Flounder Aquaculture and Stock Enhancement in North Carolina:

Issues, Opportunities and Recommendations

Program support was provided through funds from the
North Carolina Board of Science and Technology.
Additional copies of this publication are available from North Carolina Sea Grant,
NC State University, Box 8605, Raleigh, NC 27695-8605.
The report and supporting documents are on the Internet at
www.governor.state.nc.us govoffice scienceandtech

North Carolina Sea Grant Publication UNC-SG-99-02

Flounder Aquaculture and Stock Enhancement in North Carolina:

Issues, Opportunities and Recommendations

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This document is a summary of three workshops sponsored by:

the North Carolina Board of Science and Technology

with the support of

UNC-Chapel Hill Program in Molecular Biology & Biotechnology

North Carolina Sea Grant

NOAA Coastal Services Center

N.C. Department of Agriculture and Consumer Services

NC State University College of Agriculture and Life Sciences

October 1997, February 1998 and June 1998

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Executive Summary

The North Carolina Board of Science and Technology, North Carolina Sea Grant, UNC-Chapel Hill Program in Molecular Biology & Biotechnology, the N.C. Department of Agriculture and Consumer Services, NC State University College of Agriculture and Life Sciences and the National Oceanic and Atmospheric Administration's Coastal Services Center convened a series of three workshops on flounder aquaculture and stock enhancement in North Carolina. The workshops held in October 1997, February 1998 and June 1998 explored the status of the flounder fishery and identified issues and opportunities involved in pursuing flounder aquaculture and stock enhancement. Workshop participants included researchers, policy-makers, resource managers, commercial aquaculturists, commercial fishers, anglers and representatives of other groups concerned about these topics. The workshops produced a series of findings and recommendations summarized below.

Current Knowledge and Capacity

- The state must continue to develop data regarding the status of the flounder fishery and to assess demand from the fishing communities and in the marketplace. Sound information is essential to determine the need for flounder aquaculture and stock enhancement and to evaluate the costs and benefits.
- Scientific knowledge to support production of large numbers of flounder larvae is advancing, but the lack of hatchery capacity in North Carolina is delaying the state's ability to proceed with research needed to produce a large supply of small fish, known as fingerlings.
- The necessary number of fingerlings to serve both aquaculture development and stock-enhancement research could be produced in a single hatchery if appropriate safeguards are in place.
- To achieve success in marine finfish aquaculture and stock enhancement, the state must develop policies that address the full range of public concerns. This policy development should include opportunities for public comment.

Aquaculture Development Needs

- Excellent potential exists for marine finfish aquaculture in the state. Additional hatchery capacity and research are needed for this potential to be realized.
- Land-based systems, such as tanks and ponds, have potential as flounder grow-out facilities. Additional research is needed on nutrition and feeding, temperature and salinity requirements, and waste-disposal options to determine the most cost-effective and environmentally sound ways to grow flounder commercially.
- A number of waste management techniques exist to handle aquaculture wastewater. Identification of the most appropriate technologies will depend on the types of waste to be handled, culture methods implemented, capital costs and regulatory standards.
- The state should provide funds to initiate pilot flounder aquaculture operations. Additional funding should be provided to establish an effective marketing strategy for marine finfish. Once a successful pilot facility is established, private investors could be attracted more readily.
- The state should expand marine finfish aquaculture through an integrated policy and permitting procedure like the one currently available for freshwater aquaculture. This will provide state oversight of marine finfish aquaculture operations while ensuring the implementation of appropriate health and environmental safeguards.

Stock Enhancement Issues and Opportunities

- Stock enhancement is not a replacement for traditional fisheries management techniques. If used, it must be combined with other management tools and habitat restoration efforts.
- There are many unanswered questions related to flounder stock enhancement in North Carolina, including the status of the flounder fishery, effects of fish releases on wild stocks and receiving waters, and migration patterns of released fish.

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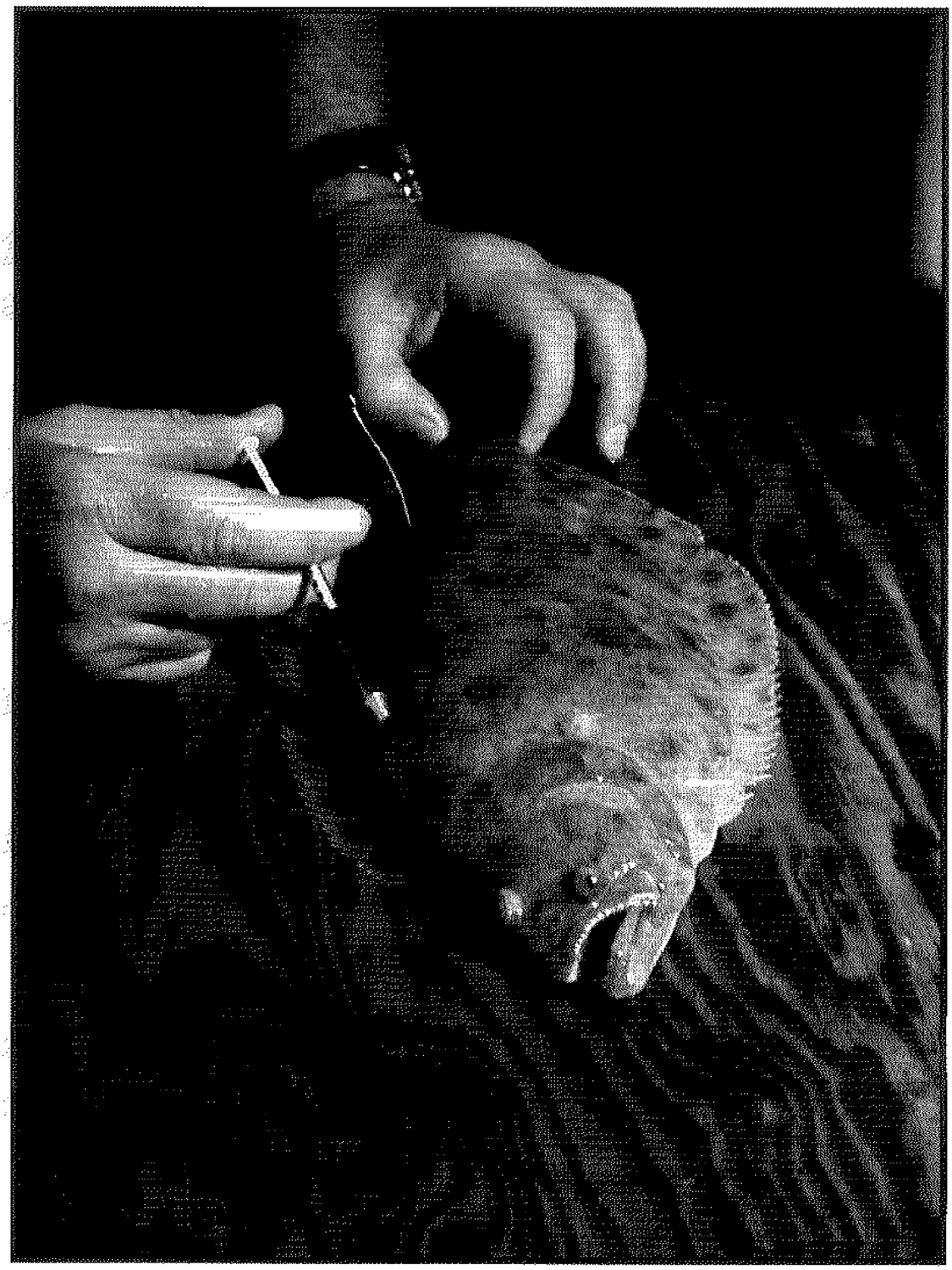

Photo by Joanne Hanke

Hormones injected into flounder will induce spawning.

• Pilot releases offer the most effective way to explore some of these unanswered questions, but the releases must be carefully designed and accompanied by comprehensive evaluation programs.

• Pilot releases can be made under North Carolina's existing Division of Marine Fisheries scientific permit. Large-scale releases would require additional state and federal permits.

• Stock enhancement is expensive. Its costs and benefits must be carefully weighed relative to the benefits that could be achieved by investing the same dollars in more traditional fishery management activities.

Recommendations

1. The North Carolina General Assembly should appropriate funds to the Division of Marine Fisheries to complete comprehensive stock assessments of flounder and other marine fish being considered for aquaculture or stock enhancement and provide funds to the Department of Agriculture and Consumer Services to evaluate market demand and potential for wild and farm-raised products.

2. The North Carolina General Assembly should provide funds to the Division of Marine Fisheries to develop a hatchery to meet the needs of flounder aquaculture development and stock enhancement research.

3. The Division of Marine Fisheries should establish a multi-disciplinary advisory committee to oversee development and use of the hatchery. There are many complex issues involved in facility design, siting, ownership and management.

4. The Department of Agriculture and Consumer Services should have primary responsibility for the development of marine finfish aquaculture in the state. This should be done in close collaboration with the Division of Marine Fisheries and the Marine Fisheries Commission, which should retain responsibility for designating appropriate marine species for aquaculture production. The Department of Agriculture and Consumer Service's Aquaculture Advisory Board should establish a Marine Finfish Aquaculture Committee to guide the process.

5. The Aquaculture Advisory Board should recommend to the General Assembly methods to promote marine finfish aquaculture research and development through grants, incentives and joint research facilities.

6. The Aquaculture Advisory Board should work with all interested parties to develop an integrated permitting process for commercial marine finfish aquaculture facilities. The Marine Finfish Aquaculture Committee should present to the General Assembly, within 18 months of authorization, a clear set of siting and permitting criteria as developed by the Divisions of Water Quality, Coastal Management and Marine Fisheries.

7. Flounder aquaculture operations should focus on land-based systems (tanks and ponds) to minimize potential environmental impacts. Net pens and other types of grow-out facilities may be worthy of exploration in the open ocean; however, such facilities within the sounds and estuarine system should not be allowed at this time except for scientific research.

8. The Division of Marine Fisheries should expand activities designed to increase understanding of the wild fishery and determine the economic and environmental costs and benefits of flounder stock enhancement in North Carolina. •

The North Carolina General Assembly should appropriate funds to the Division of Marine Fisheries to complete comprehensive stock assessments of flounder and other marine fish being considered for aquaculture or stock enhancement and provide funds to the Department of Agriculture and Consumer Services to evaluate market demand and potential for wild and farm-raised products.

Introduction

This report is designed to provide policy-makers with a comprehensive overview of the status of knowledge regarding flounder aquaculture and stock enhancement in North Carolina. It identifies the resources needed to advance these areas and to advance marine finfish aquaculture in general.

In 1996, a National Sea Grant Program task force on flounder culture and stock enhancement produced a report entitled "Sustainable Flounder Culture and Fisheries." The report documented the decline in flounder fisheries in the U.S. due to overfishing and environmental stresses. It outlined a national agenda for aquaculture development and stock enhancement to meet the growing demand for flounder in national and international markets and from recreational fishers.

To build on this national initiative, the North Carolina Board of Science and Technology, North Carolina Sea Grant, UNC-Chapel Hill Program in Molecular Biology & Biotechnology, the N.C. Department of Agriculture and Consumer Services, NC State University College of Agriculture and Life Sciences and the National Oceanic and Atmospheric Administration's Coastal Services Center convened a series of three workshops on flounder aquaculture and stock enhancement in North Carolina. The workshops, held in October 1997, February 1998 and June 1998, explored the status of the flounder fishery and identified issues and opportunities involved in pursuing flounder aquaculture and stock enhancement in North Carolina. Participants included researchers, policy-makers and resource managers from around the state.

This report provides an integrated summary of the findings and recommendations developed at the three workshops. It is divided into four major sections.

- Current Knowledge and Capacity
- Aquaculture Development Needs
- Stock Enhancement Issues and Opportunities
- Recommendations

The first section summarizes findings related to the status of the flounder fishery and the state's capability to produce large numbers of flounder fingerlings for aquaculture or release. It focuses on what is needed for the state to make headway on flounder research, aquaculture or stock enhancement in the next five to 10 years.

The second section focuses on opportunities and needs related to the development of flounder aquaculture. The third section summarizes findings and conclusions related to pursuing flounder or other marine finfish stock enhancement in the state. The final section contains recommendations for state action.

This report is designed to provide policy-makers with a comprehensive overview of the status of knowledge regarding flounder aquaculture and stock enhancement in North Carolina. It identifies the resources needed to advance these flounder efforts and to advance marine finfish aquaculture in general.

The purpose of this report and recommendations — developed by a cross-section of the research, resource management and fishing communities in the state — is to provide a useful starting point for sound public decision-making. More complete discussions of research needs, technology transfer opportunities, and stock enhancement issues and opportunities are found in separate workshop reports available from the North Carolina Sea Grant Program and the Department of Zoology at NC State. •

Current Knowledge and Capacity

A number of factors will affect whether North Carolina moves forward with flounder aquaculture or stock enhancement in the near future. These include:

- status of the fishery,
- status of scientific knowledge,
- hatchery capacity,
- public support,
- economic feasibility and
- regulatory framework.

The following is a summary of understandings reached about these basic factors during the three workshops.

Status of the Fishery

North Carolina's coastal waters are home to two principal species of flounder: summer flounder and southern flounder.

Summer flounder are found primarily from Canada to North Carolina. Commercial and recreational catches of summer flounder have declined in recent years due to decreased wild stocks. The National Marine Fisheries Service's Mid-Atlantic Fishery Management Council has placed limits on commercial and recreational catch. The council is responsible for managing this fishery.

Southern flounder are found from the Chesapeake Bay to Florida and along the Gulf Coast to Texas. The North Carolina Division of Marine Fisheries describes the southern flounder fishery as "viable." The division has expressed concern that the decline of the summer flounder fishery and catch limits placed on that species are transferring additional pressure to the southern flounder fishery, which will lead to its decline. The division has launched a full-blown stock assessment to develop a more complete picture of the status of this fishery.

Most people would agree the flounder fishery in North Carolina is now far below previous levels. Meanwhile, demands from recreational fishermen and the international marketplace continue to rise. Commercial fishermen cite over-regulation as a major cause of this decline, but most scientists and resource managers believe the decline is the result of a combination of habitat degradation and overfishing. The bottom line is that there is still debate about the true status of the fishery at this time.

Status of Scientific Knowledge

The ability to produce a large, reliable supply of very young fish, known as fingerlings, is essential to pursuing flounder research for aquaculture or release. Despite considerable progress in flounder studies in recent years, aquaculturists need more information to raise large numbers of fingerlings at a reasonable cost.

Researchers are able to induce spawning in hatcheries under controlled conditions. They are confident the flounder can spawn year-round. Temperature, salinity, circulation and light are important to the reproductive process. Temperature at the earliest stages of development affects the sexual identity of fish. The sex of the fish is important because female flounder grow much faster than males and aquaculturists will want to maximize the number of females they produce. While salinity thresholds need additional evaluation, it appears that flounder, especially southern flounder, can be raised in very low-salinity water. This significantly expands the number of locations where they can be raised. Careful planning, siting and design can lessen the potential for complications related to production of salty wastewater.

Genetic research on plants and animals can offer a better understanding of genetic characteristics of flounder species. Techniques used by others could be applied to select the hardiest and most productive broodstock for aquaculture purposes. These would be extremely valuable tools to maintain genetic diversity in fish released into the wild.

In terms of nutrition, researchers know flounder need protein, lipids, carbohydrates, vitamins and minerals in their diet, but the amounts needed are not well understood. Research is needed on the specific dietary requirements of broodstock and fingerlings. The size of food, feeding technologies and relationship between type and quantity of food and

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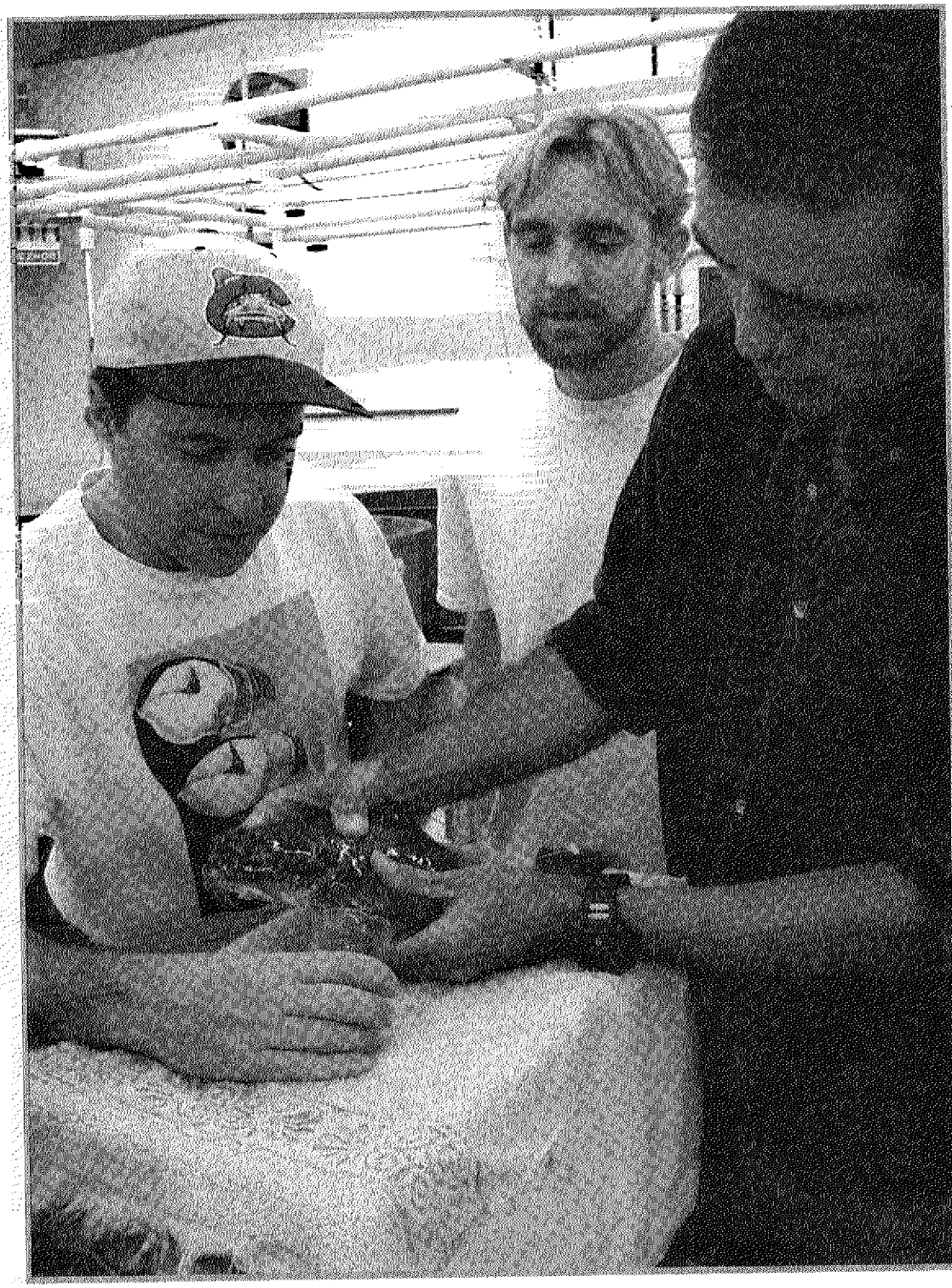

Photo by Joanne Hardee

NC State researchers strip-spawn eggs from a southern flounder. From left: John Godwin, assistant professor of zoology; graduate student Adam Luckenbach; Harry V. Daniels, assistant professor of zoology.

waste produced also need further research. One opportunity to advance understanding of flounder nutrition lies in studying methods — established in this country and others — for feeding other fish species, livestock and poultry for large-scale production.

It is generally accepted that flounder raised for aquaculture or enhancement purposes will encounter disease problems. Little is known about diseases in flounder species on the East Coast. Flounder likely will be subject to both general fish diseases and species-specific diseases. Different problems are likely to emerge at different stages of development, from chronic infections in broodstock to acute or latent infections in hatcheries. Diseases during grow-out are often related to water quality or other environmental conditions. Research done in other countries, as well as research on other fish species, may shed light on disease diagnosis, prevention, and treatment. Collaboration between flounder researchers and those in human medicine, veterinary medicine and microbiology would be beneficial.

Hatchery Capacity

At this point the state has very limited flounder hatchery capacity. Researchers produce only a small number of fingerlings each year. Current facility size and funding limit the ability to produce more fingerlings for additional research or pilot activities in enhancement or commercial aquaculture. While different characteristics are necessary in fingerlings produced for aquaculture and enhancement, scientists and marine aquaculturists believe fingerlings for both purposes can be produced 1in a single hatchery operation if appropriate safeguards and management procedures are in place.

Public Support

Experience in other states has shown that it is essential to involve all key interests — state and local policy-makers, commercial and recreational fishers, resource managers and nonprofit organizations — in deciding how to proceed with marine finfish aquaculture and stock enhancement. Failure to involve and inform major constituencies can lead to resistance and costly delays.

Economic Feasibility

Both aquaculture and stock enhancement raise important cost-benefit questions. In the case of aquaculture the major questions involve balancing production costs with market demand and determining profitablity. In the case of stock enhancement, questions include evaluating the interactions between economic costs and benefits, environmental costs and benefits, and the relative merits of investing in stock enhancement versus more traditional fisheries management activities. Economic feasibility must be carefully considered in developing any marine finfish aquaculture or stock enhancement programs.

Regulatory Framework

North Carolina does not have a legal and regulatory framework in place to move forward with saltwater finfish aquaculture and stock enhancement. While initial pieces of such a framework exist, the state must assign responsibility for policy development and permitting of these activities to ensure environmentally sound practices and to provide a level of certainty and predictability for private and public investors.

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Summary Findings

Scientific knowledge to support production of large numbers of flounder larvae is advancing, but the lack of hatchery capacity in the state is a significant barrier delaying the research necessary to produce a large supply of fingerlings at a reasonable cost.

• The state should continue to develop data regarding the status of the flounder fishery and to assess demand from fishing communities and in the marketplace. Sound information is essential to determine the need for flounder aquaculture and stock enhancement and to evaluate the costs and benefits.

• Scientific knowledge to support production of large numbers of flounder larvae is advancing, but the lack of hatchery capacity in the state is a significant barrier delaying necessary research to produce a large supply of fingerlings at a reasonable cost.

• Despite the need for different characteristics in fingerlings produced for aquaculture and release, it would be possible to produce enough fingerlings to serve both purposes in a single hatchery. Appropriate safeguards could be implemented to prevent mixing of the two stocks.

• The ultimate feasibility of marine finfish aquaculture and stock enhancement depends upon the state's formulation of policies to guide development and regulations to govern implementation. This should include soliciting public comment during policy and regulatory debate and providing appropriate information on the costs and benefits associated with these initiatives. •

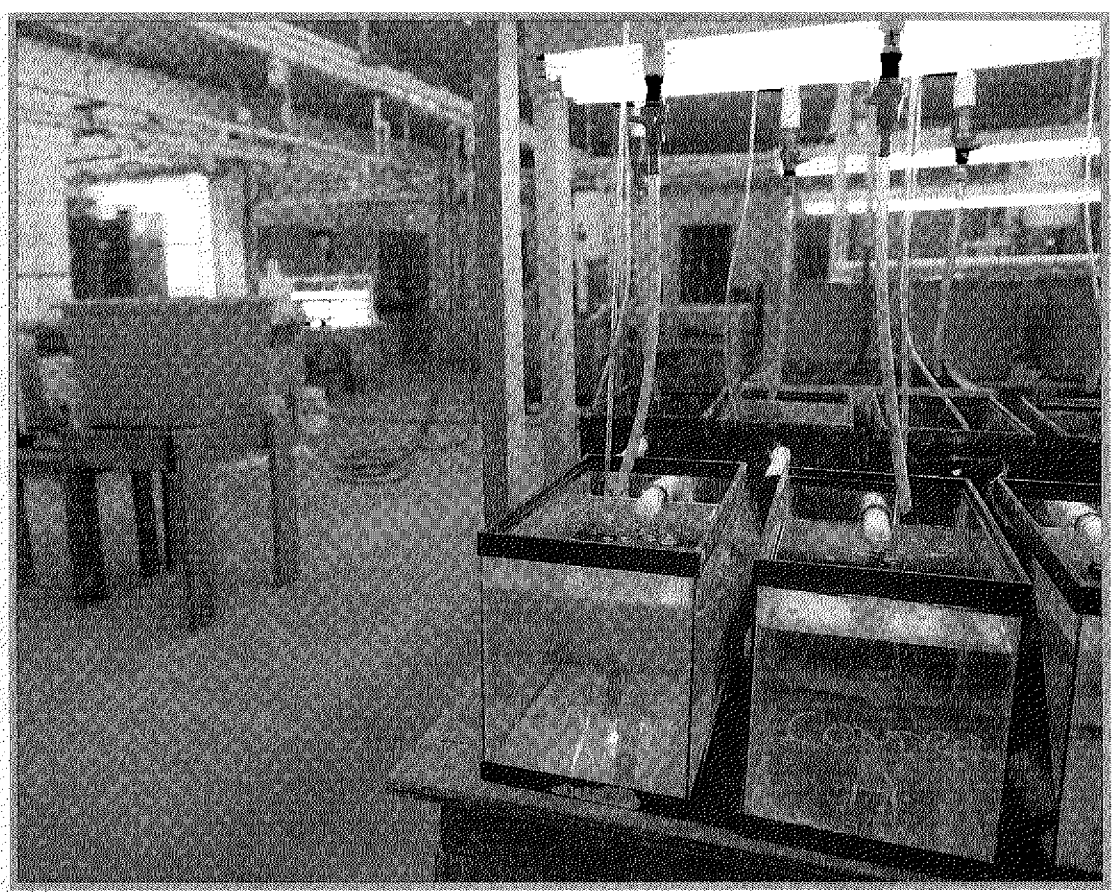

Photo by Lisa Christensen

The hatchery at the Tidewater Research Station in Plymouth is used for small-scale studies.

Aquaculture Development Needs

North Carolina has experienced considerable success raising hybrid striped bass, catfish, rainbow trout and other species in freshwater. To build on this success and understand the new challenges that flounder and other marine finfish aquaculture presents, workshop participants identified four steps needed for flounder aquaculture to move forward. In addition to developing the capacity to produce a large quantity of flounder fingerlings at an affordable cost, advancing flounder aquaculture in North Carolina will require:

- developing grow-out capability,
- refining ways to manage waste,
- developing market and cost information, and
- providing an appropriate legal/ regulatory framework.

Developing Grow-Out Capability

Harvest size for commercially grown flounder is about 2 pounds. Females take approximately two years to mature to this size. Males take about three years. Researchers and culturists believe flounder can be raised to harvest size in land-based systems such as ponds or tanks. Net-pen or cage culture may have potential offshore, but these systems should not be permitted in North Carolina's estuaries and sounds.

The Japanese have raised flounder in a variety of land-based tanks for many years. While their flounder is a different species than either summer or southern flounder found in North Carolina, much can be learned from their experience. The basic method in Japan is to pump seawater into tanks and recirculate or exchange the water 10 to 20 times per day. The fish are raised in high-density conditions, in some cases using shelves to increase the amount of "bottom space" in the tanks. Tank design and size affect the number of fish that can be produced, but tanks also must be designed with efficient water circulation, feeding and cleaning concerns in mind. In all tank systems there are trade-offs between optimum conditions for the fish, maximum production and production costs.

The Japanese do not have experience growing flounder in ponds, but given the success with rearing hybrid striped bass and other species in ponds, North Carolina should continue to explore this option. Questions regarding pond culture include temperature tolerance at extreme hot and cold, salinity requirements, maximum densities and ways to provide food to bottom-dwelling fish. Harvesting systems for pond culture are needed.

Refining Ways to Manage Waste

Whether fish are cultured in ponds, tanks or net-pens, they produce waste. The proportion of solid to liquid waste varies, depending on the farming approach or technology used. The biggest waste problems are expected to be the nitrogen and phosphorus resulting from high-protein feeds and the salty sludge produced by salt water used in hatcheries and grow-out facilities. Many of the state's coastal waters are currently experiencing difficulties due to nutrient enrichment. Flounder or other marine finfish production facilities will need systems and procedures to treat and minimize these wastes.

Promising approaches to waste management include reducing waste by using different feeds and innovative waste-filtering techniques. Waste problems will be reduced considerably if research determines flounder can be reared in fresh water. If it is necessary to use low-salinity water during some or all of the growing stages, it may be possible to construct artificial wetlands to absorb the effluent. Anaerobic digesters of various kinds possibly could be used to deal with some of the salty sludge. Also, other species, such as crayfish, catfish or tilapia, might be combined with flounder culture in efforts to further reduce the discharges from these facilities.

The Japanese have not had to deal with waste management up to this time because they have disposed of waste directly into the ocean without environmental review or permitting. This situation is changing rapidly, as they begin

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Photo by Joanne Hawke

Barry S. Daniels moves flounder eggs during genetic studies in efforts to produce all-female stock. Female flounder grow much faster than males.

to give considerable attention to the issue. In addition, some technology transfer from Scandinavian countries may be possible in this area. Opportunities also exist for collaboration on innovative waste-management techniques between aquaculture researchers and the NC State Animal and Poultry Waste Management Center.

Developing Market and Cost Information

To attract the private sector to flounder aquaculture, the state must accurately describe the economics of the species, including the length of time required for production and whether production will take place year-round or with seasonal variations. Prospective producers also will need assistance to identify sources of start-up funds before an industry track record has been established and traditional funding sources become receptive.

In considering whether to diversify their operations to include flounder or other marine finfish, producers involved in freshwater aquaculture operations need to know how compatible flounder aquaculture will be with their existing operations. They need to know whether separate saltwater and freshwater hatcheries will be needed.

Given experience with other species, there is an expectation that the high quality, freshness and dependability of farm-raised fish would ensure a market for farm-raised flounder or other marine finfish both nationally and internationally. Further research is needed on the location and size of markets and the expected selling price. Both aquaculturists and commercial fishers will want to know if cultured fish will be competing with wild fish, if there is an adequate market for both and if prices will be affected.

Providing an Appropriate Legal/Regulatory Framework

North Carolina's Aquaculture Development Act establishes policies and regulations for freshwater aquaculture in the state. According to this legislation, aquaculture is "the propagation and rearing of aquatic species in controlled or selected environments." The act lists 21 freshwater species that can be farm raised, and includes provisions for aquaculture facility registration and licensing. While the act indicates this can include "ocean ranching," at present no marine finfish species are listed in the act.

The Department of Agriculture and Consumer Services administers the Aquaculture Development Act. The Division of Inland Fisheries of the N.C. Wildlife Resources Commission may allow species not currently on the list to be farm raised. The Division of Water Quality in the Department of Environment and Natural Resources is responsible for issuing permits for discharges. A general permit for discharges from aquacultural activities has been operational since 1992. At present, the Division of Marine Fisheries grants "scientific collecting permits" to allow researchers to collect marine finfish from the wild to use as broodstock in research activities. Another aquaculture permit acts as a registration of a production facility for marine finfish.

For marine finfish aquaculture to develop in North Carolina, many legal and regulatory issues must be addressed. The Division of Marine Fisheries should identify appropriate marine finfish species for aquaculture development. The Division of Water Quality must establish discharge limits for marine finfish aquaculture facilities. Local governments and those administering the Coastal Area Management Act must evaluate facility-siting requirements. In addition, federal requirements must be met to sell farm-raised marine fish across state and national boundaries.

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In considering whether to diversify their operations to include flounder or other marine finfish, producers involved in freshwater aquaculture operations need to know how compatible flounder aquaculture will be with their existing operations. They need to know whether separate saltwater and freshwater hatcheries will be needed.

Excellent potential exists for marine finfish aquaculture in North Carolina. Additional hatchery capacity and research are needed for this potential to be realized.

The management plan for summer flounder developed by the National Marine Fisheries Service's Mid-Atlantic Fishery Management Council does not address marine aquaculture. The majority of land-based marine finfish aquaculture operations will take place on private property and will not interfere with commercial and recreational use of public waters. A very careful paper trail would ensure that commercially grown fish are not confused with wild harvest in the marketplace. Commercially grown flounder are not easily distinguished — by season or size — from commercial and recreational flounder harvests. For this reason, care must be taken to prevent abuse of the wild fishery, as fish of illegal size and weight could be misrepresented as aquaculture products.

Summary Findings

- Excellent potential exists for marine finfish aquaculture in North Carolina. Additional hatchery capacity and research are needed for this potential to be realized.
- Land-based systems, such as tanks and ponds, have potential as flounder grow-out facilities. Offshore net pens also may have some potential. Additional research is needed on nutrition, temperature and salinity requirements, and waste disposal options to determine the most cost-effective and environmentally sound technologies to grow flounder commercially.
- A number of waste-management techniques exist to handle aquaculture wastewater. Identification of the most appropriate technologies will depend on the types of waste to be handled, culture methods implemented, costs and regulatory standards.
- The state should provide funds to initiate flounder aquaculture operations. Additional funding should establish an effective marketing strategy. With the successful establishment of a pilot facility, private investors could be attracted more readily.
- The state should expand into marine finfish aquaculture through an integrated policy and permitting procedure like the one now available for freshwater aquaculture. This arrangement will permit state oversight of marine finfish aquaculture operations, while ensuring the implementation of appropriate health and environmental safeguards. •

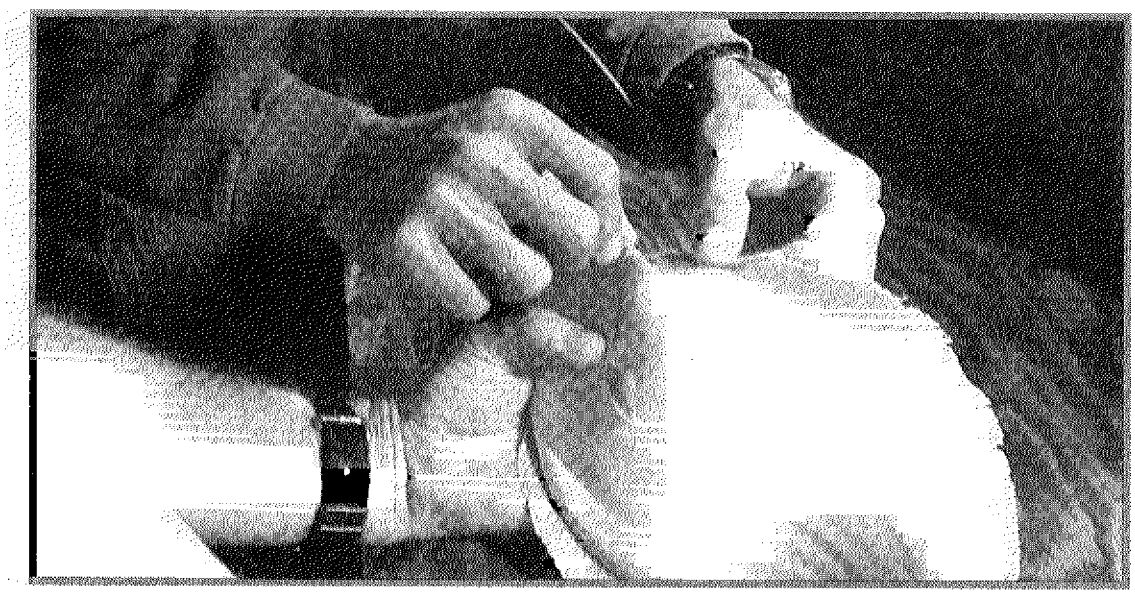

Photo by Jeanne Harke

Researchers take an egg biopsy through a catheter to determine if this female flounder is ready to spawn.

Stock Enhancement Issues & Opportunities

While there is general agreement that flounder stocks have declined in recent decades, there is considerably less agreement as to why. Workshop participants agreed that to consider stock enhancement, the following issues need further exploration:

- establishing a need for stock enhancement,
- identifying effects of releasing fish into the wild,
- preserving the genetic diversity of wild stock,
- evaluating costs and benefits, and
- examining legal and regulatory considerations.

Establishing a Need for Stock Enhancement

The first step in examining the need for stock enhancement is to determine the status of the summer and southern flounder fisheries in North Carolina. Some view stock enhancement as an attempt to find a "technological fix" to the problem of over-harvesting and habitat degradation, with many more costs than benefits. In general, stock enhancement makes sense only when there is declining stock, growing demand and excess carrying capacity.

Stock enhancement is never a replacement for fisheries management. While the term "enhancement" implies "benefit," it can only succeed if the underlying problems of overfishing and habitat degradation are also addressed. In considering stock enhancement, fish migration patterns need to be explored to determine if stocked fish will migrate out of North Carolina waters before they can spawn or be harvested. Some researchers believe small pilot releases of flounder could answer this and other questions regarding wild fish and habitat conditions even if a formal stocking program is never implemented.

Identifying Effects of Releasing Fish into the Wild

Environmental impact is a major concern in considering stock enhancement. In this regard, two fundamental issues must be explored: how the released fish will perform and what effect they will have on the receiving waters and the fish already living in those waters.

In tracking performance of released fish, questions include size of fish to release, as well as timing and location of release. Also of interest is how the released fish will make the transition to eating in the wild, whether they can avoid predation, whether they continue to thrive and reproduce, how far they migrate and whether they return. Some researchers are exploring models they anticipate will enable pilot release programs to maximize benefits and minimize negative effects.

With regard to receiving waters, it is important to track genetic changes in wild stock over time, to see whether new disease problems emerge and whether the carrying capacity of the receiving waters is exceeded. Salmon stocking programs in the Great Lakes have shown that when stocking programs succeed, political pressure to expand them increases to the point that the stocked fish consume all the smaller forage fish, making the fishery no longer viable.

If stocking programs are undertaken, great care must be given to matching the number of stocked fish to the carrying capacity of the receiving habitat. The large variations in the size of the juvenile flounder "crop" in North Carolina from year to year suggest to scientists that North Carolina estuaries do have the excess capacity needed to support released fish, but the implications for other species in these same estuaries are uncertain.

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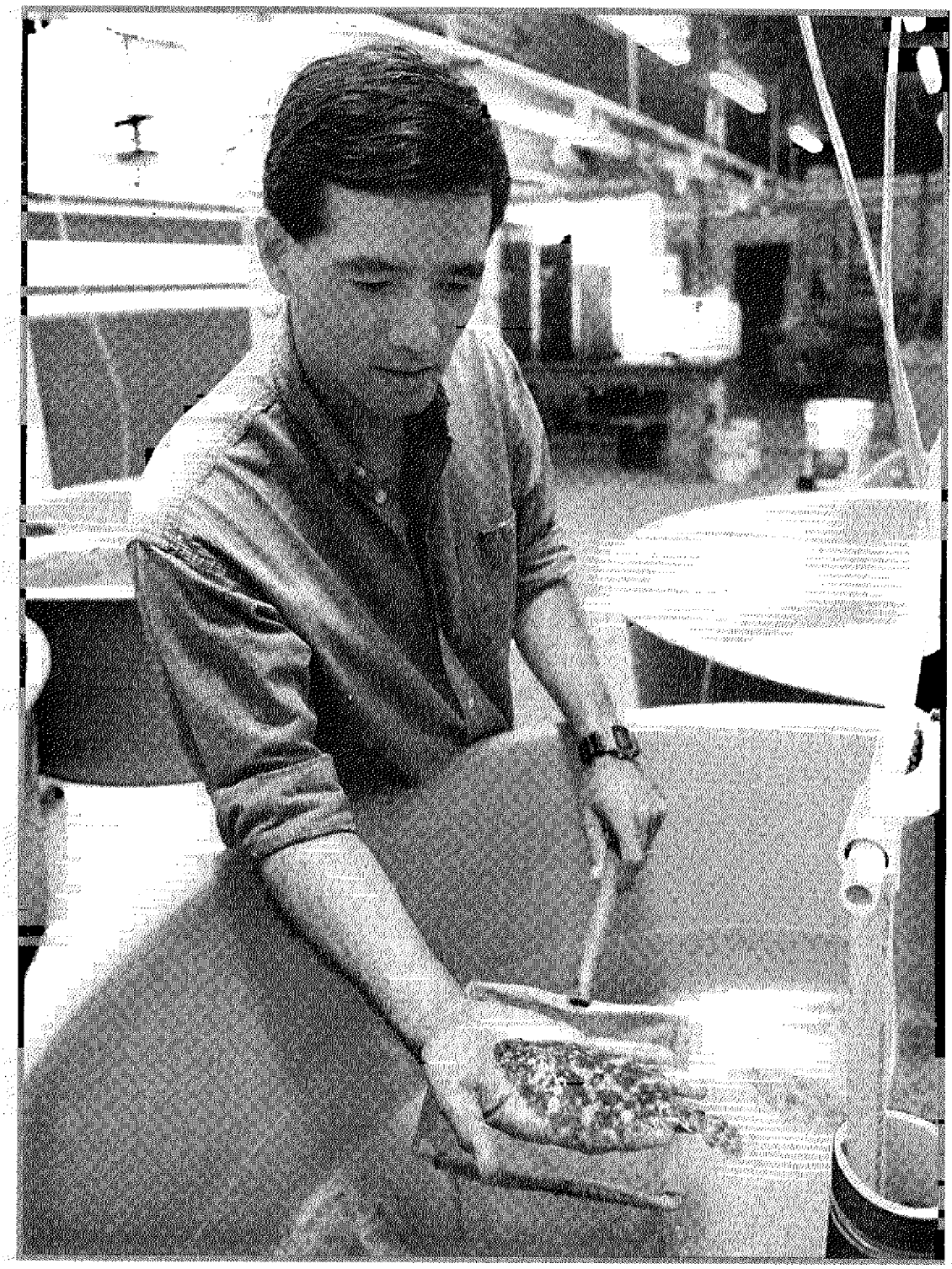

Photo by Lisa Christensen

Harry V. Daniels shows a 4-month-old fingerling produced in the Tidewater Research Station hatchery.

Preserving the Genetic Diversity of Wild Stocks

Many resource managers are concerned that hatchery-raised fish released in the wild may change the genetic diversity of wild stocks. Some supporters of stock enhancement argue that overfishing is also leading to a decline in genetic diversity, because the fastest growing genotypes are fished out first. They also point out that the science of genetic manipulation is expanding rapidly, and properly designed enhancement programs could help strengthen and maintain the genetic diversity of wild stocks.

Researchers agree that stock enhancement programs should use broodstock from the areas where the fish will be released and include genetic variations that are similar to those found in the wild stock. Some scientists and resource managers believe the best way to protect genetic diversity is to use fish releases to replace virtually extinct species, rather than trying to enhance depleted stocks.

Evaluating Costs and Benefits

The best way to evaluate the potential of stock enhancement is to undertake a series of pilot releases, with careful monitoring of both released fish and wild fish. Different groups — biologists, fishermen, resource managers and policy-makers — are likely to define success differently. For this reason, it is important to design evaluation protocols for these pilot releases as objectively as possible, with the participation of all major interests.

Elements of an effective evaluation process should include:

- estimates of the number of reared fish that survive,
- verification that survival can be maintained,
- estimates of the extent to which harvest can be managed without adverse impacts on existing wild stocks,
- estimates of biological interactions between enhanced and wild stocks, and
- evaluation of economic costs and benefits.

The evaluation process should include decisions about tracking and sampling techniques, as well as the frequency and length of monitoring. Also, the plan should clarify whether stocking is expected to restore the fishery to sustainable levels or to continue indefinitely.

Some argue that stock enhancement will take resources away from traditional fishery management efforts and habitat restoration initiatives. Others say stock enhancement brings public attention and support to a fishery and results in greater allocations for this purpose. Stock enhancement of red drum in Texas has led to much higher levels of overall spending on managing the fishery.

Costs and benefits of stock enhancement need to be carefully measured. Cost-benefit analyses of other stocking programs suggest they must be heavily subsidized. A more complete outline of issues to be taken into account in initiating and evaluating stock enhancement programs can be found in a 1995 American Fisheries Society Symposium paper, "Considerations for the Use of Cultured Fishes in Fisheries Resource Management."

Examining Legal and Regulatory Considerations

At present, the only state regulations related to marine stock enhancement involve permits for small research operations, although the Division of Marine Fisheries has regulations governing commercial shellfish production in state waters. Federal permits would be required for any stock enhancement activities involving federal waters. In North Carolina, federal jurisdiction begins three miles offshore.

There is general agreement that before the state considers permitting any large-scale stock enhancement activities, much more must be known about the genetic make-up of released fish, their behavior and survival rates in the wild, and the effect on existing wild stocks. The impact of net fishing in estuaries on the success of any stock enhancement program should be investigated. Opportunities to make these

Continued

There is general agreement that before the state considers permitting and large-scale stock enhancement activities, much more must be known about the genetic make-up of released fish, their behavior and survival rates in the wild and the effect on existing wild stocks.

Stock enhancement is not a replacement for traditional fishery management techniques. If used, it must be combined with other management tools (such as size and catch limits) and with habitat restoration efforts or the flounder fishery will continue to decline.

activities more compatible should be explored, such as requiring small-mesh gill nets to be attended during summer months.

Summary Findings

Stock enhancement is not a replacement for traditional fishery management techniques. If used, it must be combined with other management tools (such as size and catch limits) and with habitat restoration efforts or the flounder fishery will continue to decline.

Questions remain regarding flounder stock enhancement in North Carolina. These include a lack of complete understanding about the status of North Carolina's flounder fishery, concerns about the impact of fish releases on wild stocks and on receiving waters, and lack of sufficient knowledge of migration patterns to know whether released fish would stay in North Carolina waters or migrate elsewhere.

Pilot releases offer the most effective way to explore some of these unanswered questions, but they must be carefully designed. All pilot releases should be accompanied by comprehensive evaluation programs designed by a wide range of interests for maximum objectivity.

Stock enhancement is an expensive enterprise. Its costs and benefits must be carefully weighed relative to the benefits that could be achieved by investing these same dollars in fishery management or habitat restoration.

Flounder research and pilot releases can be done under the existing N.C. Division of Marine Fisheries scientific permit. Large-scale releases would require additional state and federal permits if further study determines this is an appropriate way for the state to rebuild the flounder fishery.

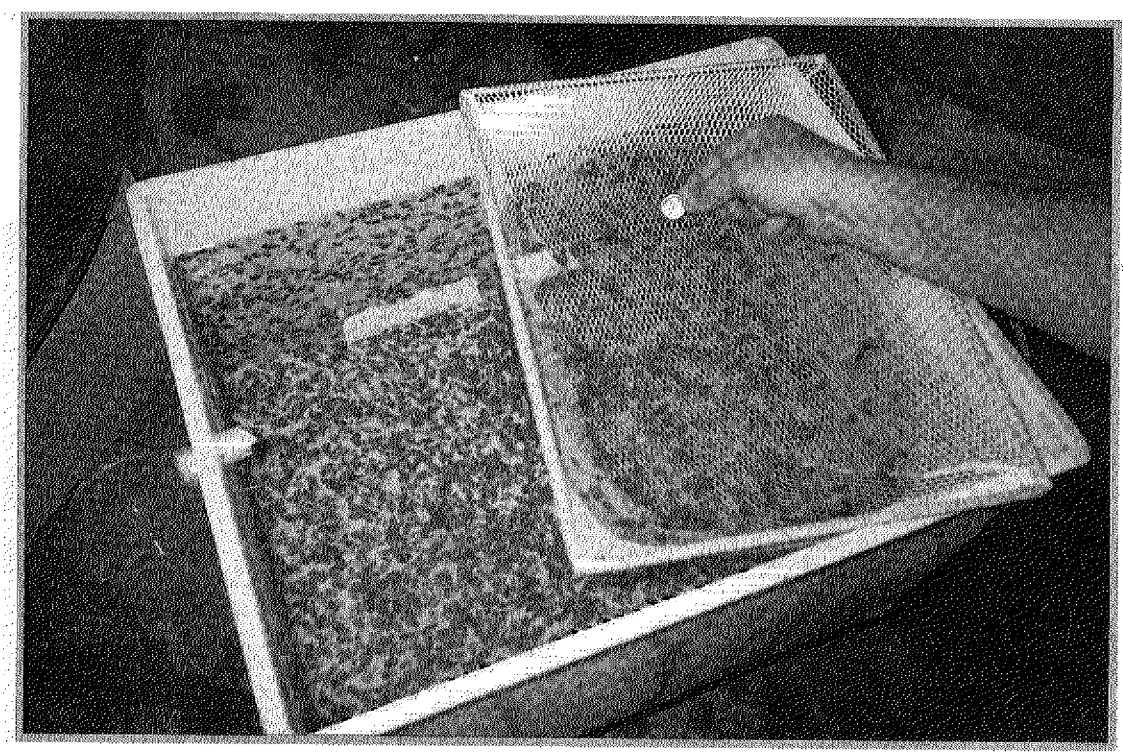

Photo by Harry V. Daniels

These 6-week-old flounder were produced in the Tidewater Research Station hatchery

Recommendations

The following recommendations emerged from the three workshops. Not every recommendation was supported by every participant, but this list represents a general consensus.

1. The North Carolina General Assembly should appropriate funds to the Division of Marine Fisheries to complete comprehensive stock assessments on flounder and other marine finfish being considered for aquaculture development or stock enhancement. Funds also should be provided to the Department of Agriculture and Consumer Services to evaluate market demand for the wild and farm-raised products. Knowledge of the status of the fishery and the market for both wild and commercially grown fish are essential to making wise policy decisions and building public support for flounder aquaculture and stock enhancement.

2. The North Carolina General Assembly should provide funds to the Division of Marine Fisheries to develop a flounder research hatchery to serve the needs of flounder aquaculture development and stock enhancement. The state cannot make significant progress in developing flounder aquaculture or answering questions related to stock enhancement without the capacity to produce a large supply of healthy flounder fingerlings.

3. The Division of Marine Fisheries should establish a multi-disciplinary advisory committee to oversee development and use of the hatchery. There are many complex issues involved in facility design, siting, ownership and management. A broadly representative panel is needed to ensure that all scientific, technical, and resource management and protection concerns are addressed.

4. The Department of Agriculture and Consumer Services should have primary responsibility for the development of marine finfish aquaculture in the state, including providing technical assistance, marketing and other support services for the emerging industry. The department should collaborate closely with the Division of Marine Fisheries and the Marine Fisheries Commission, which should retain responsibility for designating appropriate marine species for aquaculture production. The Department of Agriculture's Aquaculture Advisory Board also should establish a Marine Finfish Aquaculture Committee to guide the development of saltwater finfish aquaculture in the state.

5. The Aquaculture Advisory Board should recommend to the General Assembly methods to promote and support aquaculture research and development through the creation of grants, incentives and joint research facilities or consortiums. Areas such as culture technology, genetics, nutrition, waste disposal, and disease diagnosis and treatment offer substantial opportunities for collaborative research and technology transfer. Specific opportunities identified during the workshops include expanding support for university research in marine finfish aquaculture and an inter-disciplinary program on genetics to serve a variety of industries such as timber, poultry and aquaculture, where genetic engineering is crucial to success.

6. The Aquaculture Advisory Board should work with all interested parties to develop an integrated permitting process for commercial marine finfish aquaculture facilities. The Aquaculture Advisory Board should present to the General Assembly, within 18 months of authorization, a clear set of siting and permitting criteria as developed by the Divisions of Water Quality, Coastal Management and Marine Fisheries. Because many local, state and federal agencies have jurisdiction over siting and operating hatcheries and other aquaculture facilities in the coastal zone, an integrated permitting process must be developed to avoid duplication and delay in the process. It should be a marine version of the freshwater aquaculture license, with the Department of Agriculture and Consumer Services serving as coordinator and other agencies consulting on requirements.

7. Flounder and other marine finfish aquaculture operations should include primarily land-based systems — tanks and ponds — to minimize potential environmental impact. Net pens and other types of grow-out facilities may be worthy of exploration in the open ocean; however, such facilities within the sounds and estuarine system should not be allowed at this

Continued

The North Carolina General Assembly should appropriate funds to the Division of Marine Fisheries to complete comprehensive stock assessments on flounder and other marine finfish being considered for aquaculture development or stock enhancement.

The Division of Marine Fisheries should expand activities designed to increase understanding of the wild fishery and determine the economic and environmental costs and benefits of flounder stock enhancement in North Carolina

time except for scientific research purposes. Directing flounder aquaculture toward land-based systems will limit the questions and complications that must be addressed at this early stage of development. Research should focus on questions related to spawning and raising young flounder in the controlled settings of tanks and ponds. Once a viable enterprise is established, it will be possible to evaluate various types of grow-out facilities.

The Division of Marine Fisheries should expand activities designed to increase understanding of the wild fishery and determine the economic and environmental costs and benefits of flounder stock enhancement in North Carolina. Areas requiring additional investigation include effect on wild stocks, availability of carrying capacity, suitable locations for release, migration patterns of released fish, ways to minimize the impact of net fishing on newly released fish and cost-benefit analyses.

Photo by Scott D. Taylor

A National Sea Grant study shows the flounder fishery is in decline.

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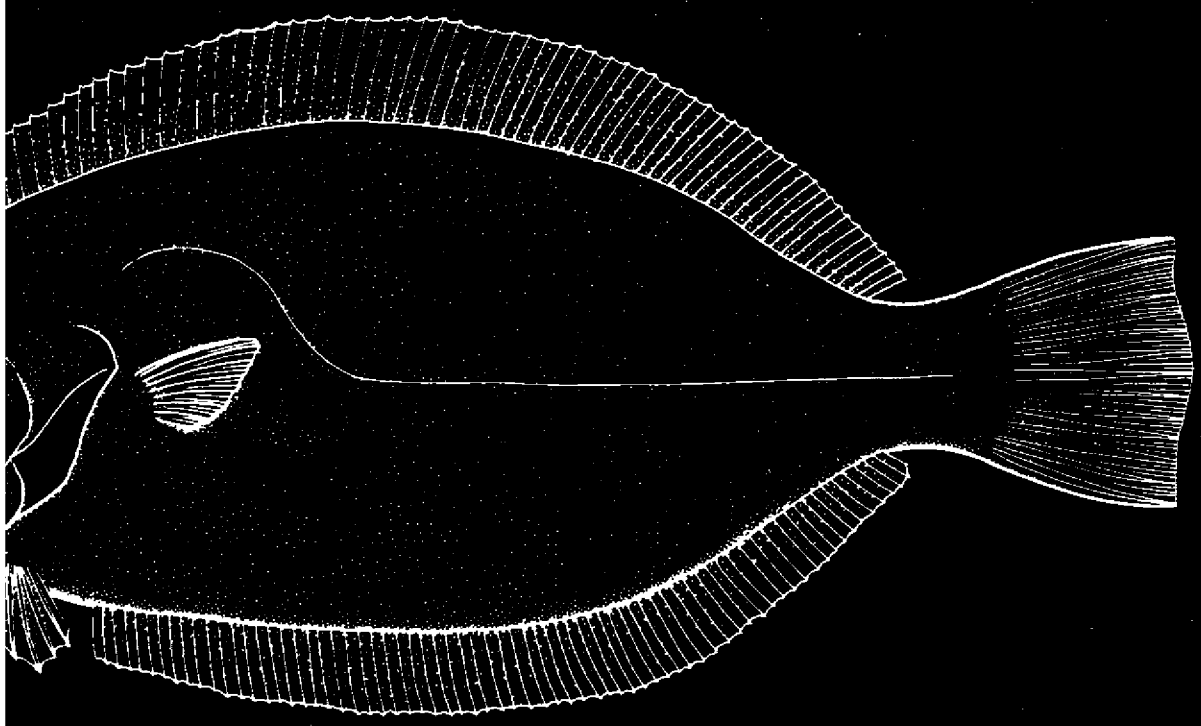

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