CHESAPEAKE QUARTERLY

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The Fishman Cometh

contents

CHESAPEAKE QUARTERLY

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Cover photo: *Adam Frederick carries living cargo into the classrooms of Maryland high schools.* ***Opposite page:*** *Fish meets student. Frederick introduces a bluegill to Erin Gu, one of the science students at Wootton High School responsible for keeping two dozen fish alive and healthy.* PHOTOGRAPHS BY MICHAEL W. FINCHAM.

Scientific Literacy for the 21st Century

HAROLD ANDERSON

The 2004 landmark report from the U.S. Commission on Ocean Policy emphasizes the importance of education and marine science literacy as a foundation for stewardship of our coastal and ocean resources. An informed, actively engaged public is key to finding solutions to the problems facing our coastlines. In a broader sense, science and technology are now part of our everyday lives, and a citizenry comfortable with the insights and innovations that scientists produce is essential as we move forward in this new century.

Education lies at the core of Maryland Sea Grant's mission and in this issue we highlight programs that span the full spectrum of our efforts. With a distinct focus on coastal and marine examples, Adam Frederick and Jackie Takacs from the Maryland Sea Grant Extension Program open doors for middle and high school students just beginning to appreciate how science can empower them to make discoveries and interpret their world. The innovative Aquaculture in Action program helps teachers find new ways to make biology, physics and environmental science relevant and fun — at the same time these new lessons address core learning goals and build a better appreciation for Chesapeake Bay. Toward the other end of our spectrum, we profile Rebecca Holyoke, an accomplished young scientist who has made the commitment of time and intellectual energy to complete a Ph.D. Years of study and dedication to a rigorous path lie before her as she works to build a career that blends her growing expertise in estuarine research with a sincere wish to contribute scientific knowledge to the public arena. Also in this issue, Maryland Sea Grant Research Fellow Brandon Puckett explains his blue crab research in his own words, taking on the challenge of communicating technical information in broadly understood language.

What links all these efforts is the belief that an essential part of learning science is doing science — at all levels. The skills that young students acquire as they plan and run their first experiments can lay the foundation for the sophisticated techniques and hypotheses that, for some, build a Ph.D. dissertation. At the same time, developing an understanding of the scientific method helps build the knowledge base and confidence necessary to interpret the information all of us must process on a daily basis. In no small part, science literacy and education are key in our ability to make informed decisions about the stewardship of coastal resources like Chesapeake Bay.

— Jonathan G. Kramer
Director

A Fish Story

Hooking Students on Science

By Michael W. Fincham

When Adam Frederick leaves home at 5:30 a.m., it's so dark he can't see the Cactoctin mountains humped up to the west. From Woodsboro, Maryland, up on the northern edge of the state, 20 miles below Pennsylvania, he drives south and east past farms, small towns and the new suburbs now spreading out through the rolling October countryside of the state's central plateau. He's got a large chunk of the state to cover before he comes home tonight. In his work year, this is the longest day.

Seventy miles later the sun is up when he pulls into a mega mall on the outskirts of Annapolis and switches into a gray van driven by Jackie Takacs, one of his co-workers in the Maryland Sea Grant Extension Program. Soon they are arcing across the Chesapeake Bay Bridge, squinting into the southeastern light to see if any watermen are out fishing for late season crabs or early season oysters. Heading south along route 50, they pass more farms, the large corn and soybean farms of the mostly flat middle Eastern Shore of Maryland. At Cambridge they cross the mile-wide Choptank River, one of the major spawning rivers in the Bay for striped bass.

Their job today is to haul young striped bass fingerlings back across the Bay and deliver them to six high schools scattered across north central Maryland. Frederick calls their project Aquaculture in Action, and he began it in 1997, soon after he came to work for Sea Grant as an Education Specialist. The plan behind the project: students will raise the fish in their classrooms, release them back in the Bay at the end of the school year — and learn a lot of science in the process. If the students learn well, the fish make it through the school year alive.

Frederick is gambling with fish by betting on Maryland students — and he's looking at some long odds. According to studies by the National Science Board, not many American students are taking science seriously. The U.S. now ranks 17th among developed nations in the proportion of college students majoring in science, and less than half the students now enrolled in college science classes are native born. For critics like Fareed Zakaria, writing in *The Washington Post*, all these trends add up to one truth: "Americans don't do science anymore."

Adam Frederick still does science, however, and he is using these striped bass to test a hypothesis about American schools. He claims American students can still do science and do it well — if they, like working scientists, are presented with real problems to solve and questions to answer.

Three miles east of Cambridge, Takacs swings a sharp right onto the grounds of the Horn Point Laboratory, an 800-acre site of the University of Maryland Center for Environmental Science (UMCES) that sits on a bluff above the Choptank River. Driving down the arrow-straight, tree-lined entrance lane, they pass offices, research buildings, and seagrass ponds, then park next to a long, low-lying metal building with a greenhouse running along one side. This is the laboratory's finfish hatchery and the birthplace of Frederick's would-be pedagogical fingerlings.

Inside Frederick makes a quick tour of three large blue 400-gallon tanks, peering down at tiny stripers alternately gliding and darting about their small watery worlds, the only worlds they've ever known. "Hey, they look good. They're pretty," he tells Andy Lazur, the hatchery operator. With 11 tanks in all, Lazur's hatchery kingdom looks like a cross between a big garage and a small barn. It is wet underfoot, and noisy with

The U.S. now ranks 17th among developed nations in the proportion of college students majoring in science.

the constant sibilation of running water and hissing compressors and murmuring pumps — all the godlike, but man-made machinery necessary to create these worlds and keep them running.

With his wiry frame Frederick has a hefty, low-end voice, the kind that could sell well on television and radio — and he has clearly sold his partners on this project. Tall, southern and soft spoken with a Ph.D. in finfish aquaculture, Lazur has agreed to release 150 of his fish into the keeping of high school students. Takacs is already hustling up fish nets and plastic bags and cardboard boxes, the tools of the day. She's ready to push fish out the door and start chauffeuring them around the state.

The fish in these tanks are the offshoots of some big stripers who swam up the Choptank the previous spring — only to find Lazur and his assistants waiting for them in a small open boat. Hot to spawn and head back out to the mainstem and the ocean beyond, the stripers were, instead, stunned by a literal bolt out of the blue. Lazur swung a short boom out from the boat, lowered several dangling electrodes into the water and unleashed lightning shocks strong enough to knock any passing stripers senseless and send them floating to the surface.

Back at the hatchery, Lazur would pick out stunned males and females who are already leaking sperm and eggs, then revive their sex drives with hormone injections. With hatchery spawning, the readiness is all. When they're back in the mood, Lazur turns his revved-up captives loose in a small, warmed-up tank, usually two males with one larger female, and waits to see what happens. The result: a scene that's pretty close to — and perhaps even better than — the belly-rubbing frenzy the stripers were looking for out there in the Choptank. And voila! — two days later, lots of new fish larvae are floating in the tank. These fish-love sessions work better than Mother Nature's, begetting more larvae per adult than any wild spawning in the river would.

For the small fry, early life in a hatchery tank, while not as scenic or adventuresome as life in the river, is certainly safer and healthier. No predators around to gulp down little larvae; instead, leaning over them, the towering figure of Lazur, first cause and prime mover in their brief lives, stopping to feed them and keep their world bubbling along with clean, waste-free, oxygen-rich water.

Their world suddenly gets smaller as Frederick, taking dead aim, stabs a long-handled fish net down at a school of stripers sliding around the bottom. He hoists the dripping net and stares at it intently. "There are a couple red marks on a few of them around the gill," he tells Takacs. They both count fish aloud as they scoop 25 fingerlings into water-filled plastic bags. This is how the fish will travel the state, floating in bags and stored in styrofoam boxes and plastic coolers, the same kind you fill with ice in the summer to chill a six pack or carry home a legal-size, freshly-caught striper.

The problem with trucking fish in bags is keeping them alive, and the solutions are oxygen, temperature and timing. Before sealing the fish bags, Frederick opens the valve on an oxygen tank and pumps in plenty of air, turning each fish bag into a bulging fish balloon with enough oxygen to keep 25 fingerlings alive through a long day. That's a taste of the problems teachers and students will face back at their schools.

Frederick calls his approach project-based science, but it's also called problem-solving science. To come up with solutions, students and teachers will have to tackle a slew of research questions just as Lazur and other working scientists do in commercial hatcheries and university labs around the country. That's a lot to handle

MICHAEL W. FINCHAM

The pioneer in a pensive moment: *Bob Foor-Hogue and the aquaculture kingdom where he sometimes goes tank swimming. The fish-raising projects he and his students created at South Carroll High School became the model for Aquaculture in Action, a program that helps teachers around the state adapt his hands-on, problem-solving approach to science education. Says Foor-Hogue, "My students have done extraordinary things."*

for teachers and students who supposedly don't do much science anymore.

Takacs slides the last cooler into her big grey Odyssey van and Frederick slams the rear door down. By 9:30, they are back on the road and Lazur's little stripers are headed north with no notion of what lies ahead. Frederick, however, knows what's at stake. He's betting some of his reputation and all of Lazur's striped bass to test a hypothesis about how much high school teachers and students can handle. If the experiment works, the fish live — and students learn more science. If it doesn't, a lot of fish start dying in high schools all around the state.

The Pioneer

In 1990, a teacher named Bob Foor-Hogue created his first fish tank system by setting up several 55-gallon barrels in the back of his second-floor chemistry classroom at South Carroll High School. One barrel held lava rocks for a primitive filter and the others held tilapia, a fish popular with professional aquaculture operators.

Aquaculture, he immediately discovered, was constant problem solving. After he flooded the first floor classrooms below him several times, his school administrators solved that problem for him by moving his operation to a greenhouse out back. When he quickly filled up the greenhouse with tank systems, they gave him a huge shed at the back of the school that was once used for teaching tractor repair to Carroll County students. He and his students knocked out a wall, built a glass-walled classroom along one side, and then proceeded to fill up their new space with more fish tanks.

Foor-Hogue was not the first to bring fish into Maryland high schools — the Maryland Department of Agriculture had tried sending tanks and tilapia to a number of vocational ag teachers as a way to popularize aquaculture — but he was, it seems, the first to use aquaculture as a tool for teaching science.

It began when he created a course called Science Research. The core concept was project-based science and the project he chose was aquaculture. The first fish he tried was tilapia, because it was adaptable and widely available from professional aquaculture operations that raised the fish for the supermarket trade. His long-term goal, however, was to raise striped bass — not to sell them, but to release them back into the Chesapeake Bay.

As a younger man, Foor-Hogue saw firsthand the great declines in the Chesapeake ecosystem. To earn money for college, he and his brothers worked as commercial crabbers out of Kent Island. Several days after Tropical Storm Agnes dumped record rainfalls throughout the Chesapeake watershed in 1972, he motored out to check on his crab pots, timing his trip for slack tide when the water starts to clear. At low tide he usually had to turn his motor off because the grass beds were so thick. But now he peered down and saw no grass beds. He motored three miles south along Kent Island and never had to cut his motor. There were no seagrasses.

It was a moment he never forgot. During the next two decades, he saw seagrasses and oysters nearly disappear and striped bass decline, leading to a controversial moratorium on the catching and selling of the fish in Maryland. When he dove into aquaculture, he went in deep, as he always does, because it was personal. He wanted to raise striped bass to re-release them into the Bay.

Project-based science works on a need-to-know basis, according to Foor-Hogue.

If his students bought into a project like restoring the Chesapeake Bay, they might also buy into raising striped bass. If they did, what would they need to know?

How do you keep fish tanks up and running, water clean and oxygenated, fish healthy and growing? How do you feed the fish, measure their growth and get them back in the water alive? His students would have to solve a lot of problems, and the answers would come from biology, ecology, chemistry, physics, mathematics, engineering and computer science.

In theory, his project-based science was an advanced course, building on what students have already learned in traditional high school courses. In practice, Foor-Hogue is not a huge fan of most of those courses, despite years teaching biology and chemistry, both mainstream science and Advanced Placement science, the high-prestige courses that are supposed to help students boost their college prospects.

Are all these AP courses the answer the country is looking for? Do they bode well for turning out more American scientists? Not according to Foor-Hogue. Memory work for test taking, he calls them. "The beauty and elegance of science get lost in all the facts," he says. As a result a lot of potential scientists may also be lost. "We may produce people who are more literate," he argues, "but we are not going to produce many scientists with AP."

Science, for Foor-Hogue, is not facts — you can look those up. Science is problem solving. That's what makes it personal for his students. "It's not how much you memorize," he told them, "but how you are able to use what you've learned." Getting his own aquaculture operation up and running, for example, was a project in itself, and his students went to work looking up facts and formulas and, piece by piece, solving most of his technical problems.

And they helped find money. Once they bought into his schemes and dreams, he put them to work writing funding proposals so they could afford even more tanks and pumps and piping. Over the last decade, the school has landed 50 grants, he says, many of them written by his students.

How much of this student buy-in came from his projects? And how much from his personality? With his passion and his peculiarities, Foor-Hogue was always popular with students. How many teachers came to class dressed like Einstein? Or like an alchemist? Or like a man named Nobel who wanted to invent dynamite. He wore his hair, now graying, in a long pony tail. He sometimes wore a beard and always had a bushy moustache. Then he added an earring.

MICHAEL W. FINCHAM

***Erin Gu inspects the fish** at Wootton High School. Students in Maryland schools are trying to raise striped bass, shad, yellow perch, bluegill, sunfish and rainbow trout. The fish come from hatcheries run by the University of Maryland Center for Environmental Science and the Maryland Department of Natural Resources.*

When students — and teachers — talked about him, the first sentence that popped out of their mouths was: "Foor-Hogue is crazy." He was, after all, known to go swimming in his fish tanks. How many teachers tried that?

There was, of course, more than madness to his method. He kept his hair long just to irritate people, he says, but the rest of his act was aimed at keeping everybody alert in their seats. "The whole thing about the nutty professor has always worked to my advantage," he admits. "I never want to be equated as an average teacher." And the way to be well above average was to have fun. "When I think of my best teachers, they challenged me," he says, "but they also made education fun."

With his growing aquaculture empire, Foor-Hogue was becoming famous in the teaching community. He won honors like Maryland Science Teacher of the Year, the Presidential Award for Excellence, the Milliken Foundation National Educator Award.

Had he discovered, by accident or design, the secret to successful science teaching?

Foor-Hogue was invited to give dozens of presentations, and teachers began dropping by for site visits. One of them was Adam Frederick, a young biology teacher at nearby Walkersville High School.

The Pioneer Solution

Frederick saw the problem. "Look around the state," he says. "There's only one Foor-Hogue." Let's call the problem the Foor-Hogue singularity.

Could you bottle his approach and sell it to other teachers? Especially to new science teachers who were trying to find their way in a profession that focused on teaching for test taking? Or to experienced teachers who were facing burnout? Or thinking of quitting? If you couldn't clone a Foor-Hogue, could you codify his tactics?

Frederick, like Foor-Hogue, saw science as problem solving. When he went to work as an Education Specialist with Maryland Sea Grant Extension, his job was to develop programs and partnerships connecting the University and the state's teaching community, partnerships that could help improve science teaching. One of his first projects: try to solve the Foor-Hogue singularity.

He drove out to visit Foor-Hogue in his aquaculture kingdom. His huge, garage-like space now held 13 major fish tanks and scattered aquaria. In a busy year his students were raising up to 20 species of fish as well as mussels and turtles. They were routing wastewater from the fish tanks out to a greenhouse to grow seagrasses. How do you replicate this kind of setup — on a small scale, at least — at other schools around the state?

Frederick's proposal: a program he wanted to call Aquaculture in Action. Maryland Sea Grant Extension would work with Foor-Hogue to design and organize week-long workshops for science teachers. They would cover the basics, build a tank system with each new teacher, teach them how to look for funding. They would even bring them the fish. He got a typical Foor-Hogue response. "Let's do it," he said. "Let's start tomorrow."

They started in 1997 by writing a funding grant and a working manual on how to build tanks, raise fish and bring students into project-based science. In 1998, with funding from the Chesapeake Bay Trust and Sea Grant Extension, they brought a dozen teachers over to South Carroll High School and went to work. Every other summer since they've restaged the workshop. With Frederick as master of ceremonies and Foor-Hogue as master teacher, the new recruits get to build their own tanks and tour the research hatcheries at Horn Point and at the Center for Marine Biotechnology in Baltimore.

It was clear that a lot of the students were hooked on solving the mystery. If the fish were going to get well, students would have to help.

Every October, Adam Frederick and Jackie Takacs fill up their water bags and coolers with Andy Lazur's striped bass and hit the road with hope and trepidation. The singularity problem remains. You can't boil the experience of a decade down to a one-week workshop. Aquaculture is problem solving, and their new teachers and students will have to solve problems they've never seen before.

Testing the Waters

When the new stripers came to Wootton High School in Rockville, it looked like they were going to die pretty quickly. Judy Parsons, a calm veteran with 30 years experience, was soon nervous. A new recruit to striped bass aquaculture, she had hustled to get her tanks ready. She set up a good salt balance, got her water temperature right on the money, and tested for pH levels. Her biofilters were ready with bacteria that were supposed to break down ammonia and nitrites, two of the waste products of fish.

As soon as Adam Frederick walked in, lugging his fish cooler, she went to work with her students, trying to acclimate the water-bagged stripers to their brand new tank. Within a day the stripers started getting sick.

Parsons called Frederick. She told him the fish looked sick, and they began working the problem. The fish, she told him, were floating near the top of the water, struggling to breathe. According to her reading these were some of the classic symptoms of fish under stress. The result was a teacher under stress. This was her first foray with stripers in the classroom, and it was not going well.

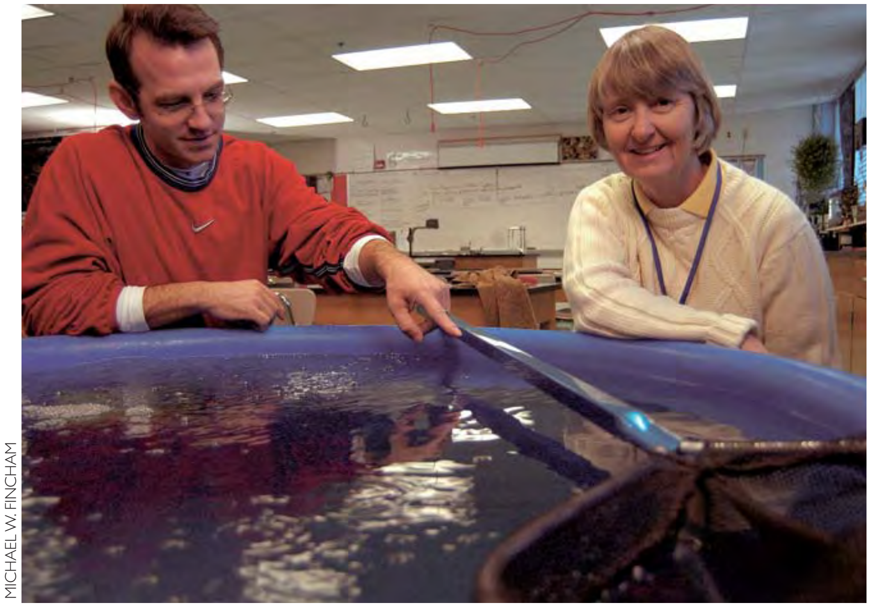
She called Frederick again. "We were changing 20 percent of the water," says Parsons, and the fish were coming apart." Now the fish had lesions, and the teacher seemed to be coming apart. "I was thinking, oh my God, I've got a flesh-eating bacteria," she says. "I thought I had *Pfiesteria*, or something really dramatic." She made her students start wearing rubber gloves whenever they touched the tanks, the water or the fish.

She called Frederick nearly every day now, and then Andy Lazur down at the Horn Point hatchery. She went online, searching and downloading articles from science journals. The nitrite levels were climbing. Every time her students stuck their test sticks in the water, they turned deep purple. The fish, Frederick feared, were toast. It was clear by now that one of the bacteria in the biofilter was not kicking in and cleaning out the nitrites.

It was also clear that a lot of the students were hooked on solving the mystery. They were clearly upset and kept asking Parsons why the fish were so sick. This wasn't a problem in a textbook or in a river miles away. These fish were getting sick in a water tank sitting in the back of their classroom. If they were going to get well, students would have to help with researching the literature and reworking the water system.

Some mysteries are solved but never completely explained. Students and teacher decided that the culprit was nitrobacter, the bacteria that is supposed to decompose nitrites. Answers, in science, always lead to questions. Why do nitrobacter populations sometimes grow more slowly than predicted? So slowly they can't keep up with the waste from 25 tiny, four-inch fish. Questions don't always lead to answers.

Parsons and her students tried a 20 percent water change, and then 50 percent. A water change in a fish tank can be a tricky, time-consuming maneuver. As



The fish tank that would not work *until and Judy Parsons (left with Adam Frederick) and her students solved some tricky problems with nitrogen cycling. Students release striped bass back into Chesapeake Bay at Fort McHenry in Baltimore Harbor (right). Other fish-release sites for Aquaculture in Action have included Sandy Point State Park by the Bay Bridge, tidewater rivers on the Eastern Shore and freshwater streams and lakes in central Maryland.*

they drain off the old water (and its overload of nitrites), they have to add new water that is warm enough, salty enough and dechlorinated enough to keep the fish from stressing out even more.

The second change was the charm. The solution to pollution is (sometimes) dilution. With new water, the fish began moving around again, instead of clinging to the surface and sucking air. When nitrobacter finally kicked off a population explosion, nitrite levels began dropping to acceptable levels. Fish are incredible, thought Parsons. Within three days they were back to a semblance of normal life in a fish tank world.

Her students, by now, had worked through some real-world science. The near-death episode made a convert out of Parsons and a lot of her students. Several students from her Advanced Placement courses applied for in-school internships to work another year with the next batch of fish. "These kids learned so much about real-life application." says Parsons. "They have to know the nitrogen cycle on the AP test, and the kids who were working with these fish and trying to keep them alive, they understood the issues of nitrites. No question about that."

Over three decades of teaching, she has seen her field swing away from classic descriptive biology towards a stronger focus on molecular biology. Hands-on, project-based programs like environmental education and Aquaculture in Action, she believes, help recapture some of the excitement of the old biology.

She can see the response even in her students' basic data-gathering work. To weigh and measure the fish, they learn how to anesthetize fish with clove oil, giving them a 30-second window to work in. "These kids are never going to get an opportunity to handle fish like this again," she says. "First when they put them to sleep, they think they've killed the fish." Then the fish wake up, and so do many of the students. "They love it. Not only that: they are amazed."

Letting Go

Over the course of their rookie year with striped bass, Parsons and her students lost only three fish. Two died during the October crisis. Another died later from leaping out of the tank.

The rest returned home in style to the Eastern Shore. In May, Parsons and twenty students rode a rattling school bus for three hours from Rockville to Bishop's Head, Maryland where the Chesapeake Bay Foundation holds weekend field trips for teachers and their students. Their stripers got a smoother ride. Needing an oxygen supply for the long trip, they cruised down in the back seat of an air-conditioned car with an aerator plugged into the cigarette lighter.

Out in the wetlands along Fishing Bay, on a sliver of land that points south toward Tangier Sound, Parsons and her students sent 23 stripers sliding out to feed and fend for themselves in the food-rich waters of the middle Chesapeake.

Over the course of the year Foor-Hogue, the master teacher, lost more. Five of his stripers died at South Carroll High School. Several leapt unseen out of their tank, several died when a pump was accidentally turned off. The perpetual educator, Foor-Hogue taught his students how to dissect fish, take blood samples, remove organs and analyze tissue. He turned each death into a teachable moment.

Twenty of his fish survived, and on a cloudy day in May they leave Carroll County the way they came — in coolers and plastic trash cans. Their chauffeur is Foor-Hogue with one of his students, Mike Steel, riding shotgun. Frederick and other students follow in separate cars. This is no funeral procession, sliding somberly through red lights and stop signs with headlights lit in the middle of the day.

Think of it as a baptismal procession. Foor-Hogue calls it the best day of the school year. His students are going to release their tank-grown fish out into Chesapeake Bay. For the stripers, now nearly a foot long, it will be total submersion baptism and the beginning of a new life in a larger world. For the students, it will be a communal event. At Sandy Point Park, they are meeting up with Doug Stransky's students from Randallstown High School, a predominately black school in Baltimore County.

Driving south in his black, four-wheel drive Cherokee, Foor-Hogue starts worrying that his stripers, raised for part of the year in a chilly greenhouse, won't look as big as Stransky's. He's heard reports that Stransky has stripers that are 20-inchers. "He had them in warm water inside," he tells Steel, "so their metabolism would have been double what ours were."

Processions like these head out every May and early June from dozens of schools in Maryland. Since the first summer workshop with a dozen teachers, Adam Frederick and Jackie Takacs have spread their Aquaculture in Action program, with its tanks and pipes and problem-solving projects, to 41 schools, including an elementary school, a middle school, a high school in Pennsylvania and another in West Virginia. In buses and vans, pickup trucks and station wagons and the back seats of air-conditioned cars, striped bass and bluegills and rainbow trout go riding to their reward.

Just north of the Chesapeake Bay Bridge, Frederick stands on a dock at Sandy Point Park, taking pictures of Foor-Hogue's fish-release ceremony. He wants to hook more teachers into his program and pictures might help. They'll go into his newsletter and up on his Aquaculture in Action web site, a resource for the network of teachers he's

In their Own Words

Aquaculture in Action

MICHAEL W. FINCHAM

The Aquaculture in Action program first began recruiting and training teachers in the summer of 1998. From the start, the basic pitch went like this: an aquaculture project is one of the best ways to get American students to plug into serious science. It brings fish into the classroom, it creates a focus for teaching all kinds of research-based, problem-solving science, and it applies science to real-world issues in ecological restoration when students release their school-raised fish back into the wild.

The catch, of course, is that teachers have to learn before they can teach. For a new teacher recruit, the "action" in the Aquaculture in Action program starts with a week-long workshop held every other summer at South Carroll High School. Each teacher has to design, build and set up his or her own 210-gallon tank system, a hands-on project with plenty of chances for problem solving. Then they have to tackle topics like fish handling, biofiltering, and tank system monitoring.

They are not working alone. Coaching them through all their problem solving are Bob Foor-Hogue of South Carroll and Adam Frederick of the Maryland Sea Grant Extension Program. They will also provide counseling and networking all the way from fish delivery to fish release.

Does it work? Here's what some of the teachers discovered once they were released back into their classrooms.

On the workshop: I thought it was going to be a lot harder than it turned out to be. I enjoyed putting the unit together because that way I knew exactly what everything did. That was really helpful. And then back in the classroom I was able to explain it easier to the kids.

On starting up: I told them we were going to do some aquaculture. They said "What's aquaculture?" And so I explained that it is raising fish in the classroom here. And we hopefully will have these guys survive until June and then set them free.

On fish: We had kids that I don't even teach, kids that were wandering in from other places — just to see the fish. They bring other kids down and they look in the window and observe the fish swimming.

The hardest part was making sure that other kids didn't do things to (the tank system). The kids got really protective of the fish. And they were ratting each other out really fast. They did not like other people coming in and messing with what they had. They took ownership of the fish.

— **Linda Toth,** Chesapeake High School, Baltimore County

On students: These kids, they are looking for a way to relate to science and to get into it. And aquaculture incorporates a lot of stuff — building, working with animals. They really enjoy that. It ties together a lot of components that I would never be able to teach in a normal biology class. And I can take kids the extra step and show them how water chemistry relates to fish health and how that relates to the ecology of our area.

On problem-solving: The hardest thing in the beginning of the class is to get them to be independent, independent thinkers and problem solvers. And by the end of the class you almost have trouble pulling them back into instruction.

— **Bob Cole,** Francis Scott Key High School, Union Bridge

On teaching: Oh my god, it is just the visual hands-on experience. For example, we teach cycles with first-year classes when we are doing the ecology unit. Not only do we talk about the theoretical nitrogen cycle, but I can take them and turn them around and walk them through the nitrogen cycle in the back fish tank. I can say these are the decomposers, this is what is taking the nitrogen and producing ammonia. Here is where these nitrifiers are living.

On results: It really is the best hands-on program that I have ever been involved with as a county teacher. Even the bad stuff is a pretty good experience. It is definitely worth doing.

— **Judy Parsons,** Wootton High School, Montgomery County already got enrolled and an ongoing advertisement for signing up more schools.

Frederick clicks off some digital frames of Foor-Hogue lying flat on his stomach, hanging over the edge of a dock. He's holding a cooler half open beneath him and sloshing some warmer, saltier Bay water into the cooler. Inside five small stripers are trying to swim circles in a rectangular world.

"Wow, they're going to take off," says Frederick, trying to get some more frames before the fish are gone.

"No they're not," says Foor-Hogue. "I'm going to put some more water in." He can't believe how warm the water is. His stripers, used to the cool waters of a Carroll County greenhouse, seem to be acclimating well enough to this sea change in their lives.

"Their final swim," says Foor-Hogue, thinking of all the time and work he and his students have put in with these fish. "They've been swimming in circles for months — the endless swim to nowhere."

Now they have somewhere to go. A few years in the Bay, then perhaps the long swim down the Bay and up the coast to Maine. Stripers born in the Chesapeake have made it that far before turning around and heading home to spawn. At a foot long, these school-raised stripers have no major predators in the Bay, except fishermen with their nets and fishing lines and scientists with their electroshock prods. The ocean is another story.

One by one, the stripers head out. Kathleen McClellan, a senior, stands in the water guiding them over the lip of the cooler. Kevin Weeks and Mike Steel, two juniors, carry the rest of the coolers down from the car. Guys are too cool to wade in the water so they work on the dock, pouring buckets of warm Bay water into the coolers, getting the rest of the fish ready.

Foor-Hogue peeks in one of Stransky's tall fish cans and confirms his suspicions. Stransky has 20-inchers, no doubt about it, beautiful and big enough to eat. The student, for this year at least, has bested his teacher. Stransky, it turns out, took his first two chemistry courses from Foor-Hogue. And he learned his fish-rearing techniques from the Aquaculture in Action workshop and web site. He's a physicist, not a biologist, but with that kind of training he's been able to raise some monster fish with his students.

The fish have somewhere to go and so, perhaps, do the students. Foor-Hogue and Frederick have helped steer students into aquaculture, biology, oceanography, aeronautical engineering and environmental science and policy. Kathleen McClellan, the girl in the water guiding the stripers, is headed to the Air Force Academy. Doug Stransky, of course, went into science teaching.

Another girl in shorts, one of Stransky's students, wades out with a trash can, and the two girls together keep guiding the big fish into the Bay. Frederick takes more pictures and then Stransky starts clicking away also. Soon the students start playing to the cameras. A girl holds up a striper: "Say bye-bye to the camera." She kisses it and slips it underwater. "Bye-bye."

Foor-Hogue, the godfather, has no prayers for the occasion but he does have a hymn. "We should do a chorus of " 'Born Free,' " he says. That dates him, of course, because none of his students know what he's talking about.

Another fish slides out of the can, looks around, then darts away looking for dinner, and Foor-Hogue tries humming the duhnt-duhnt-duhnt-duhnt theme from *Jaws*.

That dates him too, so he shuts up and starts taking pictures.

Partners in Science

The notion that science happens only in high-tech laboratories or on professional research vessels was never accurate. It doesn't describe Mendel in his monastery or Darwin aboard *The Beagle* or the backyard astronomers who've named a number of recent comets. Science happens wherever people do research with rigor — by recording observations, analyzing data, creating hypotheses and reporting results. It happens in high-tech labs — and in high school classrooms

If there is a gap between university labs and school classrooms, the Environmental Science Education Partnership (ESEP) is trying to bridge it. Comprised of educators working around the state with the University of Maryland Center for Environmental Science (UMCES), the Partnership is creating opportunities for teachers and students throughout the K-12 system to do science — not just study it. In ESEP programs, teachers, students and local citizens work side-by-side with scientists, exploring authentic scientific datasets and using state-of-the-science research tools and techniques.

ESEP projects include courses, workshops, web-based curricula and seminars for students and teachers. For information on upcoming opportunities for next year, teachers should contact the educators listed below.

Maryland Sea Grant Extension and the SciTech Education Program, Center for Marine Biotechnology – Adam Frederick (frederic@mdsg.umd.edu)

Horn Point Laboratory, Cambridge, Maryland – Donna Stotts (stotts@hpl.umces.edu) and Laura Murray (murray@hpl.umces. edu)

Chesapeake Biological Laboratory, Solomons, Maryland – Jacqueline Takacs (takacs@mdsg.umd.edu)

Appalachian Environmental Laboratory, Frostburg, Maryland – Cathlyn Stylinski (cat@al.umces,edu)

The following state and non-profit organizations also offer sponsored courses, workshops, field trips and funding opportunities for educators:

Chesapeake Bay Foundation
Chesapeake Bay Trust
Living Classrooms Foundation
Maryland Department of Natural Resources
National Aquarium in Baltimore
Maryland Science Center
Smithsonian Environmental Research Center
Patuxent Research Refuge and National Wildlife Visitors Center

For an overview of marine science education opportunities, visit the Maryland Sea Grant web site at www.mdsg.umd.edu/Education/programs.html.

Summer Students on the Chesapeake

Undergrads Sample Scientific Waters

The summer of 2004 marked the 16th time that college students from around the country journeyed to labs at the University of Maryland Center for Environmental Science (UMCES) to work alongside marine scientists.

As part of the Research Experience for Undergraduates (REU), a Maryland Sea Grant program funded by a grant from the National Science Foundation, fourteen students paired with faculty mentors at Horn Point Laboratory (HPL) in Cambridge and Chesapeake Biological Laboratory (CBL) in Solomons for a 12-week taste of academic research. Over the summer, students worked with advisors to complete projects in fields ranging from fisheries to physical oceanography. At the end, they presented their results in a symposium and wrote papers that synthesized their findings.

REU students also participated in special programs focused on communication, careers and ethics. Another highlight was the chance to get together with students from the Multicultural Students at Sea Together (MAST) program, run by Hampton University in Virginia, whose sailboat anchored at HPL and CBL during the program's three-week voyage up the Chesapeake.

Preparations for the REU program's 17th summer are currently underway, with student applications due on February 8, 2005. Please visit the web at www.mdsg.umd.edu/Education/REU/ for details. Contact Fredrika Moser (moser@mdsg.umd.edu) with questions.

HAROLD ANDERSON

2004 REU Students and Their Projects

Nicole Abel, Gannon University, Erie, Pennsylvania – Spatial Variability in Larval White Perch, *Morone americana*, Diet and Growth in the Upper Chesapeake Bay. Advisor: Dr. Ed Houde, CBL.

Barbara Beckingham, Hobart & William Smith, Geneva, New York – Nitrogen Cycling and Redox Transitions across the Pycnocline in Chesapeake Bay. Advisor: Dr. Jeffrey Cornwell, HPL.

Mitchell Buck, Johns Hopkins University, Baltimore, Maryland – Analysis of a Community Model for Chesapeake Bay: Annual Variations and Comparisons with Field Data. Advisor: Dr. Ming Li, HPL.

Cory Catts, University of Florida, Gainesville – Microzooplankton Grazing Influence on Bloom Dynamics of *Prorocentrum minimum* and *Karlodinium micrum*. Advisor: Dr. Walter Boynton, CBL.

Amanda Ellis, Virginia Tech, Blacksburg, Virginia – The Effects of Copper on Extractable Lipofuscin and Oxidative Stress in the Blue Crab, *Callinectes sapidus*. Advisor: Dr. Rodger Harvey, CBL.

Jenna Gustafsson, University of Minnesota, Morris – Factors Contributing to the Methylation of Mercury in Maryland Reservoirs. Advisor: Dr. Rob Mason, CBL.

Catherine Haberkorn, McGill University, Montreal, Canada – Effects of Wind Mixing on Dissolved Oxygen Depletion and Estuarine Circulation in Chesapeake Bay. Advisor: Dr. Bill Boicourt, HPL.

Jennifer Hurt, University of Wisconsin, Stevens Point, WI – Bioenergetics of Striped Bass and Weakfish in the Chesapeake Bay: Is Prey Limiting? Advisor: Dr. Tom Miller, CBL.

Barbara Jacobson, University of North Carolina at Pembroke – Nutrient Cycling and Biogeochemistry of Sediments Inhabited by Two Contrasting Submersed Plant Species. Advisor: Dr. Michael Kemp, HPL.

Rachel Leigh, Oxford College of Emory University, Oxford, Georgia – The Environmental Control of Toxicity in *Prorocentrum minimum*. Advisor: Dr. Allen Place, Center of Marine Biotechnology, UMBI.

Sarah Marnell, Spring Hill College, Mobile, Alabama – Nutrient Uptake Potential of Four Freshwater Ornamental Plants. Advisor: Dr. Andy Lazur, HPL.

Tracey Myers, Youngstown State University, Youngstown, Ohio – Total Ammonia Flux Measurements at the Air-Water Interface on Chesapeake Bay. Advisor: Dr. Ron Siefert, CBL.

Julie Palakovich, Boston University, Massachusetts – Effect of a Restored Oyster Reef on Water Quality in Chesapeake Bay. Advisor: Dr. Mike Roman, HPL.

Cherie Peranteau, The Richard Stockton College of New Jersey, Pomona – Estuarine Bacterioplankton Metabolism and Diversity across a Seasonal Oxygen Gradient. Advisor: Dr. Byron Crump, HPL.

A Profile of an Emerging Researcher

Mud Unearths the Scientist Within

By Erica Goldman

Becky Holyoke's feet no longer touch the bottom of the boat as she leans far over the edge to wash off the plastic tube that encases her mud core, strands of long hair distracting her peripheral vision and the sleeve of her gray sweatshirt trailing in the water. She forces her cold-numbed hands to obey her commands and carefully inserts a stopper at the end of the tube, moving slowly to avoid jostling the interface between mud and water — where all of the chemical secrets that she wants to coax out of the sediments reside.

In most ways, it is a morning like many others she has spent collecting samples for her research as a graduate student in the Marine-Estuarine-Environmental Sciences (MEES) program at University of Maryland Center for Environmental Science (UMCES). But today marks the start of a new course. These cores are the first she has collected to pilot her Ph.D. research, a path embarked upon only a few months ago — a career turning point that caught her by surprise.

Holyoke began graduate school with a single-minded purpose, to bridge the gap between science and policy. She worked as an environmental consultant for several years after college and became frustrated by the role she found herself in. She excelled at the rigorous fieldwork aimed at mapping out the boundaries of wetlands and surveying habitat for endangered species. But she wasn't comfortable with the end product of that science. She saw that some project managers came to environmental consultants for advice on figuring out the minimum they had to do to follow environmental regulations, not for guidance on going the extra step to protect the environment. Holyoke knew the regulations and the policy behind them thoroughly — well enough to know that there were ways that companies could get away with doing less. But she realized she did not want to become someone who could help companies identify ambiguities that exist in regulation. What she wanted was to help link sound science with policy decisions. So she applied to graduate school — only to two programs, both with an emphasis on environmental policy. Along the way, however, her application to the University of Maryland College Park was hijacked.

Roger Newell, a professor at UMCES Horn Point Laboratory, saw something different in Holyoke's application — a student with a strong undergraduate science background who would benefit from understanding the strengths and limitations of what science could do before entering the world of policy. He offered her an opportunity to study how oysters in the Bay affect nitrogen and phosphorus at the boundary between the sediment and the water column, research key in determining what role oysters might play in the Bay's restoration. The project had both technical and policy elements — oysters are pretty political in Chesapeake Bay these days. But the position would not be based at College Park. Newell's lab is located on Maryland's Eastern shore.

Holyoke never considered applying to faculty at the research labs. But she saw that an advanced degree in science would help her in later policy pursuits. Newell had sold her on that. Besides it would only be a few years, he had reminded her. She would stay on a strict timeline and then make the leap into the world of science policy. Holyoke was admitted to the MEES program and received a two-year fellowship offering full support from Maryland Sea Grant. She began her graduate school journey towards a Master's degree in May 2002.

Over the next two years, Holyoke grew to know mud and like it. She has a sense of sediment acquired from hundreds of core dissections. She can read the mud's colors, smells, and textures — a stench of rotten eggs means too little oxygen, a light brown color means plenty. These particulars provide some clues to the results of the experiments even before she does the time-intensive analyses to profile the amounts of iron, sulfide, carbon, and other chemical species in the core.

But sense alone is not science.

Back in the lab, Holyoke immediately launches into the experimental rigors of her work, going into autopilot to prepare for the core dissection. She moves with a technical dexterity that she has honed over the years, stowing muddy field gear and readying her equipment. Time is of the essence. It doesn't take long for the cores to begin to warm and for rising temperatures to speed up the rates of reactions carried out by bacteria in the mud, which could contaminate the results.

Holyoke must handle the mud in a carefully contrived environment that is completely devoid of oxygen — an element that could fuel confounding chemical reactions. To create a mini-world free of oxygen, she reaches for a strange contraption called a glove bag.

She rips open a package that contains what looks like a giant plastic bag with hands sticking out of it. She hooks intake and outtake tubes on the bag to a tank of nitrogen gas and a vacuum device respectively and places a spatula, plastic rack, and centrifuge tubes inside. As she turns on the suction, the objects are instantly shrink-wrapped, like vacuum-sealed bacon in a grocery store package. She switches on the nitrogen gas and the bag puffs up, its two hands sticking out like a ten-fingered snowman. The snowman deflates and reappears twice more to insure that all of the oxygen in the bag has been replaced by nitrogen. Sitting down on the stool in front of the bag, she cranks up the music on the radio and pushes her hands into the unwieldy plastic gloves—they are way too big for her — and maneuvers the spatula to slice the first section of mud from the core.

Holyoke will be the first to point out that these highly technical aspects of her work are the easy part in many ways. "Anyone can play with mud," she says. But it takes something more to be a biogeochemist. And only recently did she realize what her advisors have maintained all along — that she probably has that something.

Her sense of this something did not gel until she tackled the data synthesis and analysis she would need to do to write up her Master's thesis. She disentangled a few questions about how oysters modify the condition of the sediment they live in. But in the course of doing so, she generated a slew of additional questions. What kinds of reactions take place in the dynamic region between oxygenated and un-oxygenated sediments called the redox boundary? How does season affect the rates of these processes? What about the amount of light that penetrates to the bottom of the Bay? And what about the presence or absence of other plants and animals in addition to oysters?

The fact that the number of questions exceeded the number of answers did not come as a surprise to her, but the fact that she wanted to be the one to pursue the answers caught her off guard. She realized that she liked depth and detail — a reductionist at heart maybe — and each answer left her more curious and more determined to keep going. Could that drive to discover the next deeper piece of the puzzle be the something that makes a scientist? So as she synthesized her data and began to write, she made an important life choice: not to graduate with a Master's degree, but to switch into the Ph.D. track. She took charge of her science.

SKIP BROWN

"Anyone can play with mud," says doctoral student and former Sea Grant fellow Becky Holyoke. But to go from mud core collections to a career in science, it takes commitment, curiosity and a drive to ask the next question.

This year, Holyoke applied for and won a prestigious scholarship to support the duration of her dissertation research. The Dr. Nancy Foster Scholarship from the National Oceanic Atmospheric Administration, given to only a handful of outstanding graduate students in marine fields, will allow her to conduct research independent from a single scientist's grants. She switched her primary advisor to Jeff Cornwell, whose research on sediment geochemistry more closely aligns with her interests. She assembled a Ph.D. advisory committee, convened the members for a first meeting, and followed up with a series of one-on-one meetings. Now she is taking additional advanced coursework and trying to schedule her written and oral "comps," exams that she must take to advance to candidate status for the Ph.D. degree. She is also working to narrow down the string of exciting questions that emerged from her first project to craft and defend a cohesive proposal for her dissertation.

Down the road, Holyoke still sees herself providing a bridge between science and policy — emphatic on this point and frustrated at times that her Ph.D. advisor insists that he sees her in academia. It's a compliment, she knows, that he perceives her as a skilled and dedicated researcher. But she wants to find a niche that will put her science to public use. "I haven't changed my opinion on life yet. Everyone thinks that I am a scientist and they may be right. I really like what I do. But I still want to make a difference in policy." For now, Holyoke's closet is divided in two, her mud clothes on one side and her power suits, left over from her consulting days, on the other.

Finished dissecting the first core, she removes the stopper from a second and places a piece of flexible rubber tubing in the murky water on top of the mud in the plastic cylinder. She starts a siphon and drains the brown liquid into a bucket. The next mud core is now primed and ready for dissection and Becky Holyoke is one core closer to the scientist that lies within.

A Research Fellow's Perspective

How Old Is That Crab?

New Approach to the Growth Rate Debate

By Brandon Puckett

Known for their savory taste, awkward swimming motion and beautiful color, blue crabs remain an icon of the rich traditions of the Chesapeake. The largest fishery for blue crabs, both now and in the past, occurs in the Bay. Blue crabs also fill a key ecological niche as opportunistic bottom feeders, a role fundamental to the health of estuarine ecosystems.

But blue crabs face a growing threat, and each year the Bay continues to support a smaller percentage of total U.S. harvests of the species. Ongoing surveys suggest that both commercial landings and total abundance of Chesapeake Bay blue crabs have fallen below historical levels, stimulating questions among stakeholders about the status and sustainability of the fishery. While now may be the time for management actions, resource managers and decision-makers are counting on scientists to collect new information to answer old questions.

In particular, blue crab stock assessment methods used to inform management regulations rely on accurate estimates of age to determine growth rates, recruitment rates (age at legal harvestable size), longevity, and natural mortality rates (including predation).

Just as these feisty crustaceans are notoriously unwilling to release anything in their physical grasp, they also seem unwilling to release the mysteries of their age. Until recently, scientists have not had a direct method for aging blue crabs. The absence of accurate age estimates has not

SKIP BROWN

In the black eyes of blue crabs, *Brandon Puckett searches for clues to their age and growth rate. He measures the amount of the fluorescent pigment called lipofuscin that accumulates in neural tissue as crabs get older.*

only plagued management applications to the blue crab fishery but has also affected crustacean fisheries around the globe (e.g., crabs, lobsters, and shrimp). Unlike fish that have scales and ear bones (otoliths) that grow proportionally to their age, crustaceans grow by molting — thereby removing any evidence of previous size or age. Historically, shell width has been used as a proxy for blue crab age, but since blue crabs spawn over a protracted period (spring to fall) and grow at variable rates, size does not necessarily correlate well with age. As a result, research efforts have shifted towards alternate methods for determining age in blue crabs.

The hallmark of my thesis research is to determine blue crab age using lipofuscin, a fluorescing age pigment (also present in humans) that accumulates in neural tissue as a byproduct of metabolism.

Because the use of lipofuscin for age determination is a relatively new technique, the first goal of my research was to verify that the pigment accumulates at a rate proportional to the crab's chronological age. For this purpose, I used known-age juvenile blue crabs provided by the University of Maryland Center of Marine Biotechnology (UMBI) through their hatchery program. I released two groups about 80 days old, consisting of 300 crabs each, into separate earthen brackish water ponds. At monthly intervals, I measured the cohorts for growth, and at 2-4 month intervals sacrificed a small subset of each cohort for lipofuscin analysis. I extracted lipofuscin from crab eyestalks and quantified it by measuring its fluorescence. After establishing a lipofuscin concentration-to-age relationship, I will apply this to determine the age of field-collected crabs.

To collect wild crabs, I conducted monthly (June to October) bottom trawls in the Choptank River (2003) and Patuxent River (2004) — collecting a total of about 1,000 crabs over the two sampling years. I also measured and analyzed field-collected crabs for lipofuscin concentration. I will use these age estimates from lipofuscin analyses to determine growth and recruitment rates of field-collected crabs. As an independent check on growth and recruitment rates, I used size data generated from the field and pond studies to group crabs into monthly size classes and monitored the progression of size classes from month to month.

For crabs of a known age, lipofuscin concentration increased predictably with chronological age over the first year of life. I am therefore optimistic that lipofuscin can be applied to age field-collected crabs.

It is well known that juvenile blue crabs are capable of extremely rapid growth, but our findings from the lipofuscin method of age determination suggest that growth rates may be even higher than originally predicted. Our experiments and models showed rates of around one millimeter per day during the first year of life. Based on these results, our studies of pond-reared blue crabs indicated that they can start to recruit to the peeler fishery at four months old and to the hard crab fishery at six months old. These recruitment rates are much faster than current age estimates based on size, which project that blue crabs recruit to the peeler and hard crab fishery much older — at one and two years old, respectively.

Although I have not yet applied lipofuscin methods of age determination to all of the field-collected crabs, I expect that the measured growth rates will be similar. Findings that suggest blue crabs enter the fishery earlier than we thought would likely affect our models of blue crab population and its age structure, which in turn could hold important considerations for management of the Bay's most valuable fishery.

Brandon Puckett is a graduate student working with David Secor at the Chesapeake Biological Laboratory in Solomons, Maryland. His tenure as a Maryland Sea Grant Research Fellow lasts from fall 2003 through summer 2005. In this article, Puckett writes about the process and significance of his ongoing thesis research.

Rusello Receives 2005 Knauss Fellowship

Kristin Rusello, a Marine-Estuarine-Environmental Sciences (MEES) graduate student at UMCP, has received a Knauss Marine Policy Fellowship for 2005.

Named after former NOAA administrator John A. Knauss, the Sea Grant fellowship program was established in 1979 to match highly qualified graduate students with hosts in the legislative and executive branches of government or with associations and institutions located in or near Washington, D.C.

Rusello is spending her fellowship year in NOAA's National Ocean Service (NOS) in the Office of Response and Restoration under the supervision of the Chief of the Damage Assessment Center, Pat Montanio. Her work will focus on implementing the Estuary Restoration Act and updating and refining the National Estuaries Database. She will also serve as a contact and support person for NOS involvement in the NOAA Habitat Program, which coordinates habitat restoration and protection efforts across NOAA.

Rusello graduated with her B.S. in Natural Resources from Cornell University in 2000. Following that, she worked for two-and-a-half years as a scientist at HydroQual, Inc., an environmental engineering and consulting firm located in New Jersey. She entered the MEES program in 2002 and began work on her M.S. with Andrew H. Baldwin studying the ecology of restored freshwater tidal marshes located in Washington, D.C. Rusello is currently writing her thesis and will graduate in 2005.

2006 Knauss Fellowships

Maryland Sea Grant is currently seeking applicants for 2006 Knauss Fellowships, funded by the National Sea Grant office and administered through individual state Sea Grant programs. The Fellowships will run from February 1, 2006 to January 31, 2007 and pay a stipend of $33,000 plus $7,000 for health insurance, moving and travel.

The application deadline is March 7, 2005, but those interested in applying for fellowships should check with the Maryland Sea Grant office by mid-February for guidance and application details.

For more information, check the web at www.mdsg.umd.edu/Policy/knauss.html and www.nsgo.seagrant.org/Knauss.html or contact Susan Leet, phone, 301.403.4220, ext. 13; or e-mail, leet@mdsg.umd.edu.

One Fish Flourishes in Isabel's Aftermath


NASA

Each hurricane leaves a distinctive footprint as it blows through an area. Wind-damaged houses and flooded basements may remain the most visible signs, but large storms also have the power to encourage life as well as destroy it. Two recent studies now show that when Hurricane Isabel swept through the Chesapeake Bay region in September 2003, the storm may have created spawning conditions ideal for at least one fish species — the Atlantic croaker.

After Isabel, scientists documented up to eight times the average number of baby Atlantic croaker in some parts of Chesapeake Bay. Fisheries biologists Ed Houde from University of Maryland Center for Environmental Science (UMCES) and Marcel Montane from the Virginia Institute of Marine Sciences (VIMS) independently reported similar findings at a recent conference, *Hurricane Isabel in Perspective*, held in mid-November as a collaborative effort spearheaded by the UMCES Integration and Application Network.

The croaker-hurricane connection is not unique to Isabel, Montane found. He compiled data on storms and fish abundance over the period from 1956-2003. On average, there were three times as many croaker in hurricane as in non-hurricane years. Prior to Isabel, hurricanes Bonnie (1998), Fran (1996), Hugo (1989), Gloria and Juan (1985), and Camille (1969) had notable spikes in croaker numbers.

But a one-month boom in baby croakers does not necessarily mean croaker abundance in the Bay will stay high throughout a given year, says Houde. Houde found that by April 2004, the number of 5-6 month old croaker registered as fairly average, suggesting that the large pulse of juvenile fish did not survive the winter. "Croaker are at the northernmost fringe of their range in the Bay," says Houde, "and they are sensitive to cold temperatures."

Houde and Montane hypothesize that high winds during Hurricane Isabel brought a surge of upwelling, which transports nutrient-rich waters to the surface. Croakers normally spawn on the ocean's continental shelf in the fall, and the sudden increase in available food may have precipitated a large reproductive event. High winds during the storm may also have helped to push eggs and larvae from the ocean into the Bay, Houde says.

Timing is of the essence with hurricanes. Isabel hit the Chesapeake region in the fall. For Atlantic croaker, whose reproductive window spans a few short autumn months, Isabel proved an impetus to reproduction. Had Isabel hit in early summer, like its infamous predecessor Agnes (1972), Montane suspects there would have been no positive effect on croaker reproduction.

Moreover, an early summer hurricane like Agnes can be especially devastating, since many species of fish and shellfish — unlike croaker — spawn in spring, when heavy runoff can wreak havoc on fish habitat.

If these researchers are right, then a fall arrival could link hurricanes to croaker reproduction — though a spawning boost may prove short-lived after the inevitable onset of winter's cold.

Send us your comments on this issue — visit *Chesapeake Quarterly Online* at www.mdsg.umd.edu/CQ

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