CHESAPEAKE QUARTERLY

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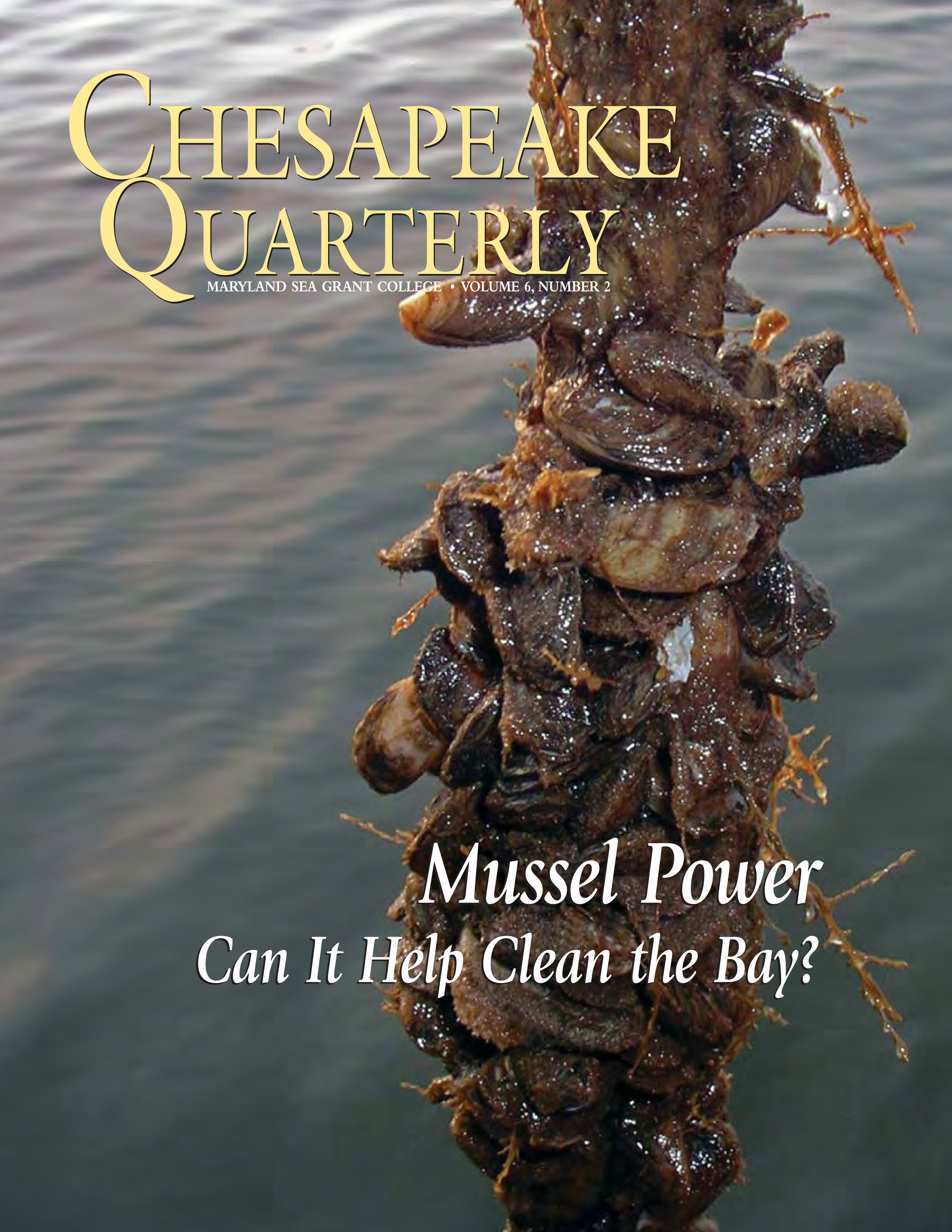

Mussel Power

Can It Help Clean the Bay?

contents

Volume 6, Number 2

CHESAPEAKE QUARTERLY

October 2007

Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed.

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Cover photo: *Clinging to any free surface they could find, dark false mussels encrusted ropes like this one in the summer of 2004, when a bivalve explosion took the Magothy, South, and Severn rivers by storm.* PHOTOGRAPH BY PETER BERGSTROM.

Photo, opposite page: *Waving graceful tentacles, this anemone occupies a nook of an artificial reef, only one of hundreds of inhabitants there.* PHOTOGRAPH BY ADAM FREDERICK.

Quote, opposite page: (Paragraph 3) From "Poached Oysters," *Harper's Monthly Magazine*, March 4, 1884; Ruley Covington, "I Remember Oystering in the 1890s," *Baltimore Sun*, March 7, 1971 in Wennersten, John. *The Chesapeake: An Environmental Biography*. Baltimore: Maryland Historical Society, 1971.

Collateral Damage We Can't Afford

We mourn the loss of the Bay's oysters, of their ecological prowess and of the way of life they made possible. We mourn the loss of the Bay's great fisheries, of 100-lb sturgeon that once cruised these waters and shad that migrated up the Bay by the millions.

We don't mourn the less charismatic creatures — the sea squirts, worms, mussels, and clams. The other filter feeders that lived in the crevices of oyster reefs and the bottom-dwellers that lived in soft sediment, they too have declined in diversity and abundance, along with the health of the Bay. But we don't miss them like we miss the oysters.

The oysters went noisily, amidst conflict and gunfire. Their loss was felt with deep regret. One waterman reflected in the late 19th century, "If I had a chance to live my life over again, I guess it would be out on the water with the gulls when the sun come up on a boat, wheeling, and whipping around for another pass across a bed where the oysters used to come up as big as a man's hand."

The others, those creatures of the benthos, were the civilian casualties of the oyster wars, of urbanization and pollution. They left quietly, their absence as inconspicuous as their presence. We don't even know exactly what species once thrived in great abundance. We've only been keeping tabs recently, our records reflecting times of scarcity, not of bounty.

During a recent visit to the National Museum of Natural History, I was struck by a diorama showing the creatures of the Burgess Shale as they might have looked living in ancient seas. The display showcased a living reef structure, reconstructed from fossils found in the Canadian Rockies in the early 1900s. Every nook and cranny was filled with life, the bottom of the ocean carpeted by ancient starfish-like crinoids and wriggling with crustaceans.

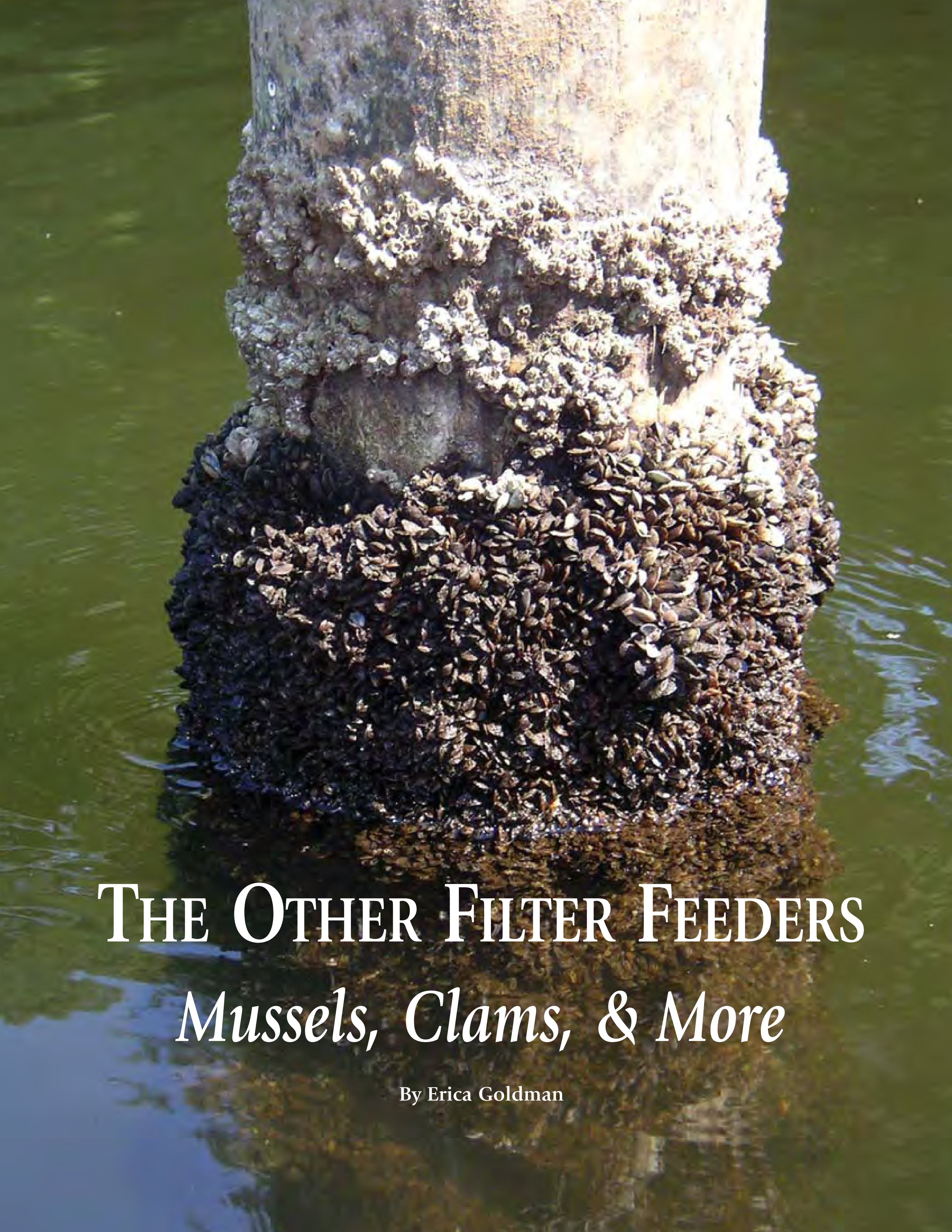
Did the Bay's oyster reefs once look like this? While historical reconstructions and maps of oyster reefs in the Chesapeake offer clues to the shape and extent of these structures, we know comparatively little about those animals that lived among the oysters and those that thrived in and on the bottom of the Bay.

We've lost more than we ever knew we had. We'll never know for sure what role these other species played in the ecology of the Bay of the past, how they may have helped to keep the waters clear. Today's Chesapeake is a changed place — a product of human engineering, intended or otherwise. The Bay's ecology has been sculpted by years of harvest, use, and often abuse.

The Bay of the future will also be shaped by acts of engineering, its ecological state reflecting choices that we make to restore or deplete aquatic resources and to develop or conserve surrounding land. We're trying as hard as we can to bring back the native oyster, and we're even considering introducing a non-native one. We're trying to spawn the great ancient sturgeon, hoping to restock the rivers with young fish raised in hatcheries. But we rarely think about mussels, sea squirts, clams, and worms. We keep some track of their comings and goings through surveys, but they've largely fallen to the sidelines of any active restoration plans.

If our goal for the Chesapeake is cleaner waters and healthier fisheries, perhaps these less glamorous animals could lend a hand, assisting oysters with the monumental task of filtering the Bay's murky water. For the Chesapeake's one species of oyster, there are dozens of other species — mussels, clams, and more — each equipped with a similar strategy for feeding, one that removes algae from the water column. Perhaps the oyster will always reign supreme among filter feeders. But aren't the others worth a closer look?

— Erica Goldman



The Other Filter Feeders

Mussels, Clams, & More

By Erica Goldman

As Peter Bergstrom wades into Old Man Creek, he's grateful he's wearing neoprene socks. Calf-deep in the chilly water of early spring, he floats his blue kayak just past the ramp at Stewart's Landing in Severna Park, Maryland and climbs in carefully, tucking his slight frame into the hull. The riskiest time for capsizing is getting in.

Bergstrom paddles into the creek, wending his way along a coastline packed with houses, their narrow backyard docks jutting into the water. The tide is on the ebb and already the water level is low enough to expose the wooden pilings beneath the piers. Bergstrom maneuvers his kayak next to a piling, reaches into the water, and runs his hand down the pole.

In 2004 just a faint touch of Bergstrom's fingers on the piling would have sent strange little bivalves cascading to the creek's silty bottom. That summer the dark false mussel, as mysterious as its name, grew thick in Old Man Creek, a tributary off the Magothy River near Annapolis. Mussels clung like heavy carpets to almost every hard surface. They would tumble off under their own weight.

Now as Bergstrom drifts from piling to piling, he comes up empty-handed, feeling only a few rough-edged barnacles. He's not surprised the mussels are gone. A biologist for the National Oceanic and Atmospheric Administration (NOAA), Bergstrom has served 16 years as the volunteer monitoring coordinator for the Magothy River Association. And he had never before seen the likes of what happened in the summer of 2004, when hundreds of millions of these creatures found a temporary home in creeks of the Magothy, South, and Severn rivers.

Bergstrom thinks that the dark false mussels rode in on the coattails of Hurricane Isabel in late 2003, their larvae catching a plume of water that moved up from the saltier mid-Bay, where these creatures tend to live among oyster reefs. Finding their surroundings suitable, they settled on any hard surface they could find — pilings, riprap, the hulls of boats.

Erica Goldman

And they ate. And ate.

The dark false mussel proved its punch as a powerful filter feeder that summer. Native to the Chesapeake and a close relative of the zebra mussel, the dark false mussel at its peak abundance was estimated to filter nearby Cattail Creek in just under two days.

The mussels ate algae and the waters of Old Man Creek cleared. In 2004 the creek measured the clearest it had ever been since Bergstrom started monitoring there in 1991. Fewer solid particles (total suspended solids) clouded the water. Bottom dissolved oxygen levels improved. Underwater grasses started to come back. According to locals, more juvenile blue crabs scuttled through new nursery grounds.

Then they were gone. The population of dark false mussels exploded practically overnight — then, just as suddenly, they disappeared. Perhaps the mussels needed saltier waters to reproduce successfully or perhaps they fell victim to predation. Scientists still don't know for sure. But to those who live on the Magothy, who fight for the health of their river, the clear waters engineered by the dark false mussel became a symbol for the power of prolific filter feeders, of what once was, and what could be again.

Bergstrom's kayak paddle draws ripples in the still morning water as he makes his way among the pilings of Old Man Creek. These days his white paddle disappears almost instantly as it dips below the creek's surface. Old Man Creek is murky again, as murky as it has ever been. And the dark false mussel is nowhere to be found.

Filter Power

Aside from oysters, filter feeders (also called suspension feeders) rarely draw much attention in Bay country. Who are these other filter feeders that call the Chesapeake Bay home? And do they — or could they — thrive in enough numbers to help clear the Bay's murky waters?

The strange epidemic of dark false mussels in the Magothy became an unanticipated biological experiment of sorts — a "proof of concept."

"What it showed is that if you could get some sort of suspension feeder in

***Dark false mussels grew so thick** on pilings like this one (opposite page) in the summer of 2004 that they tumbled off under their own weight. Balancing his logbook carefully, volunteer monitoring coordinator Peter Bergstrom (above) jots down notes as he searches for the long-gone mussels earlier this year in Old Man Creek, a tributary of the Magothy River near Annapolis.*

Peter Bergstrom

Peter Bergstrom

Peter Bergstrom

Often mistaken for the invasive zebra mussel, *the native dark false mussel (*Mytilopsis leucophaeata*) is, in fact, its close cousin — distinguishable by a distinctive tooth-like projection on the inside of its shell. These photos of the dark false mussel were taken in the summer of 2004 in the Magothy River, where it proliferated in huge numbers, attaching itself with strong byssal threads to every hard substrate available.*

Wayne Young

Wayne Young

there in a sustainable fashion, it could start to improve the water quality," says Linda Schaffner, an ecologist at the Virginia Institute of Marine Science (VIMS) in Gloucester Point, at the southern end of the Bay.

These types of feeders, she explains, could help lock up (sequester) nutrients in their body tissues, paving the way for aquatic plants and animals that need clearer waters to survive. "I used to joke that we should hang ropes and let *Molgula* (a sea squirt that fouls dock pilings) grow," she says. But that, she says, is exactly what happened when the dark false mussel settled on every available surface — ropes, boats, pilings, cages.

What's keeping these other filter feeders from thriving in greater numbers in other habitats? Lack of substrate poses one definite problem. Opportunistic filter feeders grow essentially as fouling communities, Schaffner explains. Increasing the population size of these other species would depend on being able to increase the amount of available hard-bottomed surface in open water environments.

Salinity also presents an obstacle. In streams, freshwater filter feeders can do a good job of improving water quality. In tidal marshes, salinity-tolerant mussels grow prolifically. But fewer filter feeders thrive in mid-salinity, deeper water areas, which may leave an ecological niche empty in the mid-Bay, according to Roger Newell, an oyster biologist at the University of Maryland Center for Environmental Science Horn Point Laboratory. He believes that only oysters could fill that niche, since they thrive in deeper water and can tolerate the widest range of salinity.

Scientists don't know much yet about the potential for other filter feeders to affect water quality in the Chesapeake. In the York River, so-called opportunistic suspension feeders — sea squirts (tunicates), polychaete worms, clams, and mussels to name a few — outnumber oysters five to one, explains Schaffner. "If there is any effect of suspension feeders on water quality here [in the York River], it is from these opportunistic species," she says.

These species tend not to draw a lot of scientific interest, says Schaffner. She tried to secure a grant for a larger-scale effort to survey them in the Chesapeake Bay, but the project did not mesh with current funding priorities. She ended up limiting her survey to the York River since it was easier to mobilize a smaller-scale effort on a shoestring budget, but she'd like to do more.

Looking closely at this issue really should be the next step for the Chesapeake, says ecologist Danielle Kreeger. Kreeger works in a different estuary — the Delaware Bay — studying the potential for native mussels to help restore water and habitat quality in both the tidal system and up in the streams and rivers (see From Headwater to Bay, p. 11). To thoroughly assess the potential impact of these other filter feeders, she says, you need to know what volume of water actually gets processed and how often that parcel of water comes in contact with the animal. Such an effort would require an interdisciplinary team of ecologists and hydrodynamic modelers, according to Kreeger, who is the science director for the Partnership for the Delaware Estuary, one of the 28 National Estuary Programs modeled after the Chesapeake Bay Program.

Kreeger has started down this path already, working with researchers from several institutions and students from Drexel University in Philadelphia, where she maintains her research lab. She's made preliminary calculations for several species, including the marsh mussel, *Geukensia demissa*, which thrives in the Delaware Bay's tidal marshes. Kreeger estimates that the mass of marsh mussels in summer filters 60 billion liters per hour, more than six times what the current population of oysters in Delaware Bay can filter.

Powers of Transformation

Planting her ski pole on the uneven trail, Harriette Phelps begins the half-mile trek down to the Potomac River near Indian Head, Maryland. She's recovering from leg surgery and moves cautiously down the trail, part of Fort Foote Park. Earl Greenidge, her former student and current data technician, carries her field collecting gear and walks nimbly ahead, easily managing the bulky equipment.

By the time Phelps reaches the sandy beach, Greenidge is already hunched over in the knee-deep water of low tide, scooping sand from the bottom using the exterior cage of a fan (the so-called fan guard) as a sieve. With each fan-full, he brings up more than a dozen small clams that remain behind in the fan guard after the sand falls through. Phelps, an emerita biologist at the University of the District of Columbia (UDC), instructs Greenidge to keep sampling until he gets 200 of these small, ridged clams, called *Corbicula fluminea*.

Greenidge meets the target number in under five minutes — *Corbicula* thrives at high densities in the Potomac. He wades back to the beach and transfers the clams into shellfish bags made from hard plastic. Phelps and Greenidge pack up their equipment and head back up the trail.

A potent filter feeder, *Corbicula* may take some of the credit for improving water quality conditions in the Potomac River, according to Phelps. Scientists first identified *Corbicula* in the Potomac in 1977, and they watched as populations of these clams rapidly increased. By the mid-1980s, Phelps, with help from her students at UDC, calculated that the spring-summer clam population could filter one-third of all the water in this region of the estuary daily. As early as 1981, researchers reported a tripling of water clarity in the region of the clam beds. In 1983, submerged aquatic vegetation (SAV) reappeared for the first time in 50 years. Starting in 1984, the Washington, D.C. Christmas Bird Census reported significant increases in several aquatic bird populations. By 1986, fish populations had increased up to seven times in the newly grown beds of underwater grasses. *Corbicula* may have helped trigger these system-level changes in the Potomac River, as Phelps reported in a 1994 article in the journal *Estuaries*.

But the river experienced other changes at the same time, so the role that the clams played proves tough to parse. Improved sewage treatment at the Potomac River-based Blue Plains Waste Treatment Plant, along with a ban on phosphorus in laundry detergent, helped improve water quality by decreasing the flow of nutrients to the river. The fast-growing invasive plant *Hydrilla verticillata* also appeared in the Potomac in the mid-1980s. *Hydrilla* may have also helped transform the ecosystem by stabilizing the bottom, producing oxygen, and encouraging the growth of native plants.

Corbicula's positive impact on water quality comes in a complicated package. Like *Hydrilla*, it is a non-native, invasive species. From its native range in Asia, *Corbicula* was imported to the west coast of the U.S. in the 1930s for food in Asian markets. When scientists first identified this clam in the Potomac River, they braced for the worst, fearing that it would behave like the dreaded zebra mussel, attaching to every available hard surface, clogging water intake pipes at power plants, and transforming the fundamental who-eats-whom structure of the Chesapeake's freshwater rivers. A research note published by U.S. Geological Survey scientists in *Estuaries* in 1980 adopted a warning tone, stating that this addition of *Corbicula fluminea* to the Potomac River ecosystem must be followed attentively. The paper cited another researcher who called the clam "the most costly liability of all exotic mollusks in North America."

Despite these fears, the worst did not come to pass. Unlike the zebra mussel or the native dark false mussel, *Corbicula* lacks byssal threads and cannot attach to hard surfaces. The clam did cause some problems due to fouling — the Potomac Electric Power Company reported operational problems caused by clamshells and silt clogging their condenser cooling water tubes. As they drift downstream, juvenile clams also get caught inside the intake wells of power plants. But with an open ecological niche available along the sandy bottom sediments of the river, *Corbicula* could spread rapidly without crowding out populations of native species in the Potomac. As a result, scientists do not think the clam has had a major impact on the river's food web, except as a food source for birds and muskrats.

When Phelps reaches her Honda back in the parking area, she realizes she forgot to bring the ice packs to keep the clams cold while in transit. She makes plans to stop for ice at a nearby fast food restaurant on their way to the Anacostia River.

Phelps is moving these clams from the now relatively unpolluted Potomac to the very polluted Anacostia, to a point in the contaminated northeast branch in

Continued on p. 10

Sampling Life at th

As the small survey boat passes under the imposing span of Baltimore's Key Bridge, Roberto Llanso rushes to get ready. Station 201, their first stop in the Patapsco River, is just a few minutes away and he hurries to pull on his yellow hip wader overalls, set up buckets, and label collection bags for the mud samples they will pull from the bottom.

On this first day of the spring 2007 sampling season, Llanso and his data coordinator/boat captain Craig Bruce still have some kinks to iron out. They encountered early morning mechanical difficulties and had to switch boats at the last minute so they're running late. They'll have to push to finish sampling all of the day's planned stations.

But Llanso has done the drill many times before and by the time they reach the station at the mouth of Baltimore Harbor, he's ready. Since 1999, Llanso has directed the Maryland portion of the Chesapeake Bay Program's Long-Term Benthic Monitoring Component. He's a benthic ecologist at Versar, the environmental consulting company that coordinates the survey for the Bay Program.

Since its inception in 1984, the Bay Program has been trying to inventory what lives in the soft bottom (the benthos) all over the Chesapeake. This long-term record provides scientists and managers with clues to the well-being of some of the Bay's bottom-dwellers — worms, some clams, insect larvae, and shrimp-like crustaceans. Because these creatures live entirely within the sediment they're called infauna, and in the Bay some 400 species have been identified.

Collectively, these bottom-dwellers tell a story about the state of the environment. Life on the bottom sends signals about the health of the water above it — polluted, healthy, or somewhere in-between, signs that constantly change as conditions in the Bay change. The presence, absence, or overall abundance of particular species can help managers understand the impacts of stressors such as shoreline development or nutrient loading. When species able to tolerate pollution proliferate, those organisms indicate that a particular site might have elevated concentrations of certain contaminants or low levels of dissolved oxygen. Other species that thrive only when conditions are ideal tell managers that the bottom, at least locally, is healthy.

Photos by Erica Goldman

But bottom-dwellers also change their environment. These organisms help circulate organic matter through the Bay's food web (trophic transfer). The water column affects the state of the life on the bottom and the life of the bottom affects the state of the water column. It's a classic chicken-and-egg conundrum and one that's difficult to tease apart out here on the Bay.

Sunlight glinting off the surface of the water makes it difficult for Bruce to focus, even with the shade from his sunglasses and baseball cap. He braces against the movement of the heavy metal grab as the winch jerks upward with the first sample in tow. "It's like driving someone else's quirky car," he says. Bruce too is a seasoned veteran at benthic sampling, but this is

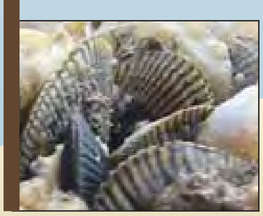
A Few Good Filter Feeders

Visit www.mdsg.umd.edu/CQ/V06N2/videos/ to see some of these filter feeders in action.

The benthos encompasses a diverse and somewhat mysterious group of organisms, each playing a distinct role in moving nutrients through the Bay's food web. As they eat, filter (suspension) feeders remove algae from the water column. Some of these organisms, like certain clams and worms, live entirely within the sediment (infauna). But many of the stellar filter feeders of the benthos attach to hard substrate and live *on* the bottom (epifauna) rather than *in* it. Epifauna — oysters, mussels, barnacles, sea squirts, and others — are not sampled systematically by the Bay Program and therefore not used in the calculation of the benthic index. According to some researchers, these groups should be added to the annual count.

Mussels (5 species in brackish/saltwater; more than a dozen in freshwater)*

Attached to rocks and other surfaces by fine fibers called byssal threads, mussels open their shells during high tide to draw in water and filter out food particles over their gills.

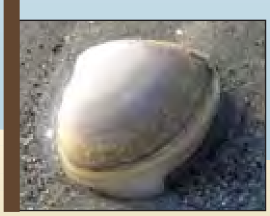


Adam Frederick

Hooked mussel (*Ischadium recurvum*)

Clams (37 species)*

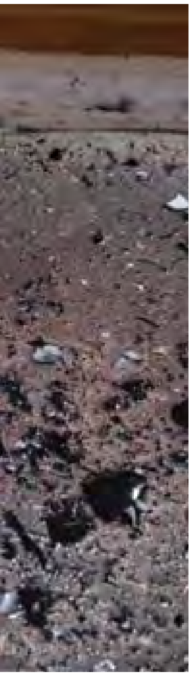
Clams draw water in one siphon, and push it out another, catching plankton material in the process within mucus on their gills.



Adan Frederuck

Hard clam (*Mercenaria mercenaria*)

e Bottom of the Bay



Grabbing mud from the bottom of the Patapsco, *ecologist Roberto Llanso (near left) and data coordinator Craig Bruce (opposite page) find only a smattering of bottom life (center). Each year, the Chesapeake Bay Program takes stock of the state of the Bay's bottom-dwellers — inventorying the creatures that live in soft sediment communities.*

the first time he's worked the winch apparatus on this boat.

When the awkward metal grab breaches the surface, Bruce recognizes immediately that the mud sample is too small, falling well short of the 15-centimeter minimum needed to compute the benthic index of biotic integrity (B-IBI). He turns to Llanso and tells him that they'll have to take an additional sample at that station. The instrument again falls quickly to the Patapsco River's mucky bottom.

The benthic index scores the health of the soft sediment benthos on a scale from 1 to 5, with scores greater than 3 indicating good habitat quality. The index compares each site to a set of reference values expected under undegraded conditions in similar habitat types. These metrics include species abundance, biomass, and diversity, as well as the percentage of pollution-indicative and pollution-sensitive groups of animals.

The metal grab surfaces again. This time the mud sample measures large enough to count for the index calculation so Bruce dumps it onto a large mesh sieve. Jet-black sediment splashes Llanso's overalls and spatters his glasses, sending up a noxious whiff of rotten eggs. Llanso stores a small amount of mud in plastic sample bags for later analysis and washes the rest through the sieve, leaving behind only bigger particles. Aside from a few empty clamshells and a couple of polychaete worms, the sediment from this polluted part of the Patapsco harbors little life.

The mud from station 201 represents one of 27 sites in Maryland that are sampled each spring and summer to identify long-term trends in the condition of particular places over time. Later in the summer, the monitoring program also takes samples from a set of sites selected randomly each year. These so-called probability-based samples, 150 in Maryland and 100 in Virginia, help estimate the area of the estuary with benthic communities that meet or fail to meet the Bay Program's goal of a benthic index score of 3 or above for every site sampled.

So how is the Bay's benthos doing? Not well. Reports from 2006 indicate one of the worst years for benthic community condition on record. The Upper Bay and lower Eastern Shore measured fairly healthy, but the mainstem of the Bay, the Patapsco and Back rivers, the lower Western Shore, and the Potomac and Choptank rivers all received failing grades. Overall, 59 percent of the tidal Chesapeake Bay bottom failed to meet established restoration goals. And no signs suggest that 2007 will rate much better.

An unhealthy benthos means an unhealthy Bay, even if worms, clams, and insect larvae fly under most people's radars. Luckily, the reverse may also prove true. Improving the integrity of life on the bottom, by reducing the flow of nutrients and other pollutants into the water, might jumpstart a cascade of improvements — less algae, clearer water, more underwater grasses. "Save the Benthos" might not make a slogan catchy enough for bumper stickers, but it could prove critical to saving the Bay.

— E.G.

Oysters (1 species)*

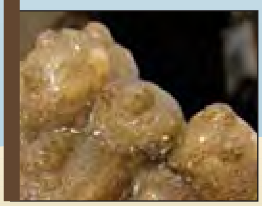
Still the go-to filter feeder in the Bay, oysters can process water at rates 2-3 times that of other bivalves. Beating cilia draw water over the gills where plankton and other particles are trapped in mucus and sent to the mouth.

Adam Frederick

Eastern oyster (*Crassostrea virginica*)

Sea squirts (3 species)*

Though immobile and almost plant-like, these filter-feeding sea squirts are chordates and thus more closely related to humans than hydroids. They siphon water in and filter out small particles through a ciliated sac. Then they expel water through a second opening, sometimes with enough force to make them worthy of their name.



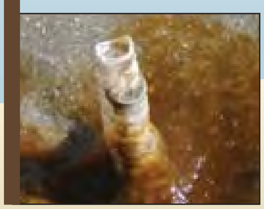
Adam Frederick

Sea grape (*Molgula manhattensis*)

Polychaete worms

(50 species of suspension or interface feeders)**

Suspension-feeding polychaetes create a tube where they wait until their long tentacle-like palps can grasp suspended prey. Of 175 species in the Bay, only 9 species are true suspension feeders. Another 41 species feed at the interface of the sediment and water, using suspension-feeding techniques when local conditions are right.

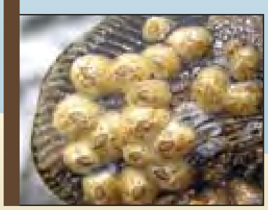


North Carolina Division of Parks & Recreation

Parchment worm (*Chaetopterus variopedatus*)

Barnacles (3 species)*

Attached to pilings, boats, rocks, and even other animals, barnacles have hard outer plates that open upon submersion to reveal feather-like legs called cirri, which whisk plankton into an internal cavity.



Adam Frederick

Barnacle (*Balanus improvisus*)

* Source: Chesapeake Bay Benthic Monitoring Program

** Source: Linda Schaffner

Photos by Erica Goldman

Biologist Harriette Phelps collects the Asiatic clam, Corbicula fluminea, *(top) from the Potomac River for her research. Thought to have bolstered water quality in the Potomac, the non-native clam thrives in this river. Phelps uses clams from the Potomac as biological indicators of pollution in the Anacostia, where data technician Earl Greenidge (bottom) is preparing to transfer them.*

Maryland. She uses them as a biological indicator of pollution, a white rat of sorts, harnessing their skill for concentrating chemicals in their body tissue to reveal the source of contaminants from upstream. The clams will stay in the polluted water for two weeks before they are retrieved and analyzed. The transfer carries no risk of invasion to the Anacostia, according to Phelps. The transplanted clams, she explains, are carefully contained in tethered cages and they can survive in the polluted river (just barely) but won't reproduce because the sediments are too toxic.

Rolling down the car window, Phelps pulls the Honda up to the intercom at the takeout window of a nearby Kentucky Fried Chicken and asks for some ice. The voice on the other end tells her to pull around to the service door. A woman soon emerges and gestures for Greenidge to follow her inside with the cooler bag. She reaches for it then hesitates. "What's in the bag?" she asks. "Clams from the Potomac. We are taking them…" Greenidge starts to explain, but she cuts him off and pulls her hands back, giving him a look that says, "Really, I don't need to know." Keeping her distance, the woman scoops ice while Greenidge holds the open bag. The clams, now comfortably cool, continue on their way to the Anacostia.

Unpredictable Outcomes

There are no plans to move *Corbicula* intentionally into habitats in which it could reproduce for the sake of improving water quality — despite its seemingly positive, ecosystem-scale impacts in the Potomac. "Wherever it has already exploited, yes, it is OK in its competitive abilities in that habitat," says Rochelle Seitz, a benthic ecologist at VIMS. *Corbicula*, however, is still a non-native species, she warns, and may behave unpredictably in a new environment.

On the other side of the country, in the tidal freshwater areas of San Francisco Bay, *Corbicula* did cause major ecological disturbances, according to Jim Cloern, a biologist with the U.S. Geological Survey. Unlike in the Chesapeake, algae grow in limited supply in that estuary where *Corbicula* competes for food with native algae-eating zooplankton. Worse yet, the clam actually eats certain zooplankton (rotifers) outright, further decreasing their abundance in the middle level of the food web and reducing the food available for fish.

Another invasive clam, *Corbula amurensis*, proved even more disruptive than *Corbicula* in San Francisco Bay, engineering major ecosystem changes in the brackish regions. "Resource managers here think about these two invasive clams in the same way people think about nitrogen and phosphorus in Chesapeake Bay," says Cloern.

Back in the Chesapeake, non-native species simultaneously provoke concern and signal opportunity. The capture this year of a third invasive Chinese mitten crab incited much worry. But, for some, a non-native oyster inspires hope for clearing the Bay's waters and bringing back a collapsed industry. Scientists, resource managers, and politicians are currently debating the pros and cons of *Crassostrea ariakensis*, an Asian oyster that could prove a powerful filter feeder and, if it thrives, boost commercial harvests.

Introducing a non-native species is an option that should be approached with caution, says Cloern. "Whenever we do these kind of biological interventions, there are always surprises," he warns. That's why it's critical to take an ecosystem-level perspective, he says. "We are never smart enough to predict what all of the consequences might be."

Structure of Cleaner Water

The Chesapeake's murky water needs all the filter power it can get. The Bay has one species of oyster, but it's home to dozens of native species of clams, mussels, worms, crustaceans, anemones, and sea squirts — just to name a few (see Sampling Life at the Bottom of the Bay, p. 8). These species are neither commercially

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From Headwater to Bay

Until we bring back oyster reefs, the mainstem of the Bay may remain poorly served by filter feeders. But what about upstream? Could restoring freshwater filter feeders in streams help clear the water before it ever reaches the larger rivers or the mainstem Bay?

Researchers are already addressing similar questions in the nearby Ohio and Delaware watersheds. Could these efforts prove useful models for the Chesapeake?

Danielle Kreeger

A powerful filter feeder, *the marsh mussel* Geukensia demissa *grows attached to the root-like rhizomes of the cordgrass Spartina. In the Delaware Bay, these mussels filter more than six times what current populations of oysters can.*

On the Ohio-West Virginia border, natural resource managers recently embarked on a mission to restore degraded biological resources in one stretch of the Ohio River. Their approach: re-establish the filter power of a complex assemblage of freshwater mussels to improve water quality enough to enable other species to come back. If they succeed, this restoration effort will prove a hallmark event, says Catherine Gatenby, a biologist with the U.S. Fish and Wildlife Service in White Sulphur Springs, West Virginia. This project will test the theory that managers can use organisms like filter-feeding mussels to jumpstart the restoration of a complete biological community.

Unfortunately, it took an ecological disaster to ignite this innovative call to arms. In June 1999, a metal manufacturing facility in Marietta, Ohio allegedly released hazardous materials into the Ohio River. The spill reportedly killed an estimated 8,600 fish, 990,000 mussels, and 12 million snails along one stretch of the river.

The United States and the states of Ohio and West Virginia filed suit in the U.S. District Court for injuries to natural resources under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and for violations of the Clean Water Act. The suit settled out of court in early 2006 and the companies paid $2.04 million specifically targeted towards rebuilding freshwater mussels, fish, and snails. This provided a dedicated source of funds for a restoration effort.

The 1999 spill wiped out at least 20 different species of mussels, explains Gatenby, some endangered species, some not. As a group, freshwater mussels are the most imperiled fauna in North America, with 43 percent of the 300 species of freshwater mussels currently in danger of extinction. The U.S. Fish and Wildlife Service (USFWS) holds an obligation to restore endangered species of mussels under the terms of the settlement, she adds.

What makes this restoration plan unique, she says, is that restoration will include the whole community of mussels in the assemblage — endangered and not. "Before we can restore the endangered species, we have to restore the habitat," says Gatenby. In this case that habitat includes the entire bed of mussels. This argument enabled biologists to convince the trustees in the lawsuit to include not only endangered but common species of mussels in an integrated restoration plan, a decision that Gatenby thinks will maximize ecological gain for economic investment.

How much filter power are scientists and managers trying to bring back to the Ohio River? Since one mussel can filter approximately six gallons of water per day and roughly 990,000 mussels were killed, the arithmetic of scale implies that this 10-mile stretch of river lost six million gallons per day of filtering capacity. That is a lot to bring back, but the members of the Mussel Habitat Partnership are optimistic. Not only do they think that they can restore the mussel bed but that the mussel bed itself will in turn modify the environment in a way that promotes the recovery of fish species and other invertebrates lost in the ecological calamity.

Gatenby's team from White Sulphur Springs National Fish Hatchery, the Ohio River Islands National Wildlife Refuge, and the West Virginia Division of Natural Resources transplanted the first 800 common mussels to the river in mid-May, kicking off what will be a ten-year restoration effort. Once the mussels get acclimated and begin to filter in earnest, the site will be reassessed to determine whether the habitat proves suitable for reintroduction of some of the endangered species.

Meanwhile in Brandywine River in Pennsylvania, a tributary that empties into Delaware Bay, Danielle Kreeger is taking a similar approach to restoring freshwater mussels for their water quality services up in the non-tidal portions of the watershed. Based at the Partnership for the Delaware Estuary and also Drexel University, Kreeger focuses on Unionids, the same group of freshwater mussels at the focus of the USFWS project in the Ohio River.

These mussels were once quite common in the Delaware watershed but their population dropped from historic levels nearly 200 years ago. Scientists believe that the population decline resulted from habitat loss, dams that interfered with the transport of larvae, and

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Headwater, continued

degraded water quality. Today only one species of Unionid — *Elliptio complanata* — remains out of at least 7 or 8 originally. These mussels can live up to 80 to 100 years. Right now, only old mussels are thriving in the Brandywine and Kreeger has not found any younger than 30. She suspects that the system of 11 dams in the lower part of this watershed is to blame. Recruitment of larval mussels depends on fish that serve as intermediate hosts. The fish cannot pass through these dams, which interrupts the life history of the mussel — a problem likely also to be true for freshwater mussels in the Susquehanna basin of the Chesapeake watershed as well.

Building on the Partnership for the Delaware Estuary's attempts to restore oysters and other native shellfish species in the tidal portion of the estuary, Kreeger has just launched a project to restore some of the species lost from the Brandywine and several adjacent streams in southeast Pennsylvania, hypothesizing that they would fill vacant ecological niches. Some environmental managers in the state of Pennsylvania have expressed interest in the potential of this approach for decreasing pollution, reducing total maximum daily loads (TMDL), she says. According to Kreeger, managers view this approach as another key tool for their restoration toolkit — one with the potential to improve the Delaware Bay itself by decreasing the load of nutrients flowing from the watershed.

Down in the tidal portion of the estuary, she's mainly working to boost populations of the ribbed mussel *Geukensia demissa*, which lives in salt marshes. There it attaches to the root-like rhizomes of the marsh grass *Spartina*. Beds of these mussels could play an important role in stabilizing shorelines subject to erosion from sea level rise, as well as performing the usual bivalve services such as improve water clarity. The marshes are the "the lungs and kidneys for the bay," Kreeger says. "Everything depends on these marshes but we are losing them to erosion." Kreeger aims to put mussel and oyster communities back in the subtidal and intertidal regions to harden the shoreline with living reefs.

If you're interested in building shellfish reefs and beds for ecosystem services, rather than historical or commercial purposes, species like the marsh mussel are preferable to oysters, she asserts. "They're great. You can spawn them, seed beds with them. You can do all of these great things for water and habitat quality," she says. And the biggest sell, she notes — no one eats them and they're not susceptible to disease.

"We are talking about restoration in the Delaware from the mouth of the bay to the headwaters up in New York," she says. It's worth asking the same questions for the Chesapeake, says Kreeger.

— *E.G.*

Clear Water through Clam Culture?

Acre per acre, the most valuable farmland in Virginia is underwater. On the distant reach of Virginia's Eastern Shore, Cherrystone Creek hosts some 100 million hard clams, worth $65,000 per acre per year.

"There are no other legal crops in the U.S. that yield that much per acre," says Mark Luckenbach, a biologist at the Eastern Shore Laboratory of the Virginia Institute of Marine Science (VIMS).

Cherrystone Creek serves as a grow-out area for Cherrystone Aqua-Farms, a commercial-scale clam hatchery in Cheriton, Virginia. Of their own accord, these bivalves would never live so densely packed in such a small underwater area. And Luckenbach wanted to know whether this city of clams packs a measurable impact on water clarity in the creek.

On the surface, the changes seem dramatic, says Luckenbach. "You can walk through Cherrystone Creek in waist-deep water and see your toes in the middle of summer," he says. "Many people will say, 'water here hasn't been this clear since my granddaddy lived here.' " Can clams claim credit for removing a significant amount of the phytoplankton?

Luckenbach and his colleagues at VIMS, including researchers Harry Wang and Jian Shen, set out to scientifically validate what they were seeing in Cherrystone Creek. The team started with a water quality model that Wang's group had shown to accurately simulate the dynamics of algae abundance (primary production) in other parts of the Bay. Once they put the necessary stats on Cherrystone Creek into the model, the team compared algae abundance predicted by the computer model to amounts actually measured in the creek. They found that the model overestimated the amount of phytoplankton present. The waters were clearer than expected.

Adding in mathematical terms to simulate the effect of clams feeding in Cherrystone Creek, the team ran the water quality model again. Now it accurately predicted the amount of phytoplankton actually measured in the creek.

"No question that the clams are removing a significant amount of the phytoplankton," says Luckenbach.

So why isn't clam aquaculture a logical answer to the Bay's water quality woes? Couldn't this economic powerhouse of an industry also prove an ecological benefit to the Chesapeake's creeks and rivers?

It's not that simple, says Luckenbach. Like any confined animal farming operation, aquaculture changes the dynamics in an ecosystem.

The caged clams take up chlorophyll and nutrients, but they also excrete a lot of nitrogen — in the form of ammonia, he explains. Since the clams are densely packed, that nitrogen is highly concentrated, acting as a ready food source for seaweed (macroalgae). In addition, predator-exclusion nets cover the clam beds to protect them from rays and other predators. Those nets further accelerate the growth of seaweed, providing an inviting surface on which to grow.

So the waters of Cherrystone Creek might

Mussels & Clams, continued

desirable nor susceptible to disease. And each plays a key role in cycling nutrients through the Bay's food web. Perhaps it's time to focus on the filter power and other benefits of these little-noticed species, says ecologist Danielle Kreeger.

How might managers maximize restoration opportunities with these less charismatic creatures? Restoring oysters could be the key, according to scientists, but only if they are restored as large, vertical reefs — and those reefs are then protected from harvest. If we rebuild the three-dimensional structure of the oyster reef, they say, and leave it alone, these other species will come.

And they will come in mind-boggling numbers. In a recent study, University of Maryland scientists William Rodney and Kennedy Paynter found that restored plots in sanctuary oyster bars held ten times as many filter feeders as degraded, unrestored areas. The sheer numbers of organisms proved even more impressive. The hooked mussel, an important filter feeder that grows in association with oysters, was more than 200 times more abundant in the restored plots. Rodney and Paynter counted over 11,000 hooked mussels in these areas, compared to just over 50 in the unrestored areas.

At these numbers, Paynter says, the hooked mussels could be filtering even more water than oysters on a restored

Erica Goldman

Jack Greer

Clam culture is a lucrative business *at Cherrystone Aqua-Farm (above) on Virginia's Eastern Shore. Could bivalve culture bring another payoff by helping to reduce nutrients in the Bay? Biologist Mark Luckenbach (right) and his colleagues at the Virginia Institute of Marine Science are trying to find out.*

now be clear, but have overall conditions improved? "Your answer might be different if you had just walked down to your beach the day before and found it piled shin-high with rotting seaweed," says Luckenbach. Aquaculturists intermittently scrape the algae off the clam beds to maintain the flow of fresh water over the clams. "Unchecked, this algae can wash onto beaches where it can rot and stink," he says.

But macroalgae may also offer an unexpected opportunity to reduce nutrient pollution in the Bay. Scientists suspect macroalgae locks up (sequesters) a lot of nitrogen. Since excess nitrogen is generally regarded as the most significant pollutant in the Chesapeake, Luckenbach wondered if simply removing algae from clam nets would decrease nitrogen loads to the Bay, helping to further improve water quality. Could clam farmers, then, harvest macroalgae in addition to their clams and remove even more nutrients from the Bay?

To explore this question, Luckenbach recently launched an effort to determine exactly how much nitrogen and phosphorus are locked up in macroalgae. He's undertaking the study in partnership with Cherrystone Aqua-Farm President Mike Pierson and Jonathan Davis from Taylor Shellfish in Seattle, Washington. Although the nutrient analysis has not been completed, the sheer quantity of algae associated with the aquaculture clam beds is quite impressive, says Luckenbach. During May of this year the team estimates that over 150,000 pounds (wet weight) of algae grew attached to the nets on a single clam farm in Cherrystone Creek.

If reducing nitrogen loads in Chesapeake Bay could be accomplished by removing algae from clam nets, what stands in the way? It comes down to economics, explains Luckenbach. In some areas aquaculturists do collect algae and remove it from the creek, but this is a costly activity, one for which clam culturists currently receive no economic returns.

Luckenbach suggests that establishing incentives might help solidify an algae-removal practice among clam culturists. He identifies two different market-based approaches that might simultaneously serve the dual goals of commercial growth and ecosystem restoration. One would involve creating a market for fertilizer made from seaweed, thereby providing an economic reason for aquaculturists to truck this macroalgae (and therefore nitrogen) away from the Chesapeake Bay. The other would involve a nutrient trading program, where aquaculturists who did remove macroalgae from the system could earn some sort of nutrient-removal credit. These credits could then be sold for money to other businesses that might be over their pre-determined nutrient load limit.

Aquaculture programs that link ecosystem services to the economic bottom line are still a ways off. At this point, says Luckenbach, we need to better understand what having these agroecosystems in our landscape means to our ecology. "They might be good, they might be bad, but they are not going away."

— E. G.

reef. Though no one has yet done calculations that include the filtration rate of the hooked mussel, he says, the combined impact of the two together could be quite significant.

Moreover, these restored reefs attract more than mussels and oysters, according to the study. The structural complexity of a mature oyster reef provides both surface area for other fouling organisms — such as sea squirts, anemones, and barnacles — and a spatial refuge from predation for species such as the insect-like amphipods and small fish, explains Paynter.

"One could argue, then," he says, "that the most important role for the oyster is making the structure for other animals to settle on."

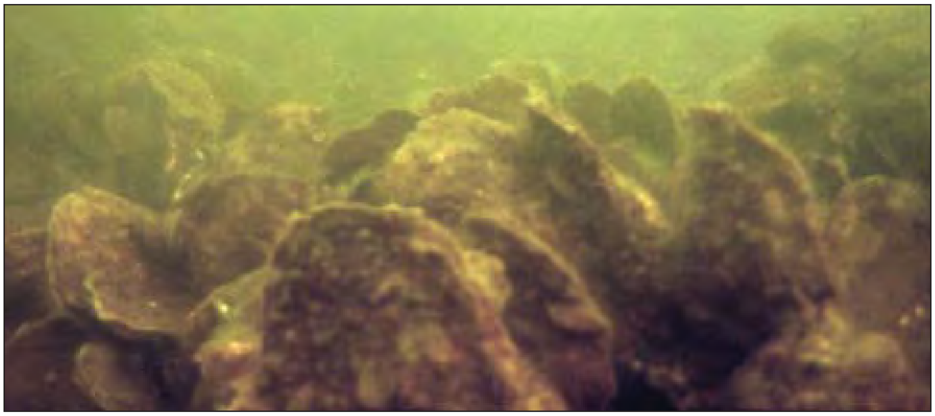
These lesser-known species not only help clear the water, they also redirect nutrients to other parts of the food web. The abundance and diversity of species like amphipods, that eat the feces and pseudofeces produced by filter feeders like oysters and mussels, creates "a huge catalytic flow" into other levels of the food web, says Paynter, sequestering nutrients away from the water column.

Oyster reefs also grow dynamically over time, like coral reefs, he says. So if the oysters can remain relatively disease-free, structure will beget even more structure and even more surface area as oysters increase in size and their offspring settle on top of existing shell.

Artificial reefs, a recent innovation, might serve similar functions, according to another recent study. Researchers Romauld Lipcius and Russell Burke at VIMS measured how mussels and oysters colonized an artificial concrete reef set out in the Rappahannock River. In four-and-a-half years the concrete reef, a design not suited for conventional harvest techniques, attracted the equivalent of nearly 10,000 filter feeders per square meter of river bottom. These are among the highest densities ever recorded for natural and restored oyster reefs. And the vast majority of the filter feeders were mussels, not oysters. Hooked mussels, in fact, outnumbered oysters by more than eight times.

For oyster reefs, with all their fellow

"One could argue that the most important role for the oyster is making the structure for other animals to settle on."



Jake Goodwin

Three-dimensional, vertical structure, *like that offered by the restored oyster reef above, encourages so-called "fouling organisms" to settle and grow in large numbers, adding more filter power than oysters alone can provide. For example, there's only one oyster living on this concrete block used as an artificial reef (opposite page), but there's a veritable smorgasbord of sea squirts, hooked mussels, and barnacles.* PHOTOGRAPH ON OPPOSITE PAGE BY KENNEDY PAYNTER.

inhabitants, to work best, they need to remain undisturbed — safe from dredges, tongs, and boat anchors. Biologist Roger Newell suggests that restoring oysters to improve water quality may simply not be compatible with a wild-bottom commercial fishery. He predicts that in the next ten years, we'll start to see a partial moratorium on harvesting and more and more oyster bars protected as sanctuaries for their ecosystem services — in low salinity areas especially, he asserts, where recruitment of larvae is poor.

The promise of ecosystem services provided by oyster reef communities holds great appeal back on the Magothy River. After the dark false mussels first appeared in 2004, the Magothy River Association, under the leadership of dive master Richard Carey, mounted a large-scale community science initiative to survey the size of populations and to calculate how much water they could filter. They counted the mussels and did the math: more than 400 million mussels in one creek (Cattail Creek) could filter all the water in 46 hours. The dark false mussels clearly had an impact on the health of their river. Now that the bivalves have gone, local citizens remain convinced that the right filter feeder could clean up the Magothy.

"If the mussels could clean up the creeks, a big enough biomass of some filter feeder could clean up the whole river," says Carey, who established the protocol and organized teams of kayakers and divers for the 2004 dark false mussel survey.

The Association looked at some of the other possibilities — clams, other types of mussels. But ultimately the group decided that oysters and their related communities would probably have the biggest impact on water quality. They also figured that the oysters would naturally resist disease because of the low salinity in the Magothy.

In June, the Magothy River Association published an ambitious oyster restoration plan. Based on their calculations of filtration rate and river area, they are hoping to plant some 250 million oysters on stone base material. If they can get the oysters — which won't be easy — the Association hopes to plant 25 million a year for the next 10 years. Planning for no harvest pressure and 50 percent survival rate for the oysters, they believe that 125 million living oysters in the river will lead to a significant boost in water clarity. Even if the oysters live just long enough to allow underwater grasses to come back, says Carey, it could make a difference. And if other organisms come along for the ride, the restoration effort may bring even more more filter power than they bargain for.

Gliding alongside a green wedge of lawn in Severna Park's Magothy waterfront, Peter Bergstrom maneuvers his kayak until he's lined up beside a riprapped bulkhead. Just then, raindrops begin to fall and he pulls on a windbreaker and wipes off his round, wire-rimmed spectacles. He turns over a large, triangular rock and sets it gently back in place. Methodically, he reaches down and picks up another one.

There, clustered on the rock's undersurface, clings a small cluster of dark false mussels. Their shells are clamped tight, a potential sign of life. Bergstrom pries one off the rock. Quickly, its shell gapes open …empty. The mussel is dead. He didn't really expect to find it alive, but for a second, his face flashed a brief sign of hope. Just a tease, really, but those few dead mussels reminded him that for a brief interlude in the creek's history, the waters had cleared, underwater grasses had come back, and crabs had flourished. Could it happen again?

— *email the author, goldman@mdsg.umd.edu*

For More Information

Mussels and Clams

Magothy River Association
About the association
www.magothyriver.org/Who_We_Are.html

Video of the group's dark false mussel survey
www.mdsg.umd.edu/CQ/V06N2/videos/

Bay Journal article on mussels and eels in the Susquehanna
www.bayjournal.com/article.cfm?article=2854

Harriette Phelps and *Corbicula fluminea*
www.his.com/~hphelps/

Benthic Communities

Versar and the benthic survey
www.baybenthos.versar.com/

Chesapeake Bay Program benthos page
www.chesapeakebay.net/benthos.htm

Maryland Sea Grant video of benthic communities
www.mdsg.umd.edu/CQ/V06N2/videos/

Oyster Reefs and Living Shorelines

The Paynter Labs
www.life.umd.edu/biology/paynterlab/paynterweb.html

Maryland Department of Natural Resources Shorelines project
shorelines.dnr.state.md.us/living.asp

Oyster reef restoration efforts
www.chesapeakebay.net/reefrest.htm

Performance Honors Rachel Carson's Life and Work

Lear/Carson Collection

Davis Spylios Management

***Rachel Carson at work** and Kaiulani Lee, who portrays her in a one-woman show about the scientist and writer.*

In celebration of its 30th anniversary, Maryland Sea Grant will host a performance of *A Sense of Wonder*, a one-woman show based on the life and work of famed writer and naturalist Rachel Carson, who would have turned 100 this year.

Carson loved the sea, and she loved to write. A marine biologist by training, she had a penchant for exploring the coast and a knack for explaining complex ecological processes with lyrical ease. Her ocean-related writings include *Under the Sea Wind*, *The Sea Around Us*, and *The Edge of the Sea*.

Though these works established her reputation, Carson is now best known for her attack on indiscriminate pesticide use in her landmark book, *Silent Spring*. This work catalyzed public concern over the issue and helped to spark an environmental movement.

In *A Sense of Wonder*, Kaiulani Lee performs as Carson, bringing to life the writer's relationship with the natural world and her efforts to protect it. For over ten years the show has played to rave reviews throughout the United States and abroad. John A. Hoyt, former Chief Executive of The Humane Society of the United States notes, "To see and hear Kaiulani Lee is to have been touched by Rachel Carson herself."

Celebrating Maryland Sea Grant's thirty years of service with a Rachel Carson performance seems a natural fit. In addition to her love of the sea, Carson had a strong connection to the state of Maryland. She received a Master of Arts in zoology from Johns Hopkins University, wrote articles on nature for the *Baltimore Sun*, and spent the later part of her life in the city of Silver Spring.

A Sense of Wonder will take place at 7 pm on Friday, December 7, 2007 in the Kogod Theatre at the University of Maryland's Clarice Smith Performing Arts Center. Admission is free, but seating is limited so please register in advance by e-mailing wonder@mdsg.umd.edu or calling 301.405.6375.

— *Jessica Smits*

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