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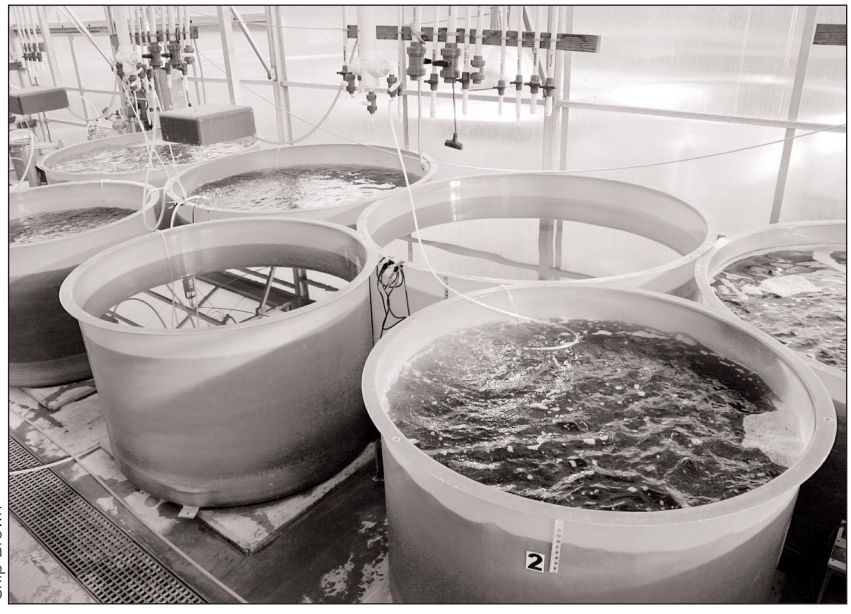
The Year-Round Oyster Hatchery at Horn Point

Don Meritt, Maryland Sea Grant Extension Shellfish Specialist

During spring and summer, the oyster hatchery at the Horn Point Laboratory is nothing less than hectic — during 2002, we produced x million eyed larvae and more than 70 million seed oysters. With the demand for seed increasing each year for restoration and research projects, we have added setting tanks and worked with the Oyster Recovery Partnership (ORP) in expanding the movement of seed oysters from the tanks to the field. For example, for years we filled mylar bags with shell for oysters to set on — rarely do we use these shell bags but now employ large stainless steel cages that enable us to move seed more efficiently.

Oysters in the Chesapeake usually begin spawning sometime in June — however, at the Horn Point Laboratory, which is part of the University of Maryland Center for Environmental Science, we begin spawning oysters in the hatchery sometime in April. To do this, we have to provide adult oysters with environmental conditions early-on that mimic what they would experience in the wild.



Skip Brown

Conditioning Oysters

The process begins with collecting selected broodstock — we try to choose oysters that have survived disease pressures, oysters from different regions or river systems, or oysters that may indicate other desirable features, such as fast growth. In the hatchery, we first examine them for their health and disease prevalence, then clean them of fouling organisms. We then place them in the HPL hatchery conditioning system — a conditioning system is a controlled environment for "ripening" oysters: while gonadal development is regulated by a number of factors, water temperature is primary.

Once they are in the conditioning system, oysters are treated like royalty: they're provided with a constant supply of temperature-controlled river water, sometimes fed algae (especially if the natural spring algal bloom has not yet begun), cleaned twice each week (more if heavy fouling occurs) and monitored for growth, mortality and stage of ripeness.

Though you will not see summer's

Contents

pace and little may appear to be going on, nothing could be farther from the truth. We are actively growing algae for feeding broodstock, while storing reserves of algae for feeding larvae later on in the summer. We are also preparing the next group of oysters for introduction into the conditioning system. We attempt to have several groups of oyster broodstock staged, to be ready to spawn when we need them. However, we try to make sure that not all of them will have fully ripened at the same time but just ripen when they are needed. Oysters do not retain their gametes, so we employ this staging process (especially during the early spawning season) to keep freshly ripened oysters on hand. This process requires planning and coordination — if not done properly larval production can be slowed down.

The expense of conditioning is considerable as a good deal of energy is required to heat river water to summer-like temperatures in April and May. The HPL hatchery operates with an open, or flow-through, system: using a series of titanium plate heat exchangers, water from the Choptank River is heated prior to its use — an automated valve system mixes the heated river water with ambient river water to produce the temperatures necessary for inducing gamete production.

Depending on the time of year and the stage of ripeness of the oysters introduced into the system, this process can take a while to complete. For instance, oysters introduced from winter temperatures require about two months of conditioning before they are ready for spawning. Oysters collected from the wild later in the season may take less time for gametes to form, while those collected when ripe can be brought into the hatchery and spawned right away.

It is advantageous to feed oysters when first brought in from winter conditions because algae are generally at a minimum in the Bay system. Once the spring algae bloom has begun, supplemental feeding from the algae we have grown is less critical. As water temperatures in the river warm, less heated river water is needed; generally by the middle of June, the system is switched over to a chiller which then cools Choptank river water and mixes it with the warm ambient water before it passes over the oysters. At this time, most oysters will be ripe or nearly ripe and the chilled water will prevent them from spawning naturally while in the system.

While uncontrolled spawns can occur, reliable temperature control can greatly reduce their occurrence, which helps ensure a stable supply of ripe broodstock for the entire spawning season. Once again, a hatchery must have sufficient numbers of ripe oysters for broodstock or it is out of business.

The dependability of the system in place to maintain strict temperature control on a twenty-four hour, seven-days a week basis is crucial. In most years it is possible to collect unspawned oysters from the wild until the end of June. After the Chesapeake's oysters have spawned naturally for the first time, ripe unspawned oysters are more difficult to find in the rivers. So it is important that we have enough ripe broodstock in the conditioning system to carry larval production through the remainder of the spawning season.

During the past two years, we have had some success re-conditioning oyster broodstocks that had spawned at least once before. However, the numbers of oysters necessary for providing an equivalent amount

of gametes increases greatly since not all oysters re-ripen at the same time — portions of the re-ripening broodstocks are often spawning naturally. We are investigating procedures that will help us more easily re-ripen brood oysters. In doing so, we should be able to significantly increase the length of time we're able to produce oyster larvae in the late summer or early fall. This will become more important as we move into the new Aquaculture and Restoration Ecology Laboratory later this season.

Our current production season lasts approximately five months from April through August. This year, we've started our conditioning process early and hope to add a month; if we can add another month to the end of the season, we could produce 40 percent more oyster spat than we have in the past couple of years.

Spawning Techniques

Unlike many hatcheries that spawn their broodstock by shucking the oysters and stripping eggs and sperm for fertilization, we employ a non-lethal method that allows us to induce spawning and collect the naturally-released gametes, so that the broodstock are available for subsequent spawns either later on in the same season or in subsequent seasons. Both stripping and non-lethal methods have advantages and disadvantages, depending on the goals.

Strip spawning is advantageous when individual paired matings are desired. Research on the production of disease-resistant strains of oysters is carried out this way; strip spawning is also more reliable for research when using selected parents. Other hatcheries such as those on the west coast, which spawn the Pacific oyster *Crassostrea gigas* (this species is the basis of the industry there), use this method to produce the bulk of their larvae.

In our mass spawning approach at the Horn Point hatchery, we place 25 to 400 oysters in flowing heated river water to induce natural spawning. Often stimulated with gametes from oysters that we do shuck, this method has successfully produced billions of eggs and sperm.

We collect eggs and sperm, combine them in the proper ratio for fertilization and then distribute the new larvae to tanks where they will feed for two to three weeks. Salinity levels vary from year to year, depending on rainfall — we need a minimum of 8 parts per thousand, preferably above 10 ppt at 25°C. Because natural algae at our location in the Choptank River rarely provide larval oysters with adequate nutrition, we produce all of the algae they will need.

Larval tanks are drained at least three times a week, the tanks cleaned and refilled with filtered river water, and the larvae culled and examined microscopically for problems — new algae are added to provide for larval nutrition. During the three weeks that larvae are feeding, they are also developing physiologically and readying for metamorphosis. Under the microscope you can observe a foot and an eye spot — this is an indication that they are ready to metamorphose from a free-swimming larvae to an attached spat. This process is referred to as settlement or setting and, physiologically, is very stressful on the larvae.

We collect "eyed" larvae and move them to tanks at Horn Point or send them to other labs or organizations, which will set the larvae in tanks at their locations. The majority of larvae at Horn Point are set on oyster shell that the Maryland Department of Natural Resources provides. Other substrate is also being used elsewhere, with varying degrees of success, for example, concrete reef balls and limestone marl rock.

Once settlement is completed, the spat (as they are now called) are typically removed from the setting tanks and placed in a shallow-water nursery near the Horn Point Laboratory pier. At this stage they are the size of a grain. After a few weeks, they will grow to almost an inch — they are much hardier and easier to transport. They are then ready for deployment to outplanting sites throughout the Bay. The Oyster Recovery Partnership, a non-profit organization in Maryland that has become a key coordinator in many restoration efforts, works with Maryland DNR, which supplies shell for stabilizing bottom grounds and identifies state sanctuary sites. ORP has also established wide-ranging partnerships with Maryland Watermen, federal agencies, non-profit organizations and community groups in oyster planting projects throughout Maryland's portion of the Bay.

Public bottom grounds in the state are designated as sanctuaries which are never to be harvested, managed reserves which are to be harvested under conditions designed to provide maximum economic benefit to the commercial oystermen, and traditional harvest bars which are part of the current oyster fishery. Research has been underway to determine the most effective planting strategies of these grounds for "smart" restoration of oyster populations.

New Hatchery

The new hatchery facility at Horn Point in the Aquaculture and

Restoration Ecology Laboratory will greatly increase out ability to produce oyster spat. It will house state-of-the-art temperature controls that have design features based on 30 years of experience at the HPL hatchery. We will be able to hold more than two-and-a-half times the broodstock that we can hold now in a controlled temperature laboratory; we will also have a second broodstock holding facility for use in the re-conditioning process. The recirculating water system will enable us to simulate winter conditions so we can better mimic conditions for out-of-season spawning. A state-of-the-art quarantine lab will allow us to work on species without the risk of animals escaping in the wild. Other improvements and the expanded size of this facility will greatly increase our ability to produce more and higher quality oyster spat for use in out research programs and with our partners in Bay restoration.

For more information about the Horn Point Laboratory hatchery, see www.hpl.umces.edu/facilities/oysters.html. In addition to photographs that detail hatchery practices, there are video clips of oyster spawning, eyed larvae and oyster setting. You can reach Don Meritt at meritt@hpl.umces.edu

New Potential Feed for Tilapia

Steven Hughes, University of Maryland Eastern Shore

Delmarva poultry farms generate an immense volume of waste litter — while a great deal of this litter has been spread on Eastern Shore farmland, recent studies at the University of Maryland Eastern Shore's Aquaculture Research and Demonstration Project indicate that litter could have a surprisingly different use as an inexpensive source of fish food.

The investigation consisted of studies with hybrid tilapia that compared the digestibilities of pelleted feeds containing either varying percentages of poultry litter (PPL) or no poultry litter and a feeding trial to determine the impact of feeding PPL on the growth and feed conversion of these fish. The first experiment assessed the digestibility of both nitrogen (protein) and phosphorus in the PPL. Indications were that both nutrients are readily digested by tilapia: nitrogen digestibility values for PPL of 86-89% were excellent and comparable to literature values for wheat products, while phosphorus digestibility values of 84-87% were also very good. These data supported the initial premise that tilapia would be able to use PPL as a significant feed ingredient.

The second experiment was designed to determine the presence or absence of the liver enzyme uricase in tilapia. This enzyme would be essential to the long-term use of PPL for tilapia because the PPL contains relatively high levels of uric acid from the poultry waste. Without an active liver uricase system, the uric acid from the PPL would build up in the blood and tissues of the tilapia and rapidly become toxic. Our data indicated that tilapia have an active liver uricase system and that the activity is intermediate when compared with data from other fish species.

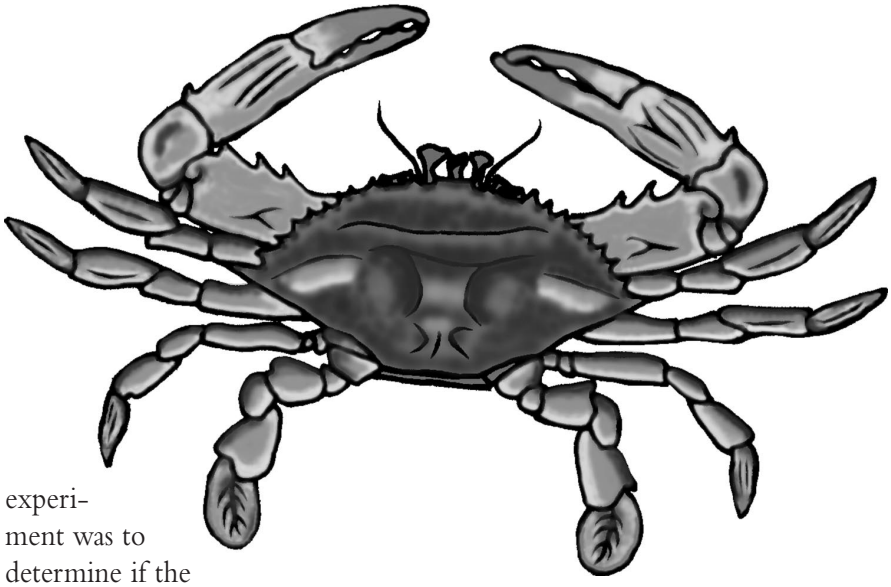
In a third experiment, in which we manufactured tilapia feeds but replaced wheat middlings with PPL, preliminary data indicate that the fish utilized PPL extremely well. PPL was able to completely replace wheat middlings (which comprised almost 20 percent of the feed) and there was no measurable difference in either weight gain or condition between fish fed this feed or the diet containing middlings. The impact of PPL feed on liver uricase levels was highly variable, though generally it had no significant effect on the levels of this enzyme. These additional data would indicate that tilapia are having no physiological problems with the uric acid in the PPL.

The results of this research support the premise that pelleted poultry litter can be used in the tilapia feeds in significant quantities and that further research to determine the most economical feeding levels is warranted.

For more information, contact Steve Hughes at sghughes@mail.umes.edu

Blue Crabs May Benefit From Algae

Barbara Garbini



Experiments to determine a more sophisticated understanding of the basic biology, nutritional requirements and water quality needs of the blue crab have been underway for two years at the Center of Marine Biology, part of the University of Maryland Biotechnology Institute. The goal of these studies is to optimize growth and reduce mortality of hatchery-reared crabs destined for research studies on enhancing of the Chesapeake Bay's blue crab stocks. The feasibility of enhancement itself may depend on advancements in large-scale, indoor, closed system hatchery and nursery aquaculture technologies for producing young crabs.

Research studies involving growth and nutrition of blue crabs have shown that juvenile crabs require refuge from both predation and cannibalism in a sea grass habitat. In an aquaculture setting, cannibalism can be reduced with the introduction of a single-size class of crab. While analyses conducted of crab stomach contents at all stages of development indicate that crabs consume microscopic algae, it is not clear whether the algae or their associated bacteria provide additional nutrition to the developing crab.

In an experiment funded by the COMB blue crab hatchery program and Maryland Sea Grant, 120 juvenile blue crabs within a single-size class (1.5 – 2.0 cm) were divided into several tanks with artificial seagrass and fed supplementary diets of microscopic algae, bacteria or a combination of both. The goal of the experiment was to determine if the presence of algae or bacteria could provide additional nutrition for growth and improve survival rates of the crabs during the juvenile stages of development, while providing for improved water quality in a closed system.

After 28 days, the overall mortality rate of the 120 juvenile crabs was 43 percent. Crabs fed large amounts of bacteria had a significantly higher mortality rate of 77 percent, became lethargic and soft, and in some cases failed to molt. Crabs fed supplemental diets of microscopic algae had a significantly higher daily rate of wet weight growth (when compared to a control group), which suggests that algae can play a role in nutrition in the juvenile stage of development. Supplements of both algae and bacteria did not show a significantly higher rate of growth, an indication that the bacterium does not provide additional nutrition and is most likely detrimental to the overall health of the crab.

All tanks that contained microscopic algae maintained higher water quality where nitrate, nitrite and ammonia levels were low throughout the experiment. This experiment implies that the addition of microscopic algae along with artificial sea grass cover may provide additional nutrition to the juvenile blue crab, increase its daily growth rate and significantly improve water quality in a closed aquaculture system.

The use of microscopic algae could have another benefit as well, an economical one. While *Artemia napollii* and commercial feeds are routinely used in the rearing of larval and juvenile crabs and are a good source of nutrition, they are expensive for large-scale operations. Inexpensive supplemental diets such as microscopic algae that can be grown on artificial sea grass, and that can support and increase growth through the juvenile stages of development, will be beneficial for aquaculture facilities.

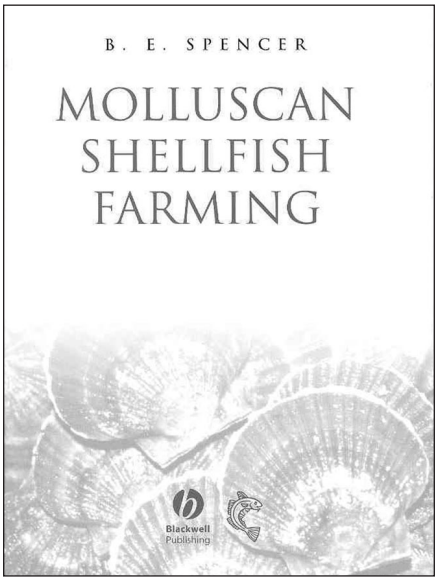
Barbara Garbini is a graduate student at Hood College; she is working under the direction of Dr. Moti Harel, Center of Marine Biotechnology, and Dr. Dan Terlizzi, Maryland Sea Grant Water Quality Specialist.

For more information on the COMB blue crab hatchery program, contact Steve Berberich at 301-990-4804 or berberic@umbi.umd.edu.

Farming Shellfish — Covering All the Bases

Molluscan Shellfish Farming, Brian E. Spencer, Blackwell Science, Fishing News Books (Iowa State Press, a Blackwell Publishing Company), Ames, Iowa. 2002. 272 pp. $96.99.
www.iowastatepress.com

Don Webster, Maryland Sea Grant Extension Program, Eastern Shore Agent



I have several shelves of publications from Fishing News Books. This United Kingdom publishing house has produced useful reference texts on fisheries and aquaculture topics for decades — *Molluscan Shellfish Farming* will now be found on my ready reference shelf.

The book derives from the Buckland Lecture, a prestigious series first begun in 1930 for addressing fisheries related topics. Brian Spencer's lecture forms the basis of the book's first chapter, "Bivalve cultivation in the UK: structuring influences." Since U.S. law is largely based upon British common law concepts, the discussion of legislation and rights to grow and harvest shellfish are similar in many respects and should be interesting to the legal novice. The chapter also covers the experience of uncontrolled imports of shellfish seed to the UK after the flat oyster industry collapsed in the 1900s. Pests accompanied some seed and finally led to control orders in 1974 that have aided in minimizing the spread of unwanted organisms.

The experience of the UK in introducing several species of non-native bivalves was similarly intriguing. These were brought in under quarantine and information is provided on the species, origin, and fate of the animals. Among those are the Pacific and American (Eastern) oyster, and the Manila clam. Protocols developed under the auspices of the International Council for the Exploration of the Seas (ICES) to assess the impact of non-native introductions are referred to throughout the volume.

With the current examination of the efficacy of the Suminoe oyster *Crassostrea ariakensis* in mid-Atlantic waters, these issues are especially relevant. They have, of course, been faced before in other countries. "Probably the most contentious issue with introducing non-native species is associated with their breeding potential," writes Spencer. "For the past 30 years, it has been (UK) government policy not to introduce a species where there is a risk of it becoming established and creating self-sustaining populations." The government seeks to protect the environment while all possible effort is made to support a healthy aquaculture industry. Indeed, Spencer makes clear the need for aquaculture in addressing a primary shortcoming of reliance on natural reproduction, that of irregularity of spatfall.

The chapter on the "General Biology of Bivalves with Respect to Cultivation," provides an overview of the natural functions of commercially important shellfish. While certainly not inclusive of all available information, Spencer gives basic data on the topic. Covering many species, his writing is concise writing and includes appropriate diagrams and bulleted descriptions of techniques that provide a clear understanding of the methods he describes. When I read near the end of the chapter this sentence — "Successful hatchery production of larvae and spat is related more to the skill and experience of the staff than to the excellence of the facilities and equipment" — I thought of the late Max Chambers and his original hatchery near Nanticoke, Maryland. (see "A Man and His Ideas," www.mdsg.umd.edu/Extension/Aquafarmer/Summer01.html#4).

The chapters on shellfish cultivation techniques make the book especially useful; the text is enhanced with photographs that illustrate grow-out techniques in use around the world. These techniques suggest a basic lesson of successful shellfish production methods: they must be adapted to local hydrological features. High, three-dimensional grow-out methods, for example, may be more effective in areas where there is high tidal amplitude; lower, more spread-out methods are generally better in areas where tidal fluctu-

Skip Brown

ations are low. Spencer also includes grow-out equipment from many nations around the world, from bottom culture in the Pacific Northwest to rotating cylinders used in Australia. It is clear that Spencer has a broad range of knowledge in mollusk culture.

There are individual chapters on oysters, clams, mussels, scallops, and abalone culture. (While not a mollusk, abalone is included because it is a shellfish and a significant body of knowledge exists on its culture. These chapters are well planned and well written. There are diagrams of culture methods along with the photographs of actual deployments. Spencer provides historical information about shellfish culture in these as well, showing that mankind has had a fascination with growing mollusks for many centuries.

His characterizations of Asian rock and stick culture show that sophisticated equipment is not necessarily required for cultivation — only human ingenuity. Of course, suitable laws or lack of prohibitions on growing areas and methods are critical for success as well. This is a primary reason why shellfish aquaculture in Maryland has had such a difficult history. These chapters, as with all others in the book, are well referenced and include relevant literature citations.

An important topic in any type of aquaculture is the control of predators. This is a basic function of culture along with preventing disease, controlling mortality, enhancing growth, and optimizing quality. Spencer's discussion on predator control and exclusion methods is wide-ranging. While he recognizes bird and fish predation, he focuses a great deal of attention on controlling the impact of crabs. He describes exclusion devices used on mollusk farms as a primary means of protection and gives examples of their use. He also discuses chemical control methods along with the more usual mechanical methods and he provides the statutory powers in the UK for these.

In a chapter on site selection for bivalve aquaculture, Spencer notes that it is "a multi-faceted problem that requires an assessment of a range of information to ensure that a new business venture stands a good chance of success." Too many businesses in Maryland and elsewhere have found this out too late to keep from failing. He gives a concise overview of site selection that summarizes the physical, biological, and legal information that must be gathered by the prospective culturist before a site can be judged as viable. As always, Spencer provides a range of topics that cover many aspects of important site criteria.

The last chapter covers important information on the "Processing of Live Bivalves for Consumption." It has been known for decades that shellfish are susceptible to bacterial pollution and can be significant sources of disease in humans. Sanitation programs have been developed to ensure that only quality seafood reaches the marketplace. Spencer gives a history of the development of depuration facilities, providing information on their design and operation to ensure that cleansed shellfish reach the consumer. He compares the advantages and disadvantages of depuration methods according to a range of criteria. These include capital and operating costs, installation and maintenance costs, dose and contact time, and toxicity to the shellfish themselves. While depuration is frequently looked upon with disdain in the United States, this discussion provides a glimpse into modern processing methods used in European markets to assure consumer health.

Molluscan Shellfish Farming is an excellent addition to any shellfish culturist's reference collection. It should receive widespread distribution and use in future years. It certainly meets the high standards set by Fishing News Books and its parent company, Blackwell Science.

Country of Origin Labeling Coming to Your Seafood Counter

Doug Lipton, Marine Economic Specialist, Maryland Sea Grant Extension

The next time you buy fish or shellfish or crab, see if the country of origin is identified, or whether the product was harvested from the wild or reared on a farm. If marketers believe that such information will increase demand, you are likely to find it easily and at a premium price. Such identification is related as well to marketing. Chilean sea bass, for example, commands a premium, whether or not it was caught in Chile. "Farm-raised catfish" may be promoted if the seller is betting that you are more likely to buy it at the posted price. Up until now, seafood labeling that identifies country of origin and farm-raised or wild harvest has been voluntary and largely unregulated — that is all going to change.

The 2002 Farm Bill, the omnibus legislation governing federal agriculture programs for the next six years, contains a provision requiring the Secretary of Agriculture to develop mandatory regulations governing country of origin labels for certain food products including wild fish and farm-raised seafood. These regulations will need to be finalized by September 30, 2004, although voluntary guidelines for labeling are currently in place.

The cost of these new requirements — referred to as COOL (Country of Origin Labeling) Seafood — may be costly to retailers and their suppliers as they will have to keep track of the different sources of their products. (Restaurants and other types of food service establishments will be exempt from labeling requirements.) Each business in the marketing chain will have to keep records and certify to the business to which they sell as to the country of origin of the product they are supplying.

So who is likely to benefit from these new regulations? The simple answer is consumers and domestic producers. Consumers will now have more information about the seafood they are purchasing. As E.F. Golan et al. discussed in "Economics of Food Labeling" (Journal of Consumer Policy. 2001. 24:177-184), there are three scenarios regarding how this information may affect consumers: (1) consumers may not care about the country of origin, (2) they may prefer the imported product, or (3) they may prefer the domestic product. Which of these scenarios holds may depend on the specific fish or shellfish product being purchased. However, if consumers do prefer the domestic product, then domestic producers will benefit from the greater demand and market share.

In a study of nutrition labeling using the 1987-88 Nationwide Food Consumption Survey, Wang et al. in "Consumer Utilization of Food Labeling as a Source of Nutrition Information" (The Journal of Consumer Affairs. 1995. 29:368-380) found that about 45 percent of households used food labels for nutrition information. They also found that the likelihood of a household using nutrition label information in their purchasing decision depended on factors such as income, level of education, geographic location and other socio-demographic factors. Interestingly, consumers were more likely to use nutrition labels when they were more aware of the health effects of food consumption. For example, people who were trying to limit their fat intake were more likely to use the labels in the purchase decision.

The study on the use of nutrition labels has important implications for the effectiveness of country of origin labeling for seafood. If consumers are aware of quality or other differences between domestic and imported seafood, or between wild and farm-raised seafood, then the country of origin labeling requirement is more likely to have an impact on their purchase decision. Thus, there are opportunities for consumer education and marketing to capitalize on this new information the consumer will have at the seafood counter.

For more information on COOL, contact Doug Lipton at dlipton@arec.umd.edu

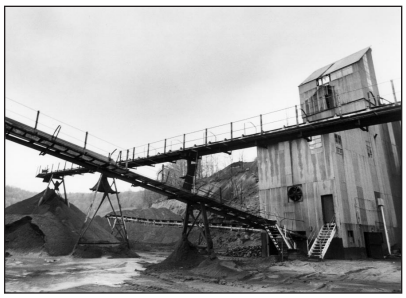
Acid Mine Drainage in the Chesapeake Watershed

Matt Hall

The Potomac River is the second largest river feeding the Chesapeake Bay (the Susquehanna is the largest) — flowing from its head waters in West Virginia through Garrett County in far western Maryland, it is fed by numbers of tributary streams. Lostland Run is one such stream. Fly fishermen are out there at the beginning of Spring casting their lines for stocked rainbow trout or cryptic native brook trout; hikers are out there as well traversing the backwoods trails. Unbeknownst to many, abandoned coal mines leach a steady stream of acid into Lostland Run's upper reaches. Were it not for a tall metal tower positioned over the south prong of Lostland, fishermen would not likely be casting their lines — there would probably be no trout to catch. Referred to as a doser by the Maryland Bureau of Mines, the tower steadily spills limestone into the water below, thereby buffering the stream against the acid it collects flowing past the defunct coal mines above.

"Acid mine drainage (AMD) is the number one water quality problem in the Appalachians" says Ray Morgan, a Professor at the Appalachian Laboratory, part of the University of Maryland Center for Environmental Science in Frostburg. "It can destroy streams. Iron, manganese, and aluminum are transported downstream and the water is unfit for consumption and industrial or municipal use." Morgan has worked for most of his career on water quality issues in Maryland and West Virginia watersheds. He has also monitored reclamation efforts in several western Maryland watersheds, including the doser on water quality of Lostland Run. High levels of acidity from abandoned mines are lethal to stream-dwelling organisms up and down the food chain — from large fish to small invertebrates. The metallic ions associated with AMD can also reach toxic levels. Because some species are more tolerant of

What Is Acid Mine Drainage?



Whether drilling deep shafts to reach coal or strip mining near the surface, coal seams and surrounding bedrock are exposed to oxygen and water. Most coal seams in the Chesapeake drainage are high in iron disulfide (FeS_2), commonly known as pyrite. When pyrite is exposed to air and water, oxidation reactions produce sulfuric acid (H_2SO_4) and ferrous iron ions (Fe^{2+}) in a water solution. This chemical reaction decreases the pH of the solution by contributing more hydrogen ions — the more hydrogen ions present in solution, the lower the pH is and the more acidic the solution (pH below 7.0 is acidic and above 7.0 basic). The ferrous iron is then oxidized to ferric iron (Fe^{3+}). These reactions do not take place spontaneously but are catalyzed by bacteria present in the underground water. Sulfuric acid is the most toxic product of these reactions and will affect most stream organisms. Ferric iron ions in solution are also acidic and cause pyrite to dissolve, producing more sulfuric acid and iron ions. As these products move into a stream, ferric iron ions precipitate out of solution as solid iron oxide $FE(OH)_3$ or "yellowboy." Yellowboy forms orange-red deposits in streams leaving a telltale sign of acid mine drainage contamination. The Maryland Bureau of Mines and other regulatory agencies combats this contamination by treating stream water with limestone ($CaCO_3$) or its derivatives: limestone reacts directly with sulfuric acid, tying up free hydrogen ions and thus raising the pH of the water, which reduces its acidity. This process is known as neutralization and is quite effective for removing acidity from stream water. (Source: S.E. Manahan, Environmental Chemistry, PWS Publishers, Boston, 1984.)

— *Matt Hall*

lower pH levels (acidity) and metallic ion concentration, they can come to dominate biota that are not so tolerant, leading to declines in biological diversity. Not only are biological impacts acute at the source of discharges, but chronic effects are evident as well, Morgan says. This is because compounds like iron precipitate ("yellowboy") may be retained in soil layers and rock below a stream channel (called the hyporheic zone) for many years.

According to a 1997 report from the U.S. Environmental Protection Agency, a large area of the Chesapeake drainage is impacted by acid mine drainage — the Susquehanna watershed, lying as it does in areas of rich anthracite coal beds, is a primary example. The bituminous coal region encompasses large swathes of the West Branch Susquehanna system in Pennsylvania and the North Branch of the Potomac River and its tributaries in West Virginia and Maryland. (Lostland Run feeds the North Branch.) According to the report, acid mine drainage affects 1100 miles in 158 streams in the Chesapeake drainage. This includes a majority of the central and western sections of the Bay watershed.

So what can be done about acid mine drainage? A number of abatement techniques, in addition to doser technology for releasing limestone into stream flow, are in use throughout the watershed. These include treating the discharges directly, reclaiming abandoned mine lands, regrading and revegetating mine refuse piles, sealing abandoned mines, and remining abandoned mine sites. Reclamation efforts also include the construction of wetlands that can act as filters for contaminated run-off. While all of these measures are being used in the Chesapeake watershed, there have been varying degrees of success.

Joe Mills is an acid remediation specialist with the Maryland Department of the Environment's Bureau of Mines in Frostburg. He says that since 1995, Maryland's permitting system provides safeguards for preventing contaminated run-off from currently operating mines. However, he adds, "our biggest priority now is locating pre-law, abandoned mines that are discharging acid. We have located hundreds of these in western Maryland, but there are probably hundreds more. This project will take years." Connie Lyons, also of the Bureau of Mines, agrees and takes the issue a step further. "Our most difficult problem is the variability in abandoned mines. Damage from acid mine drainage depends on the size of the mine and the size of the receiving stream. Sometimes, a mine may only discharge once a year, but that may be enough to damage a stream ecosystem and make recovery difficult."

Despite these challenges, both Mills and Lyons point to the success of the Bureau's reclamation efforts. Six dosers, including the one on Lostland Run, pump tons of limestone and limestone derivatives into tributaries of the severely impacted North Branch of the Potomac River. Prior to their installation in 1992 and 1993, waters flowing from several abandoned mine sites kept the North Branch at an acidic pH of between 3.24 (severely acidic) and 7.0 (neutral), depending on water flow. Fish populations were so impacted that fishing was virtually non-existent — game and non-game fishes experienced high mortality or drastically-reduced reproduction in the acidic water. Because of the dosers, 35 miles of Potomac headwater have been reclaimed to a fishable condition, including eight miles of "trophy" trout stream below Jennings-Randolph Lake.

The dosers, says Mills, have been raising pH and reducing acid-related mineral precipitation, while operating at relatively low cost. "In 1994, we spent $94,000 to run four dosers," he says. "In 2002, $67,126 was spent to operate seven dosers." A recent economic study estimated that recreational fishing areas see roughly twelve dollars in return (in fishing license fees, bait and tackle sale, local hotel and campground fees, etc.) for every dollar spent. With the reduction in doser operating costs, potential revenue per dollar spent is doubled." Though the cost reduction is attributable mainly to the use of less refined limestone, Mills says, it produces the same neutralizing effect as the high-grade compound.

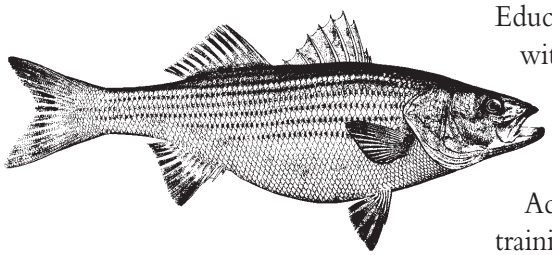
Given the success in Maryland so far in treating the impacts of acid mine drainage, we're just at the beginning, Mills says — many sources still must be located and monitored in order to determine the best strategies for eliminating or simply minimizing their impacts on living organisms. Without the research that has gone into developing current techniques for ameliorating these impacts, many of the Chesapeake's headwater streams would be virtually sterile environments.

For more information, visit the Maryland Department of Environment at www.mde.state.md.us/Programs/WaterPrograms/MiningInMaryland/MDAcidDrainage/index.asp

Matthew R. Hall is a Research Statistician in the Tidewater Ecosystem Assessment Division of the Maryland Department of Natural Resources.

Partnership to Develop Integrated Aquaculture *Enhancing Wetland Restoration Projects for Teachers and Students*

Adam Frederick, Maryland Sea Grant Extension Education Specialist



Increasing awareness about Chesapeake Bay restoration programs among teachers and students is not an end but a beginning — putting that awareness into action is the focus of a new partnership between Maryland Sea Grant and the National Aquarium in Baltimore. With the aquarium's Conservation Education staff, we will be training teachers in hands-on aquaculture and in operating an integrated system for raising brackish water fish and marsh grasses.

Over the last several years, the National Aquarium has been at work on a variety of conservation efforts, from wetland to eel grass bed restoration in the southern Chesapeake (see www.aqua.org/animals/conservation/). One such effort is the Tidal Wetland Restoration Project at Fort McHenry, Baltimore, which involves the extensive planting of marsh grasses. In league with the National Park Service, the Aquarium is spearheading a volunteer effort to restore, maintain, and monitor a ten-acre tidal wetland bordering Fort McHenry National Monument. According to Glenn Page the National Aquarium's Director of Conservation Education, the project is the basis of an initiative to develop community stewardship programs in habitat restoration. The Conservation Education group is presently working with some ten schools on wetland restoration efforts and has a similar approach to Maryland Sea Grant's Aquaculture in Action Program, which has been training and equipping teachers in summer programs to bring aquaculture into their classrooms.

These efforts require that a school have certain facilities and most of all a dynamic teacher who will bring the excitement and motivation of restoration and research to the classroom. A collaborative Sea Grant-Aquarium K-12 program directed at teachers would be a first and will also bring together unique resources with a focus on science research and Chesapeake Bay restoration. The collaborative program would help recruit new teachers into the Aquaculture in Action Network (www.mdsg.umd.edu/Education/AinA) and will enable participants to perform work on fish and plants in an integrated recirculating aquaculture system that we will design. The proposed project has grown out of continuing contacts between the two groups over that last several years as we have considered how to make greater strides in restoration efforts with K-12 teachers.

For more information on this collaboration and other Maryland Sea Grant education programs, contact Adam Frederick at frederic@mdsg.umd.edu

Web Sites

Two premier websites for keeping up to date on aquaculture and exotic species are the Sea Grant Non-Indigenous Species Site (www.sgnis.org) and the Aquaculture Network Information Center (www aquanic.org).

SGNIS

SGNIS is a national information center on aquatic nuisance species and contains a comprehensive collection of research publications and educational materials produced by Sea Grant programs and other research institutions. You'll find peer reviewed articles and so-called gray literature reports, newsletters, research findings and proceedings. The search engine is valuable in pointing to such diverse topics as nuisance species, biological controls, economic and environmental impacts. SGNIS is a project of the National Sea Grant College Program, produced by the Great Lakes Sea Grant Network.

If the numbers of visitors a website receives is a measure of its value, then both sites are high up on the list. According to Mark Einstein, AquaNIC had more than 1.1 million visitors from 150 countries; SGNIS tallied 217,000 visitors from 130 countries. If you haven't yet, check them out.

AquaNIC

AquaNIC is the major gateway to national and international web-

based sources of aquaculture information. Easily navigable, the site consolidates wide-ranging material on fish, shellfish and crustacean species, pond and recirculating systems, newsletters and publications, and web-based courses — it is the first place to go when you need to do background research or want to know what's new.

The Aquaculture Network Information Center is coordinated by the Mississippi-Alabama Sea Grant Consortium, and hosted by Purdue University and the University of Illinois through the Illinois-Indiana Sea Grant College Program. AquaNIC is a member of the National Sea Grant College Program's Network of Aquaculture Information Services along with the Department of Commerce/ NOAA Aquaculture Information Center, National Sea Grant Library, Delaware Aquaculture Resource Center, and Maryland Sea Grant Program. AquaNIC also maintains the aquaculture subject area for the Agriculture Network Information Center, an alliance between the National Agricultural Library (NAL), university librarians, and subject matter specialists at Land Grant and Sea Grant institutions.

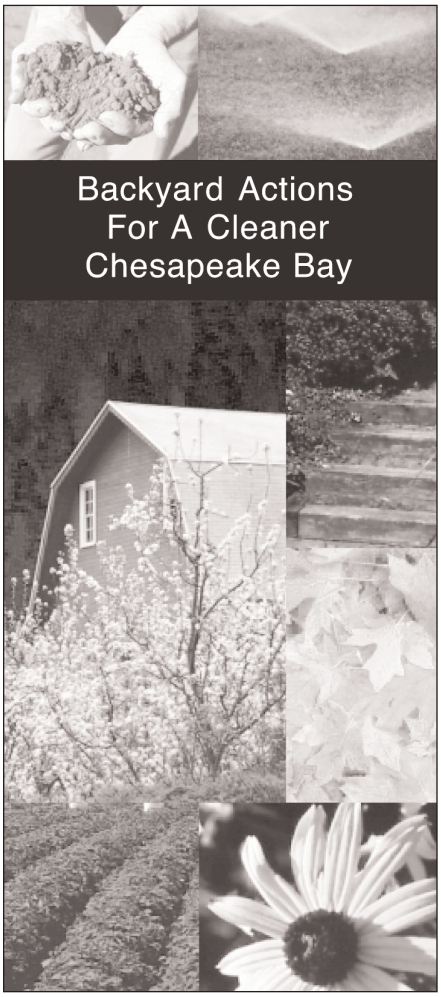
New Publications

Backyard Actions for a Cleaner Chesapeake Bay

If you do any gardening or want to better understand how individual behaviorism can affect the Chesapeake ecosystem, you'll want to get Backyard Actions for a Cleaner Chesapeake Bay, a series of five informative guides on conservation measures that you can easily put into practice. Produced by the Maryland Department of Agriculture, the recommendations are adapted from Best Management Practices that farmers employ, says Rona Flagle of MDA. For some years, Flagle has been developing innovative outreach materials that citizens with little experience or knowledge can employ in their gardens or on theirs lawns. In addition to an introductory brochure, the series includes: (1) Try Pesticide Alternatives, (2) Use Fertilizers Wisely, (3) Control Soil Erosion, (4) Try Composting, (5) Conserve Water.

Backyard Actions is an education in itself. Each of the five brochures is valuable not only for gardeners but educators, students and anyone who wants to know how the informed actions we take can add up in the long run towards improving conditions for the Bay's natural resources.

To obtain brochures directly and learn about related publications and products that MDA has produced, contact Rona Flagle at 410-847-5788; or call the Maryland Cooperative Extension Home and Garden Center at 1-800-342-2507, or go to www.hgic.umd.edu



Maryland Aquaculture Association Quarterly Newsletter

This modest newsletter sets out the goals of the Maryland Aquaculture Association, which is "dedicated to the furtherance of farming the water." A key aim, writes Association president Chip Crum "is speaking with a unified voice to the legislators of the state." This issue focuses on legislation related to aquaculture in the General Assembly; there is also a discussion about the Maryland Aquaculture Plan. To find out more about the association, contact Chip Crum at 301-874-1882, or write, MAA, 4007A Buckeystown Pike, Frederick, Maryland 21704.

Workshop

Maryland Sea Grant Hosts Charter Boat Workshops

Charterboat Industry Recognized as Part of Regional Tourism

Charles Petrocci

"And what sport doth yeeld a more pleasing comfort and less hurt and change than angling with a hooke."

Possibly with those words, 17th century explorer and fishermen Captain John Smith launched the earliest form of sportfishing in the Chesapeake Bay region. From those simple beginnings, with the most utilitarian types of equipment, sportfishing along the Chesapeake and Atlantic coast has grown into a multi-million dollar industry. And at the forefront of this economic development has been the sportfishing charter boat industry.

For more than a century, charter boats and party, or head, boats have formed the backbone of the sportfishing industry in the mid-Atlantic region. These boats have been a crucial link to regional tourism and traditional heritage efforts, and a driving force in economic development for many small coastal communities from North Carolina to New York. Charter boat operators have been guiding, entertaining and educating generations of anglers. From small waterfront towns like Crisfield, Maryland, to larger marinas like those found around Ocean City, charter boats located in these ports continue to visually remind us of our deep cultural roots in sportfishing recreation.

Michael W. Fincham

Resilient Industry

Charter boats and party boats for many years were the backbone of the sportfishing industry in the mid-Atlantic region. Anglers wishing to fish for inland bay, coastal or offshore species had to go with a hired boat to get in on the action. They offered both the occasional angler and the veteran fishermen an opportunity to participate in an otherwise rich man's game. But that has changed in the last 30 years, as increased personal wealth, especially among the middle class, has enabled many people to buy private boats of their own — and this has cut deep into the charter boat business, though the industry remains resilient.

The Eastern Shore of Maryland, a historic bastion of sportfishing, is a testimony to that. Here over 200 boats for hire still take anglers out to offshore haunts, as they have done for decades. It is here one can find generations of captains searching the Chesapeake for stripers or offshore for blue water giants. Many of these ports still cast shadows from the Zane Grey and Earnest Hemingway era. Charter boats cater to a wide variety of anglers, of every gender, race, color and nationality. On board, sportfishermen find common ground in their pursuit of game fish. Avid angler Herbert Hoover may have summed it up best when he said, "Fishing is great discipline in the equality of men, because all men are equal before fish."

Changing Environment

For some waterfront communities, the sportfishing industry, with charter and head boats at its core, have become an important attraction for tourists and tourist-related dollars. Marinas hosting charter boats also bring in non-consumptive user groups such as tourists, attracted to

weigh-ins, tournaments and daily dockside activities. Many visitors to waterfront vacation areas feel active marina sites are part of their overall vacation experience. And no doubt, marina managers and related service businesses feel the same.

Today the charter boat industry is faced with ever changing regulations, legal issues and fluctuating resources and business, yet they remain resolute and continue to have a positive impact on the economic well being of many coastal communities of mid-Atlantic states. Recognizing this impact, Sea Grant programs in the mid-Atlantic (New York, New Jersey, Delaware, Maryland, Virginia and North Carolina) developed a program to assist the industry through a series of progressive workshops. In the fall of 2002, Sea Grant conducted statewide charter and head-boat educational surveys to help design programming for these industry workshops. This survey was implemented to help develop a more effective educational program by gathering information directly from charter boat practitioners. A survey list of questions was mailed to a sample group of charter owners; topics solicited for feedback in this survey included: Federal and State Regulations; Fishing Management; Latest Coast Guard Regulations; Fish Handling Quality Control; Accounting; Legal Issues; Insurance; Marketing; Web Page Design; and Off Season Business Development. More than 400 charter and head boat operators returned the surveys.

Open to all charter and head boat owners and captains, these programs were offered in various locations from New York to North Carolina. Maryland Sea Grant hosted two programs, taking into account its strong charter industries in both the Chesapeake Bay and Atlantic regions. Teaming up with Virginia Sea Grant, one program was held on March 11th at the Holiday Inn at Solomons, Maryland. The program attracted over 35 charter captains from both states and some came as far away as Virginia Beach and Baltimore.

The primary focus was regulatory, business and safety issues relating to the Chesapeake Bay. It was a good opportunity for both Maryland and Virginia operators to interact and share mutual ideas and concerns. Another program, in conjunction with Delaware Sea Grant, was held on March 13th, and located in Ocean City at the Harrison Harbor Watch restaurant, overlooking the inlet. This program had almost 50 charter operators in attendance, with some coming from as far away as New Jersey and Pennsylvania. This program focused on regulatory, business and safety issues primarily for coastal charter boat operators. "I'm just starting out in the charter boat business and I learned more at this workshop than I have in the last six months of planning on my own," Chris Toomey said. "This was a well organized, focused program, and I would make the trip from Baltimore again for another one."

Both the Ocean City and Solomons workshops included specific business, safety and fishery resource issues, presented by professionals in their respective fields. Speakers included experts from the National Marine Fisheries Service, Mid-Atlantic Fishery Management Council, Maryland Department of Natural Resources, Virginia Marine Resource Commission, Virginia Institute of Marine Science, Delaware Natural Resources, and the U.S. Coast Guard. Speakers representing the private business sector included topics on legal, insurance, and marketing issues. Both programs also featured roundtable discussions led by charter captains from various states. "This was a great opportunity for charter and head boat operators to learn about current fishery issues, progressive business management ideas, and new Coast Guard regulations. It was also a chance for boat operators from Maryland, Delaware and Virginia, to come together to share business issues, and discuss mutual business related challenges," said Doug Lipton of the Maryland Sea Grant Extension Program. The workshops also included extensive industry related handouts and lunch.

Both the Solomons and Ocean City programs were well received with comments expressing the workshop met or exceeded expectations and that attendees would like to see future programming targeting the charter boat industry. The success of these statewide/regional programs is the direct result of a pioneer charter boat workshop that was held in Ocean City Maryland in 2001. This workshop, sponsored by Maryland and Virginia Sea Grant had an excellent turnout and participants expressed interest in additional programming.

For more information about this conference and related issues, please contact Doug Lipton at 301-405-1280, dlipton@arec.umd.edu

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Sea Grant Maryland

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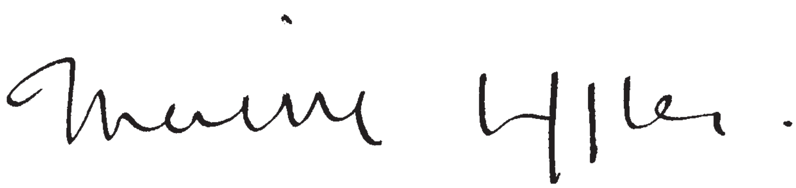
www.mdsg.umd.edu/MDSG/Extension/Aquafarmer/index.html



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