

CHESAPEAKE QUARTERLY

MARYLAND SEA GRANT COLLEGE • SUMMER 2002



Digging up the Past
Paleoecology and the Bay

Pioneer in Paleoecology

We often hear that sound management of the Chesapeake Bay is based on “good science.” On the other hand, we seldom hear very much about the scientists themselves, many of whom have spent years, decades, even their entire adult lives tracking what to many of us would seem very narrow parts of the universe. In this issue of *Chesapeake Quarterly* we focus on one of those scientists, Grace Brush, who has taken the long view — the history of the Bay’s ecosystem as recorded in the pages of its sediments. *Buried in the Bay: Seeds of Change* delves into the science of paleoecology as it follows Brush into the field in search of ancient traces of *Pfiesteria piscicida*, a potentially toxic microorganism virtually unknown until the 1980s.



SKIP BROWN

Brush has been part of another aspect of history as well in her determination to become a researcher at a time when few women were encouraged to join the ranks of serious scientists. *The Core of a Life* chronicles Brush’s career from college studies in Nova Scotia to advanced education in Chicago and at Harvard University, and details how she managed to establish a significant career and raise a family despite the obstacles. Today things have changed — percentages of women graduating from college and enrolling in graduate school have risen sharply — a trend evident in Brush’s two female graduate assistants. Despite these advances, some argue that barriers remain — often quite subtle — for women who pursue long-term careers in the world of scientific research.

The pipeline of well-trained women in science-based careers has improved considerably — an important factor has been the Research Experiences for Undergraduates (REU) program, sponsored by the National Science Foundation and locally administered by Maryland Sea Grant (see page 14). Over fourteen years, women have generally made up more than half of each summer’s class of undergraduates who have come to work directly with researchers at the University of Maryland Center for Environmental Science and the Academy of Natural Science Estuarine Research Center. Many of them have gone on to graduate work in the marine sciences.

In coming issues of *Chesapeake Quarterly* we will continue to examine the contributions of researchers who have helped us better understand the Chesapeake Bay. As we confront a number of complex challenges — the control of non-native species of fish and shellfish and the use of increasingly sophisticated computer models to help manage Bay restoration — we will continue to rely on the hard work of dedicated researchers and scholars who have devoted their lives to the study of the coast and its complex natural environment.

— The Editors

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On the cover and opposite page: *Grace Brush has taken hundreds of core samples off the bottom of Chesapeake Bay and its rivers. In these photos, she works with two young scientists, Angie Arnold and Holly Bowers, getting ready to plunge yet another piston core into the bottom of yet another river. Photos by Skip Brown.*

Buried in the Bay SEEDS OF CHANGE

BY MICHAEL W. FINCHAM



SKIP BROWN

Light gray clouds are moving low above the Chicamcomico River, diffusing the daylight, darkening the sluggish water, desaturating all the greens in the marshes and woods fringing the river. As she carries long plastic pipes to a small boat, Grace Brush keeps glancing at that shifting sky. Clouds like this could be carrying rain.

She's a 71-year-old paleoecologist who's come a long way to get here to this lonely boat landing in the soggy marshlands of the middle Eastern Shore of Maryland, and she's hoping to get in a good day's work on the water without getting drenched.

Brush left Johns Hopkins University around 7 a.m. in a large blue van loaded with her odd gear and a crew of three young scientists. They rattled through Baltimore's morning rush hour, crossed the Chesapeake Bay Bridge with its wide view of the upper mainstem, then cruised east across Kent Island on a six-lane highway flanked by shopping malls and discount outlets. Turning south they followed four-lane Route 50, running past flat farms and huge billboards for Ocean City. At Easton, and again at Cambridge, they cruised through a long gauntlet of fast food franchises and chain motels and gas stations.

At the Nanticoke River, they pulled off the highway into the small riverfront village of Vienna and hooked up with two state

Year by year, century by century, earth and leaves and seeds have been settling layer by layer into the sediments along the Bay's bottom.

Paleoecologist Grace Brush has been hauling up those sediments and using them to unlock the long-term memory of the Chesapeake.

workers towing a trailered boat. In caravan now they went bumping off down two-lane country roads that seemed to run straight back in time. Driving past small farm fields, stands of forest and open swatches of flat marshland gashed by narrow, twisty creeks, they were soon deep into the old

tidewater Maryland of a hundred years ago.

At Drawbridge, an isolated creek crossing, they parked next to the only building in sight, a long, garage-like shed that was home to a boat-building business — and a boat ramp. The state workers backed their skiff down into the river, and Brush and her crew began laying five pipes neatly along the bottom of the boat. They look like irrigation pipes or the sections plumbers install in the foundations of new buildings, but these are transparent tubes and Brush will be plunging them into the bottom of the Chicamcomico River. For more than 30 years, she has been using see-through pipes like these to look into the past, all the way back to when the foundations of the Chesapeake were first laid down. Out of her work has come an eventful story about historic changes in the Bay.

On this trip the paleoecologist is tackling a contemporary question: how long has *Pfesteria piscicida* been living in Chesapeake Bay? Only five years ago, in September 1997, this stretch

of river near Drawbridge became briefly famous when the Chicamacomico was the third river closed by the governor of Maryland because of sick fish and suspicions about *Pfiesteria piscicida*. This dinoflagellate, a one-celled microorganism with two tails, is thought to release toxins around fish, and medical researchers found evidence those toxins could also cause mental confusion in humans, especially short-term memory loss. Medical findings like these led to river closings, massive news coverage, and ongoing controversies about the role of chicken farms in causing *Pfiesteria* blooms. After months of heated debate, the state legislature passed new regulations requiring all Maryland farmers to reduce runoff into the state's rivers.

Which came first — the chicken or the microbe? Brush sought funding from the Maryland Sea Grant College for exploratory research. “We want to find out whether *Pfiesteria* is a recent kind of phenomenon,” says Brush. “Or has it occurred sporadically over time?” *Pfiesteria*'s multiple life stages include both a free-swimming cell that darts through the water as well as a tough, seed-like

cyst that buries itself in the sediment. If *Pfiesteria* was blooming here before industrial chicken farming became popular, then Brush might be able to find remnants of its cysts.

As she and her crew pull away from the dock, the clouds slide open briefly, flashing slivers of blue. At the helm of the 19-foot skiff is Cue Johnson, a state worker from the Maryland Department of Natural Resources who helps coordinate river monitoring for *Pfiesteria*. Lanky and laconic, he answers questions about the region as he guides the boat past open marshes broken by stands of woods. “These are primarily hunting areas,” says Johnson. “A lot of wealthy people own big stretches of this.” Only an occasional house can be seen behind the trees and then a farm building off beyond the marshes. It's easy to see why the low-lying landscape of eastern Dorchester County has been called “the Everglades of Maryland.”

The river, in its empty reaches, seems to flow back in time through a changeless landscape — but that's an illusion. These are not the same waters and woods where Native Americans hunted. The skiff is

gliding past stands of second, third and fourth-growth woods, dominated now by loblolly pine that grew up after centuries of land clearing for farming and timbering removed most of the hardwood trees that were here when the colonists came. Before the Europeans, Native Americans around the Chesapeake hunted in woods that also held hemlock, oak and hickory, trees that did well nearly 1,000 years ago during a two-century dry spell. Earlier still, trees like sweet gum and black gum dominated many of these woods during a long wet stretch reaching back nearly 6,000 years. If you look all the way back some 9,000 years ago to the long beginnings of the Chesapeake Bay, you'll find hemlock and pine flourishing and oak increasing as the last Ice Age retreated and the sea came creeping up into these rivers. And if you look back further still to a colder time 12,000 years ago when ice sheets still covered parts of Pennsylvania, you'll find plenty of spruce and fir, northern trees long gone from these lands.

Most of us, of course, can't look back that far, but Brush can. And that 12,000-year chronology of forests in the Chesapeake watershed has been constructed largely out of years of work by her and her graduate students. In 1969 when she first arrived in the region, Brush began taking narrow cylinders of mud out of rivers around Baltimore County. She drove to the sites of old water-powered mills that once jutted into rivers along the fall line of the Piedmont Plateau. After these aged mills collapsed, their ruins helped dam up decades of sediment, and when Brush, trained as a paleobotanist, went looking in those sediment traps, she found seeds and pollen in well-preserved layers. Why not try the same approach elsewhere around the Bay? “I thought this was a technique whereby we could study the history of the estuary,” says Brush.

The idea was simple, even elegant. River sediments all around the Bay might hold a long-term record of changes in the Chesapeake. Year by year, century by century, rains have been falling, and earth



SKIP BROWN

Core samples are marked with date and location, as Angie Arnold is doing here, then taken back to the laboratory, where they are opened and the painstaking process of analyzing the contents of each layer of sediment begins.

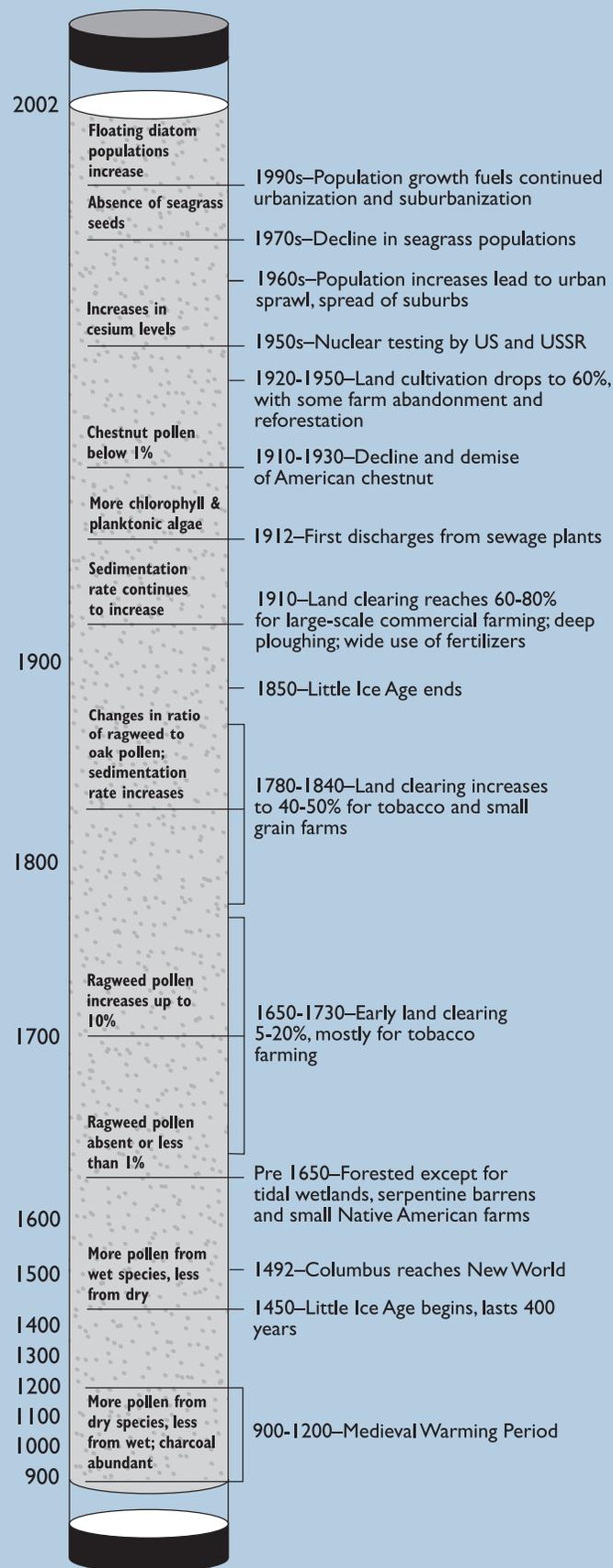
and leaves and seeds have been washing and blowing off the land and into the rivers and mainstem of the estuary. Century by century, all that stuff has been settling, layer by layer, centimeter by centimeter, into the sediments along the bottom. Those sediments could hold hidden within them remnants of what once grew on the land and lived in the water. They could hold the long-term memory of the Chesapeake.

If the idea was simple, the work was not. Back in her lab, Brush would slice her cores lengthwise, cut out a number of one-centimeter cross sections, and then chemically wash each sample to isolate the pollen grains and seeds. She would pick patiently through her samples, one centimeter at a time, counting what she found, naming what she could, then move on to the next centimeter, slowly working her way down through time. What Brush had to create, largely through lab work and brain work, was a way of reading that record — and putting dates on it. That would take time, scanning electron microscopes, carbon-14 dating techniques, library research — and a lot of graduate students.

About 20 minutes downstream from Drawbridge, Cue Johnson cuts the motor, letting the boat drift. Angie Arnold, one of Brush's current graduate students at Johns Hopkins, lifts a pipe and begins to assemble something called a piston core sampler. A slim brunette in a baseball cap, she works quickly, screwing a metal clamp around the tube and attaching a metal push rod useful for forcing the cylinder down into the river bottom. Brush threads a rope down through the tube, ties it to a plug (she calls it a piston) and then promptly jams the plug/piston back into the end of the tube, creating a seal. The piston core sampler, assembled, looks like a low-tech, home-made contraption, and it is. The plastic tube came from a building supplier and the metal clamp from a machine shop.

Today the paleoecologists from Hopkins have a couple of high-tech helpers with them in the boat. Watching and helping when they can are Holly Bowers and Torstein Tengs from the University of Maryland Biotechnology Institute. They work in the lab of David Oldach, a medical doctor and an infectious disease specialist with the Institute for Human Virology, who devised a gene probe that can find *Pfiesteria* in water and sediment by detecting its DNA. His test, created quickly after the 1997 *Pfiesteria* episodes in Maryland, is now widely used for analyzing samples collected along the East Coast. Oldach's research assistants are down on the river with Brush because they want to find out whether his probe can find *Pfiesteria* remnants that may have been buried decades or centuries earlier.

Tengs, a young buzzcut Norwegian, is here for another reason. Plunging a piston core into the bottom is muscle work. "Okay Torstein, now you know why we brought you along," laughs Brush. Leaning above the water, he and Holly slide the core sampler into the water, probing for the bottom. Then Torstein lifts up on his toes, hunches his shoulders and shoves down hard on the push rod, grunting, as the tube punches down through the mud. Bowers leans over the water, holding the tube steady, and next to her Arnold kneels on the gunnel pulling steadily on the rope, slowly dragging the piston plug up through the core. Inside the pipe, the plug creates a vacuum, holding the sediment in place, much



Captured in a core, pollen grains and seeds, diatoms and phytoplankton all signal changes that have taken place on land and in the water. This schematic lists some of the data that Brush has found in samples in the upper Chesapeake and the shifts they reflect.

What plants and animals were in the water twenty years ago — or a thousand? Poring over sediment cores, Grace Brush has unearthed vestiges of what was once abundant in the Bay and its watershed, from diatoms to dinoflagellates, along with clear evidence of the great land clearing that followed European colonization. Photo courtesy Johns Hopkins University.



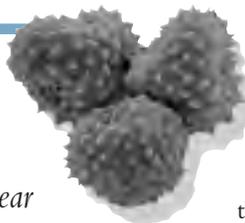
like a finger over a straw. Down below the dark water, the tube sinks into the bottom, slowly filling with sediment.

These sediments down along the bottom of the Chicamacomico could hold seed beds for future *Pfiesteria* blooms. *Pfiesteria* is one of several algal and dinoflagellate species that can drop out of the water column, switch into a cyst form and then wait in the sediment until the conditions are right to emerge again. Along the New England coast, a species called *Alexandrium*, a cause of paralytic shellfish poisoning, moved down from the northern Gulf of Maine to create seed beds along Cape Cod. In the Gulf of Mexico, *Gymnodinium breve*, a cause of neurotoxic shellfish poisoning, forms seed beds along the shores of Texas and Louisiana.

On September 13, 1997, this stretch of the Chicamacomico was the scene of some kind of toxic bloom followed by other kinds of disturbing results. On a warm, windless morning, seven state workers arrived in Drawbridge to find a heavy mist rising off the river and hundreds of thousands of fish swimming erratically, most of them menhaden. When three of the workers went out in a boat to take fish trawls, they found red lesions on every fish they hauled out. Whether *Pfiesteria* could be causing these lesions is a question still hotly debated, with some fish pathologists naming other bacterial and fungal species as the likely culprits behind lesions like these. Nevertheless, all the water samples taken that day would show *Pfiesteria*-like organisms in large numbers.

What happened next was later documented in the *Journal of Toxicology and Environmental Health*. Most of the workers at the river that morning were quickly struck with flu-like symptoms — including four workers who never went out on the water. While standing on the bridge, they apparently inhaled toxins that were rising off the river during a bloom event. The immediate symptoms included burning eyes for four of the workers and headaches or sore throats for six. Within the next three days, four workers also

Brush published groundbreaking research showing that ragweed pollen left a clear signal in estuaries, a signal that could be used to date historic land changes in the Chesapeake.



reported unusual exhaustion and mental confusion. Six of the seven suffered crampy abdominal pain, nausea or diarrhea. Could this kind of bloom event leave a seed bed behind?

The three young scientists slowly haul up Brush's core sampler, then heave the dripping pipe up out of the river and aboard the skiff. In the lower half of the tube they can see about two feet of unbroken sediment. The sediment sticking out of the bottom looks like a dark goulash flecked with rust-colored bits of grass.

Arnold kneels quickly and with her hand seals the tube until her boss can pop a red plastic cap on the bottom. Then more muscle work as the young Norwegian yanks and yanks on the rope running down through the tube, working the piston plug up the pipe, pulling up against the vacuum. When it finally pops, he gets a quick whiff of that marsh-rot stink familiar to field workers who go mucking through wetlands. Arnold quickly caps the top and Bowers wraps both ends with duct tape. While Grace snaps photographs of the site, Arnold labels the tape.

When Brush first began picking through her early cores, she found seeds and pollen in great numbers, often hundreds in a single centimeter of mud. They had been blown into the river by wind or washed in by rain. Instead of taking root as trees or plants, these seeds settled into the sediments, leaving a layered record of the trees and vegetation that once had covered the land. But how ancient were these seeds? The great puzzle was how to

put dates on all the layers in her cores.

Ragweed pollen provided one of her breakthroughs. When Brush worked her way through her core samples, she would find — at certain levels — sudden jumps in ragweed counts. Anyone with the right kind of allergies knows that ragweed pollen in the air can lead to swollen sinuses, itchy eyes and sneezing fits. The weed itself is an opportunistic plant that grows fast in broken ground, whether it be plowed farm fields or urban construction sites. Although there's a lot of ragweed around in modern life, there was probably little around to bother Native American hunter-gatherers. When she found those sudden jumps in ragweed counts in her cores, Brush was looking at a signal left by the first large-scale clearing of the land. European settlers had arrived and with their axes and hoes had left their signature on the new land and on the sediments in its waters. Those clumps of pollen gave Brush a piece of core she could point to and put a date on. She had found her first "event horizon" in the mud.

There would be other key horizons: the first use of plowing, the first use of chemical fertilizers, massive deforestation for large-scale grain farming, reforestation on abandoned farmland, the disappearance of chestnut trees, even the testing of nuclear weapons (the cesium horizon). All these eras left their marks in the mud, marks that could be dated. The simpler techniques included counting pollen; the more complicated included measuring the decay rates of radioactive isotopes. Once she could time-date several horizons, Brush could begin calculating sedimentation rates for different eras of history in different parts of the Bay.

Core by core, paper by paper, Brush slowly built a reputation as a pioneer in Chesapeake Bay science. Geologists had already been using sediment cores for decades to study the ocean and search for oil. And scientists had already begun using pollen patterns in sediments of lakes to reveal the history of land-use

changes in the upper Midwest and elsewhere. What Brush did was pioneer that approach in the Chesapeake, persisting in the face of early doubts about its usefulness here. An estuary, after all, is not a lake. Since river waters are mixing with ocean waters in an estuary, sediments could be washing out to sea. If not, they could be unreadable as a result of mixing by tidal flux and resuspension and general bioturbation. “No one thought that the estuary could be used for this type of work,” says Brush.

But with the findings from her cores, she was able to publish groundbreaking research showing that ragweed pollen left a clear signal in estuaries as well as lakes. According to the late Don Pritchard, a pioneer in Bay oceanography, her early results surprised her colleagues by showing “how much we can learn by looking at the bottom.” Her ragweed signal, he said, would help establish dates for historic changes in the watershed — both on the land and in the Bay. “That is just a great marker. It is just wonderful to use that,” explains Thomas M. Cronin, leader of new sediment coring project by the United States Geological Service. “She was the first to do this type of work in the Chesapeake Bay.”

And she found a lot more than seeds and pollen in her cores: there were microfossils of diatoms and dinoflagellates, copepods and cladocera — good evidence for the phytoplankton and zooplankton food webs once found in these waters. Also in the mix were fossil pieces of the Bay’s early bottom dwellers, from worms to clams and oysters and underwater grasses. Over three decades and 300 cores, Brush has been writing a first draft of the history of environmental change in the Chesapeake.

For centuries, the greatest force for change was climate. In the sediments



SKIP BROWN

The DNA of Pfiesteria shows up on a gene probe developed at the Institute of Human Virology. Holly Bowers checks the photo of a DNA gel for evidence of Pfiesteria in the Chicamamico River.

Brush found shifts in animal and plant populations that corresponded with climate swings like the Warm Medieval Period which lasted from 900 to 1200 A.D. and the Little Ice Age which followed it. Beginning with European settlement, human life on the land began, slowly at first, to force changes in the water. “The core records show that early agricultural activity had very little effect on the sediment,” says Brush “The first farming was simply clearing some forest, girdling trees and planting tobacco in hills as the Indians had planted corn. It was later when people were shifting to grain farming and crop rotation that soil erosion in the estuary began to really increase.” As more farmers cut down trees and plowed up the soil, sedimentation rates would double, then double again. In the upper fresh-water reaches of the trib-

utaries, the rates could run ten times higher than in pre-Colonial years.

And that changed everything. With increased sedimentation, dozens of shipping ports began to silt up. Bay waters became darker, letting less light through to bottom grasses. With the decrease in forest cover came a decrease in diversity of phytoplankton, the floating plants that form the base of the Bay’s food webs. With heavy use of fertilizers, underwater grasses actually increased at first, especially in the upper reaches of the Bay, only to decline and nearly disappear during the 1970s.

In her cores, especially in the diatom records, Brush and former graduate student Sherri Cooper found clear evidence of the most powerful change of all: the shift from a system dominated by bottom-dwelling plants and animals to one dominated by floating plankton. Phytoplankton declined in species diversity but increased dramatically in total numbers, and that increase altered the dynamics of the system. Fed by fertilizers

and animal waste and sewage, the annual blooms of phytoplankton were blocking much of the sunlight needed by bottom grasses, a key habitat for small fish and crabs. With blooms now exceeding the grazing rates of zooplankton, large die-offs of phytoplankton were sucking oxygen out of the water column, leaving in the sediments a record of anoxia that Brush and Cooper were able to document in their cores. Oysters, clams, worms, underwater grasses, even migratory fish could no longer flourish in these dark dead zones that were spreading now along the bottom of the Bay. Bottom populations kept declining, and floating populations kept increasing, especially algae and dinoflagellates.

The clouds sloshing across the skies finally unleash their rain on the Chica-

macomico. A light shower drifts along the river first, sprinkling Brush and her crew as they try and fail to punch a fifth core sample down into a hard patch of bottom. In brackish waters like these, Brush tries to bring home five or six tubes to make sure she gets one coherent core sample. At the boat ramp, the rain lets up while the scientists unload their long tubes, then a drenching rain hammers down as they head home in their blue van along slickening roads, wipers flicking.

The lab findings from these rainy-day cores are puzzling. Back at Johns Hopkins, Arnold and Bowers go to work, looking for DNA and dates for *Pfiesteria*. They slice each core lengthwise, crack it open to examine the stratigraphy, then work down the split core, cutting matching one-centimeter slices. After Bowers drives her samples across town to David Oldach's laboratory at the Institute for Human Virology, she is able to detect *Pfiesteria* DNA in only one core out of four from the Chicamacomico.

With that news, Arnold and Brush go back to their samples from that same core, trying to figure out the dates for those first appearances of *Pfiesteria*. After eyeballing and counting grains and seeds, Arnold is able to date one pollen horizon around 1700 and another around 1880. The *Pfiesteria* DNA, however, is almost right at the top of the core. That's puzzling because many scientists believe a creature as complicated as *Pfiesteria*, with multiple life stages and complex feeding strategies, must have an ancient evolutionary history. The *Pfiesteria* "horizon" in these first Chicamacomico cores, however, is so recent it looks like *Pfiesteria* just showed up yesterday.

There are similar results from other waters. Brush and her collaborators find the DNA of recent *Pfiesteria* in one core from the Pocomoke, one core from Indian River Bay in Delaware and one core from the middle of the Chesapeake Bay. This last core, donated by Thomas Cronin's group at USGS, holds over 20 feet of sediment, reaching back 18,000 years into the age of the last glaciers.

With this, their longest core, they test 14 separate slices, taken every 10 centimeters, back down to 1860 and slightly beyond. But *Pfiesteria* shows up only twice: at the 1980 level, and then once again at the 1940 level.

From these first cores, it is clear *Pfiesteria* was around before the recent explosion in industrial chicken farming — but possibly not in great abundance. Brush doesn't want to read too much into these early findings. "When it doesn't show up, it doesn't mean that *Pfiesteria* wasn't there," she says. On their longest core they tested only 14 slices out of the last 150 years, roughly a 1-in-10 sampling. If they could afford to test every centimeter, an expensive proposition, *Pfiesteria* DNA might show up in more of those untested, in-between slices. So far, however, it is proving somewhat easier to find *Pfiesteria* in recent rather than in ancient sediments.

And those recent sediments may hold other troublesome species. Since the *Pfiesteria* episodes of 1997, a number of other, sometimes-toxic species have been discovered in the Bay for the first time. The Bay is now home to microorganisms like *Chattonella*, a red-tide algae that caused fish kills in Japan and Norway; *Microcystis*, a cyanobacteria that forms a blue-green algae scum that makes animals sick; and *Dinophysys*, a dinoflagellate that caused oyster bed closures in the Potomac in 2002. Oldach's lab is already developing a gene probe that will test for the DNA of *Chattonella*, a test that could be later be applied to Brush's archive of *Pfiesteria* cores.

Brush and her young collaborators may end up documenting yet another subtle shift in the changing ecology of the Chesapeake. As they work these new cores, their goal is to analyze how changes in land use affect water quality and alter dinoflagellate communities (including *Pfiesteria*). Her earlier cores helped verify the historic shift from a Bay system once dominated by bottom dwellers to one now dominated by floating plants and fertilized by heavy nutrient

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Chesapeake Bay

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inflows. Her recent cores could show whether all those floating species and nutrients are supplying food and energy for toxic blooms, allowing species once scarce to flourish in the contemporary Bay. Then Brush, the persistent pioneer, will have written yet another new chapter in her history of environmental change in the Chesapeake. ♡

PROFILE

THE CORE OF A LIFE

BY MICHAEL W. FINCHAM

There are four scientists in a small boat on a rainy day on the Chicamacomico River — and three are women. That may be more common now, but it was rare when Grace Brush began her career. She became a scientist in an age when women were not encouraged to enter science and were seldom supported by fellowships, grants and assistantships. Her career, like one of her classic sediment cores, was laid down in layers — uneven, interrupted layers that show some of the changes in the social ecology of science.



PHOTO COURTESY GRACE BRUSH

Brush's career, like one of her classic sediment cores, was laid down in layers — uneven, interrupted layers that show some of the changes in the social ecology of science.

She came into science sideways. A native of Nova Scotia, the petite redhead graduated from a small college in Antigonish with some coursework in plants and paleontology, but a degree in economics. With that background she was able to land the unlikely position of lab assistant in a small coal geology laboratory in Nova Scotia. “My job was to make thin sections of coal and keep things clean,” she says. As she was making slides, she looked through the microscope and saw structures caught in the the coal. Digging into the research literature, she realized she was looking at the remnants of ancient spores. “So I asked my bosses if I could study them,” says Brush. “And they said sure — in between making thin sections.” From her part-time studies she was able to show how fossils could be used to identify which coal seams were best for mining.

That work kicked off her long academic odyssey. The Canadian Geological Service quickly sent her off to the University of Illinois for graduate work in coal paleobotany and just as quickly Brush discovered that her intellectual love was going to be evolutionary paleobotany. She returned to Nova Scotia to help set up a new laboratory, then headed off to Penn State where she discovered that her romantic love was going to be Lucien Brush, another graduate student. They married and then, like a lot of graduate school wives in the 1950s, she took her husband's name and began following him around from college to college and job to job.

When the newlyweds both applied to Harvard for doctoral

work, Brush found that being a wife could be an even bigger drawback than being a woman. A wife, so the thinking went, was probably not going to be a serious scientist. “Most of the people at Harvard weren't going to put all the time and effort into training some woman who would not continue in the field,” explains Brush. “It was a logical sort of thing at the time.” On the basis of her work in Canada, however, Brush was accepted and mentored by Elso Barghoorn, a paleontologist famous for discovering evidence of the earliest life on earth. “Barghoorn did not distinguish between the scientific capabilities of men and women,” says Brush.

“He accepted me as a graduate student, and I have always felt a deep loyalty to him.”

By earning a Ph.D. in science in 1956, Brush had already done something unusual for the era. In 1960, women received only 6.3% of the 6,000 Ph.D.s awarded in science and engineering by American universities. And many of those newly degreed women would have trouble finding full-time jobs or tenure-track positions in academe. A widely-cited study from 1975 found that women in science faced “a triple penalty.” They first had to overcome barriers to entering science. Then they had to live with the psychic fallout — like self-limited aspirations — that can result from perceived discrimination. And finally women had to struggle with actual discrimination in finding funding, fellowships and jobs.

With their new Ph.D.s from Harvard, Lucien and Grace made a hard pact about work and marriage. “We would go wherever Lucien would get the best job opportunity, but I would always be able to keep up my interest,” says Brush. “Basically I wanted to do paleobotanical work.” The logic behind the pact was practical. “With a family, someone has to be the major bread winner,” she says. “Someone has to be the most competitive person in their area — or nobody is going to win out in the job arena.” Lucien would find jobs at the U.S. Geological Service, the University of Iowa, Princeton, and finally Johns Hopkins University in Baltimore. And Grace would follow, looking for part-time jobs and research support, struggling

Using paleoecology, Grace Brush has led the way toward a deeper understanding of how the Chesapeake has changed over time. In her career, she has also helped to close the gender gap — when Brush received her doctorate in 1956, only a small fraction of American Ph.D.s in science and engineering went to women, compared to 32 percent in 1995. Photo by Skip Brown.



AT THE Maryland Sea Grant

If you stare at it long enough under a microscope, a grain of hickory pollen looks a lot like a basketball, an old ball beaten out of round from too many bounces and dotted with a nubby grain that's nearly worn smooth. Oak and willow look like collapsed basketballs, gone shapeless and airless. But ragweed, round and spiky, looks like trouble. You can look at it and start sneezing.

Angie Arnold, a 25-year old grad student, spends most of her work time sitting at microscopes, endlessly eyeballing tiny round shapes that could be oak or willow or hickory pollen that has been buried in the bottom of Chesapeake Bay for decades or centuries. Working with her advisor Grace Brush, Arnold extracted the pollen from sediment cores holding hundreds of years of Bay mud. She keeps a sharp watch for ragweed in particular because ragweed pollen — an irritating allergen for most people — can also be a sign of large-scale land clearing. It's a key to dating these cores and correlating changes on the land with changes in the Bay. This pollen has left a record in the sediment, and Brush and her students are using that record to assemble an environmental history of the Bay.

Even before she became a grad student, Arnold had already left a record of her own in the history of Johns Hopkins University. As a four-year starter at point guard and shooting guard for the women's basketball team, she played more minutes, made more free throws and handed out more assists than anybody before her. She also ended up second on the all-time list of scorers, averaging 15.5 points per game for her four-year career.



Hickory

to make progress in her work amid all the interruptions from moving, marriage and children.

The results were mixed. At the University of Iowa, for example, she immediately got a half-time faculty position, even though she was now a mother. “No questions asked about man or woman,” says Brush. “It was a wonderful chance, I could work part time, I had children, I could get research money.” When the couple moved back east to Princeton, however, her reaction was culture shock. “There were no women students or faculty whatsoever,” laughs Brush. “And some people were surprised that a wife would want to pursue an independent career.” When she was finally given laboratory space, she surprised people again by including salary money for herself on grant proposals. “I said I needed money to pay for baby sitters.”

For Brush, a dogged persistence was clearly one of the keys to overcoming the “triple penalty” women faced in science. “In order to get what you need to pursue a scientific career, you had better forget you are a woman,” she says. Though there were often suspicions about the commitment of women scientists, “subtleties in the atmosphere,” she tried not to see them. “If I’d let that become a factor, then I’d have withdrawn from the research I loved so much.”

The marriage pact produced early career frustration for a young woman so persistent about her science. “I resented it some of the time. I thought why am I doing this,” she admits. “But this was an agreement we made — and I’m glad we stuck with it.” The payoff included a 40-year marriage, three children and a career that would redeem her old mentor’s faith in her — a triple play as rare in science as in baseball. Planted finally at Johns Hopkins, at first with part-time support, she began building her reputation as a pioneer in the paleoecology of Chesapeake Bay. At Hopkins she moved from part time to full time, mentoring men and women and winning teaching awards. In 1990 she was finally promoted to tenured full professor. In 1994 her husband and long-time intellectual partner died from lung cancer.

How much has the world changed since Brush began her career? Perhaps not as much as you might expect — at least according to a recent report by the National Academy of Sciences, titled *From Scarcity to Visibility*. The big change is that women in 1995 were earning 32 percent of the Ph.D.s in science and engineering. That’s a huge jump from the 6.3% awarded back in 1960. And by 1995 women were holding over 30 percent of the faculty positions in many fields. “In terms of hiring, it certainly is a lot different,” says Brush. “Opportunities are made available to women.” For a number of years, organizations like the National Science Foundation, private foundations and many universities have been sponsoring gender-based programs to help new women scientists with funding, fellowships and mentoring.

There’s a reason for all those programs, however. According to the National Academy of Sciences, women still lag behind men in competitions for research assistantships, lab space, tenure-track jobs and salary raises. They are less likely to hold full-time jobs and more likely to leave science, often out of “self-discouragement.” Scientists who study gender disparities write about factors like the scarcity of women mentors, the prevalence of male-dominated professional networks, and a science culture that stresses “masculine” values like competition over “feminine” values like cooperation. According to the Academy report, the “triple penalty” is still in play, though not as strongly, for women in contemporary science.

Women are also more likely to carry most of the responsibility for child-raising, a common interruption of the degree track and the tenure track. And for Brush and many other researchers, that remains the issue that most complicates life for a woman who would be a scientist. “Sometimes I think we’ve come a long way, and sometimes I’m not sure how far we’ve actually come,” says Brush, “because when it comes to providing women support for child raising, it is still very, very difficult.”

TOP OF HER GAME

Fellow Scores at Science BY MICHAEL W. FINCHAM



SKIP BROWN

That's a lot of points for someone who played mostly point guard, but Arnold deflects any compliments. "Once you look at how much I shot," she laughs, "you say she should be scoring a lot."

In her senior year, she scored a lot when it counted the most. In the middle of March Madness, the annual basketball playoffs of the National Collegiate Athletic Association, she led her team into the Sweet Sixteen all the way to the Elite Eight. In her last college game Arnold went out big, counting 27 points on 10-for-18 shooting. A



Oak

week later, she got a compliment she couldn't deflect: She was named the best woman player in America under 5'6" by the Women's Basketball Coaches Association.

Early in her graduate career, Arnold found a new game, paleoecology, and a new coach, Grace Brush. And soon enough she won a new award, a Mary-

land Sea Grant Research Fellowship. Sea Grant Research Fellows receive a stipend, tuition remission and training under scientists working on Sea Grant projects. The scientists, in turn, get help with field and lab work. Over the last 25 years, Maryland Sea Grant has funded the graduate work of dozens of degree-seeking students, many of them women.

Grad students, of course, handle much of the grunt work in most research projects — and marine science is no exception. For the last four years Arnold's job has been to trek out with Brush and haul up sediment cores from the rivers, marshes and mainstem of the Bay; back in the lab, she helps crack open the cores and then sits down to the long labor of figuring out what's buried in the old mud. In each core there can be thousands of remnants and hundreds of species, ranging from trees, grasses and

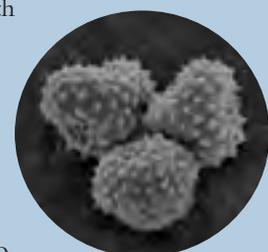


Willow

weeds to algae, diatoms and dinoflagellates. She has to put a name on those odd shapes, at least to the genus level when she can, and then count them. Next to her microscope are her key reference sources: the publications and Ph.D. dissertations of graduate students who sat at these scopes before her. Scientific knowledge, like sediment, accumulates over time.

These are time-consuming tasks, but they are only the pre-game warmups. Like a point guard running down court hoping to shoot, a scientist who wants to score in the research game has to see the patterns at play in the data unfolding in front of her. In core slices from the Chester River dated circa 1700, Arnold has been seeing some provocative patterns among one-celled protists down at the bottom of the food chain. She found that high-salinity species were declining at the same time that fresh-water species were increasing. "This change of species," she says, "suggests changes in runoff, more fresh water coming in." Out of all that digging, eyeballing and data crunching, Arnold is slowly crafting her own dissertation on some of the historic changes in the food webs of the Chesapeake.

For Arnold, it's now late in the grad-school game. With comps out of the way, she's focused on finishing her dissertation, finding a job and planning a wedding. She hopes to work in environmental restoration, perhaps with a consulting company that pays better than a fellowship. Her other game plan is to find a teaching/coaching job that could combine her first love (basketball) with her second (environmental science). Last winter, in the middle of her research, she still managed to moonlight as assistant coach with the women's team at Johns Hopkins. As she works away at her microscope, somewhere in the back of her brain, a basketball is still bouncing. ✓



Ragweed

MENTORING TOMORROW'S SCIENTISTS

This summer marks the fourteenth year of Maryland Sea Grant's undergraduate fellowship program, an effort that has brought college students from Maine to Hawaii to the Chesapeake Bay to participate in marine research. Supported by a grant from the National Science Foundation, the Research Experience for Undergraduates (REU) program pairs students with scientist-mentors at three estuarine research labs, the Horn Point Laboratory and the Chesapeake Biological Laboratory — both part of the University of Maryland Center for Environmental Science — and the Academy of Natural Science Estuarine Research Center.

The National Science Foundation began the REU program to provide undergraduates with a realistic sense of the scientific enterprise — the aim was to have them work in research labs with senior scientists as a way of promoting graduate education in the sciences. At the same time, NSF encouraged participation of women, minorities and the disabled. While participation in Maryland's program by minorities — African-Americans, Hispanics, Native Americans — and the disabled has been limited, that is hardly the case for women. Female applicants have outnumbered male applicants two to one, as has their participation.

Why so many female applicants? Many students applying for fellowships are biology and environmental science majors, which include a preponderance of women. At the same time, Sea Grant has worked to recruit undergraduate applicants in chemistry, physics and mathematics.

The REU program gets students out of the classroom and into an intense research environment. Working with their advisors, they develop a specific research

project and, at summer's end, present their findings in a seminar and research paper. Projects range over diverse issues related to the Chesapeake, among them, estuarine processes, chemical contaminant cycling, fisheries, physical oceanography, the benthic environment and submerged aquatic vegetation.

Nearly 175 students have now participated in the Maryland Sea Grant program, 110 of them women. Over these years, quite a few students have co-



ALEXANDER ZORACH

Summer 2002 REU students pose before the orientation cruise at the beginning of their fellowships.

authored peer-reviewed papers and presented their findings at national scientific meetings. During this time, NSF reviewers have given high ratings to the Maryland program, which began with 10 students in 1989, then was awarded funding to support 12 students each summer, and beginning in 1999, 14 students. This summer is the first of another three-year award.

The summer fellowships have proven a key influence for many students who have gone on to graduate school in marine and environmental sciences. Jim Hagy, an REU student in 1990, for example, returned to the Chesapeake Biological Laboratory and recently completed his doctorate and is now at the EPA Gulf Breeze Laboratory. Jill Stevenson, an REU student with Jeff Cornwell at the Horn Point Laboratory,

came to CBL to work with David Secor, received an M.S. in fisheries, then went on to work at the National Ocean and Atmospheric Administration; she is now Deputy Director of Fisheries at the Maryland Department of Natural Resources.

"The REU program was a huge influence on the career path I decided to pursue," says Krista Karlsson, a 1996 fellow from George Washington University who went on to graduate studies in fisheries at Louisiana State University. "It helped me focus my interests in marine science. My advisor Dave Secor and his tech were both major influences on my development as a researcher." Karlsson's comments typify those of most REU students who were surveyed several years after they finished their undergraduate degrees.

Numbers of former fellows have completed or are pursuing Ph.D.s, though it remains too early to assess the direct

effects that REU programs such as Maryland's have on improving the chances of academic careers for women.

For more about the REU program, student fellows, their projects and publications, see www.mdsg.umd.edu/Education/REU or contact Dr. Fredrika Moser, 301.403.4229, x 16.

REU 2002 Student Fellows

Paul Allen, Salisbury University. Mortality Index Determination for Eastern Oyster, *Crassostrea virginica*, Seed Transport. Advisor: Donald Meritt, HPL.

Sarah Bjork, University of Maryland College Park. Effects of Osmotrophy on Growth and Pigmentation in *Storaetula major*. Advisor: Hugh MacIntyre, HPL.

Elizabeth Day, Hampshire College. The Effects of Contaminated Sediments on Energy Allocation and Phenotype Diversity in the

- Grass Shrimp *Palaemonetes pugio*. Advisor: Chris Rowe, CBL.
- Carrie Fleming, University of Kentucky. The Effects of Toxicity on Microzooplankton Grazing of the Dinoflagellate *Karlodinium micrum*. Advisor: Diane Stoecker, HPL.
- Kelly Kearney, University of Miami. A Model for Nutrient Pathways in the Choptank River. Advisor: Bill Boicourt, HPL.
- Elisabeth Kittredge, Mount Holyoke College. Biogeochemical Cycling in the Seagrass Bed *Thalassia testudinum* in Florida Bay and *Zostera marina* in Chesapeake Bay. Advisor: Michael Kemp, HPL.
- Lisa Malkiel, University of Maryland College Park. The Impact of Food Concentration, Organism Density, and Chemical Facilitative Cues on the Feeding Mode and Growth of *Macoma balthica*. Advisor: Roberta Marinelli, CBL.
- Keith McCullough, Savannah State University. The Effect of Bivalve Suspension Feeders (*Mercenaria mercenaria*) on Zooplankton Dynamics in Mesocosms with Tidal Resuspension and Realistic Water Column Turbulence. Advisor: Elka Porter, CBL.
- Polly Squires, Utah State University. Heat Shock Expression in *Zostera marina* (Eelgrass) Placed in Different Stressful Water Temperatures. Advisor: Ian Davison, ANSERC.
- Sarah Stein, University of Vermont. The Demise and Recovery of a Seagrass Habitat following a Barrier Island Overwash. Advisor: Evamaria Koch, HPL.
- Timothy Tefteau, Salisbury University. The Use of Stable Isotopes to Determine the Uptake of Cadmium from Three Different Uptake Pathways on the Estuarine Fish *Fundulus heteroclitus*. Advisor: Fritz Riedel, ANSERC.
- Lee von Kraus, Vassar College. Relative Significance of Suspended Sediment and Predation in the Shaping of *Acartia tonsa* Vertical Distribution/Migration Patterns. Advisor: Marie Bundy, ANSERC.
- Marissa Yates, Massachusetts Institute of Technology. Characterizing Suspended Sediments in the Estuarine Turbidity Maximum Zone of the Chesapeake Bay. Advisor: Larry Sanford, HPL.
- Alexander Zorach, Oberlin University. Ascendancy as a Quantitative Measure of Complexity. Advisor: Bob Ulanowicz, CBL.

Newsletter Focuses on Research and the Bay



A new publication, *Healthy Chesapeake Waterways*, brings together information about watershed population, land use, and how research and scientific monitor-

ing are being applied to further our understanding of Bay processes that can be employed for resource management.

The handsome, four-color, bimonthly newsletter is produced by the Integration and Application Network (IAN), an initiative of faculty members at the University of Maryland Center for Environmental Science. IAN got underway in 1999 with the goal of synthesizing scientific knowledge across disciplines so that it could be used for addressing issues that are critical for management of the Chesapeake Bay and its watershed.

The intent of IAN is to link academics, resource managers and environmentalists together in order to inspire, manage, and produce timely syntheses and assessments on key environmental and natural resources issues.

In addition to its newsletter, IAN will undertake projects that include providing web access to GIS data, producing a software program for creating visual concept diagrams, issuing a report card on the ecosystem health of the Chesapeake and developing an eChesapeake web portal.

For a free copy of *Healthy Chesapeake*

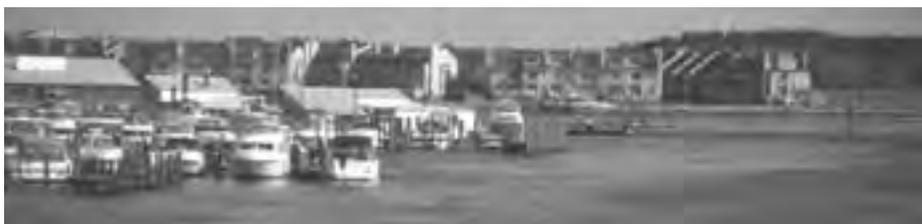
Waterways, contact Kirsten Frese, UMCES, by e-mail, kfrese@ca.umces.edu, or phone, 410.228.9250, x 614. For information about the IAN network, visit the web at <http://ian.umces.edu>, or contact Dr. William Dennison at dennison@ca.umces.edu or 410.228.9250, x 608.

Documentary Wins Emmy

In June, the Capital Region of the National Academy of Television Arts and Sciences awarded an Emmy for best long-form documentary to *The Pfiesteria Files*, a one-hour Maryland Sea Grant documentary directed by Michael W. Fincham. Co-produced with Maryland Public Television, the documentary examines the "Pfiesteria hysteria" that gripped much of the mid-Atlantic in 1997 during the September fish kill season. When the toxic microbe *Pfiesteria* was blamed for sick fish and sick people along three Maryland rivers, it kicked off political controversies, media wars among newspaper and television reporters, and an expensive science race to identify toxic blooms in the Chesapeake.

The Academy is a nonprofit professional organization serving the Maryland, Virginia and Washington D.C. television community. The Emmy Award is the industry's benchmark for the recognition of television excellence.

The documentary also received first place in its category from the Outdoor Writers Association of America. The award was presented in Charleston, West Virginia, also in June.



SKIP BROWN

Solomons Biathlon

Tenth Annual Solomons Island Biathlon, UMCES Chesapeake Biological Laboratory, September 28, Solomons, Maryland. The Biathlon is an event for competitive racers, recreational athletes, families, and those who love the outdoors. Proceeds from the Biathlon provide scholarship funds for graduate students who work on Chesapeake Bay-related environmental problems. Participants bike from the Lab at Solomons to Calvert Cliffs State Park (6.7 mi.), walk or run through forests and alongside marshes to the Chesapeake Bay and back (~4 mi.), and bike back to Solomons (6.7 mi.). For more information, call 410.326.7214.

Estuarine Conference

Atlantic Estuarine Research Society Fall 2002 Meeting, October 10-12, St. Mary's City, Maryland. A half day-workshop

focusing on submerged aquatic vegetation (SAV) restoration will precede evening registration check-in on the 10th. It is limited to 10 participants — those interested should check the AERS web site, www.vims.edu/AERS. The conference will include a welcome social, scientific papers and posters, and a banquet cruise on the St. Mary's River on the final day of the meeting. Registration is \$70 for members and \$50 for students. For more information, visit the web site or contact Dr. Bob Paul at rwpaul@smcm.edu.

Environmental Journalism

Twelfth Annual Conference of the Society of Environmental Journalists, October 9-13, Baltimore, Maryland. Among the topics for discussion will be Chesapeake Bay restoration and research, Maryland's smart growth efforts and environmental justice and health. For conference details, visit the web at www.sej.org/confer/index1.htm.

Shellfish Conference



Sixth International Conference on Shellfish Restoration (ICSR '02), November 20-24, Charleston, South Carolina. As part of a global commitment to

reviving degraded ecosystems, the conference will provide an opportunity for local, state and federal government officials, resource managers, users and residents to discuss approaches to restoring coastal shellfish ecosystems through remediation and pollution abatement, habitat restoration and stock enhancement.

The conference will feature invited keynote presenters, panel sessions and contributed posters along with case studies of successful projects with opportunities for roundtable discussions.

For more more information, visit the web at www.scseagrant.org/icsr.htm or contact Elaine Knight at 843.727.6406 or Elaine.Knight@scseagrant.org.

Chesapeake Quarterly is also available on the web at www.mdsg.umd.edu/CQ

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