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UM Hatcheries Serving Research in the Chesapeake Bay

Horn Point Laboratory and Center of Marine Biotechnology

Merrill Leffler
Maryland Sea Grant Program

The new Aquaculture Research Facility at the UMCES Horn Point Laboratory in Cambridge

Mention finfish or shellfish hatcheries and most of us think of aquaculture for producing seafood or for stocking game fish. But aquaculture for food production in Maryland remains a small industry, mostly serving niche markets — in fact, the most successful commercial operations in the state are rearing ornamental fish and aquatic plants. Hatcheries are employed in restoration programs for rebuilding stocks of depleted species such as oysters and shad in the Chesapeake Bay — the Maryland Department of Natural Resources, for example, has been producing shad in its hatchery for some years as part of a stock enhancement program that includes the removal of dams to recover upriver spawning grounds. DNR is also working with scientists at the University of Maryland Center for Environmental Science (UMCES) and the University of Maryland Biotechnology Institute (UMBI) to assess the potential of restoring sturgeon populations.

But hatcheries also play another significant role, one not often accounted for, in scientific research. At the UMCES Horn Point Laboratory (HPL) and the UMBI's Center of Marine Biotechnology (COMB), state-of-the-art research hatcheries are making it possible to conduct a host of fundamental and applied studies that could lead to innovative approaches for managing two keystone species in the bay that are in trouble, namely oysters and crabs.

Oyster Hatchery at Horn Point Lab

The HPL oyster hatchery, now part of the new Aquaculture and Restoration Ecology Laboratory, is the major producer of oysters for research on restoration efforts in Maryland, including its collaboration with the Oyster Recovery Partnership (ORP) in rebuilding oyster stocks throughout Maryland's portion of the

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Chesapeake. Under the direction of HPL faculty member and Sea Grant Shellfish Specialist Don "Mutt" Meritt, the hatchery produced 130 million seed oysters in 2003 (see "A Unique Partnership: Horn Point Laboratory and the Oyster Recovery Partnership, *Aquafarmer Online*, www.mdsg.umd.edu/Extension/Aquafarmer/Summer03.html#4). While the ORP efforts aim at rebuilding oyster reefs for sustainable production and managed harvests, University of Maryland College Park scientist Ken Paynter is studying the productivity of these reefs and assessing reef architectures and environmental regimes that will best promote survivability of the native oyster, *Crassostrea virginica*.

Meritt is also producing disease-tolerant strains of native oysters, among them, CROSBreed and DEBYs that were bred at the Virginia Institute of Marine Science (VIMS), and *C. virginica* from other regions. For example, he and Paynter are working with VIMS researchers and scientists from Rutgers University and the University of Delaware to compare the performance of a variety of these genetic strains in numbers of locations in Chesapeake and Delaware bays — eventually hatchery breeding programs may make it possible to tailor disease-resistant strains for given suites of environmental conditions. Maryland and Virginia oyster growers, especially those involved in oyster gardening projects, are already growing out some of these strains and providing scientists with data on growth and survivability.

With the accelerated drive in the Chesapeake to determine the potential effects of introducing the non-native Asian oyster, *Crassostrea ariakensis*, Paynter and Meritt will be using hatchery-reared triploids (oysters rendered sterile so they cannot reproduce) in order to compare their growth and survivability with native oysters in the Choptank, Patuxent and Severn rivers.

Blue Crab Hatchery at COMB

While breeding oysters in hatcheries has a long history, this has not been the case for blue crabs. Until the last several years, there was no interest in the Chesapeake, nor any reason for interest, in hatchery-bred crabs because of their great availability and fecundity. But research is often driven by crisis, whether real or perceived. Over the last ten years, blue crab stocks have fallen more than 80 percent according to a number of assessments that also indicate the abundance of blue crab larvae and post-larvae are down significantly as well. Concern over these declines, which have been attributed to overfishing, habitat loss and natural cycles, has led to a number of responses by policy makers, resource management agencies, and research scientists.

One of those responses, by the Chesapeake Bay Commission, was formation of the Bi-State Blue Crab Advisory Committee (BBCAC) in cooperation with the states of Maryland and Virginia. Composed of a select group of scientists, resource managers and watermen, BBCAC's mission was to help resolve controversies among different stakeholders over the status of the Bay's blue crab stocks. BBCAC brought together a Technical Workgroup that did groundbreaking work in establishing Baywide thresholds and targets for the fishery. While thresholds identify dangerous levels of harvesting that could lead to a stock collapse, targets are more conservative or precautionary harvesting levels which, according to scientific models, should promote long-term sustainability. Though a lack of funding by Maryland and Virginia brought BBCAC activities to a close last year, the Technical Workgroup continues to function, with partial support from Maryland and Virginia Sea Grant programs.

Worry over the blue crab decline also reached the Maryland General Assembly — in Fall, 2000, legislators voted to support the development of a blue crab research program at the Center of Marine Biotechnology (COMB) that would include assessing the role of hatchery-reared blue crabs for rebuilding spawning stocks. COMB, together with what has since become a consortium of institutions — the Virginia Institute of Marine Science, the Smithsonian Environmental Research Center, North Carolina State University and the University of Southern Mississippi — received further support from Phillips Seafood in Baltimore, the Maryland Department of Business and Economic Development and the U.S. Congress.

Closing the Life Cycle

The blue crab research at COMB, says director Yonathan Zohar, has a three-fold purpose: (1) to study fundamental biological issues over all life stages, (2) to develop hatchery and nursery technologies in order to spawn crabs to maturity, in other words to "close" the life cycle and (3) to test the feasibility of introducing blue crab juveniles for enhancing the Bay's blue crab breeding stocks.

A major achievement by COMB scientists has been the development of hatchery and nursery technologies for successfully spawning mature crabs and rearing progeny through their many life stages to become sexually reproductive adults. "In April 2003," says Oded Zmora, "the blue crab life cycle was closed in captivity, when a hatchery-produced female that mated at the age of 5 months produced a brood at the age of 10-1/2 months and released second generation larvae."

COMB scientists have done this through innovative uses of recirculating tank technology, which its Aquaculture Research Center has been employing in the development of finfish aquaculture technologies that include breeding striped bass and other species, such as sea bream, out of season. "Closing the blue crab life cycle" is no small achievement says Zohar. "It has never been done before." Culturing crabs has involved optimizing growing conditions, developing feeds for different life stages and dealing with the uniqueness of the blue crab itself. "To begin with," says Zohar, "they produce very small eggs and small larval stages and then go through at least eight zoeal, or developmental, stages before becoming juveniles, or megalopae."

Getting crabs from the egg through eight zoeal stages to the first megalopae (some 10 mm in length) has taken, on average, 22 days — rearing them from 10 mm megalopae to the 20 mm juvenile stage remains a hazardous journey for the young crabs. At the megalopal stage, crabs become cannibalistic — and cannibalism, says Zohar, has proven to be a major bottleneck in getting high percentages of juveniles to survive. To try to overcome this instinctual behavior, researchers have stocked the young crabs in tanks in lower densities while trying various shelter materials, so that they can better hide from each other. The aim here has been to simulate the role of underwater grasses: in the wild, young and molting crabs hide in grasses where they also find prey to feed on. We provide the crabs with large amounts of food, Zohar says, consisting mostly of adult brine shrimp (*Artemia* species), shredded squid and artificial pellets. The idea is simple: if satiated, young crabs might be less likely to go after their siblings.

Hatchery Crabs in the Bay

In the first two years of production in 2002 and 2003, COMB produced 40,000 juvenile crabs each year at about 3/4-inch. Nearly half of these crabs have been released into the Bay to study how hatchery-produced stocks will fare. Working with Anson "Tuck" Hines at the Smithsonian Environmental Research Center (SERC), about 25,000 hatchery-reared juvenile crabs during spring 2002 and 20,000 in 2003 were introduced into the Rhode River, a small subestuary of the Chesapeake on the western shore. Released in four separate cohorts, the hatchery crabs bear microwired tags so those that are recovered, either by crabbers or in monitoring, will give researchers insights into crab growth and travel patterns. Preliminary indications are that hatchery-reared crabs in the wild reach adult size some four months after release — added to the two months of growth in the hatchery from egg to 20 mm juvenile, that makes them six months old. Estimates are that it takes naturally-occurring crabs one to one-and-a-half years in the bay to reach maturity.

Is stock enhancement of blue crabs for producing broodstock a realistic objective in the Chesapeake? Answers could be a while in coming. To begin with, crabs have been released in only a few locations in the Rhode River. While 45,000 may seem like a large number, it pales in relation to the Chesapeake's wild population and the bay's enormous size. To start determining whether hatchery-bred crabs hold promise for enhancing bay stocks in any appreciable way, researchers will first have to scale up facilities far beyond the capacity of current recirculating facilities at COMB in order to conduct much larger studies on survival and recruitment. Efforts to do this are already underway, says Zohar.

For example, the Maryland Watermen's Association has begun trying to raise funds through its Chesapeake Bay Environmental Planners organization, the aim of which says Mick Blackistone, is to establish grow out nursery facilities for releasing 500,000 juveniles throughout the Bay. There are a host of ecological and socioeconomic questions that must be answered even if this number is eventually reached. What percentage of these juveniles are likely to reach maturity? How well will these hatchery-reared crabs recruit to spawning populations? Given that some 70 million blue crabs are harvested in the Chesapeake annually, how many hatchery-reared crabs will it take to make a difference? What will constitute success? What are the real costs of enhancement assuming such releases make a difference, i.e., what is the cost per crab? Who are the beneficiaries? Who pays? What is the cost-benefit of enhancement compared with science-based management? These are just a few of the questions that need to be dealt with in the coming years.

In the meantime, COMB's achievement in closing the blue crab life cycle and producing crabs "on-demand" is a boon for scientists who have begun taking advantage of their availability. COMB researcher John Trant, for instance, is employing molecular tools to study the blue crab endocrine system, while Allen Place has begun groundbreaking work on developing molecular tags for tracking crabs, a kind of DNA fingerprinting. At SERC, Hines is collecting field data on crab behavior and movement, comparing these data with wild crabs, while scientists at the UMCES Chesapeake Biological Laboratory — Dave Secor and Tom Miller — are employing hatchery-reared crabs for research on crab aging and experiments on overwintering mortality, respectively.

COMB's hatchery-reared crabs are giving scientists capabilities they did not have before. New information about reproduction, growth and behavior will not only improve our understanding of how blue crabs thrive at different life stages, but will also provide the kind of information that could eventually help resource managers better direct efforts for managing and restoring the Bay's blue crab populations.

To learn more about COMB blue crab research, visit www.umbi.umd.edu/%7Ecomb/programs/aquaculture/bluecrab.html; for more about the HPL Restoration and Ecology Center, see www.hpl.umces.edu/facilities/oysters.html; for the Aquaculture and Restoration Ecology Laboratory, see http://ca.umces.edu/AREL2/jocf.htm

Is a Non-native the Answer to the Bay's Oyster Woes?

Merrill Leffler, Maryland Sea Grant

"Our method of managing the oyster industry has been a failure. It has yielded on the average some ten million bushels of oysters annually from grounds which are capable of yielding five hundred million bushels each year." Only ten million! This was William K. Brooks, Johns Hopkins University professor and Maryland's first Oyster Commissioner, in 1905. Nearly a century later, in the 2003-2004 season, Maryland's harvest may add up to some 20,000 bushels, *two-tenths of a percent* of what they were a hundred years ago and *two percent* of what they were just 20 years ago.

For Brooks in 1905, the causes of the Chesapeake oyster's coming demise were quite clear: "our public beds have been brought to the verge of ruin by the men who fish them," he wrote. But in fact, the assaults on the Bay's oyster populations over these years, and the impacts on water quality that these losses have contributed to, can be distributed among numbers of human and natural causes, though the two are not mutually exclusive. For instance, parasitic diseases — MSX and Dermo in particular — may be natural enough, though it is unknown to what extent human activities have compromised the oyster's ability to fend off disease. Sedimentation, contaminants, nutrient overloading, harmful algal blooms, oxygen declines, widespread loss of underwater grasses are all interrelated — overharvesting and the destruction of reef habitats may be significant but so too has land development and the consequent runoff of sediments and nutrients into near shore waters.

Estuarine organisms like the oyster are adaptable to a wide range of shifting conditions that occur daily and seasonally — however, when conditions such as low oxygen levels and high sediment loading become such prominent features of the ecosystem, organisms may no longer be so adaptable. Whether this has been the case for *C. virginica* and disease is unknown. We do know that there are native oysters that can fend off disease — they have inherent genetic capabilities to do so; however, it is these survivors that have also been subjected to harvesting, which removes their gene pool and the potential of their progeny from passing on their disease-resistant genes.

Breeding of Disease-Tolerant Native Oysters

While scientists such as Standish Allen at the Virginia Institute of Marine Sciences have made significant advances in the hatchery breeding of disease-tolerant oysters, these strains were originally developed for put-and-take aquaculture, not for seeding reefs for sustainable reproduction. With support for nearly a decade from the National Sea Grant Program's Oyster Disease Research Program, Allen has been working with researchers at the University of Maryland Center for Environmental Science, Rutgers University and the University of Delaware College of Marine Studies to test the capabilities of numbers of disease-tolerant stocks to withstand disease and produce larvae. The results so far have been mixed, though, as Allen says, this research has been going on for a relatively short time.

If these strains were able to tolerate disease and successfully reproduce, it could still take a massive effort in designing and building sufficient numbers of "breeder reefs" stocked with disease-tolerant oysters that, in principle at least, could begin reproducing and rebuilding natural stocks. How long might this take? A decade? A century? No one knows. Because of this uncertainty, interest in importing a nonnative species, *Crassostrea ariakensis*, has been increasing over the last several years, especially since of indications are to some that this Asian oyster could be a quick fix. Though quite limited in extent and numbers, field tests of triploid *C. ariakensis* over the last several years in Virginia suggest that it has a remarkable ability to resist the ravages of MSX and Dermo, while growing faster than the native oyster.

Importing a Reproductive Nonnative Oyster to the Bay

The problem of importing *C. ariakensis* or any nonnative, however, is that the potential impacts on the ecosystem are unknown and thus it is not possible to estimate the ecological risks. This was the general conclusion of a year-long study by the National Research Council of The National Academies, *Nonnative Oysters in the Chesapeake Bay*. The committee considered three options in relation to importing *C. ariakensis* into the Chesapeake: (1) prohibit introduction of nonnative oysters, (2) permit open-water aquaculture of triploid (i.e., reproductively sterile) oysters, (3) introduce reproductive oysters. The committee recommended option two, which would then afford "an opportunity to research the potential effects of extensive triploid-based aquaculture or introduction of reproductive nonnative oysters on the ecology of the bay."

While Virginia leaseholders were planning to grow some 800,000 triploid *C. ariakensis* oysters in 2003, Maryland Governor Robert Ehrlich announced in June that the state would pursue the feasibility of introducing a reproducing (i.e., diploid) nonnative into the Chesapeake within a year. Virginia then joined Maryland in requesting that the Army Corps of Engineers coordinate an Environmental Impact Statement (EIS). While the Corps, the Maryland Department of Natural Resources and the Virginia Marine Resources Commission are the lead agencies, the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration and the U.S. Fish and Wildlife Service are cooperating in the EIS that has six alternative options it will consider:

- Take no action but continue current restoration and repletion programs.
- Expand current restoration and repletion programs, including deployment of disease-tolerant strains of the native oyster.
- Place a moratorium on harvesting and set up an industry compensation or buy-out program.
- Establish state-assisted aquaculture operations with the native oyster.
- Establish state-assisted aquaculture operations with triploid nonnative species.
- Introduce and propagate *C. ariakensis* or an alternative species in accordance with the International Council of Exotic Species Code of Practices on the Introductions and Transfers of Marine Organisms.

Oysters on the Web

Maryland Department of Natural Resources
www.dnr.state.md.us/dnrnews/infocus/non-native_oyster. asp

Virginia Marine Resources Commission
www.mrc.state.va.us/replenishment.htm

Maryland Sea Grant
www.mdsg.umd.edu/oysters

Virginia Institute of Marine Science
www.vims.edu/abc/CA.html

In order to identify priority research needs that would assist the EIS, the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) convened a workshop in December 2003 to make recommendations that address issues about the genetics, biology and ecology of *C. ariakensis*.

Concurring with the National Research Council's findings, the STAC report — "Identifying and Prioritizing Research Required to Evaluate Ecological Risks and Benefits of Introducing Diploid *C. ariakensis* to Restore Oysters to Chesapeake Bay" — concluded that there are major gaps in understanding that must be answered before a final decision should be made on introducing a reproductively viable nonnative oyster. The report's recommendations and prioritization of research is organized around four major questions that relate to (1) whether self-sustaining populations of *C. ariakensis* will establish themselves, (2) the risks to the native oyster and other bivalve species within and outside the Chesapeake, (3) the potential improvement in ecosystem services over the native oyster, and (4) whether *C. ariakensis* will accumulate pathogens to a greater extent than *C. virginica*.

The report lays out research recommendations for each of these major questions, estimating how long it is expected to take to answer them. These recommendations together with those set out by the National Research Council are the basis for focusing a number of research projects that Maryland DNR is now funding — in a number of cases, researchers at VIMS are being funded as well. As Pete Jensen, Maryland DNR director of fisheries says, "In its totality this effort is an unprecedented level of cooperative and collaborative research being mounted in a short period of time."

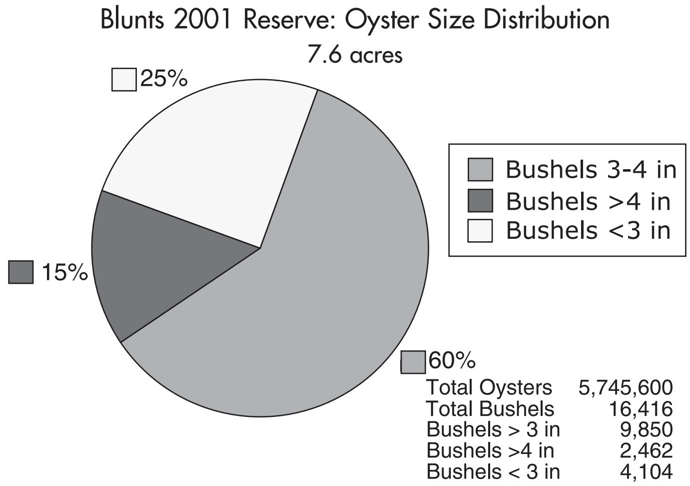
Research centers on a host of questions related to assessing risks, the economic implications of a new oyster species, the impacts of disease, comparisons of larval behavior and dispersal characteristics between the nonnative and native oyster, and susceptibility to the oyster pathogen *Bonamia* species, which has appeared in triploid *C. ariakensis* oysters in North Carolina. A summary of the research projects that Maryland DNR is supporting is available at the DNR website: www.dnr.state.md.us/dnrnews/infocus/researchsummary. html.

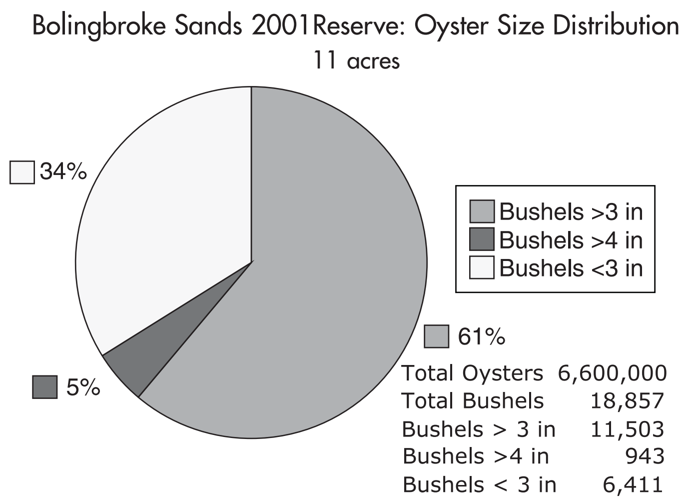
Whether researchers can provide the answers quickly enough for a fast-track EIS is questionable — when the findings do start coming in, they could begin to give more confidence in projecting the potential implications of introducing nonnative oysters to the Chesapeake.

Spotlight on *C. virginica* Restoration Efforts

While MSX and Dermo disease have been overwhelming the Bay's native oyster, efforts to rebuild *Crassostrea virginica* populations continue. And there have been successes, says Ken Paynter, a scientist at the University of Maryland College Park who has been monitoring the fate of disease-free seed that the Oyster Recovery Partnership (ORP) has planted on bars throughout Maryland's portion of the Bay system.

ORP has been working with a number of partners, among them the Maryland Department of Natural Resources, the National Oceanic and Atmospheric Administration Chesapeake Bay Program and the Maryland Watermen's Association, to plant oyster spat that Don Meritt and his staff have been producing at the UMCES Horn Point Laboratory hatchery. Meritt has upped the production of disease-free spat each year, from 38 million in 2000, to 55 million in 2001, 73 million in 2002 and 130 million in 2003. These oysters have gone to sanctuaries, where oysters are off-limits to harvesting, and managed reserves, where oysters can only be harvested after having reached a four-inch minimum — the bulk of the seed plantings has been on these managed reserves.





Paynter has recently analyzed the condition of oysters on two reserves, Blunt Bar, located in the lower Chester River, and Bolingbroke Sands, located in the upper Choptank River. Both these oyster bars were first cleared of all oysters; then a three-inch base of dredged shell was laid over some 18 acres. According to ORP, 14.5 million spat ranging in size from 0.5 to 0.8 inches were planted on Blunts Reserve in 2001. In a survey of about half the bar, Paynter estimates a total of 5.7 million oysters — some 15 percent were greater than 4 inches and 60 percent were between 3 and 4 inches.

At Bolingbroke Sands, the bottom was cleared and then a two-inch base of shell was laid over 12 acres. About 15.4 million spat ranging in size from 0.4 to 0.74 inches were planted in 2001. Paynter estimates a total of 6.6 million oysters. About 5 percent were greater than 3 inches, 34 percent less than 3 inches, and 61 percent greater than 3 inches.

To learn more about monitoring and disease, see The Paynter Labs on the web at www.life.umd.edu/biology /paynterlab/. For information on ORP plantings, see www.oysterrecovery.org.

Diagnosing Stress and Disease in Wild and Farmed Fish: The Aquatic Pathology Laboratory

Merrill Leffler, Maryland Sea Grant

If you're a commercial fisherman, a weekend angler or an aquaculturist, you've probably seen fish with ulcerated lesions in the Chesapeake or elsewhere — some of these fish may otherwise appear healthy, others listless or weak. The causes of infection could be many: like human beings, fish are subjected to a variety of microbial stresses. Though their immune systems are generally able to stave off most infections, at times they are simply unable to. That seems to be the case for many striped bass in the Chesapeake. For several years now, harvesters have been bringing in stripers with an infection called mycobacteriosis, a potentially wasting disease. Affected fish tend to lose their appetites, appear debilitated and emaciated, have impaired growth and become more susceptible to other infections from opportunistic microbes.

Mycobacteriosis in fish is caused by bacteria in the genus *Mycobacterium*, a group of at least nine species of slow growing microorganisms. Just where *Mycobacterium* comes from and why stripers are so vulnerable is unknown. Are they more so today than they were a decade or two ago? We don't know, says Andrew Kane, Director of the University of Maryland Aquatic Pathobiology Laboratory. (The lab is part of the Virginia-Maryland Regional College of Veterinary Medicine.). Laboratory studies indicate that the disease is slow growing, though how early stripers

and other species contract it is also unknown. How widespread is the disease in Chesapeake Bay? Kane says that "many associate the presence of external lesions such as ulcers and areas of reddening as an indicator of mycobacterial infections, though that is not necessarily the case." In fact, he adds, "observable lesions such as these are typically non-specific in origin. In other words, they can be associated with a variety of different causative agents or stress factors." So how is it transmitted and can we better identify the disease in the field? Furthermore, can mycobacteriosis spread to human beings?

The question of transmission is tricky. In recent years, fisheries managers have begun to consider food-web or predator-prey relationships as important factors in setting fishing "targets," levels of harvest that aim at promoting sustainable stocks. A case in point is the relationship between striped bass and menhaden, a commercially harvested species, which is also a nutritionally-critical prey for striped bass. (See "Managing the Bay's Fisheries," Chesapeake Quarterly Online, *www.mdsg.umd.edu/CQ*.) Consideration of such relationships has also led them to ask about the potential link to disease between predators and prey. For instance, are menhaden or other forage fish first infected by *Mycobacterium*, which then serves as a "vector" or transmitter of the disease? This is one of the questions that Kane and his colleagues at the Aquatic Pathobiology Lab hope to answer in an ambitious study they have recently begun.

The study, which is supported by the Maryland Department of Natural Resources, has a four-fold purpose, says Kane: to (1) determine the distribution and incidence of striped bass infection of different age classes, (2) assess whether young-of-the-year menhaden are susceptible and a potential means of transmission, (3) analyze region, incidence, age, severity and gender relationships in relation to mycobacterial infections, and (4) work with DNR, NOAA and other agencies on outreach and development of strategic monitoring plans.

To begin with, Kane says, we'll be working with DNR to collect striped bass of different age and size classes and menhaden — fish from four tributaries, the Potomac, Patuxent, Nanticoke and Choptank rivers, as well as at the head of the bay (near the Susquehanna Flats). Larger, mature fish will be taken through electroshocking from spawning grounds on the Choptank and Nanticoke rivers. Researchers in Kane's lab will be looking for cellular evidence of mycobacteriosis as well as sores or lesions that are caused by the bacteria. The aim, he says, is to estimate disease prevalence and its distribution, and to determine if there are indications of how mycobacteriosis is transmitted to stripers.

Behavioral Toxicology Provides More Subtle Diagnoses

A fish ulcer or tumor that results from stressors such as mycobacteriosis or a toxin can be referred to as an "endpoint" — it is an observable effect of that stressor. When fish or other organisms are subjected to low or sublethal levels of contamination, they may not exhibit such evident endpoints — however, there could be others, for instance, behavioral reactions, that might go unnoticed because of their subtlety though they may still have important ecological implications. Until recently, tracking behavioral reactions of fish to low-level stressors has been labor intensive and not always accurate. New, computer-based camera technologies are now making it possible to examine such impacts. A study underway in Kane's lab makes use of this camera technology to differentiate the effects on fish of exposure to harmful algal bloom toxins such as brevetoxin.

This past year, researchers demonstrated the effectiveness of accurately tracking mummichog (*Fundulus heteroclitus*) movement after the fish were first exposed to sub-lethal doses of an anaesthetic. For example, they found that over a 30-minute exposure, fish responded with a 12 to nearly 50 percent increase in motion and an increase in movement velocity that was accompanied by a decrease in path complexity and a significantly-altered "startle response." The exposed fish tended to increase their speed and stay in motion to compensate for the slight loss of equilibrium that resulted from the anaesthetic, Kane says.

In studies now underway to measure the effects of different brevetoxin concentrations, researchers in the lab will be looking not only at changes in movement but also at the dynamics of groups of fish, that is, their social interactions. Kane's group plans to complement this work with molecular studies of brain tissue to try and determine if there are related alterations in the brains of fish exposed to sub-lethal concentrations of brevetoxin as well as other harmful algal bloom stress agents.

These behavioral studies could reveal important insights into how fish are affected by environmentally-relevant exposures," says Kane. "It's one step further to integrate the link between controlled, quantitative laboratory studies and ecologically-relevant effects that can happen in the field." Field studies of wild fish are one aspect of Kane's research — another key focus is on aquaculture and the ever-present threat of disease.

Treating Disease in Aquaculture Systems

"Sick or disease-stressed fish in aquaculture facilities often lead to mortalities and loss of stock if left untreated," Kane says. "Veterinary drugs are desperately needed to support aquaculture and provide safe, legal means of increasing aquaculture production. Unfortunately," he says, "only a handful of Food and Drug Administration-approved drugs are available for use in finfish aquaculture." The lengthy approval process necessary for testing each drug with each species can be prohibitively expensive, more than the industry can afford. It is for this reason, his lab has been focusing on studies that aim at developing a rationale for grouping multiple fish species for drug approvals. Called "group cropping," the groupings will be based on similarities in anatomy, physiology, and drug metabolism. Supported by the Joint Institute for Food Safety and Applied Nutrition at the University of Maryland, Kane has partnered his lab's biochemical expertise with FDA's Center for Veterinary Medicine. If successful, this work could contribute to shortening the time for drug approvals, thus adding capabilities that could better ensure aquaculture success.

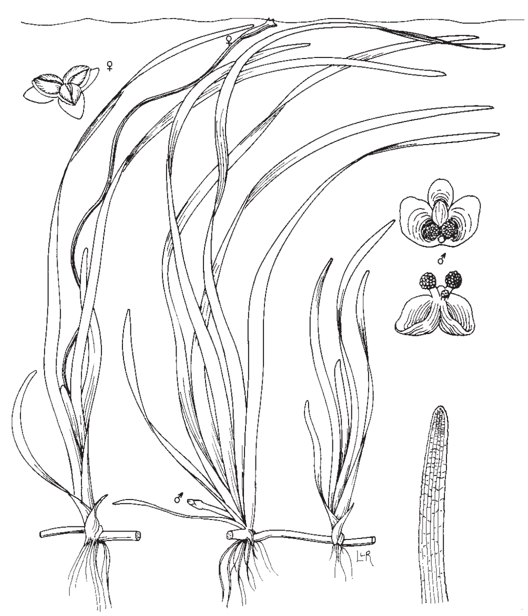
For more information on the Aquatic Pathobiology Program, contact Andrew Kane at 301-314-6808 or visit: http://aquaticpath.umd.edu/

Restoring Bay Grasses: Bringing Research to the Field

Laura Murray, UMCES Horn Point Environmental Laboratory

It is often said that as underwater grasses go, so goes the health of Chesapeake Bay and its living resources. To begin with, grass beds, often referred to as submerged aquatic vegetation (SAV), are important habitats for fish and molting crabs. SAV beds were once so dominant in the Chesapeake that water clarity in some nearshore areas is said to have reached 10 to 12 feet. Through the 1960s, diverse species of aquatic plants covered more than 400,000 acres of bay bottom — by the mid-1980s, however, aerial surveys were documenting less than 40,000 acres of SAV bay wide. Though grasses have rebounded to some extent, their bottom coverage is still far below historical levels, averaging some 70,000 thousand acres over these last five years. The Chesapeake Bay Program 2000 Agreement set a goal of 114,000 of restored grass beds by 2010.

The role of underwater vegetation in the bay ecosystem goes far beyond habitat — grasses also provide other "services," for instance, they produce oxygen during the day when plants are photosynthesizing; they trap suspended sediments and can thus help increase water clarity; they take up organic nutrients from the water column, in effect competing with algae; furthermore, they can ameliorate wave action, thereby reducing the impact on erosion-prone shorelines. In short, the widespread decline of SAV has had a cascade of impacts on water quality.

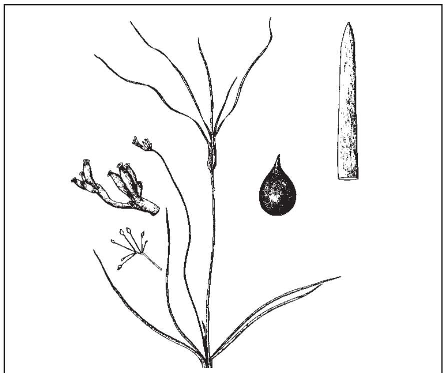


Wild Celery

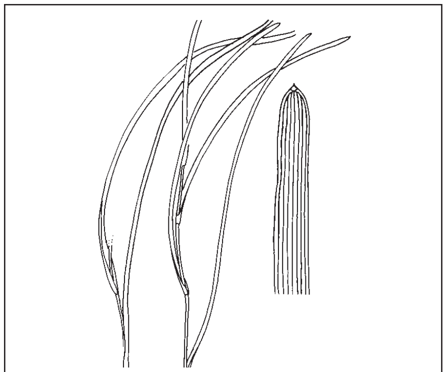
What is preventing submerged aquatic vegetation from returning to their previous levels? The simple answer is that Bay waters are too dark: they are clouded by high concentrations of algae and sediments, which prevent sunlight from penetrating to the bottom where plants are rooted — without sufficient light, plants cannot produce enough energy to grow and reproduce.

For grasses to return in appreciable acreage, nutrient and sediment loading will have to be curtailed significantly throughout the Chesapeake watershed. It is easy enough to say what must be done — curbing runoff as a means of promoting SAV recovery has been a key goal of the Chesapeake Bay Program. Complementary to efforts at stimulating natural recovery are diverse programs to restore grass beds by transplanting and seed dispersal. Though these programs cannot restore bay grasses in themselves, they can play an important role in increasing species diversity and plant abundance and providing a seed source for adjacent areas.

While I provide guidelines below on SAV restoration, it is important to recognize at the outset that restoration is still open to unpredictability. Weather patterns, rainfall and associated runoff, and other meteorological events, have the potential to heavily influence the best efforts, especially in the upper and mid portions of the bay. Here's one example: in the summers of 2001 and 2002, relatively dry years with little runoff from the land, we successfully transplanted redhead grass (*Potamogeton perfoliatus*) into widgeon grass (*Ruppia maritima*) beds in areas of the lower Choptank River, with an 80 percent survivorship. In 2003, one of the wettest years on record, we planted 22 nine-square meter plots in five locations, again in the lower Choptank River. By mid-growing season, late July, all the transplants had disappeared. In contrast, similar restoration efforts in the Severn River near Annapolis, Maryland, resulted in nearly 100 percent cover of the transplanted area. The Severn River also hosts one of the largest redhead grass bed in the mid region of the Bay. Did this grass bed modify the local water quality of the area to the extent that transplants could survive? Is the Severn River watershed that different from the Choptank River to allow for significantly improved conditions? These are just



Widgeon Grass



Eelgrass

Redhead Grass

some of the questions we need to address in our efforts to help restore grasses to the bay.

Despite the need for answers to fundamental questions, there are lessons we can take away from our experience with SAV restoration. For instance, a number of considerations must be taken into account when considering how best to restore a site — these include a criteria-driven selection of suitable sites, propagation of plants, planting of grasses, and monitoring survivorship.

Site Selection

The success of any restoration project will depend first on climatic conditions, which makes it important at the outset to choose bottom grounds that have the best chances for success. Researchers at the University of Maryland Center for Environmental Studies, the Virginia Institute of Marine Science and other institutions have been working with the EPA Bay Program to define habitat criteria that are likely to best promote SAV growth and survival in different salinity regions of the Chesapeake.

A site under consideration for transplanting should first be monitored for such water quality parameters as nutrient levels, light attenuation and suspended solids. While monitoring data from the Chesapeake Bay Program (www. chesapeakebay.net) can be used as a guideline, these data are generally collected in deeper offshore waters where conditions differ from the shallower inshore areas of SAV growth. It is important to assess water quality at the specific areas being considered for transplanting.

Composition of the sediment must be considered as well as the potential exposure of plants to waves. Most SAV species cannot survive in sediments with high organic content (the amount of material directly associated with dead or decaying plant and animal matter) or in densely packed clay soils. Areas with high wave energy and exposure to strong currents are also unsuitable for growth of underwater vegetation, because plants are likely to be uprooted and thus breakage can occur. A good indication that both sediment characteristics and energy regimes are suitable for SAV growth is the historical presence of grasses beds in the area. Such records may be obtained from the Virginia Institute of Marine Science (www.vims.edu).

Plant Propagation

Currently, the supply of healthy propagation units (a unit is 4 to 5 shoots of a transplant species) is one of the limiting factors in SAV restoration. Techniques have been under development for propagating several species of Chesapeake Bay SAV: *Zostera marina* (eelgrass), *Ruppia maritima* (widgeon grass), *Potamogeton perfoliatus* (redhead grass), *Potamogeton pectinatus* (sago pond weed) and *Valisneria americana* (wild celery). Three techniques are currently used in the bay area: (1) direct dispersal of seeds at the restoration site, which involves collecting seed from naturally-occurring grass beds at the time of maturation, holding the seeds until they are released from the plant, and planting in the field — this method has been successful for *Zostera* or eelgrass, particularly in the lower Bay; (2) propagation of plants from cuttings. Typically, sections of parent plants (e.g., *P. perfoliatus*, redhead grass) taken from the field or those grown in the greenhouse are planted in trays of sediment, which take root and grow after a given period of time. Trays of adult grasses are planted in the restoration sites — this method is labor intensive and costly; (3) planting of seeds in trays of sediments. Grasses are allowed to mature and then planted in the field. This method is used for *V. americana*; though less labor intensive, it also has had limited success.

The supply of healthy propagation units for diverse species is one of the limiting factors in restoration projects — continued research in plant growth, planting techniques and site selection will be critical if we are to have increase success.

Planting Techniques

Planting techniques depend on the type of propagation that is to be used. Seed dispersal is generally done from a boat and seeds are broadcast by hand into the restoration site. Rooting adult plants from trays involves placing handfuls of plants with sediment and roots into the ground at the site. Regardless of the method used, we recommend that test plots be employed before any major restoration efforts are undertaken. We have used small areas (3m x 3m) with approximately 25 planting units per plot planted on 0.5 m centers. If the seed dispersal technique is used, a small area should also be planted before major efforts are made. Monitoring these test plots over the growing season for plant survival should indicate if the site can support SAV growth.

Locating restoration projects close to or in existing single species SAV beds has the added benefit of the host bed serving as a nursery crop for other grass species. Aquatic vegetation can in effect modify its environment by trapping particles and thereby improving water quality. The presence of existing grass beds also indicates that water quality is suitable for their growth. In some of our experiments, we have used existing mono-specific stands of *Ruppia maritima*, widgeon grass, as nursery crops to increase survival and growth of other ecologically valuable species that we transplanted into these beds. The increased plant species diversity in these "restored SAV beds" would, in turn, expand habitat diversity and increase abundance and health of resident faunal assemblages

Given our current knowledge of restoration, large-scale projects should be limited to seed dispersal of eelgrass (*Zostera*) in the southern sections of the Chesapeake Bay, where water quality is more suitable for SAV growth. Such plantings have been relatively successful, with moderate costs and efforts.

Learn more about SAV in the Chesapeake Bay

Maryland Sea Grant
www.mdsg.umd.edu/CB/ecology_life.html#f
Chesapeake Bay Program
www.chesapeakebay.net/info/baygrass.cfm
Maryland Department of Natural Resources
www.dnr.state.md.us/bay/sav/index.html
NOAA Chesapeake Bay Office
http://noaa.chesapeakebay.net/sav.htm
U.S. Fish and Wildlife Service
www.fws.gov/r5cbfo/CBSAV.HTM
Virginia Institute of Marine Science
www.vims.edu/bio/sav/

Restoration Site Monitoring

Restoration sites must be monitored for a minimum of two years in order to record plant density and growth for each area. If plant density decreases significantly, supplemental planting may be necessary to maintain a critical density of plants.

Laura Murray is a Research Associate Professor at the Horn Point Laboratory, University of Maryland Center for Environmental Science. With Maryland Sea Grant support, she, W. Michael Kemp and Jeff Cornwell, also at Horn Point, have been conducting research to better identify the influence of SAV spatial patterns and sediment biogeochemistry on plant survival and the implications for sustainable restoration. To learn more about these projects, see www.mdsg.umd.edu/Research/R_P-56.html. Contact Laura Murray at murray@hpl.umces.edu.

Managing Community Ponds: *Defining Objectives*

Don Webster, Sea Grant Extension Eastern Shore Agent

Many housing developments have been built with storm retention ponds as a means for retarding storm water runoff from flowing directly into coastal waters. Their aim is to retain soils and nutrients that can cause turbidity — suspended sediments darken the water and prevent sunlight from reaching submerged aquatic plants below. As Laura Murray writes in "Restoring Bay Grasses," without enough light, plants cannot photosynthesize and consequently they die or become weakened and vulnerable to a variety of stresses. Landborne soils and nutrients are two major problems that impact water quality in the Chesapeake — if ponds do the job they are designed for, they can help minimize those impacts.

The good news is that they have been doing their jobs very well. The bad news is that they have been doing their jobs very well. While retention ponds give sediments time to settle before moving into the tributaries, they have also created problems for the homeowner associations that manage them.

Water is a selling point in real estate, whether oceans, bays, rivers, ponds or lakes. People pay more for the privilege of waterfront views or easy accessibility. Even ponds built for storm water purposes can become attractive to buyers. In many subdivisions these ponds and lakes are managed for their aesthetic beauty even while they carry out important environmental tasks. Sometimes, however, the lack of a defined management structure in a community association, or conflicting views of property owners about management directions or rules can lead to frustration on the part of residents. Accountability can also be a problem when no clear lines of authority are created or methods of oversight instituted to ensure that ponds are managed in the best interest of all.

Who Will Do the Management?

Association-managed ponds often are overseen by people with little or no training in their design or operation. The lack of these skills can lead to poor decisions that may impact water quality, vegetation control, or management objectives. In most instances managers are volunteers and frequently they are retired; this may reflect upon the amount of time that they are able to devote to the work of pond management. Contracting with lake management firms can save time but may be expensive. Local owners must still make fundamental decisions about the pond or the same problems will exist whether volunteer or paid labor is used.

Ponds frequently suffer from multiple opinions on the part of local property owners regarding what is desired. For example, most people want to have water that is clean and free of unsightly flotsam or aquatic weeds. But others may like to see wildlife, especially waterfowl, on the water and in the surrounding watershed. Some actually feed animals to encourage their residency. This can lead to high nutrient loading, translocation of unwanted vegetation, and water that becomes more turbid because of waterfowl in the watershed and expanding populations of resident geese.

Another example of conflicting opinion with associations is controlling aquatic weeds. First, there is the subjective question of exactly how much vegetation and what species constitutes a "weed" rather than a "plant." Then there is the debate over management options. Some people have a negative reaction to the use of chemical control agents while others are inclined toward their use.

The best pond management programs have been implemented in communities where there is open dialogue about objectives for the pond and there is the appointment of an individual or committee to oversee the work of reaching those objectives. "Buy-in" from the affected property owners is important in developing an effective program to ensure that a pond is managed properly for many years.

Creating a Management Structure

First, there should be a community association with a structure of officers. There should be a standing committee or office created for the management of the pond. It is always desirable to fill that office with someone who knows water quality management. If this is not possible, information and training is available from the University of Maryland Sea Grant Extension Program.

The association should prioritize goals for the pond. For example, will it be managed only for aesthetics or will it be used for swimming and boating, recreational fishing, fire protection, or other uses? Each of these uses requires different management decisions and planning. There should be consensus on the objectives and it should be clearly stated to the members.

While a committee can put together a management plan, it should be presented to the entire association membership for comment and ratification. Often this is a good method of finding other people who are interested in helping to manage the pond. At any rate, a plan should be written and made accessible to any member. It should be sent to all new residents to ensure that they know what is expected of them in the shared governance of the pond.

Basic Rules of Management

An inventory of the watershed should be conducted to determine the area that is drained by the pond and the nutrients and pollutants that exist within that area. Where possible, these should be controlled and minimized. While nutrient input from large animals such as horses can be easily located, the droppings from smaller domestic animals may not be. Many communities have instituted rules requiring the pickup of this waste from streets so that it does not run into the pond during a rainstorm.

Over-fertilization of lawns is another known problem. Many people apply too much fertilizer in the mistaken belief that it will make their lawn better. Others do not know how to properly calibrate spreading equipment and this leads to poor application and the creation of "hot spots" with high nutrient levels. When this occurs, the nutrients often run into the pond rather than remaining on the land where they are wanted.

Other techniques that can work to preserve your pond are the construction of grass buffer strips in the surrounding area; picking up leaves in the fall from surrounding properties to prevent them from entering the lake and possibly creating elevated levels of tannin or decomposing in the water; having local residents "adopt" a storm drain and checking it quarterly to see that it is not full of junk and is flowing freely; encouraging shoreline property owners to properly protect their land with approved erosion control techniques so that soil does not run into the pond; and discouraging the use of concrete driveways and walks in favor of stone so that water can percolate through the soil before entering a pond rather than quickly and directly running off.

Controlling Nuisance Weeds

Properly maintaining a pond through pro-active management can help to alleviate many emergency problems. Of all of these, nuisance aquatic weeds can be the most troublesome. Generally, the larger the pond, the more expensive it will be to control weeds and the more time and resources it will usually take.

There are three general ways to control aquatic weeds: mechanical, biological, and chemical. Mechanical control includes pulling, cutting, raking or shading of weeds. This is usually a time consuming and laborious task that can require frequent renewal. There is also the need to dispose of large quantities of plant material with high wet weight. Cutting and raking can result in fragmentation of plants that then spread to other parts of the pond. While laborious, mechanical methods can sometimes offer a reasonable option in places where local control is needed, equipment like rakes or cutters are often relatively inexpensive or can be constructed of easily obtained material. Homeowners may not mind working together to help keep their pond looking nice; they know that it helps maintain their property values.

Biological control methods are

not much of an option in Maryland where the use of grass carp is banned. Other herbivores have minimal use in controlling vegetation and should not be used without prior knowledge of how they may affect water quality.

Chemical controls are available although the number of herbicide compounds is limited. Before using chemicals to kill aquatic weeds, the plant(s) must be identified, various parameters of the pond must be known, and proper permits must be obtained. Using the wrong chemicals or at the wrong time will result in poor control and high expense, since these compounds are usually quite expensive.

Long Term Planning

Ultimately, ponds built to control runoff are going to need maintenance. Years of retaining sediment and nutrients will yield ponds that become progressively shallower and are lined with nutrient-laden soil. This causes aquatic weed problems to compound and become more complex. As ponds get shallower, weeds such as filamentous algae grow. Having shallower depths causes root zones to be more accessible to sunlight that further stimulates growth. The use of shading agents, a non-lethal method of controlling rooted aquatics, then becomes ineffective.

In mature ponds, the ultimate answer to severe aquatic weed problems is to renovate the pond. This involves dredging sediment and returning the pond to the original depths and contours. Unfortunately this is a costly procedure but one that is often the only viable long-term option if it is desirable to keep the pond in operation. Without maintenance dredging, ponds will ultimately fill with sediment and become wetlands. While this may be desirable to some, the use of the pond will have changed and it will no longer be available as a control for runoff.

Renovating a pond involves discussion with the local Natural Resources Conservation Service. Located in each county, these government professionals are pond design experts who often have copies of the "as-built" plans for the pond. If not, they can usually assist in calculating the size of the pond through the use of their aerial maps and the use of a planimeter. If the pond is just going to be returned to its design contours the permit process may not be too onerous. If major changes are requested, it can take time for them to be approved. The NRCS office is listed in the local directory.

Funding for renovation is usually the burden of the association members or property owners. This is another problem area since it will involve high cost to those who participate in funding the project. There is also a need for decisions about access for construction equipment across what may be private land as well as the disposition of the spoils. These may be nutrient-laden and have undesirable odors, which may cause nearby landowners to balk at allowing them to be deposited on their lands.

The management of community ponds is a process that requires involvement of local residents and a plan for the long-term goals of the water. Creating a structure that involves input and proactive management can ensure that the community minimizes problems that may lead to short-term fixes and expensive mistakes.

More Information and Training

The University of Maryland Sea Grant Extension Program has a range of publications available concerning pond management topics as well as aquatic weed control. Springtime will see educational programs for community associations taught with an expanded schedule during the following winter.

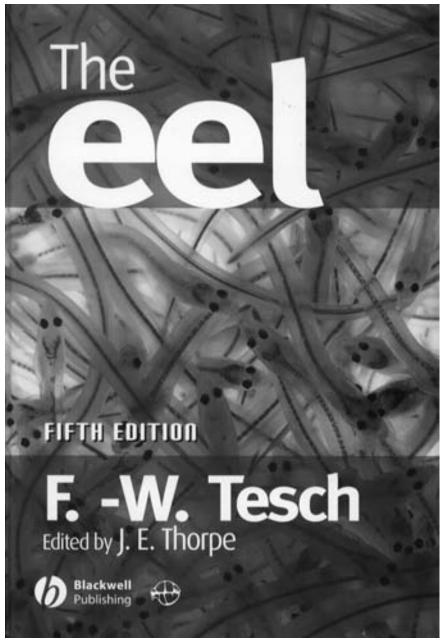
For more information, please see the Maryland Sea Grant Extension Program website at: www.mdsg.edu/Extension.

Eels — Uncovering Their Mystery

The Eel (Third edition), edited by Friedrich Wilhelm Tesch. Iowa State Press (A Blackwell Publishing Company). 2003. 336 pp. $129.99.
www.iowastatepress.com

David Secor, UMCES Chesapeake Biological Laboratory

Whoever coined the expression, "nature abhors a vacuum" may have had eels in mind. Here, eel refers to the family Anguillidae, which until recently has been termed the "freshwater eel" family (more on that later), comprising 15 species inhabiting all major continents except Antarctica. Eels live in ponds, swamps, reservoirs, and creeks; they swim in streams, rivers, marshes, estuaries, and coastal seas; eels shimmy up small dams and slither across wet fields; they reside in caves. Despite all these possible waypoints, all eels must begin life in the deep ocean hundreds to thousands of kilometers distant from continental shores. No one knows exactly where in the deep Atlantic and Pacific waters eels spawn. Expeditions to identify spawning areas for European eels, initiated nearly 100 years ago, led Johannes Schmidt to the Sargasso Sea. These investigations also spawned the field of fisheries oceanography and principal ideas on marine fish population dynamics. Still, it is remarkable that as we search for life in deep ocean vents or on the surface of Mars, scientists have yet to



discover a spawning eel.

That is not to say that progress on eel research has not taken place in recent times. So it was that I eagerly awaited the new edition of F.-W. Tesch's *The Eel*. Tesch is arguably the world's foremost expert on eel biology and behavior. When I began my research on eels eight years ago, I devoured Tesch's first edition (1973), which gave an exhaustive and authoritative account of the physiology, biology, and ecology of the eel. Eels are important economically and are also vigorous in the laboratory, making them favorite subjects of fish physiology studies. Their resiliency to temperature and salinity extremes and their unique sensory capabilities have generated an impressive literature, both technical and popular. Tesch did a brilliant job helping his readers understand what was really known of eels. Since that time, the volume of literature has grown substantially. Consider some developments, including eel aquaculture, that have taken place in only the past eight years:

- Major stocks of eels — European, American, and Japanese eels — have all declined over 10-fold during the 1990s, largely as a result of high international demand for eels by Japan.
- Japan's market is currently about 120,000 metric tons: on average every Japanese citizen consumes 5 to 10 meals of eel each year.
- Scientific and conservation groups are advocating government action to stem further losses of natural eel stocks.

Aquaculture, which meets approximately 90 percent of the Japanese demand for eels, relies upon natural harvests of glass (juvenile) eels of European, American, Japanese and other eel species. Most glass eels are shipped to China, Japan and elsewhere for intensive culture to supply Japanese markets. Glass eel harvests, particularly for European eels, the dominant eel population in terms of wild harvests, are one of several factors that have led to the rapid decline in eel stocks.

Japan, eager to become less reliant upon imported eels, has spent generations of scientific effort developing artificial propagation methods. The largest hurdle has been what to feed the leptocephalus larvae of eels: bizarre leaf-like forms that feed on marine snow in the wild. An artificial diet composed of powdered shark eggs in recent years has permitted the first ever successful rearing of larvae through the juvenile period. This remarkable advance completes the life cycle of eels in captivity and should permit Japan to rely less upon worldwide supplies of glass eels. Japanese scientists are aggressively investigating where eels spawn in nature through a series of large oceanographic expeditions. Dr. Tsukamoto and his colleagues believe they have discovered the likely site of spawning for Japanese eels: sea mounts near the Marianas Trench. They have proposed that American and European eels may also home to seamounts near the Sargasso Sea.

Tsukamoto's group has discovered that not all European and Japanese eels are in fact freshwater eels; some eels complete their life cycles in marine water. Our group at the Chesapeake Biological Laboratory has confirmed this observation for American eels: so-called "freshwater eels" can complete their life cycle without ever entering freshwater habitats.

New genetic evidence indicates that the Anguilla family originated in the SE Pacific, where the greatest diversity of eel species remains; European and American eels resulted from dispersal of ancestral eels through what is now the Mediterranean region, long ago a corridor between oceans known as the Tethys Sea.

Thus, Tesch's challenge was to integrate important new discoveries and issues into the 1983 volume (second edition). He enrolled the assistance of eight fellow-German scientists and two other European scientists. The updated edition was published in 1999 in German; together with R.J. White (translator) and J.E. Thorpe (publisher), an English fifth edition was published in 2003. Unfortunately, the update was fairly unrewarding. No doubt the very exciting developments reviewed above came after information was compiled for this book (most literature before 1999; most fishery/aquaculture statistics through 1996 only). However, a major fault of this book is that it was a parochial undertaking. Rather than working with international experts, who have been very actively researching eels worldwide during the past two decades (among them, Wickstrøm, McCleave, Castonguay, Tsukamoto, Tzeng, Jellyman), he chose to work with scientists "down the hall," and almost exclusively on the European eel. The first edition of *The Eel* was comprehensive for its time and wonderfully authoritative. In the fifth edition, over half of the material was contributed by other authors, resulting in uneven emphasis, scholarship, presentation, and perspective. An example: Chapter 3 (Tesch) largely discounts the view that eel species radiated East to West through the Tethys Sea corridor, favoring a Pacific Ocean diaspora, yet in Chapter 7 (Reimer) we find support for this view.

Much of the volume (Chapters 1. Body structure and functions, 2. Development stages and distribution of eel species, 7. Diseases, parasites, and bodily damage) seems intended for scientists and eel experts who are well steeped in the technical terms of ichthyology, physiology, and zoogeography. The other sections are more generally written (Chapters 4. Harvest and environmental relationships, 5. Fishing methods, 6. Eel culture, and 7. World trade and processing). I found most edifying and new from the first edition, sections on eel zoogeography and fishing methods. Sections on the ecology and behavior of specific life stages of eels were the strongest elements in the first edition, but are in need of greater revision in the current edition. Despite this criticism, there is much to be learned in reading Tesch's treatment of eel ecology and behavior. Of interest to readers of *Maryland Aquafarmer*, the eel culture chapter by A. Kamstra is good background on yellow eel culture methods, though it is fairly brief – 10 pages; further it contains none of the recent developments of controlled spawning and larval rearing occurring in Japan. The disease chapter is also abbreviated, containing lists of agents of disease and parasitism, but little on diagnosis and epidemiology, identification, life cycles, and treatment.

I noted several errors, including repeated misclassification of eel species (*A. australis* and *A. dieffenbachia*) as short- or long-finned eel types (p. 105, 159), an incorrect placement of decimal (p. 268), and mis-referenced figures (Fig. 1.2 on p.

104; Fig. 3.15 on p. 191). Figures are inadequately referenced in the text; often results are discussed well before the figure related to the results is referenced. Many figures, modified after figures published in the scientific literature, are overly complex or not completely labeled; further modification and simplification of figures would have assisted readers. Figures in the chapter on fishing methods are a notable exception: these are original to this volume and well integrated with text.

The text is often laborious and could have been improved with more deliberate paragraph structure and simplified sentences. Translation of such a technical volume deserves praise, but occasional odd phrases occur. Examples include: "According to the studies by Penaz and Tesch (1970) on eels of the lower Elbe area it must be assumed that the fears that have existed until now mainly about prematurely emigrating male eels can no longer be shared." (p. 145) And "Poles studied such for small eels from various lakes (Opuszynkski and Leszczynski, 1967)." (p. 158) I would think it more important where the lakes were located rather than the nationality of scientists.

The book, in my view, will provide useful background to those who study eels, but should be used with caution since it does not contain advances over the past 10 years, particularly for American eels. Age determination is a noteworthy example here — technical improvements have largely solved past difficulties in age determinations, yet none of that literature is covered. The book will have limited value as a text for graduate students, or as a general reference for scientists and laypersons.

Further, it is clear to me that the book is written for a European scientific audience. In all chapters, save the very nice section on eel zoogeography, we mostly learn about European eels. This treatment may have been warranted several decades ago when most eels were harvested, consumed, and studied in Europe, but this is no longer the case. International discoveries and fisheries/aquaculture issues are not given due emphasis in this volume. Fortunately for those interested in learning more about these discoveries and issues, two recent volumes from international eel symposia are available:

Aida, K., K. Tsukamoto and K. Yamauchi, eds. 2003. *Eel Biology, Proceedings of the International Symposium Advances in Eel Biology,* Tokyo, September 2001. Springer-Verlag, Tokyo. 497 pp.

Dixon, D.A., ed. 2003. *Biology, Management and Protection of Catadromous Eels.* American Fisheries Society Symposium 33. Bethesda, Maryland. 388 pp.

The Aida et al. volume in particular contains some of the new exciting developments in eel aquaculture. For those interested in the nuts and bolts of eel aquaculture, references contained in Chapter 6 of this book are a good place to start. A noteworthy book remains A. Usui's *Eel Culture* (1974, Fishing News Books, West Byfleet & London), which is a coffee table quality pictorial of modern eel culture methods in Japan.

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The Bivalve World

Elizabeth Gosling. 2003. Bivalve Molluscs. Biology, Ecology and Culture. Iowa State Press (A Blackwell Publishing company). 454 pages. $129.99 www.iowastatepress.com

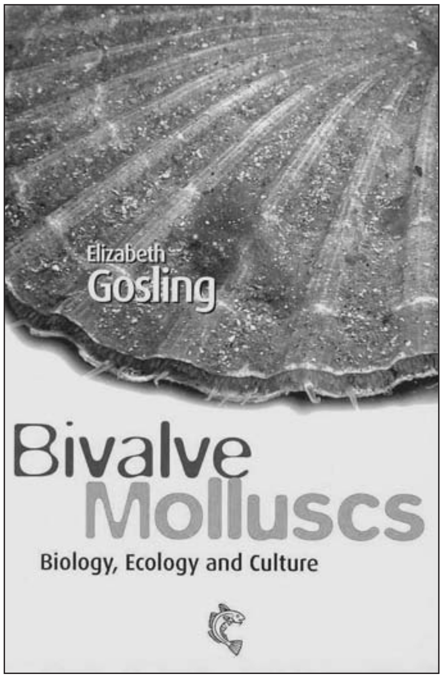
Victor Kennedy, UMCES Horn Point Laboratory

Dr. Elizabeth Gosling, a population geneticist at the Galway-Mayo Institute of Technology in Ireland, wrote this book to support her teaching of bivalve biology to undergraduate aquaculture students. At the same time, she also intended it to serve as a basic resource for graduate students and professionals. Most of the chapters do a reasonable job as such a resource.

Beginning with a six-page introduction that examines bivalve evolution, the remaining 11 chapters focus on mussels, oysters, scallops, and clams as the main bivalve groups — each chapter has a helpful introduction that highlights what is to follow. Biological issues are covered with chapters on morphology, feeding, reproduction and recruitment, growth, physiology, and diseases and parasites (oddly, the chapter on ecology follows morphology, while the disease chapter is near the end of the book).

The morphology chapter describes the molluscan shell, emphasizing differences among the four bivalve groups, and then describes the internal organs. These descriptions set the stage for detailed chapters on their functioning. For example, a long chapter on bivalve feeding covers filtering, particle processing by gills, and palps and food types, digestion, and absorption.

The discussion of physiology



(i.e., circulation, respiration, excretion, and osmoregulation) is relatively short and skims the surface. The final biology chapter succinctly describes a diversity of diseases and parasites, then touches on defense mechanisms (this is the only chapter with a formal section on future research).

The relatively brief chapter on ecology, which focuses on distribution patterns (unfortunately, the symbols on the distribution figures are difficult to discern) and factors affecting distribution and abundance — these are characterized as physical such as temperature and salinity and biological, i.e., predation and competition, shortchanges the importance of bivalve ecology. Students would benefit, for example, from learning about the role of bivalves in controlling the abundances of phytoplankton — there is good data to draw from on mussels in estuaries and zebra mussels in North American lakes; they would also benefit in learning about bivalves serving as hard substrate exploited by other epifauna in soft-bottom habitat (e.g., oysters, mussels, zebra mussels) or their role in biodeposition and sediment nitrogen dynamics (oysters again). Discussion of these topics would have incorporated information available in the biology chapters, strengthening the internal cohesion of the book.

Two long chapters deal with aquaculture and aquaculture genetics. Given the author's expertise, these provide extensive and useful information. The well-illustrated aquaculture chapter has a short section on the fundamentals of farming bivalves, and describes aquaculture of European, Japanese, and Chinese species. The chapter on genetics covers breeding issues and programs, ploidy manipulations, and application of genetics to management.

Fisheries management, the book's longest chapter, begins with a useful section on population dynamics, including descriptions of sampling techniques and gear and ways to estimate age, growth, mortality, and recruitment. Dr. Gosling has selected fisheries management for the four bivalve groups in different regions of the world: scallops in Europe and northwest Atlantic; oysters in the U.S.; mussels in the Wadden Sea; clams in eastern North America and northwestern Europe. The brief sections in this chapter on age and growth and on reproduction and recruitment might have been better incorporated into the earlier chapters on growth and on reproduction.

The book ends with a short chapter on public health issues — because bivalves feed by filtering, they can concentrate pathogens and contaminants and pose a potential risk to human health.

Given the abundance of information available on bivalves, it is unusual for one author to write a book on such a broad topic; it might be even more unusual to have every detail correct. At the same time, single reviewer cannot identify every mistake or misconception. The fact that I found a few errors in some details and place names in the description of the oyster fishery in the U.S., a familiar topic to me, suggests that there will be errors of fact elsewhere in the book. However, my impression is that the book will be a dependable text for undergraduates and a useful resource for those needing a basic introduction to bivalves. Unfortunately, an undergraduate student will probably think twice about buying this book, given its high price.

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Fisheries and Worldwide Markets

Fish to 2020: Supply and Demand in Changing Global Markets, by Christopher L. Delgado, Nikolas Wada, Mark W. Rosegrant, Siet Meijer, Mahfuzuddin Ahmed. International Food Policy Research Institute, Washington, DC. 226pp. 2003.

Douglas Lipton, Marine Economic Specialist

A walk into any seafood shop reminds us how globalized the seafood industry has become and especially how aquaculture has come to play an increasing role in the seafood products we buy. While many of us tend to have a narrow view of our domestic market, the prices we pay are being influenced by events throughout the world. *Fish to 2020* describes the changing trends in the world's seafood markets, with a special focus on comparing such changes between the developed and developing countries.

Drawing on the United Nations Food and Agriculture Organization's (FAO) data on fish production and trade from 1973 to 1997, the authors' economic approach first meant that they had to deal with the dilemma of aggregating species into different categories than the FAO typically reports, in which classifications are done on an ecological basis such as pelagic and demersal fish. These categories have little relevance to markets, so the authors have adopted more meaningful classifications of high-value finfish, low value finfish, mollusks and crustaceans along with a category of fish meal and oil. They also distinguish whether fish derive from wild harvests or aquaculture.

Among the chapter topics are the following.

Changing Trends in Fish Production (Chapter 2). While others have documented the slowed growth in production from capture fisheries and the rising importance of aquaculture, it is interesting to see how these growth patterns are manifested by market category. For example, while there's been almost as much annual growth in aquaculture of low-value finfish (10.9%) as in high-valued finfish (13.4)%, in absolute terms low-valued finfish production exceeds high-value production by more than a 12:1 margin. Equally significant is the change in developing countries from 1973 to 1997: once net importers of fisheries products, in general they are now net exporters. Much of this change can be attributed to aquaculture, which developing countries, particularly in Asia, dominate.

Role of Demand in the Fish (Chapter 3). Fish consumption for food has doubled over the past 30 years, and developing world countries are responsible for 90% of this growth. Demographic changes, particularly higher incomes and the response of seafood demand to income growth (income elasticity), seem to be the major force behind this trend. Higher demand has resulted in a significant increase in fresh fish prices at the same time that prices for red meat products has declined.

Modeling Agriculture Policy (Chapter 4). Prediction is a precarious occupation for economists. IFPRI initially developed a model relating production and fish prices that would enable policymakers to make projections under varying scenarios to the year 2020. Though the level of documentation makes its difficult to critique the model, it is worthwhile to compare predictions under the scenarios that the authors run. These scenarios are based on different assumptions about how fast or slow aquaculture will grow, or whether there will be improvements in fish meal and oil efficiency in aquaculture feeds.

Remaining chapters cover a variety of topics of relevance to the growth of fisheries and aquaculture. They include the following

Interactions of Capture Fisheries, Aquaculture and the Environment (Chapter 5). Though the authors cover some of the negative impacts of aquaculture, they also examine the positive role that environmentally sustainable aquaculture can play in mediating some of the problems.

Role of Technology with Emphasis on the Reliance of Aquaculture on Capture Fish Meal and Oil (Chapter 6). Other areas such as improved breeding, genetics and the potential role of biotechnology are covered.

Implications of Trade in Fisheries (Chapter 7). Authors examine global impacts of fisheries and how trade policies such as tariff and non-tariff export barriers come into play.

Recommendations for Policy (Chapter 8). Both the supply side and demand side of the fisheries equation are covered.

This book grew out of a partnership between the International Food Policy Research Institute (IFPPRI) and the Worldfish Center (www.worldfishcenter.org). IFPRI has published two companion pieces: *Outlook for Fish to 2020: Meeting Global Demand* by the same authors and publishers, a 28-page summary of the findings and conclusions in the larger report; and *The Future of Fish: Issues and Trends to 2020* (again same authors and publisher) that is a more condensed version of the findings. Each of the publications can be at the IFPRI website or ordered in hard copy ($11.97 included shipping for the book; the other publications were free) downloaded without cost (www.IFRI.org).

After reading *Fish to 2020* or any of the companion documents, you will be much more prepared to ask the informed questions with regard to your role and future in this changing world of fisheries.

New Publications

Managing Fisheries for the Future:* Chesapeake Quarterly*, volume 2, number 4. Traditional management of fisheries has focused primarily on regulating commercial and recreational catches as a way of achieving maximum sustanable yields. While that approach may have helped reverse severe declines of striped bass, which were heavily overfished during the 1960s and 1970s, it didn't address other factors — in particular, poor water quality, habitat loss, disease, competition for prey — that can affect the health of other popular species such as Bay oysters, sturgeon and blue crabs.

For some time, fisheries scientists and managers have been exploring how to effectively take these factors into account in fisheries management plans in order to promote sustainable populations from one year to the next. This issue of *Chesapeake Quarterly* discusses these topics and why new ideas for multispecies management and ecosystem-based fisheries management are finding their way into policy making. For a copy, call 301-403-4220, ext. 22, or visit *Chesapeake Quarterly Online* at www.mdsg. umd.edu/CQ/

Oyster Research and Restoration in U.S. Coastal Waters: Research Priorities and Strategies. Co-published by Virginia Sea Grant and Maryland Sea Grant. For a copy, call 301-403-4220, ext. 22.

Crassostrea ariakensis: Panacea or Pandora? Mark Luckenbach, IAN (Integration and Applications Network) Newsletter. University of Maryland Center for Environmental Science. The introduction of *Crassostrea ariakensis* has been proposed for both economic and ecological gain. Some data suggests that *C. ariakensis* grows significantly faster and is more resistant to the diseases that have devastated the native oyster. However, there is still a great deal of uncertainty regarding species identification, competitive interactions (food and space), ability for larval dispersal, introduction of new diseases, and reef building capabilities. Current knowledge suggests that the most likely outcome of a large-scale introduction would be neither panacea nor pandora. The newsletter can be downloaded at www.ian.umces.edu/newsletters.htm.

Identifying and Prioritizing Research Required to Evaluate Ecological Risks and Benefits of Introducing Diploid* Crassostrea ariakensis *to Restore Oysters to Chesapeake Bay. Report of the STAC Workshop, December 2-3, 2003. To be available from the Chesapeake Research Consortium. www.chesapeake.org.

Japanese Hatchery-based Stock Enhancement: Lessons for the Chesapeake Bay Blue Crab. David Secor, Anson Hines and Allen Place. 2002. Maryland Sea Grant, UM-SG-TS-2002-02. Available on the web at: www.mdsg. umd.edu/crabs/stock_enhance/ or for a published copy, call Jeannette Connors, 301-403-4220, x. 22 or connors@mdsg.umd.edu.

Differences between Hatchery-raised and Wild Blue Crabs: Implications for Stock Enhancement Potential. Davis, J.L.D., A.C. Young-Williams, R. Aguilar, B.L. Carswell, M.R. Goodison, A.H. Hines, M.A. Kramer, Y. Zohar and Oded Zmora. 2003. Transactions of the American Fisheries Society 133(1):1-14. For a reprint, contact J. Davis, Smithsonian Environmental Research Center, 410-482-2200

The Blue Crab 2003: Status of the Chesapeake Population and Its Fisheries. 2003. Chesapeake Bay Commission: Blue Crab Technical Work Group. Available on the web at www. chesbay.state.va.us/pubs.htm or for a printed copy, call 410-263-3420.

Aquaculture around the Sea Grant Network

The following publications are available from individual Sea Grant programs. To order, visit program web sites listed below.

Aquaculture Systems

G.J. Flick et al., 2002. Commercial fish and shellfish technologies: Instructional resources for aquaculture (CD-ROM). Virginia Sea Grant. VSG-02-15. www.virginia.edu/virginia-sea-grant/

C.S. Lee, P.J. O'Bryen (eds). 2001. Biosecurity in aquaculture production systems: Exclusion of pathogens and other undesirables. Workshop, Honolulu, Hawaii, July 23-26, 2001. Oregon Sea Grant. www.oregonseagrant.edu

H.V. Daniels, J.E. Harcke, 2000. Avoiding ammonia and nitrite toxicity in hybrid striped bass hatcheries and ponds. North Carolina Sea Grant. UNC-SG-BP-00-03. www. ncsu.edu/seagrant

Crab Shedding

M. Turano, 2002. Closed crab shedding system quick reference guide. North Carolina Sea Grant. UNC-SG-02-01. www.ncsu.edu/seagrant
W. Wescott, 2002. Reducing peeler and soft crab mortality from harvesting to delivery. North Carolina Sea Grant. UNC-SG-02-02.

Shellfish

J. Supan, 2002. Extensive culture of *Crassostrea virginica* in the Gulf of Mexico region. Louisiana Sea Grant. www.laseagrant.org

Offshore culture of blue mussels — a component of the Open Ocean Aquaculture Demonstration Project. Version 2 (video). New Hampshire Sea Grant. UNHMP-V-SG-03-15. www.seagrant.unh.edu

Oesterling, M.J., ed. 2003. Shellfish culture forum: Industry issues, an annual evaluation. Virginia Sea Grant, 8 pp. VSG-03-08. No charge.

Sturmer, L.N. et al. 2003. Enhancing seed availability for the hard clam (*Mercenaria mercenaria*) aquaculture industry by applying remote setting techniques, 37 pp. Florida Sea Grant. FLSGP-T-03-002. No charge. www.flaseagrant.org.

Widman, J.C., Jr. et al. 2001. Manual for hatchery culture of the bay scallop, *Argopecten irradians irradians*. Connecticut Sea Grant. CONN-H-01-002. $10. Order from irene.schalla@uconn.edu.

Finfish

H.V. Daniels, 2000. Improved production of hybrid striped bass fingerlings through better feeding practices. North Carolina Sea Grant. UNC-SG-BP-00-02.

G.M. Weber et al. 2000. Morpho-physiological predictors of ovulatory success in captive striped bass (*Morone saxatilis*), 14 pp. North Carolina Sea Grant. NCU-R-00-0015. No charge.

Schwarz, M. 2003. Flatfish research and production in USA: Status and perspectives. Virginia Sea Grant, 2 pp. VSG-03-G-05. No charge.

Ornamentals

S.L. Larkin 2003. The U.S. wholesale ornamental market: Trade, landings and market opinions. From Marine Ornamental Species: Collection, Culture & Conservation, 13 pp. Florida Sea Grant. FLSGP-R-01-040. $3.00

J.S. Corbin et al. 2003. Marine ornamentals industry 2001: Priority recommendations for a sustainable future. From Marine Ornamental Species: Collection, Culture & Conservation, 7 pp. Florida Sea Grant. FLSP-R-01-039. $3.00

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www.mdsg.umd.edu/MDSG/Extension/Aquafarmer/index.html

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