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MARYLAND AQUAFARMER ONLINE

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MARYLAND SEA GRANT EXTENSION•4321 HARTWICK ROAD, SUITE 300•UNIVERSITY OF MARYLAND•COLLEGE PARK, MD 20740•(301) 403-4220

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In This Issue:

Upcoming Programs

21-22 October 1995
Oyster Festival, Leonardtown MD
    A celebration of the famous bivalve featuring displays, activities, great food, and the National Oyster Shucking Championship. For more information contact the St. Mary's County Extension Office at 301-475-4485.

07 November 1995
Kent County Pond Management Field Day, near Chestertown MD; 1 pm-3 pm
    A pond side program showing how management practices can affect your pond. For more information contact Kent County Extension Office at 410-778-1661.

09 November 1995
Maryland Aquaculture Advisory Committee, Annapolis MD; starts at 7 pm
    The group which advises the state on matters pertaining to aquaculture development and other issues. For more information contact any Area Marine Agent.

30 December 1995
Southern Maryland Crops Conference, Holiday Inn, Waldorf MD; 9 am-3 pm
    Information and update for farmers, will include program on nutrient management and water quality in ponds. Pre-registration required. For more information contact St. Mary's County Extension Office at 301-475-4485.

19-21 January 1996
East Coast Commercial Fishermen's and Aquaculture Expo, Ocean City (MD) Convention Center
    Trade show and seminar programs on issues impacting the farm raised and wild caught seafood industry in the Mid Atlantic. For more information contact any Area Marine Agent.

So You Want To Get Into Aquaculture?

by Don Webster, Eastern Shore Area Agent

Every week extension agents and specialists receive inquiries from people who want to start an aquaculture business. Most, we know from experience, will never get to the point where they actually start an enterprise. Because of lack of capital, lack of experience, or the developing realization that this business takes more than just a notion, many fall by the wayside.

For those who do stick it out, there is the knowledge that they are getting into one of the fastest growing areas of American agriculture. It's an industry that has seen a great deal of growth during the past two decades and seems to have a bright future. How do you go about getting into business and where are some of the areas where you will face challenges? Let's take a look at some of them:

Species Selection

This is one of the first things you will need to do and it will, in many cases, also decide on the production system that you will use. Fish such as tilapia require warm water. If you decide to raise them, you will have to use an enclosed reuse system to retain heat in the cold months. On the other hand, if you're raising trout, you will need cold water. That means you won't be trying to raise them in ponds on the Eastern Shore where summer water temperatures can go over 90 degrees F. If you are going to pursue shellfish aquaculture, you will need to have a salinity profile in the areas you are considering. Many areas of Maryland are too fresh to be able to raise species like *Mercenaria* (hard shell) clams. In short, you need to match the biological needs of the animal to the growing area and system.

Site selection

Location can be critical to success in aquaculture. Not only must the biology of the animal be taken into account, but available utilities, transportation system, and proximity to markets. Aquaculture operations can use large amounts of electricity to drive pumps, aerators, and other equipment to keep fish alive and energy is often expensive. Investigate off peak power rates with your utility company since this may save you a great deal. Also, three phase power is cheaper than using single phase but it may not be available in many rural areas.

Roads and airports need to be considered since you're going to be moving fish and/or shellfish and need to get to market rapidly. Are there truck terminals where you can ship your product with companies that handle fresh product? How reliable are the airlines in getting fresh product to market? Are there other producers nearby to pool loads and feed shipments with?

Most importantly, what is the price of the real estate that you're going to need? How much water is available in surface or underground sources and what is the quality of that water? Spending time investigating these things at the beginning will save you from expensive mistakes that could jeopardize your business before you get your first crop to market.

Capital

Financing an aquaculture business is usually hard. Banks have little experience with them in many areas. Those that would freely make a loan for a poultry operation will be reluctant to make one for aquaculture because they have not done so before and may have heard of one or more that never made it to financial success. Government loan and/or guarantee programs can sometimes be used to help minimize the banks exposure in a loan.

Bear in mind that few aquaculture ventures develop a cash flow in a short time. Many take several years in order to develop one. In that respect, financing an aquaculture business can be more like starting an orchard rather than grain farming. You need to allow for that in your financial planning.

In all instances, spending the time to put together a professional looking business plan will assist you. It shows the banker that you have taken time to do your homework in gathering and analyzing the economic figures and a good business plan will be used to guide your business as it develops.

Permits

This can be a frustrating road, depending upon what you want to do. If you are developing ponds on existing farmland, you may not have many problems. If, on the other hand, you want to engage in open water aquaculture in the Chesapeake Bay using one of the experimental permits, you may be in for the bureaucratic ride of your life. Find out beforehand what permits you will need, including such things as zoning changes. Doing so will keep you from being surprised at some point down the road. Many states have aquaculture coordinators who can advise you on the permits you will need for the operation you're proposing.

Markets

You need to have an idea of where you are going to sell your product and who your competition is going to be. Marketing is the strategic positioning of your product and should not be confused with sales. If you are going to be raising 50 or 100 acres of fish that will come to size at a particular time, your market strategy will be far different than someone who has a few cages of fish in a pond and can afford to harvest a few hundred pounds at a time.

Aquaculture is a fascinating business and offers potential for those who have the drive to seek out opportunities, plan their business strategy, and pursue their goals. It's not easy but it can be done. Doing the background work necessary to make sound business decisions is critical to success. We all probably heard it enough during our school years but, if you want to get into the business, it is still necessary to, "Do your homework"!

Further information

If you would like more on this subject, please call or write any of the Area Agents listed in the newsletter or send a request by e-mail to dw16@umail.umd.edu. We will be glad to send you copies of the following fact sheets:

- "Species Suitable for Cultivation in the Northeast"
- "Systems for Aquaculture Production in the Northeast"
- "Pros and Cons of Aquaculture"
- "What Is Aquaculture"

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High Energy Diets For Fish

by Rich Bohn, Southern Maryland Area Agent

Aquaculture is a risky business and often dependent on fair weather as well. Farming salmon and trout in sea cages and raceways may seem well controlled, but storms and floods often mean lost fish and equipment. Raising fish quickly can reduce this risk by shortening exposure time. Both systems are also under scrutiny because of excess nutrients entering the environment, but recent advances in altering fish diets may provide a partial solution to both problems.

As our understanding of energy use and fish metabolism has increased, high energy diets have been developed to speed growth rates. Higher levels of proteins and fats and lower amounts of carbohydrates can increase growth rates when the diet is fed properly. By using contents with higher digestibility, nitrogen and phosphate wastes also appear to decrease; reducing nutrient impacts leaving fish farms.

Much of the research began with salmon raised in ocean pens. Diets using around 40 percent protein and up to 36 percent fat were produced using extruders, which can maintain fat content in diets better than other types of pellet makers. Fish were fed the diet to their maximum capacity daily, increasing the growth rate substantially. The food conversion ratio (feed to flesh) was similar to standard diets used by the industry, but fish reached market size in less time.

Diets developed next for trout farms use 45 percent protein and 28 percent fat, and have shown similar success. Differences in diets between species reflect the optimum ratio of digestible protein to total digestible energy needed by different species of fish. Incorrect ratios can cause excessive fat deposits which are lost during processing or impact flesh quality.

While additional research is required before applying the approach to other fish farmed in our region, the results have shown promise for reducing growing times and the environmental impact of nutrient wastes. Finishing diets may also be needed in some instances before marketing. Salmon used for smoking, a process that requires leaner fish fillets, are often placed on a lower fat and protein diet for the final four to eight weeks before processing.

Finishing diets also may be changed to improve fillet quality or even extend shelf life after processing. However, the research always demonstrates the importance of proper feeding practices, in addition to appropriate diets, in reducing growing times as well as feed costs.

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Choptank River Oyster Recovery Area Activities Begin

by Don Meritt, Shellfish Aquaculture Specialist

The summer of 1995 began a new era in oyster repletion as the oyster hatchery at the University of Maryland Horn Point Laboratory (HPL) geared up to produce seed oysters for use in the Choptank River oyster recovery area. As the first major thrust of the historic Oyster Roundtable Action Plan for Oyster Recovery in Maryland, the Choptank River received some two and a half million oyster seed.

Seed oysters were produced from local broodstock spawned in the hatchery. The larvae were then set using a newly refurbished production setting system at Horn Point. The newly set oyster spat were then transported to nursery areas in the upper Choptank where they remained for a few weeks and allowed to grow. Once the spat had reached planting size (1/2 to 3/4 inch) they were deployed on specially built beds for final growout. The beds were constructed during 1994 by the Maryland Department of Natural Resources using dredged shell mined from the upper Chesapeake Bay. A ten acre shell plot was divided into two segments, one which received hatchery seed this summer and a second plot which is due to receive a similar amount of seed during the summer of 1996.

Oyster seed produced in the HPL hatchery were monitored for disease during the hatchery phase and while they were deployed in the nursery areas. Monitoring will continue as part of a scientific evaluation that includes researchers from other University of Maryland departments and the Cooperative Oxford Laboratory. Data collected will help with understanding oyster spat growth, survival, and the dynamics of disease pressure that has so severely limited oyster production in the Chesapeake Bay in recent years.

The test plots will also be used to document the overall changes in the area and should contribute to a better understanding of the ecological value of oysters to the Bay's general health. Oysters are the foundation of what were major reef structures scattered throughout the Bay and its tributaries. Many of these reefs have undergone major changes as oyster populations have severely declined. Other organisms which depend on this reef structure for food, shelter, or substrate have also undergone drastic population changes. This study is designed to better quantify the importance of oysters to these associated organisms.

The work in the upper Choptank this summer was funded by the Department of Commerce NOAA, Maryland Department of Natural Resources, and the Maryland Oyster Recovery Partnership. This cooperative effort was accomplished by coordinating the efforts of researchers, watermen, and management agency personnel, and by utilizing schoolchildren brought to the region by the Living Classrooms Foundation. Middle school students from the Baltimore area were instrumental in providing much of the labor involved in moving large volumes of material from the hatchery to the nursery areas and from the nursery areas to the planting grounds. In this way, the project got a much needed labor force and the students got a first hand demonstration of what is involved in oyster repletion and a great hands on example of the Bay's ecology.

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Water Reuse Short Course: Some Lessons From School

by Steve Bogash, Enterprise Consultant

From July 10 thru July 15, 1995, Dr. Michael Timmons of Cornell University led a group of producers and extension representatives on an excursion into the world of recirculation aquaculture systems. This "Short Course on Water Reuse Systems" was supported by the Regional Extension Project of the Northeastern Regional Aquaculture Center (NRAC), one of five such centers funded by the USDA. The project reimbursed travel and tuition for extension agents and specialists within the region to attend. The knowledge gained will be put to use in their respective states for the benefit of the aquaculture industry.

Rich Bohn (Southern Maryland Area Agent) and I attended the program representing the University of Maryland. While it seems that the engineering aspects of recirculation have come a long way in recent years, an operator must still be part engineer, part grower, and part magician to keep a system operating well. Fish kills and other lesser but still equally serious problems that affect the bottom financial line are still common in water reuse systems. Still, the promise of producing economically competitive fish in reduced water demand systems continues to attract attention and research. The design of recirculation aquaculture systems and their subsequent management continues to evolve and develop.

The following are some of the rules regarding the systems which we learned at the course:

Tank Design:

1. Too deep a tank and the solids are removed too slowly from the system.
2. Too shallow a tank and the fishes swimming motion keeps the waste particles in suspension, making removal more difficult.
3. Keep in-tank disturbances to a minimum. Remember that every valve, pipe, sensor, etc. provides locations for organic residue buildup.
4. As tank diameter increases, the depth can also increase and still operate efficiently.
5. Design your drain grids to be as large as possible but still retain fish. This will lessen opportunities for biofouling.

Other system design rules:

1. Capture the waste solids before they enter the pump. Once the solids go through the pump, their size is greatly reduced, making them much more difficult to remove.
2. If a foam fractionator is used, install it before the biofilter.
3. Use HD polystyrene (approximate R value = 5/inch) for any building insulation. Avoid batts or fiberglass insulation for your structure since these hold far too much water.
4. Every gallon per minute of well capacity can effectively service 1,000 gallons of system operating capacity.
5. Each pound of food will generate 1.375 pound of carbon dioxide and 2-3 gallons of sludge.
6. 4 grams of oxygen are required to oxidize every gram of ammonia broken down by the biofilter. Adding oxygen before the biofilter will greatly increase ammonia removal by increasing the oxygen available to the bacteria in the biofilter.

Of great interest in recirculation aquaculture is the development of microbead biofilters. These operate in the same fashion as the more standard biofilters, that is they provide a large surface area for the nitrogen-cycling bacteria to react with the water undergoing treatment. One large difference is the greatly decreased cost per square foot of reactive area and the much smaller floor space required for support. The beads in question are simply polystyrene micro beads, commonly used in casting Styrofoam objects. Dr. Timmons and his staff have become adept at designing and building components from many common materials.

Recirculation aquaculture systems show promise for locations that either have limits on the size of a system or the quantity of water available. As technology and management skills improve, it appears likely that we'll see more enterprises develop that concentrate on water reuse technology.

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Seafood Technology Specialist Joins SGEP Staff

Tom Rippen has joined the Maryland Sea Grant Extension Program staff as a Seafood Technology Specialist. He will be based at the University of Maryland Eastern Shore in Princess Anne and will work primarily with the seafood processing industry.

Tom earned degrees in fisheries and food science from Michigan State and has spent the past fourteen years as a Cooperative Extension Service specialist at Virginia Tech and director of the Virginia Seafood Research and Extension Center in Hampton VA. He has published articles on seafood pasteurization and sea scallop processing, and has authored two industry reference manuals on blue crab processing. He gained a national reputation in seafood technology research and outreach and has been involved in many regional efforts including "Aquaculture In The Mid Atlantic", where he helped develop many of the programs aimed at seafood processing and quality. He also was a principal educator in "Fish Tech", which trained many of this region's home economists in seafood quality, preparation, and nutrition.

The faculty of the Sea Grant Extension Program would like to welcome Tom to Maryland and we look forward to supporting his program activities. He will be a contributor to the Maryland Aquafarmer, including information on the important area of seafood technology which impacts farm raised, as well as wild produced, species.

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Food Safety Regulations Affect Aquaculture

by Tom Rippen, Seafood Technology Specialist

U.S. Food and Drug Administration (USFDA)

The U.S. FDA regulates the production and marketing of sea foods entering (or likely to enter) interstate commerce under the Federal Food, Drug, and Cosmetic Act. As with other sea foods, the safety and wholesomeness of aquaculture products fall within FDA's purview. The agency has announced its intentions to more aggressively monitor the aquaculture industry in the future, including proper use of approved therapeutics and prevention of product contamination with agricultural chemicals or pathogenic microorganisms. Growers can expect to bear increased responsibility for documenting compliance with the Act. Issues which may not at first appear to be of a product safety nature may, in fact, be very significant. For example, run-off from surrounding farmland into grow-out ponds may contaminate products with disease-causing bacteria or chemical contaminants.

HACCP

Most business managers are familiar with quality assurance strategies such as Total Quality Management (TQM) and ISO 9000. Whereas ISO 9000 is the international standard system for manufacturing industries, the Hazard Analysis Critical Control Point (HACCP) system is the international standard for the food industry. Numerous national and international organizations have endorsed HACCP as the most effective and rational approach for achieving a safe food supply.

Under HACCP, processors identify potential food safety hazards and implement a system of controls and checks which reduces the probability of unsafe products reaching the consumer. HACCP development involves a series of steps beginning with a thorough analysis of potential hazards (Hazard Analysis) at each processing operation, given the expected end-use of the product. Steps which must be controlled to assure safety or other requirement are designated Critical Control Points (CCPs). At these points (and only there) Critical Limits are established. The appropriate parameters are Monitored to assure that these limits (such as product storage temperatures) are not exceeded. Records are kept as documentation that the CCPs are under control. When a critical limit is exceeded, a Corrective Action is taken and documented. The final step is periodic Verification that the HACCP system is working.

Steps for Implementing the Seven Principles of HACCP

- Assess Hazards -- include input from employees, advisors
- Identify Critical Control Points (CCPs)
- Define Critical Limits for CCPs -- e.g.. maximum value or range
- Monitor CCPs -- usually simple in-line measurements
- Determine/Take Corrective Action -- e.g.. an adjustment or hold product for testing
- Establish Record keeping System -- e.g.. pre-printed forms
- Verify that the System is Working -- audits, product testing

Proposed Regulations

Most seafood processors are currently excluded from the prescriptive process controls and record-keeping requirements of the canned food industry, provided processors show evidence, satisfactory to the FDA, that they produce safe products processed under sanitary conditions. However, this situation is expected to change in 1996 when FDA publishes regulations for a national mandatory HACCP-based inspection program for the seafood industry.

In January 1994 FDA published proposed rulemaking (Federal Register vol. 59, no. 19) detailing the responsibilities of industry under mandatory HACCP inspection. They also released guidelines and model HACCP plans to assist the seafood industry in developing HACCP systems acceptable to the agency. Much of the proposal is very specific, including such areas as plant clean-up and employee practices previously covered only under the umbrella Good Manufacturing Practices (GMPs). FDA would have access to HACCP records during inspections to determine if problems occurred prior to their visit and how those problems were resolved. Even if no other problems are identified, an inadequate HACCP plan will likely constitute a violation of the Food, Drug and Cosmetic Act.

Comments solicited by the Federal Register announcement are under review and final rules should be published by early 1996. Implementation is not expected until mid- to late 1996 and an additional one year phase in period is likely. The actual requirements under HACCP vary according to the expectations of the responsible regulatory agency or company. For example, corrective actions and verification procedures are usually predetermined during HACCP development but, in their proposed rules, FDA would not require them in the written plan.

Aquaculturists (growers) were excluded from FDA's HACCP proposal. Also excluded were transporters (e.g.. trucking firms), and retail and food service sectors which are inspected by state and local agencies. The proposal would place responsibility for HACCP on processors and importers.

Aquaculturists may question their need to develop an HACCP program given this expected exclusion. However, the issue is quite complex. FDA's position is to conduct HACCP inspections at facilities of the type they currently inspect. For this reason, they include warehouses and wholesale companies in their definition of "processor", even though these firms may not directly handle the product. This policy allows FDA to inspect and intercept non-compliant products at some point in distribution. It seems doubtful, therefore, that FDA will permit the direct sale of aquaculture products to end users without HACCP controls, even when each step (production and harvesting, trucking, retail) appears to be excluded. For example, simply icing or boxing fish is likely to meet the definition of processing for inspection purposes.

Even if FDA does not directly inspect aquaculture facilities, they will require processors who receive aquaculture products to provide documentation that the products they purchase are under HACCP controls. This liability will almost certainly translate to an economic reality for producers: buyers of seafood for processing plants and wholesale distribution companies may soon purchase only from suppliers who operate under HACCP.

Special provisions apply to molluscan shellfish, which come under the National Shellfish Sanitation Program, jointly administered by the FDA and designated state agencies. This program will become more HACCP-like as it too, falls under the proposed HACCP inspection system.

Safety and Management Implications of HACCP

The extent of regulatory scrutiny and the complexity of HACCP plans is determined largely by the type of products produced. Pathogenic bacteria and viruses are generally regarded as the greatest safety hazards in seafood. Since adequate heating kills these microorganisms, ready-to-eat products and raw molluscan shellfish attract the most concern. They are not normally cooked or fully reheated at time of consumption.

Any product which is deemed to be high risk, especially when it involves numerous, complex processing steps is likely to require extensive monitoring and Record keeping. Complexity results from the number of potentially hazardous operations, or their interaction, which may be difficult to control. Hazards are heightened, for example, by steps involving the combination of raw ingredients from various sources or reliance on multiple processing parameters to assure the destruction of pathogens. Most processors will require assistance with assessing the food safety significance of value-added processing procedures, and with the identification of appropriate HACCP controls.

Hazards of Priority to Aquaculture

In the "Fish and Fishery Products Hazards and Controls Guide" FDA identifies three safety categories (chemical contamination, food and color additives, and aquaculture drugs) and three non-safety categories (filth, decomposition and parasites) which should be controlled in aquaculture. Implicit in their comments is the need to implement HACCP at the grow-out site to control hazards, including the contamination of products with agricultural chemicals.

The agency identifies several pathogenic bacteria of concern in seafood including a few which are especially significant for aquaculturists: Clostridium botulinum, Listeria monocytogenes, Salmonella, and, Staphylococcus aureus. The first three microorganisms are associated with ponds and other outdoor facilities. C. botulinum is a soil organism which, under certain conditions, can produce the toxin responsible for botulism poisoning. Listeria and Salmonella are often associated with the intestinal tracts of livestock and wildlife, including birds which may frequent ponds. Individuals may also shed these bacteria. Listeria is readily tracked into packing facilities on feet and adapts especially well to cool, moist areas such as storage coolers. Staph. aureus is most commonly transferred to food by people during handling. Other pathogens also should be considered during hazard analysis, and new organisms will emerge in the future.

As previously stated, FDA expects to hold processors responsible for products produced by aquaculture producers. FDA anticipates that processors will periodically visit production sites and audit procedures. They recommend that, before product is accepted, field agents review the grower's animal drug and medicated feed usage records and any veterinary prescriptions. FDA also expects that products will be periodically tested for drug residues.

An aquaculture setting offers the potential for tight controls. However, aquaculture products are not inherently safer or of higher quality than their wild harvest counterparts. Only through effectively managed safety and quality assurance programs is this potential realized. For liability reasons, the aquaculture industry is urged to be extremely cautious when promoting food safety as a marketing advantage.

For more information, contact the Maryland Sea Grant Extension Program (Tom Rippen at 410-651-6636) or the National Fisheries Institute in Arlington, Virginia (703-524-8880).

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Getting Good Numbers

by Douglas Lipton, Marine Resource Economic Specialist

Aquaculturists and others interested in the fish business would do well to get hold of a copy of the National Marine Fisheries Service annual fishery statistic report entitled "Fisheries of the United States, 1994 (NMFS, Current Fishery Statistics No. 9400, August, 1995). The document is available from the U.S. Government Printing Office, Washington, DC 20402. The phone number is 202-512-1800.

Examination of the information available in Fisheries of the United States reveals much about the trends and status of the fishing industry and its implications for the growth and development of aquaculture. For example, one can find that total U.S. fish landings were down ever so slightly (less than 0.1%) from the record 1993 landings. However, the value fishermen received for their catch was up 11 percent over 1993, due to higher dockside prices.

The gap between imports and exports of edible seafood products increased to $3.5 billion in 1994, following several years of decrease. The increase in the value of exports was more than offset by record imports. Shrimp continues to dominate fishery imports, accounting for over 40 percent of the value of imports. Salmon dominates the export market with over 22 percent of the export value.

Seafood consumption increased to 15.2 pounds per person in the United States in 1994, 0.2 pounds higher than in 1993. This is still a full pound per person lower than the peak consumption in 1987, but it is still the highest since 1989. The 0.2 pound increase was accounted for by fresh and frozen product, while canned and cured consumption remained level. Of the fresh and frozen product, fillets and steaks increased 0.2 pounds, and the ubiquitous shrimp increased 0.1 pound to a record 2.6 pounds per person. These increases were slightly offset by a 0.1 pound per person decline in fish sticks and portions consumption.

Aquaculture production and value information is not available in Fisheries of the United States, but it contains a wealth of information about the marketplace in which aquaculture competes.

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Grass Carp: A Biological And Ecological Overview

by Reginal M. Harrell, Aquaculture and Biotechnology Specialist

Currently the possession or stocking of grass carp (*Ctenopharyngodon idella*) in Maryland is illegal, yet there is considerable interest in using the species as a means to control nuisance aquatic vegetation. At a recent meeting of the Maryland Aquaculture Advisory Committee there was a special session devoted to the pros and cons associated with the introduction of grass carp as a biological control for aquatic vegetation in Maryland ponds. Speakers presented their perspectives about the potential or concerns of introducing grass carp into Maryland. I provided an overview on the biology and ecological requirements of the species while the others, including Dr. Bob Bachman, Maryland DNR; Mary Jo Garreis, Maryland Department of the Environment; Ernie Tresselt and Andy Gillis, representatives of Maryland's aquaculture industry; and John Sproch of Pennsylvania and Hugh Warren of the Catfish Farmers of America, as representatives of industry interests outside Maryland, presented specific points of view.

The meeting brought to light many misconceptions and concerns about the species and people came away with a better understanding about the **potential** of grass carp as an effective biological control as well as the **damage** they can bring if stocked in the wrong situations or allowed to escape into the natural waters of the state. The primary theme of the meeting was that live diploid (reproductively viable) grass carp should not be allowed in the state for biological control purposes. The following text is a compilation of my presentation, and excerpts taken from the presentations of several of the speakers.

Life History of Grass Carp

The grass carp (*Ctenopharyngodon idella*) is a native of China from the Amur River south. This is why many culturists of the fish for food purposes euphemistically refer to this fish as the White amur instead of labeling it with the negative connotation usually associated with carp species in the U.S. As a carp, it is a member of the minnow family, Cyprinidae, along with its cousins, the common carp, goldfish, and many other minnows.

Introduced in the U.S. in 1963 by researchers at Auburn University and the U.S. Fish and Wildlife Service, the fish was sought as a means to biologically control noxious aquatic vegetation in lieu of the "more hazardous alternative -- chemicals." By 1972, the fish had been introduced (legally or illegally) into 40 states, and now is known to reproduce in the Mississippi and Missouri River systems with reports of reproduction occurring in the Trinity River-Galveston Bay system in Texas.

They have been found in Chesapeake Bay waters in the tidal Potomac, James, Mattaponi, and Cohansey Rivers, and in the Chesapeake and Delaware Canal.

Grass carp are a hardy, highly migratory, eurythermic (able to live in a wide variety of temperatures), herbivorous species of fish that normally is found in freshwater systems. However, the species tolerates salinities up to 17.5 parts per thousand (ppt) for short periods of time and can live in salinities less than 9 ppt, although they do not grow well or reproduce at those salinities. The fish is also very tolerant to poor water quality conditions in that the lethal range of dissolved oxygen is in the 0.3-0.4 parts per million range. As a migratory species, the fish will leave static ponds or rivers if the opportunity presents itself and will move both upstream and downstream of their original stocking location. That is why screened barriers, even on emergency spillways, are a crucial management strategy.

In the southern U.S., the males mature in two years while the females mature by age three. Spawning normally occurs during springtime when river temperatures reach 19-20° C (66-68°F). The fish require moving water for the eggs to hatch. Classified as pelagic spawners, the fish move upstream during early spring and, when the conditions are right, they release their eggs, which are then fertilized in the open water column.

Under culture conditions, a mature female produces an average of 820,000 eggs, or about 60,000 eggs per kilogram of body weight. When the eggs are first released they are about 1.2 millimeters in diameter and, as long as there is flowing water, the eggs will float. Because of this "semipelagic" condition, the eggs require long stretches of flowing river water to allow them to hatch. If the water flow stops, due to the nature of the eggs being slightly heavier than water, they will sink to the river bottom and die from oxygen depletion or be covered with silt.

In general, hatching time is temperature dependent, and at 19°C (66°F) the eggs need about 112 river miles of uninterrupted flow or about 40 hours to hatch if the flow rate is about 3.8 feet per second. Yet, at 28°C (83°F) the eggs need only about 31 miles of river flow at about 3 feet per second or about 11 hours to hatch. Using this information, the only Maryland river that would probably support reproduction of grass carp would be the Potomac because all the other rivers are very short or are tidally influenced and the first slack tide will probably result in the eggs sinking to the bottom. There is a valid empirical argument that due to the salinity of some of the rivers changing the specific gravity of the water it may be possible for the eggs to remain afloat until the tide turns, in which case the Susquehanna River below Conowingo Dam may be another system that could support reproduction. However, this argument is purely academic as, to my knowledge, no one has looked at the effects differing specific gravities of the water have on suspension of the egg.

When the eggs hatch the larvae are around 1/4 of an inch long and white in color. This white coloration and the fact that they have a proclivity to school in large groups, coupled with their initial poor swimming capabilities, make them very susceptible to predation from largemouth bass, catfish, white perch, and a host of other predators. However, the fish is very fast growing and can quickly outsize a predator susceptibility range. The record grass carp is recorded in excess of 110 pounds, although the more common sizes are 25 pounds or less. Triploid grass carp, although they are reproductively sterile (see below and accompanying article on Biotechnology in Aquaculture), usually do not grow as big as their diploid counterparts and usually only live a few years.

Food Habits

Grass carp are very effective herbivores and consume a large variety of vascular plants and some algae and, stocked at very high densities, can completely eradicate the vegetation from a given system --dependent on the size of the system, the plant species present, and the number of grass carp present.

In the early life stages, grass carp feed on small planktonic animals such as copepods and *Daphnia* . As they grow, they switch to planktonic and filamentous algae, then to more fleshy plants such as *Hydrillia* by the time they are juveniles.

Grass carp have specialized structures in their throats called pharyngeal teeth that grind together as plant material passes through them and breaks the food into small particles. This grinding action affords an efficient means for the fish to digest important nutrients found in food because, for an herbivore, grass carp have a very short digestive tract and they process and eliminate food quickly. Using the pharyngeal teeth and digestive system, the fish is able to digest 60-70% of the nutrients eaten, however, actual assimilation of the entire plant matter is poor, ranging from less than 30% to as high as 70% depending on the species of plant consumed. Poor assimilation efficiency is one of the ecological concerns in that it releases a considerable amount of partially digested plant material into the water that can cause water quality problems when the plant starts to decay.

Feeding begins when water temperature is around 52°F and is optimal between 68-86°F. Small fish prefer small or soft stemmed plants such as duckweed and soft pond algae, while older fish accept more fibrous plants. In general, a fish less than 6 pounds will eat close to 100% of its body weight per day, while a fish over 12 pounds will eat less than 26% of its body weight per day. They feed very little to not at all in the absence of preferred food or under crowded conditions.

Contrary to popular belief, grass carp are not indiscriminate feeders, in fact they are very selective in their food choices. These choices depend on a variety of factors such as geographical location of the fish; size, age, and density of the fish; system composition and density of the plants; and water quality.

In general, grass carp prefer *Hydrilla, Elodea, Egeria, Potamogeton* (common pondweeds such as sago pondweed and redhead grass), watermilfoils (except Eurasian), duckweed, watermeal, bladderwort, coontail, the naiads, and filamentous algae. They do not like tough waxy-type plants such as water lilies, water pennyworts, lotus, cattails; *Ludwigia* ; Eurasian watermilfoil; and occasionally tape grass or wild celery. One problem with the more waxy-type plants is that since grass carp do not have teeth in the front of the mouth they cannot bit off pieces of larger-leafed plants and therefore cannot get the plant leaf into the back of their throat where the pharyngeal teeth are situated. Thus, these plants are rarely eaten.

Due to their selectivity, grass carp will feed very little to not at all on non-preferred aquatic plants until all or nearly all of the more preferred species are eliminated. They will simultaneously graze on several species of plants at the same preference level. They will not actively seek out animal prey (beyond the larval stage), but will consume them in the absence of plant matter or if they are incidental to the vegetation they are consuming.

One of the problems with feeding selectivity is that the non-targeted species can overachieve and grow at a pace much faster than they would have if the preferred species had not been cropped at all. The corollary to this faster compensatory growth is that you have to stock higher levels of grass carp to control the fast growing non-preferred species. At the much higher stocking rates the control of non-preferred plants can be achieved but the ecological risk is much greater.

Ecological Concerns

One of the biggest questions that needs to be answered in Maryland before consideration can be given to allow the use of grass carp as an effective biological control is if there are viable alternatives that serve the same purpose without the potential environmental risk that grass carp pose. Unfortunately there is no clear cut answer to that question because the only real viable option is chemical control which, like grass carp, poses a considerable environmental risk if used improperly. Compounding the chemical problem is the fact that many of the places where an effective biological control is preferred over chemical control are those places where the water is being used for irrigation purposes. Obviously, you cannot use an herbicide in a golf course irrigation pond or in a pond from which a farmer is watering his crops or livestock.

So there are certain situations where chemical control is not a viable option and mechanical control (physically removing the vegetation) is not feasible either. Therefore biological control may be the best answer, yet, with biological control, the most obvious concern is the potential eradication of all plant material from the pond. Aquatic plants are part of the natural ecology of an aquatic ecosystem and are needed in certain percentages to keep the natural balance of the environment. Also plants are the primary source of oxygen production in ponds upon which all animal life depends for survival, and act as a protective haven for small fish and insects from larger predators. Thus eradication of all the plants places the entire aquatic ecosystem in danger.

The ecological effect grass carp have on a system is dependent on many factors, most importantly is whether or not the target plant is a preferred species, whether or not the plants are at a high or low biomass, and whether the system has a historical record of lush growths. Low stocking rates on high plant biomass can result in the target plant spreading or increasing density such as what happens to ornamental shrubbery once it is pruned. Likewise, if the target plant is one of the non-palatable or nonpreferred species, the effect of these plants is magnified because of the elimination of other plant competitors for the naturally limited availability of nutrients and space. Thus stocking rates sufficient to control non-palatable target plants will result in substantial impacts to both submersed and emersed flora. Other concerns include the direct competition grass carp would have on species of animals that have overlapping food habits such as waterfowl, or that depend on the vegetated habitat for protection, growth, and reproduction, such as sportfish.

If the stocking rate is high enough and the target plant species is a preferred plant, grass carp can ultimately eliminate all the plants in the system causing dramatic imbalances in the natural ecology. Likewise, inefficiency in digestion can lead to water quality problems. Together these changes in the aquatic plant community can affect the overall ecology of the community, by increasing phytoplankton and filamentous algae production resulting in increased "turbidity" which, in turn, further reduces plant growth because of shading.

Conversely, if the target species is a highly palatable plant and of relatively minor composition of the abundant and diverse plant community, then it may be possible to effect control by using a relatively low stocking rate.

Management Strategies

Although there is a sound management strategy for stocking rates of grass carp in relation to the species and density of plant biomass, because it is illegal to stock grass carp in Maryland, discussing the management strategies and stocking recommendations is irrelevant. Maryland's DNR is the agency responsible for the protection and management of our state's natural resources and at this time they feel that the risks posed by grass carp (even triploids) outweigh any advantage the fish may provide. Therefore, until state resource managers change their mind about the grass carp's status, it is highly advisable not to stock the fish in Maryland. Use other alternatives and consult with your county extension office, Maryland's Departments of Agriculture, Natural Resources, and/or the Environment about what options are available to you for controlling and managing aquatic vegetation in your ponds.

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Maryland Aquafarmer Feature Article

Biotechnology In Aquaculture: Production Of Triploid Fish

by Reginal M. Harrell, Aquaculture and Biotechnology Specialist

We often read or hear about fast growing sterile fish called "triploids." What exactly are they, and do they perform as well as claimed? The first part of the question is easy to answer, the second appears to depend on the species and situation.

Triploids are fish or hybrids that have been genetically manipulated to possess an extra set of chromosomes (the structures found in cells that contains all the genetic material that makes an organism what it is). Almost all plants and animals have only two sets of chromosomes -- one set from the mother and one set from the father. Triploids have been artificially manipulated to contain three sets of chromosomes -- usually two from the mother, and one from the father. The creation of triploids is the type of chromosomal manipulation with which most aquaculturists are familiar. This technology has created fish farming industries, such as the triploid grass carp in the Southeastern United States.

The reasons for originally creating triploids were sound. In theory, because the triploid has three sets (an odd number) of chromosomes, when it came time for the fish to mature and develop reproductive products (eggs and sperm collectively known as gametes), the odd number of chromosomes would cause mispairings and misalignments during the gamete formation process, and result in failure of the sexual product to form. Thus, the organism would be functionally sterile. Also, in theory, because the fish would be sterile, all the energy (food) taken in by a triploid would be used directly to meet the organism's normal everyday requirements to survive (metabolic functions) and to grow. The energetic intake would not be split between and normal metabolism, growth, and the formation and maturation of the reproductive system. Triploid fish should grow faster than normal diploids because part of a diploid's energy intake is partitioned into reproduction.

Because fertilization occurs externally for most species of fish it is relatively easy to manipulate the chromosome number. Techniques have been developed to produce haploid (one set of chromosomes), triploid (three sets), and tetraploid (four sets) fish and even produce fish whose chromosomes come solely from the mother (gynogens) or father (androgens).

The techniques that are used to alter the chromosome number are similar and can be divided into three categories: **temperature, pressure, and chemical shocks**. Most researchers use temperature or pressure with the exception of shellfish culturists. These physical shocks are applied to eggs that are newly fertilized (See Figure 1).

An unfertilized egg has two complete sets of chromosomes -- one in the egg nucleus and one in the second polar body (a remnant set of chromosomes that are left over from earlier egg maturation and development processes). Under normal conditions, when an egg is fertilized, the second polar body is discarded and the single set of haploid (**1n in Figure 1**) chromosomes from the sperm unites with the single set of haploid chromosomes (1n) in the egg nucleus and a diploid (**2n or two sets of chromosomes**) state is established. In triploid induction, the second polar body is forcibly retained in the egg and contributes its haploid set of chromosomes (**1n in the Figure 1**) to the fusion of the sperm and egg nucleus. Consequently, the fertilized egg will contain three haploid nuclei: one from the egg nucleus, one from the sperm, and one from the second polar body. The three haploid nuclei will fuse to form a triploid zygote nucleus which creates a triploid organism (**3n in Figure 1**).

The second polar body is forcibly retained by one of the three types of shock mentioned above. In pressure treatments, pressure chambers are used to apply the shocks. These devices range from cylinders attached to a mechanically operated screw-press to those controlled by computers. Pressures used to shock eggs range from 7,000 to 10,000 psi for several minutes.

Temperature baths are more frequently used to shock eggs. Both cold and warm temperatures can be used to alter ploidy number. Although both warm and cold shocks can be used for either warm or cold water fishes, heat shocks seem to have produced the better results from coldwater species, while cold shocks seem to have produced better results in warmwater species. In general, the temperature needed to produce the best results is near the lethal limit for that species. The temperature needed to alter chromosome number is quite precise, so it is important that both water bath volume and temperature control mechanisms are sufficient to prevent temperature fluctuations while the eggs are being shocked.

Cytostatic chemicals such as cytochalsin-B are theoretically suitable for chromosome set manipulation and have been used frequently in shellfish production however, it appears to be unsuitable for use on fish eggs. The complex membranes of fish eggs appear to act as a barrier to the chemicals.

Lastly, triploids can be created de facto by crossing a tetraploid with a diploid producing offspring that have three sets of chromosomes. The direction will, of course, depend on which sex has the tetraploid set of chromosomes making a diploid pronucleus. To avoid confusion with triploids created by the interference of meiosis (forcing retention of the second polar body), triploids created in this manner are called **interploid triploids**.

In general, the exact timing of treatment after fertilization is not critical, but the window of opportunity is narrower at higher incubation temperatures. This is compatible with cytological observations in developing eggs. Higher temperatures are also used for short periods, and duration of these is critical for survival of the eggs -- at low temperatures the duration of treatment is not critical.

The critical features of the techniques for chromosome set manipulation to produce triploids are (a) the nature of the post-fertilization shock treatment, (b) the timing and duration of this treatment, and (c) the species of fish to be manipulated.

In summary, triploids should be larger than their diploid counterparts because the cell size is larger; the nucleus contains 33% more genes for growth; and triploids reportedly do not divert energy for growth into gamete production, reproduction, or care of young. Unfortunately, improved growth is not 100%. Even when growth was monitored after sexual maturity, which is when superior growth should be expressed, some triploids do not produce the expected growth bonus.

However, more importantly and more successfully, triploids are created to produce sterile fish so that a species that might cause adverse environmental impacts can be cultured on farms or used in natural resource management. The grass carp is a good example where triploidy induction has thus far achieved those goals.

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Aquatic Vegetation Management Tip

Have you ever heard someone say, "If a pound of treatment is good then two pounds will be twice as good"? This could not be further from the truth when it comes to applying herbicides to control or manage aquatic vegetation, or for that matter any use of chemical control whether they be for aquatic or terrestrial use. The recommendations that come with the labels on each container of herbicide are there for a reason. They have been carefully researched and should be adhered to closely. Follow the recommendations so you will not be the one responsible for causing a fish kill either in your pond or downstream. Indiscriminate use of chemicals will probably be much more expensive in the long-run and you will likely not achieve better control of your nuisance plants.

Remember, you need to have permits to apply herbicides in Maryland. In order to obtain one, you need to properly identify the nuisance aquatic plant and plan to use the appropriate control agent. In all instances, remember to **read and follow the label**. Contact your local County Extension office or District Soil and Water Conservation office for further information.

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Farm Pond Management Tip

Fall is the time to apply lime to your ponds to assist in improving productivity. Proper pond and soil pH helps the fertilizers you apply in the springtime be more available for the plankton responsible for the desired blooms. If applied at the proper rate, allowing the lime to interact with the pond's current soil structure and chemistry, should provide stability by the spring. If you have not yet taken soil samples from your ponds to get liming recommendations **do it now** so you will have time to apply the lime so it will be available to the pond by next spring. Soil sample bags can be obtained from your local County Extension office. Be sure to mark "Farm Pond" on the outside of the bag.

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Zebra Mussels : A Concern To Agriculture

by Dan Terlizzi, Water Quality Specialist

Zebra mussels are natives of Europe and western Asia that were introduced into the Great Lakes from ballast water discharge in 1986. Since their discovery in 1988 they have spread rapidly throughout the Great Lakes, the Mississippi and Hudson rivers and now threaten the Chesapeake region. Zebra mussels are fresh water fouling agents and can interfere with any use of water including municipal water, power generation, or industrial water intakes. In addition, zebra mussels can have severe environmental impacts by interfering with food chains and competing with native species. Agriculture is no exception, and it is fair to say that any agricultural use of surface water, in particular aquaculture, is likely to be impacted in areas of zebra mussel infestation.

For the past three years, with funding from NOAA National Office of Sea Grant, Maryland Sea Grant has been preparing for the arrival of Zebra Mussels in the Mid Atlantic region. A large part of this effort has been directed at educational activities including fact sheets, identification cards, posters and public presentations to increase public awareness of the problem. Most of these activities have been undertakes cooperatively with the Maryland Department of Natural Resources to avoid duplication and make the most effective use of funding. Zebra mussel impacts on the environment and municipal water supplies have been emphasized previously and we will continue addressing these topics, however other areas of concern like agriculture will be emphasized in future efforts.

Agricultural activities dependant on surface water in the Chesapeake region are likely to be impacted by zebra mussels. The developing aquaculture industry, for example, includes fresh water ponds that are fertile, have high lime content, and high concentrations of phytoplankton (microscopic plants), all of which favor the growth of zebra mussels. Fish culturists routinely depend on pumping and aeration devices to maintain water quality that are likely targets of zebra mussel invasion. Piping to supply water to overhead irrigation systems are also a concern. In the former Soviet Union, clogging of irrigation pipes by zebra mussels has been a problem for some time.

Agriculture is at a significant disadvantage compared to other water users like municipal water systems since effective and relatively inexpensive treatment like chlorine cannot be applied at the point of intake to prevent zebra mussel fouling. Irrigation systems would require expensive dechlorination before irrigation water could safely be applied to crops. Natural controls for zebra mussels in agricultural applications do not appear to be promising. Water chemistry of irrigation systems includes high ammonia and low oxygen that were hoped to interfere with zebra mussels but so far do not appear to prevent zebra mussel fouling. Biological control agents like the black carp are known to eat zebra mussels, but are as controversial as the grass carp which is used for aquatic weed control (see article entitled Grass Carp: A Biological and Ecological Overview in this issue), and are not likely to be accepted readily into the Chesapeake region.

When zebra mussels do arrive in this area it appears that options to agriculture will be limited to switching to ground water or using sand filters as in drip or trickle irrigation systems. In areas infested with zebra mussels, knowledge of peak times of abundance and high fouling risk will enable farmers to avoid surface water that could lead to clogged irrigation systems.

To learn more about exotic species in this area, please visit Exotics in the Chesapeake.

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