and

compacting,” Douglas explains.

Over the same period, New Jersey has been calculating a budget to determine its sources and sinks of mercury statewide. And that led to Reinfelder's grant for measuring the contribution from the stabilized sediments.

Reinfelder and his colleagues found that 1–2 days after the cement containing the contaminated sediments was deposited onto the area where it was to serve as landfill, the concentration of total gaseous mercury (TGM) ranged from 2 to 7 ng/m³. The mercury content of the dredged material was relatively



JOHN REINFELDER

Measurements taken at this site when it was being reclaimed with cement made with contaminated sediments showed that it emitted similar amounts of mercury to New Jersey industrial facilities. The site has since been capped and will become a golf course.

low, ranging from 1.3 to 2.6 ppm, because the N.J. Department of Environmental Protection (NJDEP) required that more highly contaminated dredge materials not be used at the site, Reinfelder said.

The measurements showed that the TGM concentrations at the landfill site "were significantly higher" than those at an urban site that the researchers measured for comparison, according to their paper. They estimated that the annual volatilization rate during construction at the landfill site, which is slated to become a high-end golf course, "was comparable to those of other industrial sources in New Jersey (140–450 kg per year)."

"We know that stabilizing sediment with Portland cement causes an exothermic reaction, which in turn causes mercury and other contaminants to be volatilized to some degree," points out Elizabeth Southerland, director of the U.S. EPA's Superfund assessment and remediation division.

Reinfelder and his colleagues reported "pretty high fluxes for material that wasn't all that highly concentrated in mercury," said Steve Lindberg, a corporate fellow emeritus of the environmental sciences division at Oak Ridge National Laboratory.

"The fluxes [Reinfelder and his colleagues] reported are pretty high based on the mercury concentrations in the substrate, so I would expect that disturbance and also soil moisture, which also exacerbates emissions, might be influencing mercury flux," adds Mae S. Gustin of the natural resources and environmental sciences department at the University of Nevada, Reno. Gustin notes that contaminated soil and sediments generally emit higher amounts of mercury after they are disturbed or placed in a new setting. "It takes a while for the system to settle down to a baseline flux," she says.

Reinfelder and other scientists interviewed for this article stress that the mercury emissions from the cement made with the stabilized dredge material cease

as soon as it is capped. Although some of the scientists feel that the emissions Reinfelder recorded should necessitate policy changes requiring the material to be capped relatively quickly, Douglas disagrees. The emissions are "very low" and fall within regulatory limits, he says. The material is always fully capped before any reclamation project is completed, he stresses. The criterion NJDEP uses for cleanup of residential soils is 14 ppm of mercury.

Douglas argues that the research actually serves as an argument for why dredging and stabilizing contaminated sediments constitutes a good policy. He and Reinfelder found that the mercury emissions were highest in the presence of sunlight; this "indicates the presence of a photochemically active form of mercury in the dredged material." Because the state has a long history of mercury use in the days before the compound was regulated, the mercury in the sediments remaining in the waterways may be volatilizing out when they are exposed to sunlight during low tides, they agree. "Dredging the sediments, amending and capping them eliminates future emissions from those sediments and lowers the overall mercury load," Douglas says.

"The results suggest that volatilization of mercury from tidally exposed estuarine sediments, which cover a much larger area than stabilized dredge material sites, could be an important part of the mercury cycle in coastal states," Reinfelder says. "Our preliminary laboratory flux chamber results suggest that photochemistry is critical to mercury flux from both stabilized and unstabilized sediments," he adds.

Tidally exposed sediments contaminated with mercury represent "a really good example of a source that we don't know about and haven't quantified," Lindberg agrees. "The trouble with mercury is that there are too many sources and not enough sinks," he says.

—KELLYN S. BETTS

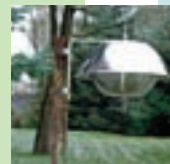
News Briefs

Tracking POPs around

The first results from a pilot test of passive air samplers demonstrate that the inexpensive technology can be used for compliance with the UN Persistent Organic Pollutants (POPs) treaty, reported Karla Pozo of Environment Canada at the Dioxin 2005 meeting held in Toronto in August.

The pilot testing for the Global Atmospheric Passive Sampling (GAPS) study, which began in December 2004, involves 50 sites on all 7 continents. Pozo presented results from the first 3 months of testing for PCBs and organochlorine pesticides.

Some of the most noteworthy data collected thus far was for pesticides that are not yet on the treaty, according to Pozo. For example, of all the pesticides analyzed, the levels of endosulfan I varied most widely. The highest levels were detected in rural Argentina (11,200 pg/m³) and the Canary Islands (4700 pg/m³).



Mercury removal technologies move toward commercialization

A second technology for removing mercury from the emissions of coal-fired power plants developed by the U.S. Department of Energy's National Energy Technology Laboratory (NETL) has been licensed by a commercial company. The patented technology, which is known as the Thief process, supports the U.S. EPA's new mercury rule, which will result in a 70% reduction in mercury emissions when it is fully implemented in 2018. At least a dozen technologies are now being developed for removing mercury from coal-burning power plants, according to Evan Granite, a chemical engineer at NETL. Like the UV-based technology that NETL developed and licensed last year (*Environ. Sci. Technol.* **2004**, *38*, 158A–159A), the Thief technology is an alternative to using activated carbon for removing mercury from power-plant emissions.

How a global-warming skeptic became famous

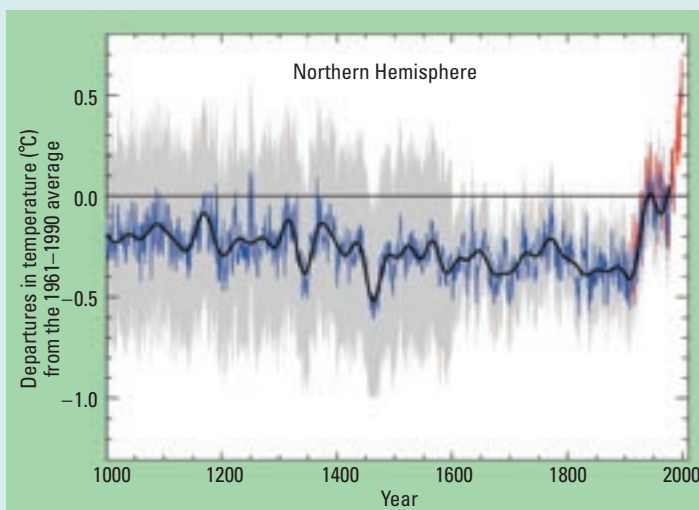
Why do so many U.S. business leaders and members of Congress doubt the scientific consensus on global warming? Consider the case of Stephen McIntyre, a semiretired businessman. His attack on one climate-change study, known as the “hockey stick”—a study often cited to make the case for global warming—plucked McIntyre from obscurity and got him featured on the front page of the February 14, 2005, *Wall Street Journal*. The page-one story caught the attention of Rep. Joe Barton (R-TX), chair of the House Committee on Energy and Commerce. By late June, Barton was creating his own headlines by demanding that prominent researchers turn over the raw data from the hockey-stick analysis.

When *ES&T* contacted more than a dozen leading scientists to find out how these events affected the scientific consensus on climate change, many researchers began criticizing the *Wall Street Journal* and Barton. But to former director of the geophysical fluid dynamics laboratory at Princeton, Jerry Mahlman, the chain of events reads like a slapstick comedy. “It is all eminently lampoonable,” he says.

However scientists look at these events, the success of climate-change skeptic McIntyre hints at why the findings of the Intergovernmental Panel on Climate Change (IPCC) report and other mainstream, peer-reviewed global climate studies have failed to persuade Congress and the Bush Administration that action is needed to curb greenhouse gas emissions.

McIntyre began his career in climate studies in 2003 when he published a paper in *Energy &*

Environment, an obscure social science journal that eschews traditional peer review (2003, 14, 751–772). McIntyre and his coauthor, economist Ross McKittrick, outlined what they called serious errors in the hockey-stick analysis that throw all the results into



Since the hockey-stick paper was first published, it has been a prime target for climate-change skeptics seeking to repudiate the science of global warming.

dispute. The original hockey-stick analysis plotted reconstructed Northern Hemisphere mean temperature variations since 1400 and found that since 1900, temperatures have increased to give the graph its distinctive shape (*Nature* 1998, 392, 779–787). The hockey-stick study’s lead author is Michael Mann, who recently became the director of the Earth System Science Center at Pennsylvania State University. Multiple subsequent studies by other researchers have yielded similar hockey-stick results, but climate-change skeptics continue to attack the research.

As a result of the *Energy & Environment* paper, lead author Stephen McIntyre, a Canadian, was flown to Washington, D.C., to brief U.S. business leaders and the staff of Sen. James Inhofe (R-OK), chair of the committee on Environment and Public Works. He also presented his findings that year at the

Marshall Institute, a nonprofit organization whose chief executive officer is ExxonMobil lobbyist William O’Keefe.

After this fleeting brush with fame, McIntyre retreated to Canada and began a more aggressive attack on the hockey stick. He launched a blog to attract attention to his research and created a website where he posted his manu-

scripts that had been rejected by *Nature*. But in early January of this year, he finally had a paper accepted into a real science journal—*Geophysical Research Letters* (GRL).

Decades of research have created a massive body of scientific literature on climate change, and thousands of new studies on the subject appear every year in different science journals. Yet, within weeks of publishing his first peer-reviewed study,

McIntyre was profiled on the front page of the *Wall Street Journal*. The article ran 2209 words and was written by reporter Antonio Regalado.

Four days later, the *Wall Street Journal* editorial page praised Regalado’s reporting and launched an attack on the hockey stick, the IPCC, and the science of global warming.

To discover how often the *Wall Street Journal* carried stories on climate-change science, *ES&T* examined one year of coverage by the newspaper. In April 2005, the paper ran a 169-word story highlighting a *Science* article authored by well-known climatologist Jim Hansen, director of NASA’s Goddard Institute for Space Studies. A third, 576-word story, which was based on a press conference about scientific research, appeared in August 2004.

“It’s a bit out of balance, obviously,” laughs John Orcutt, president of the American Geophysical Union

(AGU). "But the *Wall Street Journal* has a conservative point of view, and studies like [McIntyre's] are the type of stuff that attracts them."

"It is a concern if there is a group that thinks that this one paper is the most important to come out on climate change," says Jay Famiglietti, an associate professor in earth system science at the University of California, Irvine, and editor-in-chief of *GRL*. "If I had a student come to me and say, 'I found this one paper that proves that climate change is hogwash,' I'd say, 'Well, that's one paper out of how many?'"

But the harshest critic of the whole issue is former *Wall Street Journal* page-one editor Frank Allen. He now directs the Institutes for Journalism & Natural Resources in Missoula, Mont. He described the front-page story to *ES&T* as a "public disservice" littered with "snide comments" and "unsupported assumptions". He says he does not understand how the story got past the editors.

"It was a strange story 'cause it had this bizarre undertone of being investigative but it didn't investigate," says Allen. "And this piece—what I thought was bothersome about it—it purported to be authoritative, and it's just full of holes."

ES&T asked Regalado and his immediate editor to respond on the record to the criticisms of the story and the paper's coverage of climate-change science. *ES&T* was then directed to set up an interview through Dow Jones & Co., the owner of the *Wall Street Journal*. After four days of phone calls and emails, Robert Christie, director of corporate communications for Dow Jones, responded by email: "We've made it clear [that] when you submit your questions, we'll be more than happy to provide written on-the-record answers."

ES&T then emailed 19 questions and asked to receive a response within three days. Six days later, editor Bob McGough confirmed by phone that the questions had been received.

ES&T has never received a response.

McIntyre says that after he was profiled in the *Wall Street Journal*, he received a phone call from the congressional staff of Rep. Barton. "They wanted to know if I had spoken to the *Wall Street Journal* and if the article was true," McIntyre tells *ES&T*.

In late June, Barton swung into action and sent out letters to Mann, his colleagues, and two scientific groups. The letter to Mann begins: "Questions have been raised, according to a February 14, 2005, article in *The Wall Street Journal*, about the significance of methodological flaws and data errors in your studies of the historical records of temperatures and climate change." The same letter makes extensive requests for raw data. Mann and his colleagues have complied with Barton's demands, and the investigation is apparently still open.

"I'm a pretty unlikely protagonist to this whole story—a middle-aged, Canadian businessman who nobody's heard of doing battle with an IPCC superstar," admits McIntyre.

Jim Hansen of NASA agrees. "Although I have been carrying out research in the atmospheric science and climate field for more than four decades, I have never heard of either of them," wrote Hansen in an email, referring to McIntyre and McKittrick.

When asked why his debut into science gained so much attention, McIntyre responds, "It intrigued reporters and, to some extent, reporters have driven the story. They've almost forced people to read it."

"All I can say is that story gave an undeserved amount of attention to a controversy that most scientists regard as ludicrous," says Michael Oppenheimer, professor of geoscience and international affairs at Princeton University.

Global-climate-change scientists interviewed by *ES&T* say that there is some basis for questioning the hockey-stick study, but Regalado's story blurred any distinction between businessman Stephen McIntyre and scientist Hans von

Storch, who directs the Institute for Coastal Research at the GKSS Research Center (Germany). Von Storch disagrees with Mann about the degree of variability in past temperatures before the present warming. Mann's research finds little variability; von Storch argues that there was more.

"We are speaking about the shaft of the hockey stick, not the blade," says von Storch. "We have no conflict about anthropogenic warming. That's not the point."

While scientists have essentially dismissed McIntyre's research, professional societies have gone after Rep. Barton and his letters. The American Association for the Advancement of Science and the AGU, for example, have protested Barton's intrusion into the scientific process. Mann provided an 11-page point-by-point refutation of every issue raised by Barton.

Attempting to resolve the issue, the National Research Council has even offered to perform an independent review of the controversy for Barton. Bill Colglazier, the council's executive director, declares, "It was a sincere good-faith offer, but [the congressman] didn't seem too positive on this."

For his part, McIntyre says that his analysis of climate-change science is far from complete. Studies by other researchers with similar results to the hockey stick contain the same glitch, he says. Meanwhile, his blog has received more than 500,000 hits, and McIntyre reports that he is getting more web traffic from Washington, D.C.

"I had no idea that there would be any interest in my work, and the fact that some people have found it interesting, I find very flattering," McIntyre admits.

He adds that he is not making any definitive statements on the science of global warming. "I'm just saying that I don't know," he said. "I looked at one narrow topic. I haven't studied issues of infrared radiation and water vapor. And there are a host of issues that need to be studied."

—PAUL D. THACKER