# CHESAPEAKE QUARTERLY

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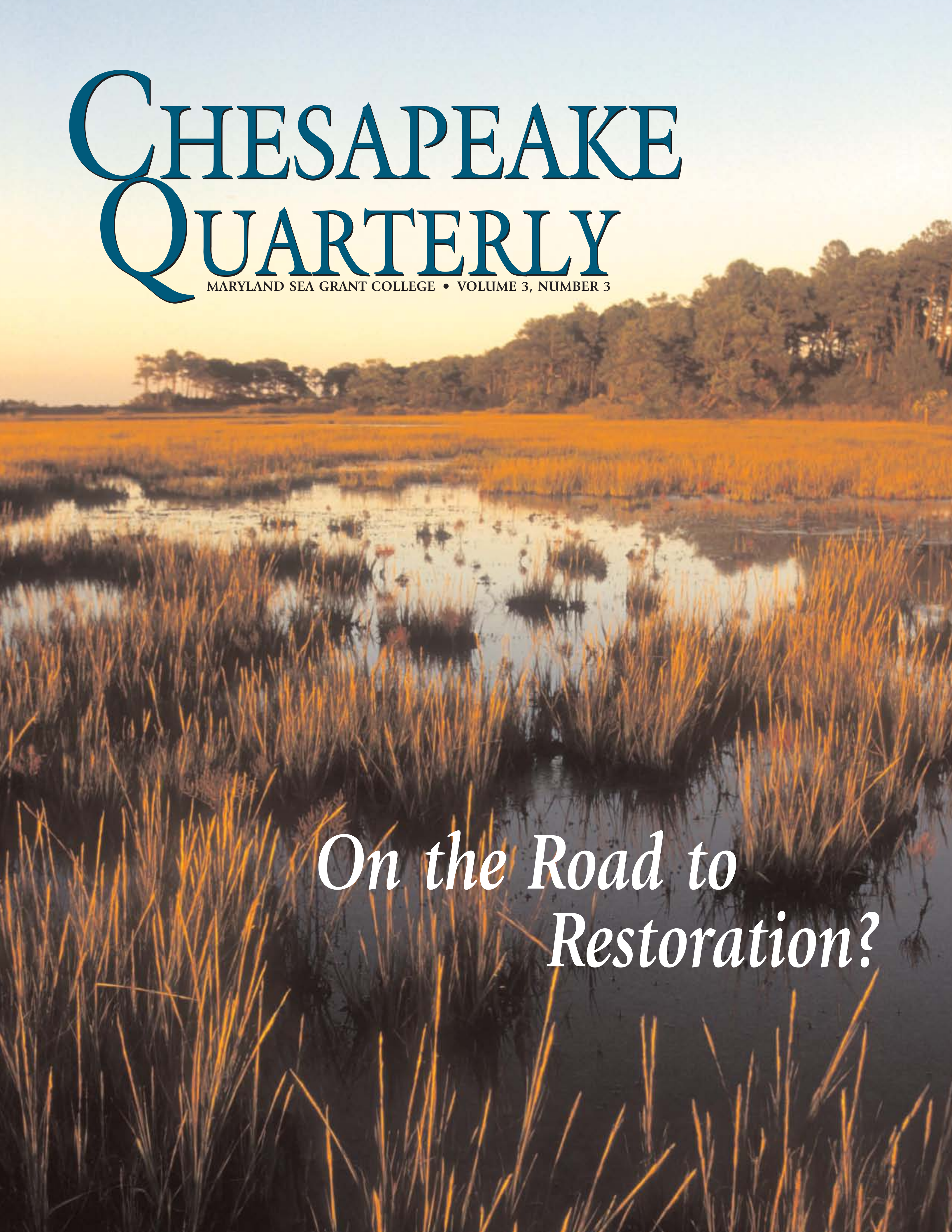

## *On the Road to Restoration?*

# The State of the Bay

For most of us, the concept of resilience can be grasped intuitively when we think of our body's ability to fend off a cold or make a speedy and full recovery from illness. More complex, however, is the concept of ecological resilience — the ability of organisms and natural communities to absorb stress, either natural or human-induced, without significant alterations in the structure or function of the ecosystem.

Ecosystems are elastic within the boundaries set by physics, geology, and climate. But over time, as pressures mount and key components of these interconnected systems are altered or removed, buffering capacity (the ability to return to sustainable stable states) can also decline. The result can be a transition to a new, potentially undesirable condition that may be extremely difficult to alter — one that is resilient in its own right. For those dedicated to restoration and for those who rely on the Bay for recreation or livelihood, the implications of these shifting states are profound.

In this issue of *Chesapeake Quarterly*, Erica Goldman explores the concept of ecological resilience from the vantage point of scientists actively engaged in studying the ecology and potential for restoration of this Bay and also from that of experts confronting similar issues nationwide. The conceptual maps these individuals have drawn are starting to move resilience from the theoretical to the practical — a step that may be critical to developing strategies that bring Chesapeake Bay to a healthier state.

Jonathan Kramer
*Director, Maryland Sea Grant*

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## CHESAPEAKE QUARTERLY

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***Buffers:*** *Wetlands are major buffers, filtering out large quantities of sediment, pollutants and nutrients before they reach streams, rivers and bays. The cover photo and photos on pages 2 and 3 show marshes in Maryland and Virginia.*
*COVER PHOTO BY SKIP BROWN. PHOTOS ON PP. 2 AND 3 BY SANDY RODGERS.*

# Recovering Resilience

## *Can Restoration Bring Back the Bay's Buffers?*

BY ERICA GOLDMAN

> *Forests and wetlands trap sediments and help slow the flow of pollutants into the Bay. Their loss, coupled with the decline of grasses and oysters in the 1970s and 1980s, caused the Bay to lose much of its resilience.*

The plankton net abruptly breaks the water's surface and dangles precariously from the winch, a long porous stocking trailing behind a 2-foot-square metal frame, dripping brackish water. From the deck of the research boat bobbing in the Rhode River this summer morning, two scientists and the captain lean out and swing it aboard, soaking their shirts as they lower the net onto the deck. The lead scientist, Denise Breitburg, kneels and carefully unscrews the large cylinder at the base of the net — the so-called cod-end that traps whatever is floating in the water. She pours some of the gelatinous contents into a giant measuring cup, pausing to record the volume. Then she empties the cupful into a large, circular metal sieve.

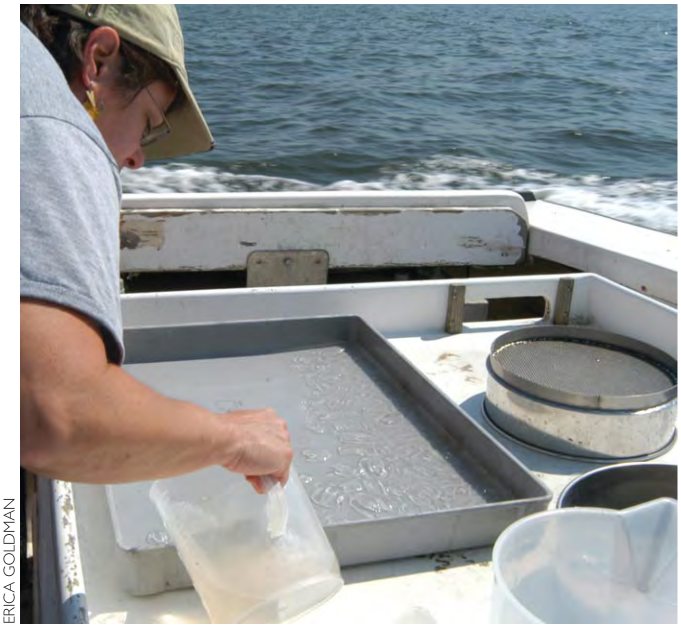
*Blop, blop, splat*. Like raw eggs hitting cookie batter, gelatinous animals fall by the hundreds onto the sieve. Breitburg swiftly sorts through the organisms, which range in size from fingernail to nearly whole hand, surveying the catch. Standing quickly, she flings the contents of the sieve overboard — gelatinous animals flying through the air before hitting the water. As the boat cruises ahead to the next station, she turns back to the cylinder and pours another sample into the measuring cup.

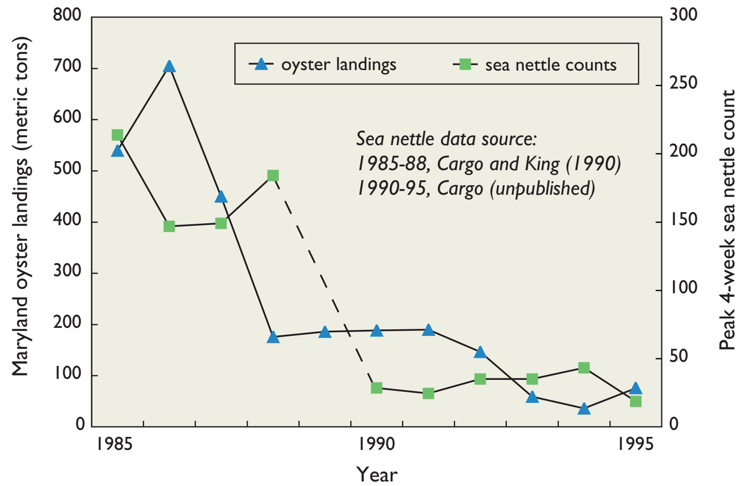
"Only comb jellies again," Breitburg says, shaking her head. "We haven't seen a single sea nettle in the area this season."

All summer, Breitburg's group had been using a small 16-foot skiff to sample the Rhode for sea nettles, the stinging jellyfish well known to anyone who has swum in the Chesapeake, and comb jellies, their non-stinging cousins. Each week yielded the same result…no nettles. Today, Breitburg, an estuarine ecologist at the Smithsonian Environmental Research Center (SERC) in Edgewater, Maryland, along with her graduate student and post-doctoral fellow, is aboard SERC's 42-foot *R/V Saxatilis*, sampling for nettles and comb jellies again, using a bigger net. Breitburg wants to verify that the smaller net pulled by the skiff was not simply missing the larger nettles. But the 12-foot-long Neuston net pulled by the bigger boat filters huge volumes of water over and over again, with the same result…no nettles.

Absent nettles in the Rhode might not be so unusual, Breitburg explains, especially since the river's salinity is low and these animals gravitate toward saltier waters. She has only just begun sampling this river for gelatinous creatures so it is hard to tell if the missing nettles, *Chrysaora quinquecirrha*, and bountiful comb jellies or ctenophores (pronounced teen-o-fors), *Mnemiopsis leidyi*, in the Rhode are part of a more ominous story that has been steadily unfolding two tributaries to the south.

In the saltier Patuxent River, located roughly 40 miles south of the Rhode, the decline in sea nettles has been unmistakable.




***Declining in concert,*** *sea nettles and oysters followed the same downward path in the Patuxent River from 1985-1995 (above, no data for 1989). Denise Breitburg (left) pours the contents of a catch — only comb jellies — into a tray for sorting. Graph adapted from Breitburg (unpublished).*

Breitburg has sampled the Patuxent since 1992, creating a data set that complements a long-term inventory started in the 1960s by the late fisheries biologist Dave Cargo, of the University of Maryland Center for Environmental Science (UMCES) Chesapeake Biological Laboratory in Solomons, Maryland. Breitburg and Cargo independently documented a strong downward trajectory in the jellyfish population that has steadily gained momentum since 1985.

Of course, to most the absence of nettles in the summer is cause for celebration — allowing carefree swims in the Bay. So demonized are these "stinger nettles" that, in 1966, the U.S. Congress passed a "Jellyfish Control Act," for the purpose of "promoting and safeguarding water-based recreation for present and future generations…by controlling and eliminating jellyfish…and other pests." The federal government authorized up to $1,000,000 per year for studies of innovative extermination techniques and control programs.

Despite their historical unpopularity with swimmers and boaters, the Bay's long-tentacled jellyfish are powerfully influential in the food web. Voracious predators, they spread across the Bay and its rivers during the summer months, eating comb jellies and other zooplankton as they go. Without sea nettles to keep their numbers in check, the seemingly benign comb jellies prey heavily upon young (larval) bay anchovies and on oyster larvae, says Breitburg. They also compete directly with adult bay anchovy for food. In the world of eat or be eaten, bay anchovies are a major food for top fish-eating predators — such as striped bass — who may go hungry as anchovies and other forage fish decline.

"I've always been fascinated by jellyfish," Breitburg says. "They are such simple animals, yet they are so dominant in the ecosystem."

Forty years ago, it would have been impossible to imagine the downside of a diminishing sea nettle population. But today, nettles are dwindling in number in the Patuxent and possibly beyond — not through any force of Congressional action — and Breitburg, for one, takes it as a troubling sign.

## Regime Change

The Chesapeake's declining nettle population is a symptom of bigger forces at work, explains Breitburg. Nettles have followed a downward trajectory that closely mirrors the downward spiral of the native oyster, *Crassostrea virginica*, which began its unabated freefall in the early 1980s as the result of the cumulative effects of overfishing and the diseases MSX and Dermo.

Like oysters, "sea nettle densities in the Patuxent are now more than an order of magnitude lower than in the mid 1980s," says Breitburg. And these parallels are hardly a coincidence.

Oyster shells provide a hard surface for sea nettle polyps, the sedentary, bottom-dwelling stage of the jellyfish's life cycle, to settle upon, explains Breitburg. Without enough hard surfaces available, sea nettles cannot complete their reproductive cycle. Breitburg suspects that the Bay reached a "threshold" level of hard surface availability in the Patuxent right around 1985, beyond which the nettle population could not sustain a constant level (see graph above). In addition, since the decline of nettles has also led to a rise in the population of comb jellies and since comb jellies feast upon free-swimming larvae, oyster larvae face higher and higher predation rates. So the food web's sea nettle-oyster link could now be stuck in a rut, explains Breitburg — fewer oysters mean fewer nettles, fewer nettles mean many comb jellies, many comb jellies mean fewer oyster larvae, fewer oyster larvae mean fewer oysters — and so on.

A Bay with fewer oysters, of course, heralds a whole slew of problems. Oysters achieved ecological fame for their ability to filter algae from water and to help maintain water clarity by locking up nutrients (nitrogen and phosphorus).

Historically, they've helped the Bay to absorb natural and human-caused insults without a change in "ecological state." "Oysters helped to make the Bay resilient, providing a buffer to the whole ecosystem," says Breitburg.

The Chesapeake's troubled tale of shifting states and resilience lost has been widely told by now. First came changes in land use, the loss of oysters and underwater grasses, overfishing and the spread of low oxygen zones. Then in 1972 came the onslaught of a monster tropical storm called Agnes that pounded the Bay with water, nutrients, and sediment loads. This cascade of catastrophes proved more than the ecosystem could handle.

"Something fundamentally changed in the 1970s," says sediment biogeochemist Jeff Cornwell at UMCES Horn Point Laboratory in Cambridge, Maryland. The shallow regions reached a threshold, which basically caused a shutdown of coastal processes. "It is somewhat of a chicken and egg problem, though, because many of these changes occurred at the same time," he says. Reduced light penetration, the growth of small plants (epiphytes) on underwater grasses, oyster mortality, and increasing anoxic conditions caused a shift from an ecosystem driven by photosynthetic bottom processes (dominated by underwater grasses), to one in which phytoplankton in the water column carry out the lion's share of the Bay's photosynthesis (primary production).

Many scientists suggest that the Bay's dramatic regime change occurred because of a combination of factors that limited its ability to bounce back. In his book, *Turning the Tide*, journalist Tom Horton eloquently characterized the lost buffering capacity of the Chesapeake, citing the highly interdependent environmental problems caused by the conversion of forests, wetland and shoreline areas to impervious surfaces, like pavement. Forests and wetlands trap sediments and help to slow the flow of pollutants into the Bay from agricultural runoff higher in the watershed. Their loss, coupled with the decline of Bay grasses and oysters in the 1970s and 1980s, caused the Bay to lose much of its resilience, its ability to recover from disturbances without undergoing a fundamental change, making it more and more sensitive to events that could push it over the edge, such as storms like Agnes.

MARY HOLLINGER, NOAA

KEITH BAYHA

***Gelatinous powerhouses** of the Bay's food web, both sea nettles (*Chrysaora quinquecirrha*) (left) and comb jellies (*Mnemiopsis leidyi*) (above) are simple in form, yet profoundly influential in the Bay's ecosystem.*

Efforts to "Save the Bay" are usually synonymous with bringing it back to a stable state that had clear water, underwater grasses, bountiful fish, crabs and oysters. But the current state of the estuary lacks many of the buffers, such as oysters and grasses, which helped sustain that state in the first place. The question remains unanswered: Can we restore some of the Bay's resilience and, by doing so, jump-start its ability to rebound the rest of the way back to a bottom-driven system? If so, will we see a Bay similar to the 1970s? If not, what will this "restored" Bay look like?

## Resilience and Ecological Change

Ecological resilience is a slippery concept — it is relatively straightforward in theory, but it remains very difficult to measure. In its most general definition, ecological resilience provides a measure of the amount of disturbance that an ecosystem can withstand without shifting into an "alternate stable state" (see sidebar on page 6, "The Language of Resilience"). For the Chesapeake, the shift from a food web dynamic driven by benthic processes — such as underwater grasses and oysters — to one driven by phytoplankton in the water column is a classic example of what some ecologists call a *regime shift*, a shift between stable states.

What is less clear, however, is what weight to give multiple factors that caused such a transition to take place. "Ecological systems are idiosyncratic," says ecologist Lance Gunderson from Emory University in Atlanta, Georgia. "Some systems are very resilient to a wide range of perturbations; some are not. It often takes a lot of work to see what is involved in state transitions."

Gunderson is an expert on the Florida Everglades and one of the founding scientists of a group called the Resilience Alliance, a research organization of scientists and practitioners from many disciplines who collaborate to explore the dynamics of social-ecological systems. Their goal is to understand how different systems function, mostly through case studies, to learn how to effectively influence their resilience and adaptability.

The Alliance has its conceptual roots in a framework that is more than 30 years old. In a classic 1973 paper theoretical ecologist Crawford (Buzz) Holling first introduced the concept of resilience to the ecological literature as a way to help understand non-linear dynamics observed in ecosystems — such as an unexpected major change following a storm. Today, the appeal of this approach is growing, as a way to think about how humans interact with their environment and how they may move toward a workable framework for management (see sidebar, "Towards Adaptive Management," on page 7).

"Resilience offers a satisfying way of thinking about ecological changes," says Gunderson. "Humans have preferences about the desirable states of ecological systems and want to know how to either maintain the current state or what to do if a system is not in a desired state."

But before resilience can inform management decisions, researchers must develop a systematic way to anticipate when a system is getting close to a threshold or tipping point and prevent it from going over the edge (see sidebar, "Identifying Thresholds," on page 8). They must also learn how to turn around systems that, like the Bay, have arguably already shifted into an undesirable stable state — one that may be resilient in its own right.

## Reversal Potential

Picture the following scenario: On a hot and humid summer Friday, you join the exodus from the oppressive D.C. metro area and head to Ocean City, Maryland. You leave work early, so traffic on the Bay Bridge isn't too bad and you cover the 150 miles in a little more than three hours. On Saturday, you spend a pleasant day at the beach. That night, an unexpected storm hits the area, with record winds and raging surf. Sunday is rainy, so you pack up to leave early. You turn on the radio to hear the latest traffic report. Astonished, you learn that the Bay Bridge has sustained severe damage in last night's weather; the twin bridges are being evaluated for structural damage and both spans are closed to all traffic. You weigh your options. You can head south and take the bridge connecting the Eastern Shore to Cape Henry, Virginia, or you can head north and cross over from Delaware to Chesapeake City, Maryland. After a quick consultation with a map, you learn that the Virginia route will take roughly 7 hours (without traffic) and is roughly 370 miles. The Delaware route is quicker — about 4-5 hours to cover 210 miles. Resigned to a long and frustrating trip, you get in your car and start driving north toward Delaware. The trip home is no longer straightforward.

Ecosystems work in a similar manner. When an ecological regime reaches a tipping point, goes over the edge, and settles into a new stable state, it will often sustain fundamental changes that make it virtually impossible to go back along the same path. A return is still often achievable, but the route back might be longer and much more circuitous than anticipated. Ecologists call this *hysteresis*: the loss of a symmetrical pathway between two stable states of an ecological system.

These functional changes that accompany regime shifts present a clear challenge for restoration efforts. In many

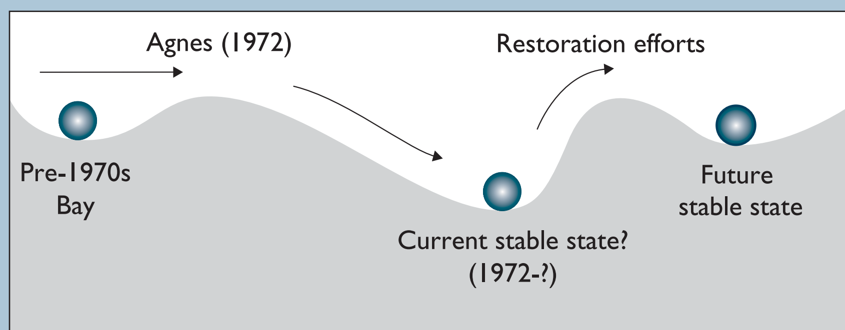
*Continued on page 9*

## The Language of Resilience

Resilience is a formal theoretical construct that has its roots in dynamic systems theory — the body of math that characterizes the behavior of complex systems. Ecologists use two different definitions of the term: *engineering resilience* and *ecological resilience*. Engineering resilience is defined as the rate at which a system returns to a stable state following a perturbation. This assumes that a system does not, after a perturbation, shift into an alternate state. Ecological resilience, in contrast, is measured by the magnitude of disturbance that can be absorbed before the system changes its structure. This definition applies both to ecological and social systems and it assumes from the outset that there exist multiple stable states for any given system.

The Resilience Alliance has adopted the definition of ecological resilience as the foundation for its exploration of the dynamics of ecological-social systems. They assert that ecological resilience is a better fit because "the interplay between stabilizing and destabilizing properties is at the heart of present issues of development and the environment — global change, biodiversity loss, ecosystem restoration and sustainable development." In contrast, "emphasis on engineering resilience reinforces the dangerous myth that the variability of natural systems can be effectively controlled, that the consequences are predictable and that sustained production is an attainable and sustainable goal."

The diagram below illustrates ecological resilience in the context of the Chesapeake Bay. Ecological resilience forms the operative framework for this story.




***Despite deforestation and diminished wetlands,*** *until the 1970s the Chesapeake Bay existed in a stable state with abundant fish, shellfish and underwater grasses. Over time, however, the accumulated loss of oysters, forests and other buffers weakened its resilience and left the Bay vulnerable to the torrential runoff brought by Tropical Storm Agnes in 1972. Since then, many ecologists feel that the Bay has found a new steady state, but one with far fewer grasses and many more algal blooms. Getting to a state that more closely resembles the past will require a difficult push up a hill made steeper by the loss of the Bay's buffers. Diagram adapted from Gunderson (2000) (for full reference, see "For Further Information" on page 12).*

# Towards Adaptive Management

BY ERICA GOLDMAN

ERICA GOLDMAN

*Some of the services that ecosystems provide — clean drinking water, soil stabilization, fish, or recreation — can be assigned a value by people who use them, which can help scientists advise on how to restore them.*

Ideas like stable states and thresholds may help us think about how ecosystems work, but translating theoretical precepts into practical management can be a tall order. For the Chesapeake, restoration aimed at recapturing at least some of the past is largely uncharted territory, one that will require management efforts that can be constantly tweaked and fine-tuned as they progress. And, while scientists can provide advice and insight into what a system might look like as it moves along a restoration trajectory, ultimately the decisions rest with those who use the Bay and live in the surrounding watershed to determine what ecological and economic services they want it to provide.

"The resilience framework resonates for a lot of people because it acknowledges that ecosystems are dynamic and change," says Barry Gold, a program officer for the David and Lucille Packard Foundation. But it will take a "different kind of ecological science — adaptive management" — to restore ecosystems based on these concepts, he says. "We won't have controls or replicates. We will go in with the current models and strong monitoring, implement restoration actions, and see how the system responds. The response will guide the next decisions," he says.

In theory, this back-and-forth management paradigm sounds logical, but in practice it has proved quite difficult to implement. In the Bay community, according to some, adaptive management has not yet taken root. "We have fallen into a cultural pathway of deterministic modeling," says University of Maryland Center for Environmental Science president Don Boesch. "No one can answer the question about how well observations match the predictions because we haven't focused on constantly checking the model with experiments and monitoring."

When funding is awarded for a restoration project, monitoring is the part most often cut, explains ecologist Margaret Palmer, from the University of Maryland, College Park, who is spearheading the National River Restoration Science Synthesis (NRRSS) — a project to develop a comprehensive national database to review and analyze the success of stream river restoration projects and to present information in a way useful to scientists, restoration practitioners and policy makers. "Our goal is to advance restoration in practice by tracking what has been done with their outcomes — we need an adaptive scheme that involves close monitoring to see what is working and how to improve the underlying science," she says.

In order to implement an adaptive management approach, according to Palmer, it is critical to involve a diverse group of managers, developers, environmental advocates and citizens in an iterative process. Scientists evaluate the environmental implications of meeting the stakeholder goals, go back to the stakeholders to decide if the environmental costs are too high, and then re-visit other options. "I am a firm believer that stakeholders should decide where a system should be restored to," she says. Once stakeholders agree about what they want, only then should science advise restoration efforts.

"It is a value decision," agrees ecologist Heather Leslie from Princeton University. "I don't think it is our role as scientists to dictate what is an acceptable state for an ecosystem." Leslie is working to develop a conceptual model for coastal marine ecosystems that is grounded in a resilience framework, linking local, regional and national institutions. She will test the model through a series of case studies, one of which will likely be the Chesapeake Bay.

Along similar lines, a growing group of scientists focus on "ecosystem services" as a way to frame the goal of restoration efforts. Some of the services that ecosystems provide, such as clean drinking water, soil stabilization by plants, fish, or recreation, can be assigned a value by people who use them, which can help scientists advise on how to restore them.

"It is more difficult to develop a restoration strategy if society cares both about a particular function and about individual species," says Palmer. In the case of the Bay, for example, if society decides that we care only about clean water, we could put in additional wetlands with non-native species that optimize this function. But the connection with Chesapeake's heritage places value on specific species, such as the native oyster and blue crab, she says.

"When the first [ecosystem services] work was published in 1994, it seemed utilitarian and cold-hearted," says ecologist Shahid Naeem at Columbia University in New York City. But like pistons and carburetors, assemblages of species in their environment do play a role in how the system operates, he says. "Biodiversity for its own sake is wonderful, don't get me wrong," he says. Still, the "aesthetic of biodiversity," will not move the science of restoration forward for ecosystems in which people are inextricably intertwined, he says.

The Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program took an "ecosystem services" approach in its landmark report, *Chesapeake Futures*, published last year. Without assigning value to any of three possible scenarios that are developed, the report challenges its audience to envision the Chesapeake Bay in the year 2030 — charging the reader to make choices about what is important. Based on these choices, the report outlines science and management roadmaps for each vision of the future.

Ultimately, movement towards any of the futures that we choose requires scientific progress, political buy-in, and social investment. In many ways, the science of ecology is playing catch up with engineering and space science and we have only begun the Herculean effort to understand how ecosystems function as an integrated whole.

"I find it appalling that we know how to put a missile together, but not a salt marsh," says ecologist Andrew Dobson at Princeton University, who studies the ecology of infectious diseases.

But there has been progress on the political-social front. Just this summer, the Maryland legislature passed the "flush tax," which adds a $2.50 per month charge to each household to pay for sewage treatment plant improvements and directs the revenue to the newly created Chesapeake Restoration Fund. As the link between the investments people are willing to make to build a different future for the Bay grows stronger, the slope of the uphill trajectory towards restoration gets incrementally less steep.

# Identifying Thresholds

BY ERICA GOLDMAN

Just off a country road in the coal-mining region of western Maryland, about as far in the state from the Chesapeake Bay as one can get, Bob Hilderbrand scrambles down an embankment and plows through dense vegetation. He carefully avoids the broken bottle shards and litter underfoot until he comes to a spot where the overgrown foliage is just thin enough to see through.

"Look up there," he says, pointing to a small waterfall cascading into a fast-flowing stream, with a dilapidated structure perched atop the cliff. It takes a moment to register that this is not the usual mountain stream tableau. The water pouring down is a vibrant, burnt orange — the color of a rusted pipe.

"Acid mine drainage," Hilderbrand explains. It happens when water and oxygen interact with rock that has been drilled to expose pyrite — an iron sulfide that is not a typical feature of the outermost layer. The reaction releases sulfuric acid and dissolved iron, which are devastating to fish, plants and invertebrates that live in the stream. The switch to a degraded state can happen very suddenly, he says.

Further downhill from the orange stream, called Braddock Run, Hilderbrand pulls the car off the road and points at a rusty rivulet on the ground that flows a short distance and then abruptly turns bubbly white, like Alka Seltzer. "Here, the acidic water is flowing over rock rich with aluminum. The acidity dissolves the aluminum from the rocks and causes it to precipitate out of the water downstream," he says. "Aluminum is also extremely toxic to everything that lives in the stream."

"This stream system cannot be restored without constant chemical treatment. It is an example of an irreversible regime change," he says. "Furthermore, its water will eventually drain into the Potomac River, and from there, into the Bay."

Hilderbrand, a young theoretical ecologist at UMCES Appalachian Laboratory in Frostburg, Maryland, studies thresholds and works to develop quantitative methods to identify them in stream ecosystems. The streams in western Maryland that ultimately drain into the Chesapeake Bay are much simpler ecosystems than the estuary as a whole and present an opportunity to characterize what biological and physical factors can make a system resilient and what can push it to the brink.

Specifically, Hilderbrand is comparing the different ways in which land use has modified streams in order to pinpoint what characteristics make them more or less vulnerable to disturbance. Funded largely by the National Park Service, he is building upon the Maryland Biological Stream Survey (MBSS) dataset, which has sampled over 800 streams in the

ERICA GOLDMAN

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***Ranging from pristine to degraded,*** *streams in western Maryland run the gamut. Bob Hilderbrand (top) turns over a rock to look for insect larvae in a pristine stream. Acid mine drainage (below) releases sulfuric acid and iron from the rock, turning the water burnt orange. The acidity of the water can also cause white toxic foam to bubble out of aluminum-rich rocks.*

state, in order to assess the biological composition and condition of streams. Using a Geographic Information System (GIS) and spatial data on land use, agriculture, and percent cover for each, combined with samples of community composition, he is trying to predict how continued land use practices will affect these streams.

"We want to be able to predict how changes in the watershed relate to functional and taxonomic changes in the community structure of the streams. We suspect some streams will be more vulnerable or more resilient to land use based on their size, channel gradient (slope), and location," he says. Using a statistical approach, Hilderbrand will construct clusters of minimally disturbed streams based on structure and function. He hypothesizes that streams falling outside of these clusters will match to GIS data that can be pinpointed as thresholds. Ultimately, he plans to construct a model that predicts state shifts in streams given the form and magnitude of the landscape alteration and stream class.

Identifying thresholds in different ecosystems presents a major challenge, but also offers a potential opportunity for framing management decisions. There are a lot of general features common to major regime shifts, but few specifics that can be extrapolated directly across diverse environments. Slowly, on a case-by-case basis, however, scientists are beginning to build a searchable database of thresholds to characterize what conditions cause shifts to take place and to compare across ecosystems. The database, established as a joint activity of the Santa Fe Institute and the Resilience Alliance, contains 64 examples from across the globe and across historical periods. They range from local, recent regime shifts such as the sudden eutrophication of Lake Washington in Puget Sound in the early part of the 20th century, to more distant changes such as climate-induced abrupt switches between vegetation and desert in the Sahara some 14,800 years ago, and again 5,500 years ago.

So far the responses to the project have been good, says database co-founder Brian Walker from the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Canberra, Australia. But it is early in the process, he emphasizes. "There is a bias towards lakes and drylands and we want to increase the range of systems included.... It is important to increase the number and diversity of examples before people begin to analyze and draw conclusions from too small a sample size," he says.

In terms of content, the developing database aims to extend beyond the ecology of regime changes to provide information about the social causes and responses to these shifts and their potential for reversal. The idea that social and ecological systems are coupled is crucial — that is, that the behavior of a society can cause ecological shifts and that those shifts, in turn, can influence the way that a society behaves.

In the extreme, a society-driven ecological change can lead to the subsequent collapse of that society — such was the case described in the database for human society in Easter Island in the Pacific Ocean. Settled around 800 A.D., Easter Island was covered by a tropical forest, with six species of land birds and 37 species of breeding sea birds. Inhabitants cut down trees for firewood, for making gardens and building canoes and for moving the giant statues carved on the island. By 1600 A.D. the population had swelled to an estimated high of around 10,000 people, and all the trees, land birds and all but one of the sea birds had become extinct. Without trees, tropical rains washed the soil away and islanders could no longer build the canoes they needed to fish and hunt. The society resorted to cannibalism and the population of Easter Island collapsed — irreversibly.

In fact, of the 64 examples currently presented in the thresholds database, an impressive 24 have undergone an irreversible regime shift, 8 are unknowns, and 32 appear reversible — but at least 8 of these show signs of permanent changes or hysteresis (see main article, page 6).

Although Chesapeake Bay is far from the doomsday scenario experienced by this small island nation over a millennium ago, it is similar in that there is a tremendous feedback between humans and the environment in the way that they effect change in each other. The Bay has already crossed one threshold — when it underwent a shift from bottom-driven to water column processes in the 1970s. The question now is whether another shift lies ahead on the road to recovery.

## Bay Buffers, continued from p. 6

northern lakes, for example, high phosphorus input from sewage, industrial, and agricultural sources can cause a switch from a state characterized by low phytoplankton biomass and clear water to one with high phytoplankton biomass, cloudy water, high phosphorus regeneration from sediments, and anoxic conditions for living organisms. "Once the tipping point is reached for these lakes, the cost of going back is enormous," says limnologist Steve Carpenter at the University of Wisconsin-Madison. "To revert to the original state, it is necessary to reduce the phosphorus to a lower level than it was before the shift occurred in the first place."

So what does this mean for restoration efforts in the Chesapeake Bay? Lost ecological buffers, such as oyster reefs, underwater grasses and forested coastlines, combined with changed land use are clear signs that the road home will follow a different route. The *Chesapeake 2000* agreement, a historic partnership between Virginia, Maryland, Pennsylvania, the District of Columbia, the Chesapeake Bay Commission and the U.S. Environmental Protection Agency signed in 1983 and 1987, outlines a time frame over which to restore the Bay in an integrated and coordinated manner — with clear benchmarks for progress, such as new water quality standards for oxygen and water clarity by 2010. Recent criticism of the Chesapeake Bay Program's modeling efforts, however, suggests that the Bay is not responding as quickly as predicted. Could loss of a symmetric road back (hysteresis) be the culprit?

There are, in fact, clear signs that metaphorically washed out bridges may already be a problem for the Bay. In a recent *Estuaries* paper, UMCES scientists Walter Boynton and James Hagy (now with the Environmental Protection Agency) present a long-term analysis of low oxygen (hypoxia) in the Bay from 1950 to 2001. They found that moderate hypoxia has increased almost three-fold for an average flow year over that time period. Furthermore, they found that the relationship between nitrogen influx (nutrient loading) and hypoxia is nonlinear — meaning that for a given amount of nitrogen the volume of low oxygen water is greater than can be explained by the quantity of nitrogen alone.

This relationship is both intriguing and troubling, UMCES president Don Boesch reported in his testimony to the U.S. House of Representatives Committee on Government Reform at a hearing held in August. It suggests that the Bay appears to have lost some of its ability to assimilate nutrients without becoming seriously hypoxic, possibly because of long-term losses of species in the benthic community. "This diminished resilience probably means that we simply have to accomplish much more reduction in nutrient loading before we see greatly reduced hypoxia," Boesch testified to the committee.

"In general, it may take considerable action to move the Bay along a restoration trajectory," Boesch says. "A linear ratcheting back along the curve may not be possible; it may require more to reverse the decline of the Bay than it took to get there in the first place. So, in the short run, the slope of recovery may be steeper, but there are ledges along the way and these ledges might be self-sustaining," he says.

### Jump-starting Recovery

Angie Hengst sits on the edge of the boat and quickly pulls on a skin suit. She draws a mask and snorkel over her face and slides into the water, holding a cylindrical gray tube in one hand and a buoyant float attached to a piece of PVC pipe in the other. She could stand easily in the four feet of water in Broad Creek on Maryland's Eastern Shore, but wears a mask and snorkel to make repeated surface dives to embed a sampler, called a "peeper," into the mucky substrate.

Hengst, a graduate student with researcher Laura Murray at Horn Point Laboratory, is surveying the geochemistry of the sediment in beds of underwater grasses. She is trying to determine

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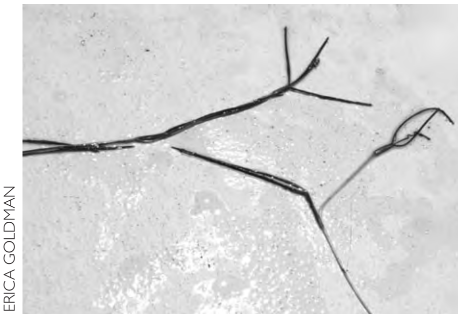

ERICA GOLDMAN

***Feeling around in the mucky substrate,*** *graduate student Angie Hengst (above right) tries to locate the edge of a bed of underwater grass,* Ruppia maritima *(shown at right, below). Faculty research assistant Debbie Hinkle (above left) holds a marker float and the "peeper" (shown at right, above) they will embed in the mud to measure sediment chemistry. They will retrieve the device and its data in 10 days time.*

whether one species of grass, *Ruppia maritima*, modifies its environment chemically and, if so, whether it makes conditions more favorable for other species of underwater grass to grow. Since *Ruppia* is one of the only species to have made a significant comeback so far, Murray and Hengst, along with systems ecologist Michael Kemp, are trying to determine if it could serve as a pioneer species of sorts. They ask whether *Ruppia* could make the sediment more hospitable for other species to colonize, if planted through active restoration efforts.

To look for differences in the sediment possibly caused by Bay grasses, Hengst puts peepers inside, outside and at the boundary of multiple *Ruppia* beds. After the water inside the peeper is the same as its surroundings, which occurs in roughly 7-10 days time, Hengst will retrieve the peeper and analyze the water for ammonia, nitrate, phosphate, and sulfide.

Like oysters, underwater grasses provide certain critical services to the environment — they are used as food and habitat for waterfowl, fish, invertebrates, and shellfish; serve as nursery habitat for young fish and crabs; filter and trap sediment that can cloud the water and bury bottom-dwellers; and oxygenate the water through photosynthesis. Together, the decline of grass abundance in the past few decades, along with the loss of oysters, has dramatically diminished water clarity and oxygen content, helping to maintain a state in the Bay that is turbid and dominated by phytoplankton primary production.

Kemp, a professor at Horn Point Laboratory, has identified specific cycles of positive feedback — where one change serves as a catalyst for other changes — in the interaction between grasses and the sediment, and he believes that these interrelated processes might help to jump-start recovery. Microorganisms in the sediment use oxygen to turn ammonia, a waste product, into nitrate through a process called nitrification. Other sediment microbes then remove fixed nitrogen (i.e., nitrogen available for algal growth) out of the environment by reducing it to nitrogen gas — through a process called denitrification. Since the roots of underwater grasses help bring oxygen to regions within the oxygen-starved sediment, they can accelerate the coupled nitrification-denitrification cycle, explains Kemp. In the Bay, as grasses died off in the 1970s, nitrification (which requires oxygen) and its coupled denitrification slowed down. This led to an accumulation of nitrogen, which supports more growth of algae. Since algae are better competitors for light than grasses, their presence further accelerated the demise of grasses by shading them.

Kemp believes that the positive feedback between nitrification-denitrification and underwater grasses could help to jump-start the Bay's restoration trajectory. Once water quality is good enough to sustain some healthy underwater grass beds, he says, the amplification process that accelerated their decline (positive feedback) should happen in reverse, helping to further improve water quality and decrease nutrient loading. But in order for the Bay to help catalyze its own recovery, water quality may need to be even better than it was before the decline of these grasses — the washed out Bay Bridge problem (hysteresis) again.

There are other ways by which the Bay might be able to accelerate its own recovery. For example, as oxygen penetrates bottom sediments, the release of phosphorus to the water column will decrease dramatically, explains ecologist Walter Boynton. In the absence of oxygen, phosphorus is less likely to separate from the iron-rich sediments, leach into the water and promote algal growth. Other good things will happen as bottom sediments become oxygenated again. For example, animals that live in the sediment, such as tubeworms, will become

# A Meeting of Minds

BY ERICA GOLDMAN

As Pacific Northwest rains drenched the forested hill on Puget Sound's San Juan Island, a group of more than 90 prominent scientists and students from across the country and overseas packed into a lecture hall in late August at Friday Harbor Laboratories (FHL). The weather was uncharacteristic for summer in the northwest as was the carefully crafted collision of science, sociology and policy. Experts had come to discuss the role of resilience in ocean and coastal ecosystems.

The Managing for Resilience Symposium, held as part of FHL's centennial celebration, set out to break new ground in a historic setting. The Laboratories have been at the epicenter of thinking about marine ecology for the past century, and the current meeting attempted to merge two scientific traditions: on the one hand, field and lab-based findings about how marine organisms interact with their environment; on the other, theoretical frameworks for thinking about how people affect the coastal ecosystems in which they live.

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***A younger generation of emerging marine ecologists*** *sorts through the contents of a Puget Sound dredge. Sixteen stellar students from underrepresented groups participated in this symposium as "Mellon Scholars," with support from the Andrew W. Mellon Foundation.*

Organized by ecologists Jane Lubchenco and Karen McLeod from Oregon State University in Corvallis, and biologist Trish Morse from the University of Washington, the symposium challenged participants from different disciplinary backgrounds to negotiate new territory. The concept of resilience, the amount of perturbation an ecosystem can withstand before shifting into a different stable state, has been applied more clearly to rivers and lakes than to oceans and estuaries. The research presented at the meeting suggests that the scientific underpinnings of resilience in marine systems are beginning to emerge.

## Research Highlights

Diversity and redundancy — at the level of genetics, species and communities — build resilience into an ecosystem, reported several of the scientists. Talks ranged from explorations of the theoretical basis of resilience to experimental tests of it in practice. For example, ecologist Jay Stachowicz, from the University of California at Davis, presented several case studies to illustrate the role of diversity as an ecosystem's "biological insurance." First, he presented results from a study in which he challenged an experimentally assembled community of marine bottom-dwellers with invasion by three species of non-native sea squirts. He found that communities with more species filled available space more completely and were better able to resist sea squirt invasion. In a second case study, Stachowicz showed that beds of the sea grass *Zostera marina* with high genetic diversity resisted disturbance by grazing geese better than beds with less genetic variation.

Genetic diversity may also play a key role in making an ecosystem resilient, according to initial insights from a study on phytoplankton — tiny plants that drive the ocean's food web. The study, conducted by marine biologist Brian Palenik from Scripps Institute of Oceanography in La Jolla, California, compared strains of phytoplankton from coastal locations and open ocean. Preliminary findings suggest that coastal species can better withstand environmental stresses and this resistance could be linked to variability in the genome. The first complete sequence of a species of diatom, one of the dominant groups of phytoplankton, was published in *Science* at the beginning of October, an effort that will pave the way for whole genome studies of these omnipresent algae.

Social scientists at the meeting also focused on the interaction or "coupling" between humans and their environment. Charles Perrings, from the University of York, U.K., for example, presented a study that linked economic data to large-scale ecological regime shifts. Perrings showed that changes in the environmental conditions of Lake Victoria, the world's second largest lake, which spans Kenya, Tanzania and Uganda, might be forecast by trends in the economy. Specifically, he provided evidence that the switch to a state dominated by high algal biomass (eutrophication) closely follows changes in land use in the watershed. If we know how a fishery responds to price-driven changes in land use, such as the price of fertilizer, he explains, then those prices can also predict changes in the fishery.

"In this case, the market provides a lever on behavior," Perrings says. Even though people make decisions in their own self-interest, these decisions place predictable pressures on the environment, he says.

## Beyond Academia

But how does the construct of resilience apply to management? The graduate students and postdocs present identified resilience in practice as a shortcoming of the meeting and seized upon a clear opportunity for leadership. We have heard debate on the question "what is resilience?" but we have not identified solutions for policy or management, says graduate student Tanya McKitrick from Stanford University. "Policy decisions will be made with or without input from scientists and the consequences of misinterpretation are too great," she says. The students argued for a follow-up meeting between scientists and managers to grapple with how to use ecosystem-based approaches to manage for resilience.

Last year's Pew Oceans Commission report and this year's U.S. Commission on Ocean Policy report delivered grave warnings on the state of the oceans and coasts. Political momentum resulting from the reports has already initiated legislation proposing sweeping changes in ocean policy and management at federal and state levels. Scientists, it's clear, have a role to play, not only in building empirical knowledge, but also in developing a new framework for thinking about ocean management — a framework that can translate key concepts about how ecosystems respond to and recover from perturbation into strategies for preserving and recovering resilience in disturbed areas. The younger generation, it is also clear, is ready to share the mantle of leadership with the giants who have paved the way.

more abundant and will help to further stabilize the physical and chemical composition of the Bay bottom, he explains.

But first, says Boynton, we need to significantly reduce the nitrogen and phosphorus inputs to the Bay that cause sediments to become anoxic in the first place — rather than "nibbling at the fringes" of nutrient reduction. "That will start the process of rebuilding this resilience."

And what about oysters? The verdict is still out as to how much we can bring back the native oyster (*Crassostrea virginica*) and a whole host of issues must be resolved before we can introduce the non-native oyster (*Crassostrea ariakensis*) (see article, "A New Bay for the Oyster?" on page 13). But restoring water quality would certainly be easier with a prolific filter feeder in the mix.

"We might be able to improve water quality through nutrient reduction alone, without restoring oysters, but it would likely be a less resilient Bay, one that is forever sensitive to perturbations like storms and other random events," says Breitburg. "Still, it is a better alternative than an un-restored Bay," she says.

A test of Breitburg's intuition on the Bay's continued susceptibility came in the third week of September, just after Hurricane Ivan pummeled the coasts of Florida and Alabama. Major flooding in Pennsylvania and New York rivers caused uprooted trees and pieces of debris to race through the Conowingo Dam into the Susquehanna River and, from there, into the Bay. A few days later, watermen noted large swaths of sediment-laden, deep brown water the color of dark coffee, as far south as one mile above the Bay Bridge.

Ivan's timing couldn't have been worse. The storm blew through just when the Susquehanna had been showing some signs of recovery — likely due to efforts in phosphorus reduction, says UMCES researcher Cornwell. Just a month earlier, scientists and managers found healthy stands of at least a dozen species of underwater grasses and clear water in the Susquehanna flats for the first time in years. Now there is concern that the huge sediment load that surged down the river might severely harm these newly grown grasses. The Susquehanna is clearly not resistant to a perturbation like Hurricane Ivan — no system would be. But if the Susquehanna can recover from the storm, if healthy underwater grasses and clear waters reappear next year, that will be a sign that some resilience has been restored to the river. If the new grasses are gone again and do not come back for several years, then the improvements seen last summer were ephemeral.

So the restoration of the Chesapeake Bay is back to the chicken and egg conundrum. Which comes first? Restoration of grasses and oysters? Or improved water quality? Can we help the Bay jump-start its own recovery by replanting oysters and underwater grasses? Or do we have to restore water quality first to help them survive and withstand perturbations like storms that flood the bottom with sediment? Can we upgrade water quality through nutrient reduction alone, without the filtering power of oysters and grasses — both of which create positive feedback for improving water clarity?

## Restoration's Sting

As the boat turns back towards SERC's pier, Breitburg finishes filling out her data sheets and sits down on the edge of the boat. The day has confirmed her suspicions — the plankton nets towed by the skiff were not too small. There were simply no nettles in the Rhode to be caught.

It's too soon to tell whether or not the Rhode is following a path similar to that of the Patuxent. Scientists do not have a parallel historical record of nettle abundance for comparison. In the Patuxent, however, Breitburg is confident that the declining oyster population is strongly implicated in the disappearance of nettles. She has plans to do follow-up studies to nail down the specifics of this broken link in the Bay's food web.

And, if Breitburg is right about a decline in oysters leading to a decline in sea nettles, then the opposite may also prove true. Although the return of oysters should bring improved filtration and cleaner water, it could also bring a big rise in sea nettle populations.

So one of the results of a restored Bay could be a return to the era of jellyfish-exclusion nets at swimming beaches, a state of the Bay that first sparked Maryland Congressman Edward Garmatz, the chair of the former U.S. House of Representatives Merchant Marine and Fisheries Committee, to author the "Jellyfish Control Act" in the 1960s. But now that we are beginning to understand the crucial role that these enigmatic creatures play in the Chesapeake's intricate food web, now that we see that a robust population of sea nettles comes with oysters, underwater grasses, clear waters, recreation, and healthy fisheries — it would be worth it, wouldn't it?

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# A New Bay for the Oyster?

BY MICHAEL W. FINCHAM

On the last Saturday of October, there's an oyster party out on the Choptank and the Chester, two Maryland rivers littered with broken-down reefs and scattered, disease-ridden oysters. Watermen are invited as well as environmentalists, scientists, politicians and the press.

There have been other oyster parties along these rivers in recent years, but these were *planting* parties organized by the Oyster Recovery Partnership, a coalition of organizations, agencies, scientists and volunteers who want to put oysters back in the Bay. On this Saturday, however, there's an old-fashioned *fishing* party, a "trying of the grounds," a test case for the idea that oysters can be restored — and that the Bay's resilience can be revived.

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Oystermen in narrow, deadrise workboats driven by diesels and old car motors chug out in the pre-dawn light to oyster grounds called Emory Hollow and Blunts and Bolingbroke Sands. They haul out their long-shafted hand tongs and hop up onto the narrow edge of their open cockpits. As dawn breaks there are several workboats parked over each oyster bar with watermen balanced on their washboards waving their arms and working their tongs back and forth as they dig into a pile of oysters along the bottom.

There will be no October surprise this Saturday morning. Charley Frentz, the man who's throwing the party, already knows what kind of oysters the watermen will find on these bars. "It will be a golden opportunity to actually see these 4-, 5-, and 6-inch oysters that we've got in the Bay now," says Frentz, director of the Oyster Recovery Partnership. "They are gorgeous." He knows they're gorgeous because his organization put them there three years ago and scientists have monitored their growth ever since.

Think of the event as an opening, a groundbreaking — which it literally is. These oyster grounds were closed for business for three years, while the Oyster Recovery Partnership under Frentz reorganized its approach to restoration. The new plan called for stepped-up spawning of disease-free oysters, new mass production techniques for moving and planting oysters, the establishment of off-limits sanctuary bars where watermen could not harvest and other managed reserve bars where they could, on occasion, go fishing for oysters.

These three oyster bars are the test case for the new approach and a trying ground for the new director. "Everybody has been very patient the last three years with me," says Frentz, who took over as director in 2000. "They have been giving me the benefit of the doubt on these managed reserves and sanctuary programs and how we are cleaning the bars, how we are using the watermen. And until these boys get these oysters on October 30th, I don't have a deliverable."

## Two Estuaries: The Old and the Now

The great oyster dieoffs of the last four decades have changed the ecology of the Chesapeake. When H.L.Mencken, back in the 1940s, called the Bay "an immense protein factory," the estuary was turning out more seafood per acre than any other body of water in the world — and oysters were one of the reasons. Sitting silently along the bottom, oysters were, in effect, the heavy machinery on the factory floor.

The most profitable species in the Bay, oysters were both a foundation fishery for the region's economy and a keystone species for the Bay's ecology. They built reefs, creating three-dimensional habitat for crabs and finfish and dozens of other species. They held barnacles and mussels and jellyfish larvae on their tough shells. They were food for blue crabs and for odd little animals like oyster drills and ugly, big-toothed toadfish. More importantly, oysters on the bottom were indefatigable filter feeders, noiseless vacuum cleaners quietly sucking nutrients and


MICHAEL W. FINCHAM

***What's the best way to restore oysters in the Bay?*** *Replanting with the native oyster? Or importing an oyster from overseas? Don Meritt (right) and his staff have developed techniques for spawning, feeding and setting the native oyster,* Crassostrea virginica. *The aquaculture hatchery he runs at the UMCES Horn Point Laboratory is the major source for the native oysters now being replanted in Maryland waters. Ken Paynter and Tim Koles (opposite page, left and right) get ready to test-plant oysters from China,* Crassostrea ariakensis, *in the Chesapeake. Sterile by design, those oysters are fast growing (in the lab) and disease resistant (so far). Which will be king in the once-great shellfish Bay?*

phytoplankton out of the water. Stacked in huge beds, oysters were engines for clarity, magnets for biodiversity.

And then, in only three decades, they were nearly gone. Two parasites, MSX and Dermo, infected the oyster grounds of southern Virginia in the early 1960s and spread steadily northwards into Maryland waters during years of drought or low rainfall. By the early 1990s populations of *Crassostrea virginica*, the native species, were down to less than one percent of their historic levels.

There were less drastic declines with three other great filters: forests, wetlands and seagrasses. These natural systems are the major buffers in estuaries like the Chesapeake, the primary causes for water clarity, the sources for ecosystem stability. They help absorb, in different ways, the intermittent insults of tropical storms and the ongoing onslaught of sediments and nutrients that can overwhelm and over-fertilize the estuary.

In theory, these buffers are reservoirs for resilience. When one buffer declines — say oysters — then the others would still be at work: filtering, absorbing, mitigating. The Bay would still have a built-in capacity to bounce back. When several buffers trend down at the same time — say, oysters and seagrasses and wetlands — then funny things start to happen. Feedback loops activate. One trend starts to magnify another. Ecosystem change accelerates.

The end result is regime change: the ecosystem transitions from one self-sustaining state to another. The Chesapeake over the last three decades has shifted from an ecosystem driven by bottom dwellers and benthic processes to an oysterless ecosystem driven by plankton blooms in the water, bacterial blooms along the bottom and large, low-oxygen zones. These two estuaries are very different. And the new state has its own built-in resilience — it can resist recovery.

## Oyster Futures

When watermen start fishing the Choptank and the Chester in the first light of the last Saturday in October, they like what they find. "On these three bars," says Frentz of the Oyster Recovery Partnership, "we probably have more oysters for the watermen than they caught in the entire Chesapeake last year." Frentz will have his "deliverable," one that's simultaneously impressive — and sobering.

For the onlookers on the press boats, a scene full of tongboats clustered over oyster bars will look a lot like an old photo from the past, from a half century earlier when the Bay was still a protein factory. It's more likely a snapshot of what the future will look like.

The oysters coming out of those rivers were put there by science, not by nature. They were born in a laboratory, not in a river. They are the product of progress in breeding disease-resistance, in turning out larger numbers of hatchery-spawned oysters and in getting them planted in the right places.

Research results like these are the other "deliverables" from the oyster recovery crusade. They are starting to answer some of the big questions about the future Bay: Does oyster restoration work? Will it help the whole ecosystem bounce back? Can it kick off a new round of regime change in the Chesapeake?

The research answers are incomplete, impressive — and also sobering.

The progress that put oysters in the Choptank and Chester should continue. With each passing year, Stan Allen at the Virginia Institute of Marine Science (VIMS) is able to breed yet more generations of native oysters with stronger disease resistance. At the UMCES Horn Point Laboratory, Don Meritt is setting up a hugely expanded, industrial-level oyster hatchery. The near future could bring an exponential increase in the amount of native seed oysters available for planting.

The good news from the field is that reef restoration works — in places — and when it does "good ecological things happen," according to UMCES scientist Ken Paynter. Wherever the Partnership has planted oysters, Paynter has taken samples in every season except the dead of winter, sending divers down with cameras and quadrats and grab bags to videotape the

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reefs and bring up oysters for growth and disease analysis. "When you do restore an oyster reef, then the oysters grow and survive. You get animals recruiting to form a diverse benthic community in the reef," he says. "And it appears that oysters filter lots of water."

The bad news: reef restoration is working only in low-salinity regions. Everywhere else they went, Paynter and his divers saw oysters grow well for two years, then die quickly from Dermo or MSX, as the two parasites continue to invade and overwhelm oysters in moderate to high salinity waters.

Oyster restoration with native oysters, says Paynter, will work only in low-salinity waters below 10 parts per thousand. Healthy high-filtering oysters could be restored on tens of thousands of upriver acres, totaling perhaps 25 percent of the Bay's historic oyster grounds, according to Paynter's rough estimate.

That's a significant chunk of the ecosystem where rebuilding oyster reefs could restart water filtering and biodiversity and other "good ecological things." But it still leaves 75 percent of the old oyster grounds stuck with a dwindling supply of disease-ridden oysters.

Can native oysters drive a major ecosystem rebound, a regime change towards a restored Chesapeake? According to the research so far, that's a little like kick-starting a four-cylinder motor that's got only one spark plug firing.

## Progress and its Paradoxes

On a mild April morning earlier this year, Ken Paynter and his field technician Tim Koles pulled on their dark, rubbery dry suits and went wading in the chilly waters off Solomons Island. Pushing into chest-deep water, they floated between them a rack of wire cages holding dark shells, each the size of a thumbnail. The event was a first for Maryland: the test-planting of oysters from China in the Chesapeake Bay.

There are a number of paradoxes in the progress of oyster science. The success with replanting native oysters (albeit, only in low salinity waters) has raised some optimism about planting non-native oysters in the high-salinity waters that make up most of the Bay's oyster grounds. Since reef restoration works, it might work more widely if we can find an oyster that won't get sick from MSX or Dermo.

A second paradox: Chinese oysters may be introduced to repair oyster grounds that were ruined by an earlier introduction of Japanese oysters half a century ago. Forty years after MSX began devastating oyster beds in Delaware and Chesapeake bays, Gene Burreson of VIMS was able to prove that MSX was a natural parasite carried by *Crassostrea gigas*, a Japanese oyster brought into the Bay by oyster growers, scientists or international shipping. *Gigas*, it turned out, does not thrive in the Bay, but its parasite, MSX, does.

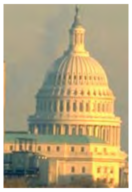
The oysters that Paynter and Koles are planting are called *Crassostrea ariakensis*, or the Suminoe oyster. The known native ranges for the species include northern China, western Korea and southern Japan. Paynter's test oysters, however, never lived in Asian waters. They were conceived in a lab in southern Virginia — as were their parents and grandparents. These third-generation lab specimens were also crossbred for sterility by Stan Allen of VIMS. In both lab and field tests, they have grown faster and fatter in Chesapeake waters than the native *Crassostrea virginica*. They are not reproducing in the Bay because they are, for now, sterile animals bred for testing. Most importantly they are not dying off from the local diseases.

No wonder a lot of watermen and some scientists think the Asian oyster holds a key to the future economy and ecology of the Bay. Paynter, however, is cautiously optimistic, calling the prospects promising. "It is not in my mind an either/or sort of thing," he says. "But rather *virginica*, the native oyster can do its job in lower salinity waters where disease is not as prolific, and perhaps *ariakensis* will be more successful in higher salinities. And we can accomplish restorations in both areas."

A final paradox: the road back to a restored Chesapeake will, it seems, require a detour through China. The stakes are high, of course, given the example of MSX, but the potential benefits are enticing. If it can reproduce in Bay waters, if it can build reefs, if it holds no unknown viruses or exotic diseases — those are a lot of ifs.

But if this Asian oyster keeps passing all its many tests, then there may soon be new biological engines on the floor of the Bay, turning plankton into protein and kick-starting once again the Chesapeake's famous old seafood factory. And October mornings in the future might see a lot more planting parties and fishing parties on a lot more rivers, all of them running clearer in the early morning light.

## Graduate Policy Fellowships



**Dean John A. Knauss Marine Policy Fellowships, National Sea Grant College Program.** Maryland Sea Grant is seeking applicants for 2006 fellowships, funded by the National Sea Grant office and administered through individual state Sea Grant programs. Knauss Fellows spend a year in marine policy-related positions in the legislative and executive branches of the federal government. Past Fellows have worked in the offices of U.S. Senators and Representatives, on Congressional subcommittees and at agencies such as the National Science Foundation and NOAA. Fellowships run from February 1, 2006 to January 31, 2007 and pay a stipend of $33,000 plus $7,000 for health insurance, moving and travel.

To qualify for a fellowship, students must be enrolled by April 1st of the year of application in a graduate or professional degree program in a marine-related field at an accredited institution in the United States. The application deadline is April 6, 2005, but those interested in applying for fellowships should check with the Maryland Sea Grant office by mid-February for guidance and application details.

For general information, please check the web at www.mdsg.umd.edu/Policy/knauss.html and www.nsgo.seagrant.org/Knauss.html. For application details, contact Susan Leet, Maryland Sea Grant College Program; phone, 301.403.4220, ext. 13; e-mail, leet@mdsg.umd.edu.

## Coastal Management Fellowship

**NOAA Coastal Services Center.** The Coastal Management Fellowship was established in 1996 to provide on-the-job education and training opportunities in coastal resource management and policy for postgraduate students and to provide project assistance to state coastal zone management programs. The program matches postgraduate students with state coastal zone programs to work on projects proposed by the state and selected by the fellowship sponsor, the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. This two-year opportunity offers a competitive salary, medical benefits, and travel and relocation expense reimbursement.

Students completing a master's, doctoral, or professional degree program in natural resource management or environmental-related studies at an accredited U.S. university between January 1, 2004, and July 31, 2005, are eligible. Those studying in a broad range of environmental programs are encouraged to apply. Students from non-U.S. institutions are not eligible.

The application deadline for the fellowship program is January 31st, 2005 for the class of 2005. Those interested in applying for 2005 fellowships should check with the Maryland Sea Grant office in early November for guidance and application details.

For general information, please check the web at www.csc.noaa.gov/cms/fellows.html. Then contact Susan Leet, Maryland Sea Grant College Program; phone, 301.403.4220, ext. 13; e-mail, leet@mdsg.umd.edu

**_Chesapeake Quarterly_ is also available on the web at www.mdsg.umd.edu/CQ**

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