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Non-native Species

The Need for Balanced Evaluation

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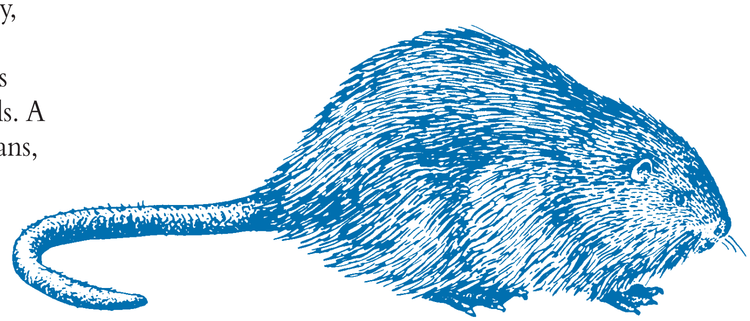
Introductions of species from one region or ecosystem to another have been occurring for eons, long before the emergence of human beings. They occur naturally, of course, whether through climatic events such as winds and storms that can sweep up all manner of organisms and carry them to far distant places, or by animals and birds that routinely ferry hosts of seeds and microorganisms along their migration routes. Major introductions of non-native or nonindigenous species also occur through human activities — there are hundreds of examples of plants, animals and aquatic organisms that have been, and are, moved around the world, sometimes inadvertently, sometimes not.

Increasingly, a major source of invasive species has been ballast water discharges from ocean-going vessels. A diversity of organisms — microbes, shellfish, crustaceans, finfish — can be entrained in ballast water intakes in one port, ferried across the ocean and then discharged into another port. As these vessels have become larger, so has their need for immense volumes of ballast. The consequence is that greater numbers of more species able to reproduce are being transferred around the world every day. Zebra mussel invasions in the Great Lakes — the most prominent example in the last decade — helped catalyze public awareness and state and federal legislation, particularly the 1990 Nonindigenous Aquatic Nuisance and Prevention Control Act and the 1996 National Invasive Species Act.

The Aquatic Nuisance Species Task Force, which coordinates prevention and control activities among federal agencies and stakeholder groups, defines nonindigenous as "any species or other viable biological material that enters an ecosystem beyond its historic range, including any such organism transferred from one country into another." Nonindigenous species may be relatively benign and have tolerable impact on the functioning of an ecosystem — think of "transplants" such as cattle and



While there is an obvious distinction between transplants and invasives, the distinction can break down: what may be beneficial in one region can be problematic in another, sometimes for complicated reasons.

sheep — or they may be "invaders." The task force defines an invasive or nuisance species as one that "threaten[s] the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural or recreational activities dependent on such waters."

While there is an obvious distinction between transplants and invasives, the distinction can break down: what may be beneficial in one region can be problematic in another, sometimes for complicated reasons. Consider the Japanese oyster, *Crassostrea gigas*, which was first imported to the Pacific Northwest in the late 19th century after the native oyster, *Ostrea lurida*, had been virtually eliminated by overharvesting and pollution. Today, *C. gigas* is the foundation of the flourishing hatchery-based industry on the west coast. It is also the commercial species in other parts of the world — in France, England, Australia and New Zealand — all of which imported the oyster from Japan because of the loss of their native oyster populations. *C. gigas* was brought in because of its hardiness and resistance to diseases that were devastating native oysters.

There is strong anecdotal evidence that in the early 1950s, *C. gigas* was brought east to Delaware Bay for commercial trials and research purposes. Though no commercial industry developed, *C. gigas* appears to have brought with it a hitchhiker that no one expected: recent research at the Virginia Institute of Marine Science (VIMS) suggests that those oysters were carrying MSX. While *C. gigas* can tolerate the disease, that is not the case for *Crassostrea virginica*, the oyster native from Canada to the Gulf Coast, including Chesapeake Bay. In 1956, MSX disease spread throughout Delaware Bay and crippled the industry; in 1959 it arrived in Chesapeake Bay, according to the VIMS website. MSX was an inadvertent introduction, an invader, an "alien" or "exotic," all synonyms for nonindigenous invaders. Scientists and resource managers were caught unawares: they didn't think about MSX because they didn't know about it until the occurrence of widespread deaths of Bay oysters, especially in the higher salinity water of Virginia's lower Bay — in drought years, when higher salinity waters push up into Maryland, oyster deaths can occur from MSX there as well.

The designation MSX stands for Multinucleated Sphere Unknown because researchers couldn't identify it — in fact, the parasite that causes the disease was first misdiagnosed as a fungus, then identified as a protozoan, *Haplosporidium nelsoni*. Its life cycle still remains a mystery. The take home point is that introduction of a species may

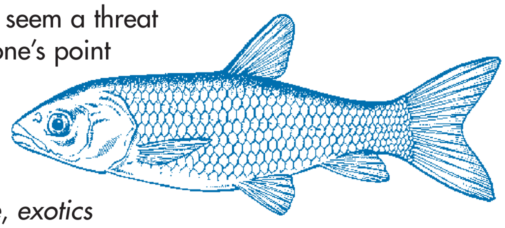
not appear to be a threat in itself, but there can be other complicating factors. This is where thorough research comes in.

Non-native Invasions in the Chesapeake

Whether inadvertent or intentional, the "invasion" by non-natives has been of growing concern for aquatic ecosystems because of their potential impacts on native organisms — those impacts can also ripple through the economy and, in some cases, even affect public health. Without natural predators or climatic and other controls, nuisance or invasive species can become so dominant that they alter the structure of long-established food webs — MSX and perhaps Dermo disease (*Perkinsus marinus*), which was first found in the Chesapeake Bay in 1949, are two prominent examples in the Chesapeake. Not only have these diseases decimated oyster populations, they have frustrated wide-ranging programs aimed at restoring oyster reefs that have been damaged by overharvesting, pollution and disease itself. The ecological costs have been enormous — the oyster is a key filter-feeding organism in the Bay system and provides habitat not only for other commercial species but for other filter feeders such as mussels and barnacles that attach to oyster shells. The economic costs for commercial fishermen, processors, service industries and the rippling effects on bayshore communities have also been enormous as has yet another, this one a cost to the nation, namely the federally-legislated Oyster Disease Research Program. While ODRP is seeking practical techniques for developing disease-tolerant oysters and exploring innovative ways to manage around disease, there might have been no need for a program of such scope had those oyster diseases not been unintentionally introduced into the mid-Atlantic.

Beyond oyster disease, other introduced species are also causing damage in the Chesapeake. Mute swans and nutria are two current examples of non-native animal invaders that have been so disruptive to estuarine and marsh habitats that resource managers are now facing bold challenges on how best to reduce their numbers. Beautiful as mute swans may be, their populations have increased to such an extent that many argue they are a formidable threat to efforts aimed at restoring submerged aquatic vegetation in some areas of the Bay.

Friend or Foe? The Case of Triploid Grass Carp



Non-native species can seem a threat or a benefit, depending on one's point of view and, sometimes, the words one uses to describe them. For example, referring to non-native species as *invaders*, *aliens*, *nuisance*, *exotics* and *foreign*, all of which have negative connotations, can prejudice our ability to clearly evaluate benefits and risks.

Consider the grass carp. Brought to the United States from its native Asia, the grass carp — also called the white amur — has been used to help control plants that can choke ponds, lakes and reservoirs. On the other hand, the Chesapeake Bay Program's Invasive Species Workgroup has placed the grass carp on a Watch List because of concerns about the ecological damage it could cause by feeding on the Bay's underwater grasses, which are critical for restoration of water quality.

The story of the grass carp's introduction and use provides a useful case study, as scientists and aquaculturists joined together to turn a problem into a solution.

Aquatic plants, whether native or not, can over-run ponds, lakes and reservoirs, especially when an overabundance of nutrients flows in from nearby farms, golf courses or suburban lawns. Those plants can restrict recreational uses, cause a general nuisance and even make irrigation difficult. While herbicides can often control such plants, the widespread use of chemicals can itself cause concerns, and so citizens and managers alike went looking for a biological control. They found it in the grass carp (*Ctenopharyngodon idella*), which can grow to some 100 pounds and can consume its weight in underwater grasses daily.

While the grass carp performed their grazing function well in targeted ponds and lakes, they also remained voracious in areas where they were not wanted. The threat arose that they could reproduce and spread into bodies of water where underwater grasses provide important roles in maintaining water quality, trapping sediments and providing habitat. Some resource agencies began to ban their use.

Such bans could have spelled the end of the grass carp as a biological control, but for the inventiveness of scientists who were able to render the fish infertile. Now aquaculturists and others can use sterile grass carp to hold down vegetation without worrying about them escaping and reproducing in the wild. Many states — including Pennsylvania, Virginia and Delaware — have embraced the use of triploid grass carp, and the aquaculture industry is producing them regularly.

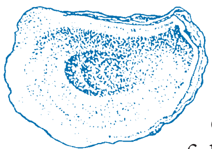
The example of triploid grass carp reflects how clearly defined goals — the need for environmentally benign, non-toxic controls of problematic weeds — helped catalyze a response by scientists and the industry to get around what at first seemed an intractable problem. Even now, though, these triploid fish have not been universally accepted — perhaps because the name "grass carp" still carries the stigma of an exotic species.

The swans are an instance of an inadvertent introduction: originally part of a private waterfowl collection on a Bay creek, five swans escaped during a storm in 1962. According to *Invasive Species in the Chesapeake Bay Watershed* — a briefing book for a recent Maryland Sea Grant-Chesapeake Bay Program jointly sponsored workshop (Baltimore, May 7-8, 2002) to develop regional invasive species management strategies — mute swan growth rates in Maryland averaged 36 percent between 1962 and 1979. From 1986 to 1999, their numbers increased 1,390 percent, from 265 to 3,995. One estimate puts the potential mute swan population at 20,000 by the year 2010, if growth rate continues unchecked. Pulling up plants by their roots or rhizomes, adult mute swans may consume some six pounds of plant material a day. The math for calculating the impact on submerged grass is simple enough.

Nutria were purposely introduced to the marshes of the Eastern Shore in the 1950s for use in the fur industry. However, nutria fur was not highly valued, and demand for animal fur declined; as a result nutria populations have swelled — their reproductive capacities are prodigious. Like mute swans, their feeding habits can be extremely destructive to vegetation. Nutria feed on the root mat of plants, causing "eatouts" — such feeding loosens a plant's hold on the soil and without this binding, the soil washes away. In the Blackwater National Wildlife Refuge near Cambridge, nutria eatouts may be exacerbating the impacts that rising sea levels and land subsidence have had in turning productive wetlands into barren mudflats and open water that cannot be re-vegetated.

Clearly, the introduction of any species into a new environment, whether intentionally or unintentionally, must raise serious concerns about the potential risk to the environment. Years ago, species introductions were undertaken with little awareness about the potential environmental impacts. As we have come to understand the impact of many nonindigenous species, we have become considerably more wary and cautious.

Introductions and Research-Based Knowledge: *Crassostrea ariakensis*



There are at least two key questions that we must ask about introductions, particularly those species that we have the opportunity to control. As David Lodge of the University of Notre Dame pointed out at the Invasive Species workshop, one of those questions has to do with human values, namely, what do we want — what are we trying to achieve? All management considerations must begin, he says, with answering this question. The second is what do we know? What can research and experience tell us that will help us predict the likely consequences of an introduction.

Once we can define what we are trying to achieve, the challenge is to figure out our options, which may include introducing a non-native species. While we may never know all the risks, we must have the best information and the best science that we can obtain. There is currently an intense discussion in the Chesapeake about introducing a non-native oyster. This is not the first time. A decade ago, the Japanese oyster, *C. gigas*, was proposed for the Chesapeake but was rejected on a number of fronts (see www.mdsg.umd.edu/oysters/exotic/ gigas.html).

Since 1983, oyster harvests have consistently been at all-time lows. Faced with the devastation of the native oyster, many are demanding the introduction of the non-native Suminoe oyster, *Crassostrea ariakensis* (formerly *Crassostrea rivularis*), a species from China that has shown remarkable capabilities for resisting disease and serving as a commercial substitute for *C. virginica*. The economic arguments for introducing *C. ariakensis* are compelling. The losses of the native oyster in the Bay have had severe economic impacts on commercial watermen, the processing industry and service sectors throughout Maryland and Virginia. Furthermore, the ecological impacts appear to be extensive: because oysters have been the Bay's key filter feeder and provided habitat for other filter feeders as well as entire benthic food webs, their widespread loss, many argue, has hampered restoration of water quality. In effect, oysters and associated organisms remove nutrients from the water by filtering phytoplankton.

C. ariakensis has been farmed successfully in other regions of the world, including the Pacific Northwest where they have been produced and planted in hatcheries. In Virginia triploid (or infertile) oysters have been tested with initial success by growers and scientists at the Virginia Institute of Marine Science (see VIMS website), and there is widespread pressure to expand their use Baywide. Studies indicate that triploids revert to diploids over a period of time — whether they can once again become fertile is currently unknown. It is unclear at this time how great the probability of reversion is or whether a naturally reproducing population would be established. Nor do we know the ecological implications if a naturally-reproducing population became established in the Chesapeake Bay.

Research is critical here. For example, we don't know about the relationships between *C. ariakensis* and *C. virginica*: would reproducing populations of the former drive out the native oyster? This is an especially important question if fertile Suminoe oysters are planted in the Bay: there have been calls by some to do that. Native oyster populations are so low, it is argued, especially in Virginia, that introductions can do no harm. They can only help, say such proponents. We don't know if that's the case.

In Maryland, for example, where water salinities are generally lower, the prevalence of MSX and Dermo disease shifts each year in response to precipitation — disease flourishes in high salinity and is moderated by lower salinity. In Virginia, which is closer to the ocean, salinities are higher and oysters are more consistently subject to heavy disease pressure. If the upper Bay (Maryland) could be separated from the lower Bay (Virginia), both states could make separate decisions. But we have one Bay, not two.

There is a great deal of hope among many in Maryland that to some extent native oysters can eventually be restored; many in Virginia are not so optimistic. Research findings on disease-resistant strains of *C. virginica* (developed with support from the Oyster Disease Research Program) currently being tested throughout the Bay offer prospects for successfully countering disease, as do new strategies for managing around disease. In addition, resource management efforts to set up oyster reef sanctuaries that are off-limits to harvesting could one day provide conditions that will enhance oyster recovery. Whether all these efforts will be enough is uncertain.

The introduction of *C. ariakensis* is but one tool we may be able to use to remediate some of the environmental damages that the loss of native oysters has caused to the Chesapeake Bay system. To begin with, however, we have to be clear about what we want. We also have to be clear about what we know and what we don't. Towards these ends, the National Academy of Sciences began a one-year study on June 1, 2002, to examine the economic, social and ecological risks and benefits of both aquaculture and direct introduction of *C. ariakensis* into the Chesapeake Bay. The committee will address how *C. ariakensis* might change the ecology of the Bay, including effects on native species, water quality, habitat and the spread of human and

Resources on the Web

Nonindigenous Species

Aquatic Invasions Research Directory
http://invasions.si.edu/aird.htm
Aquatic Nuisance Species Taskforce
www.anstaskforce.gov/
Chesapeake Bay Program
www.chesapeakebay.net/iswg.htm
Global Invasive Species Database
www.issg.org/database/welcome/
Invasive Species in the Chesapeake Bay Workshop
www.mdsg.umd.edu/exotics/workshop/
Maryland Sea Grant College
www.mdsg.umd.edu/exotics
Sea Grant National Aquatic Nuisance Species Clearinghouse
www.cce.cornell.edu/aquaticinvaders/nan_ld.cfm
National Invasive Species Council
http://invasivespecies.gov/council/main.shtml
United States Coast Guard Aquatic Nuisance Species Information
www.uscg.mil/hq/g-m/mso/mso4/ans.html

Crassostrea ariakensis

Chesapeake Bay Program
www.chesapeakebay.net/nonnativeoyster.htm
Maryland Sea Grant
www.mdsg.umd.edu/oysters/exotic/index.html
National Oceanic and Atmospheric Administration
www.lib.noaa.gov/docaqua/oyster.html
Virginia Institute of Marine Science
www.vims.edu/abc/CA.html

oyster diseases. The potential range of the introduced oyster will be explored, both within the Bay and in neighboring coastal areas. The study will include examination of the socioeconomic impacts of culturing *C. ariakensis* and the adequacy of regulatory and institution frameworks to oversee these activities. Finally, the committee will assess whether the breadth and quality of existing research is adequate for use in risk assessments to evaluate three management options: (1) no use of non-native oysters, (2) open-water aquaculture of triploid, infertile oysters and (3) introduction of reproductive diploid oysters.

The decision about whether or not to introduce *C. ariakensis* must rest on the best available knowledge and, equally important, on setting well-defined goals. The latter may be the most difficult challenge of all.

Managing Ponds for Fishing

Jackie Takacs, Marine Agent

For many, spring marks the beginning of fishing season. If you're one of the lucky ones and have a pond, you have your own personal fishing hole, or could have. If you are using your pond for fishing, or are thinking about it, the first rule for success is proper management. This means stocking the right fish, stocking the right number of fish and harvesting the right number of fish

To begin with, in stocking your pond, there are several Do's and Do Not's.

First the Do Not's:

- Do Not stock fish from rivers, streams or other ponds. Stocking wild fish can lead to the possible introduction of disease or other undesirable organisms to the pond.

- Do Not stock fish on top of an existing population of fish of unknown sizes and numbers. In most cases, newly stocked fingerlings will just become lunch for the other larger fish.

- Do Not stock fish without the proper permits. In Maryland, all ponds owners are required to obtain a permit to stock fish in a pond (exception: fathead minnows, golden shiners, channel catfish, bluegills, and redear sunfish).

Here Are the Do's:

- Stock new or reclaimed ponds. Reclaiming a pond requires that you eliminate all existing fish within the pond so you can start fresh. Reclamation can be achieved by draining a pond or the use of a toxicant.

- Stock the appropriate species and number of fish. (See box on Species and Rates.)

- Obtain fish from a reputable hatchery or dealer. In Maryland, all fish vendors must be registered with the Maryland Department of Natural Resources (DNR). This policy allows for quality control, reducing the chance of unwanted disease and organism introductions. The Maryland DNR Fisheries Service has a stocking program that will provide a pond owner with a balance of fish species and numbers to provide for sportfishing.

In Harvesting Your Pond, Pay Attention to the Following:

Harvesting a pond is necessary to keep it in balance. A balanced pond means that there is a proper ratio of predators to prey — in other words, each species keeps the others in check, with no one species overpopulating the pond.

- Do not harvest the same year you stock. Species should be fished on a catch-and-release basis until they have a chance to reach maturity and reproduce — this would be the first summer after stocking for bluegills and the second summer after largemouth stocking.

- General Rule of Thumb, 10:1. In traditional largemouth/bluegill ponds, fish should be harvested at the same rate they were stocked, usually 10 bluegills to every 1 largemouth. Remove bluegills whether you eat them or not — if they go unharvested, they can overpopulate and stunt the population, as well as interfere with largemouth reproduction.

Species and Rates Recommended for Stocking

Largemouth Bass (100/acre)
- Highly prized predatory sportfish
- Mature at 10 inches (1/2 lb)
- Spawn once a year in spring when water temperatures reach around 68° F
- Stocked in the spring

Bluegill (500-1000/acre)
- Easily establish in ponds
- Highly reproductive
- Spawn June thru August
- Can easily overpopulate a pond
- Stocked in the fall prior to largemouth stocking

Channel Catfish
- Mature at 3 years
- Do not successfully reproduce in sportfishing ponds
- Stocked fall or spring (size dependent)

Golden Shiners (400/acre)
- Forage species
- Highly reproductive
- Reach 8-9 inches
- Stocked anytime

Fathead Minnow (10 lbs/acre)
- Forage species
- Highly reproductive
- Do not exceed 3 inches
- Stocked anytime

Related Issues for Managing your Pond

- Acclimate fish prior to stocking. When stocking fish, the water temperature of the transport tank or box should not differ from the water temperature of the pond by more than 5° F. In cases where there is a temperature difference, the fish will need to be acclimated to the pond's temperature. This can be accomplished by slowly adding small amounts of pond water to the transfer tank or box until the temperature of the container equals the pond temperature.

- Do not add supplemental food to your pond. There should be enough natural food in a pond to support the growth and reproduction of fish when they are stocked at recommended rates. Artificial feeding is not recommended because excessive amounts of uneaten feed may cause water quality problems.

- Fish kills. Low/no oxygen (associated with drought conditions and turnover) is the primary cause of fish death in most ponds; however fish death can occur as a result of disease or chemical toxicity.

For more information, contact the following:

Maryland DNR Stocking Program, Certified Fish Vendors or Stocking Permits, contact: Tamara O'Connell, Fisheries Biologist, Maryland DNR, 410-260-8323.

Pond Reclamation, Fish Population Analysis, Fish Kills Due to Low/No Oxygen, Contact: Jackie Takacs, Regional Marine Specialist, Maryland Sea Grant Extension Program, 410-326-7356.

Fish Kills Due to Disease or Chemical Toxicity, contact Maryland Dept. of the Environment, 410-631-3000.

Stepping Up Fish Production: Looking Towards the Future

Merrill Leffler, Maryland Sea Grant College Program

While finfish aquaculture in the U.S. has made great strides over the last two decades, the industry has a long way to go if it is to make a major leap forward — with production at some $1 billion annually, U.S. growers rank a far eighth behind China, the leading producer, and trail other countries such as Japan and Indonesia. A key stumbling block is the ready availability of seed (i.e., larvae or fingerlings) when a grower needs them.

Though fingerlings of tilapia, catfish, hybrid striped bass and trout are generally available all year round — hatcheries have been maintaining captive broodstock and spawning them out of season — that is not the case for yellow perch or blue gill or flounder or cobia or any number of species. Getting fingerlings at any time you want them can be a dicey proposition. The reason is that most hatchery operators depend on trapping gravid broodstock on their spawning grounds — a period that might last a few weeks — in order to obtain the eggs and sperm they need to spawn larvae. This means that a year's production of fingerlings of yellow perch or blue gill could well depend on hatchery production during the brief period of time when adult fish are ripe. Even when sufficient numbers of broodstock are captured, the process of trapping and transporting them, then handling them in the hatchery, is stressful on fish and can impact the quality and numbers of eggs.

Spawning domesticated fish year-round has been at the top of the research agenda of a number of laboratories — Yonathan Zohar at the Center of Marine Biotechnology (COMB), part of the University of Maryland Biotechnology Institute, is a leader in the field. For some years, he has been conducting basic research on the molecular mechanisms that regulate ovulation and reproductive processes in striped bass, sea bream and several other species. In a key breakthrough, he and his colleagues discovered that fish held in captivity do not produce a gonadotropin-regulating hormone — by injecting this hormone into hatchery-maintained broodstock and altering light and temperature cycles to mimic the natural environment that condition adult fish to develop gonadal tissue, Zohar and his colleagues have been successfully maintaining striped bass and sea bream broodstock in recirculating tanks at the Columbus Center in Baltimore's Inner Harbor and getting them to produce larvae out of season. This technology is already providing hatchery operators with the kind of tools they need to better serve the aquaculture industry. (For more information on aquaculture research at COMB, see www.umbi.umd.edu/~comb/programs/aquaculture/aquaculture.html)

Another avenue of research for providing seed on demand is through the cryopreservation, or the low temperature freezing, of eggs or embryos for rehydration when a grower needed them. The capability to cryopreserve eggs and embryos would be a boon not only for aquaculture but for conservation of endangered species and restoration programs. With the ability to freeze eggs, says Mary Hagedorn of the Smithsonian National Zoo, species that are endangered because of environmental conditions could be spawned and fertilized, so that their embryos might be stored until habitats were restored. The cryopreservation of eggs, she adds, would allow "the maintenance of large gene pools and reduce inbreeding, and yet minimize space." Much of the research underway on low-temperature freezing of eggs is being conducted with a surrogate species, the zebra fish.

While researchers have had some success in freezing fish sperm that can be rehydrated, eggs and embryos have presented major difficulties. They are more difficult to work with than mammalian eggs, says Hagedorn, because the yolk-laden eggs are so complex — they have more "compartments." Getting cryoprotectant compounds uniformly into these compartments before freezing the eggs has so far eluded them.

Hagedorn and Frederick Kleinhans of Indiana University discovered that the boundary separating the developing embryo (the blastoderm) from the yolk is impermeable to a number of commonly used cryoprotectants. A membrane called the yolk syncytial layer blocks their entry — how to break through this barrier is a goal that Hagedorn has been pursuing. Earlier last year, she organized a meeting of world experts from the U.S., Russia and England on fish cryopreservation — the purpose was to conduct collaborative experiments on a new cryoprotectant, first reported on in Russia. "We wanted to test this new formulation on post-hatch embryos," she says. While the researchers were successful in getting cryoprotectant into the zebrafish embryos, they haven't yet been able to rehydrate them. "We are getting closer," says Hagedorn. Once we do that for zebrafish," she says, "we can then begin extending that capability to other species."

Mary Hagedorn's work has been supported, in part, by research grants from Maryland Sea Grant. For more information on this research, see www.mdsg.umd.edu/Research/R_AQ-02.html and www.mdsg.umd.edu/Research/R_F-84.html).

Maryland Soft Crab Production

Douglas Lipton, Marine Economic Specialist

In a previous article I examined the expansion of east coast soft crab production as determined from landing data, "State of the Soft Crab Market," (*Maryland Aquafarmer*, www.mdsg.umd.edu/Extension/Aquafarmer/Winter01) Recently, we had the opportunity to conduct a survey of Maryland's crab shedders. The impetus for the survey was a set of regulations proposed by the Maryland Department of Natural Resources that increases the minimum size of peeler crabs from 3 inches to 3-1/2 inches and the minimum size of soft crabs from 3-1/2 inches to 4 inches. The regulations are part of a bi-state effort to reduce fishing mortality in the Chesapeake Bay blue crab population by 15 percent. Industry leaders wanting to document the impact that these regulations would have on the typical crab shedder asked Maryland Sea Grant Extension for assistance by way of conducting a survey of their industry.

Crab shedders are not required to be licensed, which made it difficult to determine the extent of the population we were sampling, let alone where to send the surveys. While soft crab processors provide us with a list of their customers, there was no way to verify what percentage of the total producers this sample represented since many crab shedders bypass the large processors when marketing their product. As a result, we were unable to extrapolate the results from our survey returns to determine the extent of the entire industry's production. Only 37 surveys (33 shedders and 4 processors) out of the 284 mailed were returned (13%). Nevertheless, the information of this admittedly non-representative sample of the industry provides some valuable insights.

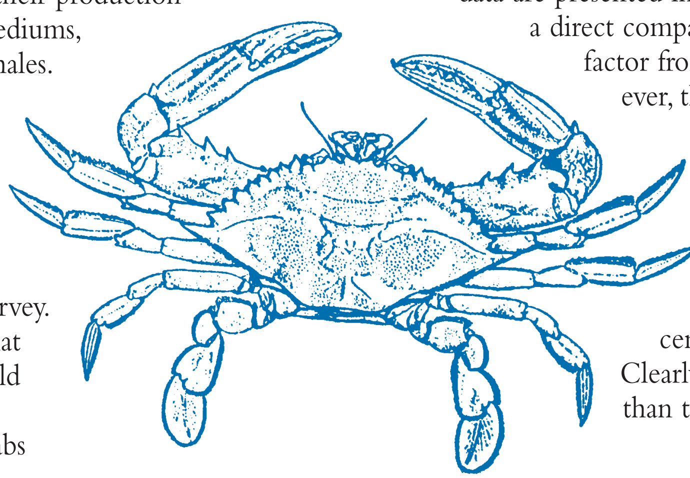
Soft crab shedders divide their production into five market categories: mediums, hotels, primes, jumbos, and whales. These categories are not standardized and change with location and market conditions. Table 1 summarizes the average production and value by size category for the shedders who returned our survey. Several processors indicated that the Maryland regulations would result in an elimination of the entire category of medium crabs and about half the hotels. The result would be a loss of 26 percent of the production, though only 14 percent of the value since the smaller crabs command a lower price per dozen than the larger ones.

Table 1. Average soft crab production and value in 2001 by market category.

Market Category	Number of Dozens	Value
Medium	1,156	$8,190
Hotel	1,198	$11,578
Prime	1,539	$21,762
Jumbo	1,895	$37,886
Whale	979	$22,121
TOTALS	6,767	$101,536

Fisheries managers hope that the new size limits will result in more crabs surviving to be captured in the larger market categories, thus partially compensating the shedders for their loss of sales in the medium and hotel categories. Crab shedders, on the other hand, are skeptical that they will see such an increase if these crabs are susceptible to predation and other natural mortality, are caught as hard crabs or are harvested in Virginia.

The most striking aspect of these limited survey results is the indication they provide that the soft crab industry is significantly larger than the landings data indicate. The 33 crab shedders who make up our sample, sold a total of 223,327 dozen crabs valued at $3.4 million. Since harvest data are presented in pounds, it is difficult to make a direct comparison without a conversion factor from dozens to pounds. However, the harvest data also estimates harvest value in Maryland at about $7 million. While we are unsure of the size of the shedder industry, we know our small sample appears to be producing almost 50 percent of the reported production. Clearly, this industry is much larger than the landings data indicate.



Book Review

Recirculating Aquaculture Systems

M.B. Timmons, J.M Ebeling, F.W. Wheaton, S.T. Summerfelt and B.J. Vinci, Northeastern Regional Aquaculture Center, NRAC Publication No. 01-002

Reviewed by Don Webster

Where can you find a single book that can answer your questions about building and operating a recirculating aquaculture system? *Recirculating Aquaculture Systems* is the one that can probably do it. It is a reference text compiled by the best experts in the field and written to be as user-friendly as possible. While that's a tall order, the authors have succeeded.

The book has been designed to be the text for the popular week-long course that several of the authors teach annually. Mike Timmons is at Cornell University and has trained many people to design, build and operate systems for seven years now. Fred Wheaton is Chairman of the Biological Resources Engineering Department at the University of Maryland, College Park, where he has conducted aquaculture research for many years and published one of the first texts on the subject. Ebeling, Summerfelt and Vinci are at the Freshwater Institute, where a great deal of research into production systems has taken place; it is also the site of the hands-on recirculating system short course each summer.

There has been a long-time need for a reference book such as this one, one that is comprehensive and covers the major topics in a straightforward manner. The best take-home piece of advice is placed right up front in Chapter 1 in a text box that reads, "Only invest what you can afford to LOSE!" Many people have found out the hard way that these systems, while fascinating and profitable in some cases, have frequently caused economic woes for those who thought they were a quick way to success.

The authors cover water quality in aquaculture, as well as the physics involved in moving water through the system by pumps and piping. For some reason, people too often believe that basic physical laws don't to apply to aquaculture, a notion that the authors quickly dispel.

Once into the text, you will find information on all sorts of devices that are used in units to carry out specific tasks. A chapter on culture tanks covers circular and rectangular units. The book then goes into the critical tasks of solids capture, biofiltration, and gas transfer necessary for successfully raising fish. An entire chapter is given to system monitoring and control, since animals in recirculating systems need to be constantly watched, either by a person or an automated system. Recirculating systems aggregate waste which must be disposed of in some approved manner — what to do with these wastes is another topic treated fully.

System management and operations is given a large chapter, where many sub-topics are covered, all of which can affect the ultimate success of a fish farm. The authors have used their many contacts to amass a wealth of knowledge about the various factors that can make or break a recirculating fish farm. Included is a section on how to collect, analyze and interpret data. This is a topic that can be frustrating to growers, as they consider how much information is needed to base business decisions upon, without being too time consuming, and how best to use it for maximum effect.

Modern technology is evident in the section that addresses Ozone and Ultra-Violet Irradiation as disinfecting techniques that can be successful in a production system. While useful, there are many things that need to be considered before incorporating these into a fish culture operation. Along this line, the chapter on fish health management emphasizes a topic that is not considered by many fish farmers until they have a problem. In a recirculating system, disease can be a critical problem since medicated feeds will usually kill the important bacteria in the biofilter that are helping to keep the fish alive. Once disease becomes established in a system, disinfecting it can be very difficult as well.

Excellent information is provided on environmental controls that need to be considered for incorporation into the systems, as well as a chapter on nutrition and feeds, which can quickly affect the success or failure of an aquaculture enterprise. Along those lines, the authors have provided a chapter on economic issues and management options, which deals with the operation of the production system as a business. It must be remembered that there is a major difference between asking whether you can raise a particular species and whether you can raise it and make a profit. By including business management information, this book moves from just being a technical reference manual to being perhaps the most all-encompassing volume available for successful recirculating system operation.

The authors have gone way above the call of duty in providing many excellent drawings, schematics and diagrams about how system components work and how they need to be inserted into the operation. They provide a reference list of examples in each chapter that takes the reader through the steps necessary to carry out calculations for system design. Their appendices are comprised of information that will allow the reader to quickly find information on various design parameters from conversion factors to friction losses in PVC pipe. Perhaps one of the most useful additions to the text is the CD-ROM included in a pocket at the front of the book, that contains a suite of software programs allowing the reader to calculate oxygen, tank design, pipe flow, and to work out a cost analysis for the business.

Recirculating Aquaculture Systems will be used for many years as the standard text for teaching students about designing and operating these intriguing production systems. The book provides the best reference text for practical system design that I have yet seen. As a project of the Northeastern Regional Aquaculture Center, it shows what can be accomplished to help serve the industry by combining the knowledge of the excellent researchers we have in this region. The yellow cover that binds the book was an excellent color choice. It will help you to keep an eye on it because as useful as this book is, it could wander off into the hands of others.

Copies of *Recirculating Aquaculture Systems* ($79.00 + $6.00 shipping) available from Maryland Sea Grant, 0112 Skinner Hall, University of Maryland, College Park, Maryland 20742, e-mail: connors@mdsg.umd.edu.

Upcoming Conferences

Fourth International Conference on Recirculating Aquaculture

July 18-21, 2002, Roanoke, Virginia

This major biennial conference will include eight symposia topics:

Symposium 1 — Nutrition. Focus on established as well as emerging aquaculture species.

Symposium 2 — Waste. With EPA scheduled to release new effluent standards for aquaculture facilities, this session will make use of research findings and case studies to address conventional and emerging technologies for waste management, regulatory issues, and best management practices for achieving regulatory compliance.

Symposium 3 — Fish Health. Presentation. Common and emerging infectious diseases of commercial species; attendees will learn whether environment or non-infectious syndromes may be causing problems in their facilities.

Symposium 4 — Species. Emerging species for recirculating production systems.

Symposium 5 — Genetics and Physiology. Summaries of advances in understanding cultured fish physiology and development of genetic stocks for production.

Symposium 6 — Systems. Contemporary system, component design and practical applications.

Symposium 7 — Economics and Business Management. The appropriate distribution methods for both wild caught and aquaculture species. Among the topics: how marketing decisions help determine whether you should be big and efficient or small and creative. This symposium will detail the linkage between recirculating production and marketing, and the economics associated with the Low Head Recirculating Aquaculture System through an actual interactive economic model.

Symposium 8 — Use of Recirculating Technologies in Shrimp. Shrimp maturation, nursery production, production of shrimp to market size, and broodstock production.

In addition to the symposia, the Aquacultural Engineering Society (AES) and the Freshwater Institute will be running information sessions: AES will cover commercial recirculation systems, while the Freshwater Institute session will focus on coldwater fish culture systems.

Attendees can choose among three facility tours on Sunday, July 21: the Virginia Tech Recirculating Aquaculture Center, The Freshwater Institute in Shepherdstown, West Virginia, or the Vic Thomas Striped Bass Hatchery in Brookneal, Virginia.

There will also be a number of programs before and after the conference:

July 16-18 — Design and Operation of Aquaculture Systems
July 17-19 — Aquaculture in the Classroom
July 22-26 — Eighth Annual Aquaculture Water Reuse Systems Short Course

For registration and further information, see www.conted.vt.edu/aquaculture.htm call (540) 231-6805 or e-mail aqua@vt.edu

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