

**NORTH CENTRAL
REGIONAL AQUACULTURE CENTER**



ANNUAL PROGRESS REPORT

December 1993

ANNUAL PROGRESS REPORT

For the Period
September 1, 1992 to August 31, 1993

December 1993

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North Central Regional Aquaculture Center

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North Central Regional Aquaculture Center

I. INTRODUCTION

Title XIV of the Agriculture and Food Act of 1980 (P.L. 97-98) amended the National Agricultural Research, Extension and Teaching Policy Act of 1977 (P.L. 95-113) by authorizing the establishment of aquaculture research, development, and demonstration centers in the United States (Subtitle L, Sec. 1475[d]) in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. These Regional Aquaculture Centers have been reauthorized in the Food Security Act of 1985 (P.L. 99-198) and Food, Agriculture Conservation, and Trade Act of 1990 (P.L. 101-624). Five such centers have been established: one in each of the northeastern, north central, southern, and western regions of the country, and one in Hawaii. As used here, a center refers to an administrative center. Centers do not provide monies for brick-and-mortar development. Centers encourage cooperative and collaborative aquaculture research and extension educational programs that have regional or national application. Center programs complement and strengthen other existing research and extension educational programs provided by the Department of Agriculture and other public institutions. As a matter of policy, centers implement their programs by using institutional mechanisms and linkages that are in place in the public and private sector.

The North Central Regional Aquaculture Center (NCRAC) serves as a focal point to assess needs, establish priorities, and implement research and extension educational programs in the twelve state agricultural heartland of the United States which includes Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. NCRAC also provides coordination of interregional and national programs through the National Coordinating Council (NCC) for Aquaculture. The council is composed of directors of regional aquaculture centers and is chaired by a representative of the U.S. Department of Agriculture.

II. ORGANIZATIONAL STRUCTURE

Michigan State University and Iowa State University work together to develop and administer programs of NCRAC through a memorandum of understanding. Michigan State University (MSU) is the prime contractor for the Center and has administrative responsibilities for its operation. The Director of NCRAC is located at MSU. Iowa State University shares in leadership of the Center through an office of the Associate Director who is responsible for all aspects of the Center's publications, technology transfer and outreach activities.

The Board of Directors (BOD) is the primary policy-making body of the NCRAC. The BOD has established an Industry Advisory Council (IAC) and Technical Committee (TC). Membership of the BOD consists of two persons from the IAC (the chair and an at-large member), a representative from the region's State Agricultural Experiment Stations and Cooperative Extension Services, a member from a non-land grant university and representatives from the two universities responsible for the center: Michigan State and Iowa State. The IAC is composed of representatives from state's aquaculture association and six-at-large members appointed by the BOD who represent various sectors of the aquaculture industry and the region as a whole. The TC is composed of a sub-committee for Extension (TC/E) and a subcommittee for Research (TC/R). Directors of the Cooperative Extension Service within the North Central Region appoint a representative to the TC/E. The TC/R has broad regional make-up and is composed of scientists from university and state agencies with varied aquacultural expertise. Each sub-committee of the TC has a chairperson who serves as an ex-officio member of the BOD.

NCRAC functions in accordance with its *Operation Manual* which is periodically amended and updated with BOD approval. It is an evolving document that has changed as the Center's history lengthens. It is used for the development of the cooperative regional aquaculture and extension projects that NCRAC funds.

III. ADMINISTRATIVE OPERATIONS

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Since inception of NCRAC February 1, 1988, the role of the Administrative Center has been to provide all necessary support services to the Board of Directors, Industry Advisory Council, Extension and Research sub-committees of the Technical Committee, and project work groups for the North Central Region as well as representing the region on the National Coordinating Council. As the scope of the NCRAC programs expand, this has entailed a greater work load and continued need for effective communication between all components of the Center and the aquaculture community of the region.

The center functions in the following manner. After BOD approval of Administrative Center costs, the Center submits a grant to USDA/CSRS/Awards Management Division for approval. To date the Center has received six grants from USDA for FY88 (Grant #88-38500-3885), FY89 (Grant #89-38500-4319), FY89 (Grant #90-38500-5008), FY91 (Grant #91-38500-5900), FY92 (Grant #92-38500-6916), and FY93 (Grant #93-38500-8392) with monies totalling \$4,155,661. The Center annually coordinates a program planning meeting which sets priorities for the upcoming fiscal year and calls for regional workshops to develop project outlines to address the problems identified. Work Groups, which are formed at the workshops, submit project outlines to the Center who then solicit peer reviews from experts both within and outside of the region. Reviewers responses are presented to the BOD who then decide which research and extension activities will be funded. The Center conveys BOD decisions to all Project Work Groups and those that are approved for funding are asked to submit revised project outlines incorporating BOD and reviewers comments. The Center then submits the revised project outlines as a Program Plan to USDA for funding approval. Once approved, the Center then prepares subcontracts for each participating institution. The Center receives all invoices for subcontractual agreements and prepares payment vouchers for reimbursement. Thus the Center staff serves as fiscal agent for both receiving and disbursement of funds in accordance with all terms and provisions of the grants. To date, the Center had funded or is funding 12 projects through 134 subcontracts from the six grants received.

NCRAC has funded research and extension projects with six different starting dates. May 1, 1989 marked the initiation of projects on extension, economics/marketing/policy, yellow perch, hybrid striped bass, and walleye. Funding for these projects came from the first two grants that the Center had received: Grant numbers 88-38500-3885 and 89-38500-4319. The extension project received additional monies on March 17, 1990 from Grant #89-38500-4319. On June 1, 1990 projects were begun on yellow perch, hybrid striped bass, walleye, sunfish, salmonids, and a regional conference. The yellow perch, hybrid striped bass, and walleye projects that began June 1 expanded upon projects that had begun in 1989 by undertaking new objectives. Monies for these projects were from Grant #90-38500-5008. September 1, 1991 marked the beginning of new funds for the continuation and enhancement of the first projects NCRAC funded in May 1989: extension, economics/marketing/policy, yellow perch, hybrid striped bass, and walleye. Those funds were from Grant #91-38500-5900. Projects that began September 1, 1992 include additional work on walleye, bluegill and crappies, and salmonids as well as three new ones on crayfish, bait fish, and characterization of aquaculture effluents. Funds for those projects were derived from Grant numbers 89-38500-4319 and 92-38500-6916. New projects were begun on September 1, 1993. This included additional work on extension, economics, yellow perch, hybrid striped bass, and walleye. Funding for all Center supported projects is summarized in Table 1 below (page 5).

Reports on progress of all projects that were funded for the period September 1, 1992 through August 31, 1993 are presented below in Section IV beginning on page 6.

NCRAC's 1993 program planning meeting was held in Madison, Wisconsin on February 14-16, 1992. The Industry Advisory Council (IAC) and Technical Committee (both research and extension subcommittees) met to set priorities for uncommitted grant monies. The Board of Directors approved two priority areas and set funding levels for development of project outlines. Workshops for those areas were held in Chicago, Illinois on June 15-16, 1993: Culture of Centrarchids for Food Fish and and Culture Technology for Salmonids. From these workshops project outlines were developed during summer 1993. These project outlines were submitted to the Center during fall 1993. They will be peer reviewed before the NCRAC Board of Directors meeting that is scheduled for February 1994. At that meeting the Board will decide on which projects to fund.

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During this reporting period, the Publications Office at Iowa State University, under the direction of the Associate Director, produced and distributed a number of publications including fact sheets, technical bulletins, videos, and two issues of the Centers newsletter, the *NCRAC Journal*. A complete list of all publications from this office is included in the Extension Project Progress Report on page 8.

Other areas of support during this reporting period included: monitoring research and extension activities and developing progress reports; preparing project reports for the National Aquaculture Accomplishment Report being compiled by the Northeastern Regional Aquaculture Center; developing liaisons with appropriate institutions, agencies and clientele groups; preparing testimony and coordinating with other Regional Aquaculture Centers to testify before the U.S. House Appropriations subcommittee on Rural Development, Agriculture and Related Agencies hearing in Washington, D.C.; participating in the National Coordinating Council (made up of the Administrative Directors of the five regions and USDA aquaculture personnel); numerous oral and written presentations to both professional and lay audiences; and working with other fisheries and aquaculture programs throughout the North Central Region.

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Table 1. North Central Regional Aquaculture Center funded projects.

Project Title	Duration	Funding Level	Grant Number
Extension	5/1/89-4/30/91	\$39,221	88-38500-3885
	3/17/90-8/31/91	\$68,389	89-38500-4319
	9/1/91-8/31/93	\$94,109	91-38500-5900
	9/1/93-8/31/95	<u>\$110,129</u>	91-38500-5900
		\$311,848	
Aquaculture Economics, Marketing and Policy for the North Central Region	5/1/89-12/31/91	\$127,338	88-38500-3885
		\$34,350	89-38500-4319
	9/1/91-8/31/93	\$53,300	91-38500-5900
	9/1/93-8/31/95	<u>\$40,000</u>	93-38500-8392
	\$254,988		
Advancement of Yellow Perch Aquaculture	5/1/89-8/31/91	\$76,957	88-38500-3885
		\$85,723	89-38500-4319
	6/1/90-8/31/92	\$92,108	90-38500-5008
	9/1/91-8/31/93	\$99,997	91-38500-5900
	9/1/93-8/31/95	<u>\$150,000</u>	93-38500-8392
	\$504,785		
Advancing Hybrid Striped Bass Culture in the North Central Region	5/1/89-8/31/91	\$68,296	88-38500-3885
		\$68,114	89-38500-4319
	6/1/90-8/31/92	\$101,000	90-38500-5008
	9/1/91-8/31/93	\$96,550	91-38500-5900
	9/1/93-8/31/95	<u>\$168,000</u>	93-38500-8392
	\$501,960		
Cultural Technology of Walleye	5/1/89-8/31/91	\$177,517	89-38500-4319
	6/1/90-8/31/92	\$111,657	90-38500-5008
	9/1/91-8/31/92	\$109,223	91-38500-5900
	9/1/92-8/31/93	\$75,000	89-38500-4319
	9/1/93-8/31/95	<u>\$150,000</u>	93-38500-8392
	\$623,397		
Culture of Bluegill and Crappie for Food Fish (Sunfish)	6/1/90-8/31/92	\$130,758	90-38500-5008
	9/1/92-8/31/94	<u>\$149,867</u>	92-38500-6916
	\$280,625		
Culture Technology of Salmonids	6/1/90-8/31/92	\$9,000	89-38500-4319
		\$120,799	90-38500-5008
	9/1/92-8/31/94	<u>\$149,997</u>	92-38500-6916
	\$279,796		
North Central Regional Aquaculture Conference	6/1/90-12/31/91	\$7,000	90-38500-5008
National Aquaculture Extension Workshop	10/1/91-9/30/92	\$3,005	89-38500-4319
Culture of Crayfish in the North Central Region	9/1/92-8/31/94	\$50,000	92-38500-6916
Status of the Bait Industry in the NCR	9/1/92-8/31/94	\$62,000	92-38500-6916
Characterization of Aquaculture Effluents	9/1/92-8/31/94	\$153,300	92-38500-6916

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IV. PROJECT PROGRESS REPORTS

A. North Central Regional Aquaculture Center Extension Project

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$311,848

WORK GROUP MEMBERS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James E. Ebeling	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Jeffrey L. Gunderson	University of Minnesota	Minnesota
F. Robert Henderson	Kansas State University	Kansas
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Ronald E. Kinnunen	Michigan State University	Michigan
Joseph E. Morris	Iowa State University	Iowa
Robert A. Pierce II	University of Missouri	Missouri
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
LaDon Swann	Purdue University	Indiana/Illinois
Administrative Advisor		
David C. Petritz	Purdue University	Indiana

PROJECT OBJECTIVES

- (1) Strengthen linkages between North Central Regional Aquaculture Center (NCRAC) research and extension work groups.
- (2) Enhance the North Central Region (NCR) aquaculture extension network for aquaculture information transfer.
- (3) Provide in-service training for Cooperative Extension Service (CES) and Sea Grant personnel and other landowner assistance personnel.
- (4) Develop aquaculture education programs for the NCR.
- (5) Coordinate NCRAC publications.

ANTICIPATED BENEFITS

The NCRAC Extension Work Group will promote and advance commercial aquaculture in a responsible fashion through an organized education/training outreach program. The primary benefits are: increase in public awareness through publications, short courses, and conferences regarding the potential of aquaculture as a viable agricultural enterprise in the NCR; technology transfer to enhance current and future production methodologies for selected species, such as walleye, hybrid striped bass, yellow perch, salmonids, and sunfish, through hands-on workshops and

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field demonstration projects; improve lines of communication between interstate aquaculture extension specialists and associated industry contacts; and enhance the legal and socioeconomic atmosphere for aquaculture in the NCR.

PROGRESS AND PRINCIPAL ACTIONS (ACCOMPLISHMENTS)

Extension Service personnel in aquaculture serve as liaison between research personnel and several clientele groups. The largest group of clientele are individuals interested in starting an aquaculture operation who lack basic knowledge of aquaculture technologies and opportunities. A second group of clientele have some basic knowledge of aquaculture and sites with potential for aquaculture development. These individuals need more specific information to develop plans for establishing a commercial operation. The third clientele group is comprised of established fish culturists who need information to solve specific problems. A fourth clientele group includes industries involved in production of inputs for aquaculture or in the processing and marketing sectors.

The demand for aquaculture extension education programs cannot be met by the few specialists in the NCR. Networking of specialists and CES designated contacts will maximize efficiency of education programs and minimize duplication. Printed materials will be an important component of the extension education effort in aquaculture and county agents and Sea Grant agents will be educated to serve as initial information sources. The NCRAC Extension Project is designed to assess and meet the information needs of the various clientele groups through cooperative and coordinated regional educational programming.

PRINCIPAL ACTIONS

At least one contact person has been designated by CES for each NCR state, an extension contact directory has been developed and is kept current, and a mechanism for sharing materials produced by states in the NCR has been established. Workshops for CES and Sea Grant personnel on how to develop a strong interdisciplinary effort, enhance information sharing, establish priorities for development of educational materials, plan workshops, etc., have been held and will be hosted in additional sites. Liaisons with state and federal agencies, and with state aquaculture organizations have been made to identify industry needs. Specific principal major actions during this reporting period include:

- Strengthened linkages between NCRAC research and extension work groups through the extension liaisons.
- Provided in-service training for CES and Sea Grant personnel and other landowner assistance personnel in basic aquaculture in Illinois (Selock and Swann); Minnesota (Gunderson and Morris); Iowa, Kansas, and Nebraska (Kayes and Morris); Wisconsin (Binkowski); in seafood handling in Illinois (Selock); and the National Extension Wildlife and Fisheries Workshop (Morris).
- Delivered workshops on general aquaculture in Minnesota (Gunderson); Nebraska (Kayes); Wisconsin (Binkowski); fish diseases and commercial aquaculture recirculation systems in Ohio (Ebeling); aquaculture business planning in Nebraska (Kayes); crayfish in Minnesota (Gunderson); and pond management in Illinois (Selock).
- Delivered in-service training programs to vocational agriculture and science teachers on basic aquaculture in Michigan (Garling), Illinois (Selock), and Iowa (Morris).
- Developed, delivered and evaluated a pilot regional in-service training program entitled "Investing in Freshwater Aquaculture" using television satellite uplink/downlink with leadership from Purdue University (Swann) and participation from Iowa State University (Morris), Southern Illinois University at Carbondale (Selock), University of Nebraska (Kayes), Michigan State University (Garling and Batterson), and Ohio State University (Ebeling). The program consisted of 10 five-to-seven minute video tape segments which addressed production aspects of channel catfish, crayfish, rainbow trout, hybrid striped bass, tilapia, yellow perch, baitfish, and sportfish. A set of course materials was available prior to the program. Three times

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during the program, a question and answer period was available to the audience through a toll free telephone number. Questions not answered during the program were answered by mail afterwards. Satellite coordinates had to be requested from the host.

- Completed 13 bulletins and fact sheets and a video that were provided to all members of the extension network.

PUBLICATIONS, MANUSCRIPTS, AND VIDEOS

NCRAC Extension Fact Sheet Series

- #101 Making Plans for Commercial Aquaculture in the North Central Region, by D. Garling (Michigan State University)
- #102 Pond Culture of Walleye Fingerlings, by L. Harding, C. Clouse, R. Summerfelt, and J. Morris (Iowa State University)
- #103 Choosing an Organizational Structure for Your Aquaculture Business, by S. Kohler and D. Selock (Southern Illinois University-Carbondale)
- #104 Transport of Fish in Bags, by L. Swann (Purdue University)
- #105 Use and Application of Salt in Aquaculture, by L. Swann (Purdue University)
- #106 Pond Culture of Channel Catfish in the North Central Region, by J. Morris (Iowa State University)
- #107 Pond Culture of Hybrid Striped Bass Fingerlings (in preparation), by J. Morris (Iowa State University)
- #108 Trout Culture in the North Central Region, by K. Cain and D. Garling (Michigan State University)
- #109 Fish Health Management (in press), by J. Mittlemark (University of Minnesota)
- #110 Cage Culture of Fish in the North Central Region (in review), by J. Morris (Iowa State University), J. Reipe (Purdue University), D. Selock (Southern Illinois University-Carbondale), and L. Swann (Purdue University)

NCRAC Technical Bulletin Series

- #101 Aquaculture Law in the North Central States: A Digest of State Statutes Pertaining to the Production and Marketing of Aquacultural Products, by S. Thomas, R. Sullivan, R. Vertrees, and D. Floyd (Ohio State University)
- #102 A Basic Overview of Aquaculture, by L. Swann (Purdue University)
- #103 North Central Regional 1990 Salmonid Egg and Fingerling Purchases, Production, and Sales, by R. Kinnunen (Michigan State University)
- #104 Survey of Wholesale and Retail Buyers in the Six Southern States of the North Central Region (in preparation), by L. Hushak, C. Cole, and D. Gleckler, Research Associate (Ohio State University)
- #106 Factors to Consider in Establishing a Successful Aquaculture Business in the North Central Region, by F. Lichtkoppler (Ohio State University)
- #107 Niche Marketing Your Aquaculture Products (in press), by L. Swann and J. Rosscup Reipe (Purdue University)
- #108 Aquaculture in the North Central Region (in review), by G. Brown and L. Hushak (Ohio State University)
- #109 Basic Principles of Biofiltration System Design (in review), by B. Tetzalff and R. Heidinger (Southern Illinois University-Carbondale)

NCRAC Video Series

- #101 Something Fishy: Hybrid Striped Bass in Cages, by L. Swann (Purdue University)
- #102 Whiskers and Cages (in preparation), by D. Selock (Southern Illinois University-Carbondale)
- #103 Investing in Freshwater Aquaculture, edited by L. Swann (Purdue University)

One copy of any of the above that has been completed is available free from (multiple copies at cost):

NCRAC Publications Office

North Central Regional Aquaculture Center

Department of Animal Ecology
124 Science II
Iowa State University, Ames, Iowa 50011-3221
Telephone: (515) 294-5280; FAX: (515) 294-7874.

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WORK PLANNED FOR NEXT YEAR

At least one Extension Work Group member has been assigned to work with each funded NCRAC research project to provide ongoing needs assessment, to provide input for design and prioritization of future research projects, and to identify results useful in extension programs.

Very successful in-service training workshops have been held. Based on the results of these workshops, additional regional aquaculture in-service training workshops will be conducted. A regional in-service training program will be coordinated by Terry Kayes and Joe Morris for South Dakota, Iowa, Missouri, Kansas, and Nebraska. The in-service training activities will be conducted at the sites in Nebraska which meet topic and facility requirements. Dan Selock will conduct six workshops for retail seafood handlers (including aquaculture producers) in Illinois, Indiana, and Missouri (two in Chicago, two in Indianapolis, and two near St. Louis, respectively).

Terry Kayes is developing two 30-minute video tape segments that summarize the 1992 "Investing in Freshwater Aquaculture" teleconference. Those segments will be included in a video entitled "Investing in Freshwater Aquaculture: A Reprise," which can be used by aquaculture extension and outreach professionals as a teaching tool in conducting workshops.

At the 1992 NCRAC Program Planning Meeting, the Industry Advisory Council expressed a need for technique-centered educational tools to help farmers and prospective aquaculturists rear high priority fish species. To meet this need, NCRAC Extension Work Group members will focus their program efforts on the following:

Techniques Guide/Proceedings	Leader(s) ¹ + Team
Hybrid Striped Bass Workshop Proceedings	Dan Selock ¹ (Southern Illinois University-Carbondale) Joe Morris (Iowa State University) LaDon Swann (Purdue University) Terry Kayes (University of Nebraska-Lincoln) Chris Kohler (Southern Illinois University-Carbondale)
Walleye Techniques Guide/Videos	Joe Morris (Iowa State University) Bob Summerfelt ¹ (Iowa State University) Ron Kinnunen (Michigan State University) Jeff Malison (University of Wisconsin-Madison) John Ringle (industry) Jeff Gunderson (University of Minnesota-Duluth)
Yellow Perch Culture Guide/Videos	Terry Kayes ¹ (University of Nebraska-Lincoln) Don Garling ¹ (Michigan State University) extension liaisons work group researchers
Sunfish Production Guide/Videos	Dan Selock ¹ (Southern Illinois University-Carbondale) Don Garling (Michigan State University) Joe Morris (Iowa State University) Terry Kayes (University of Nebraska-Lincoln)
Marketing Aquaculture Products Video	Bob Henderson ¹ (Kansas State University) Bob Pierce ¹ (University of Missouri) Terry Kayes (University of Nebraska-Lincoln) Industry and University Members Economics Work Group members

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Three major regional programs will be developed for individuals with demonstrated potential to develop commercial aquaculture operations are planned in conjunction with development of culture techniques guides: (1) Hybrid Striped Bass Workshop, (2) Walleye Culture Workshop, and (3) Yellow Perch Culture.

Additional workshops developed and hosted by state Extension contacts will be advertised in surrounding states to take advantage of the NCRAC Extension network and the individual expertise of Extension Work Group participants. Examples of these workshops include:

Workshop Topic	Extension Contact	Location
General Aquaculture	Fred Binkowski	Wisconsin
General Aquaculture	Terry Kayes	Nebraska
Yellow Perch Aquaculture	Terry Kayes	Nebraska
Pond Construction	LaDon Swann	Indiana
Spawning and Production of Fry and Fingerlings	Jim Ebeling	Ohio
Fish Farm Forum V	Jim Ebeling	Ohio
North Central Aquaculture Conference '95	Jeff Gunderson	Minnesota

LaDon Swann will develop Aquaculture Handbooks for 20 CES or Sea Grant field staff per state. The Aquaculture Handbooks will be based on handbooks successfully field tested in Illinois and Indiana. Each Handbook will consist of a three-ring notebook divided into 26 sections for fact sheets and bulletins relevant for each selected topic. Where possible NCRAC publications and state specific information will be used. Identification of field staff and their in-service training on the use of the Aquaculture Handbook will be the responsibility of each state Extension Contact.

IMPACTS

The positive impacts to aquaculture clientele from all NCRAC Extension activities are oftentimes hard to measure. Direct assistance provided to individuals by the Extension network will enhance the development of aquaculture in the region. For example, Jeff Gunderson (Minnesota) conducted a crayfish workshop in Minnesota and developed handout information related to crayfish marketing, soft shell production, business development and species identification. Although not specifically a NCRAC function, knowledge gained from working with the northern Minnesota and Wisconsin crayfish producers during this workshop will facilitate more effective dissemination of Crayfish Work Group results throughout the region.

In-service training for CES and Sea Grant personnel has enabled those professionals to respond to initial, routine aquaculture questions from the general public and allows the aquaculture specialists to work on more difficult problems. The development of aquaculture education programs for the NCR provides "hands-on" opportunities for prospective and experienced producers.

Approximately 2200 individuals have attended workshops organized and delivered by the NCRAC Extension Work Group. Clientele attending regional workshops learned of aquaculture development strategies in other areas of the country and acquired information which was of direct use to their own enterprises. Education programs also created situations where problems encountered by producers were expressed to extension personnel who later relayed them to researchers at NCRAC work group meetings for possible solutions through the research effort.

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Fact sheets developed by the Center will serve to better inform clients about suitable aquaculture practices. In addition, the increased cooperation of various state extension personnel allows for an increased amount of education of the public. For instance, "Making Plans for Commercial Aquaculture in the North Central Region" (Garling, Michigan) is often used to provide clients with initial information about aquaculture, while species specific publications on walleye (Harding et al., Iowa), catfish (Morris, Iowa) and trout (Cain and Garling, Michigan) have been used in numerous regional meetings and have been requested by clients from throughout the U.S. Publications on organizational structure for aquaculture businesses (Kohler and Selock, Illinois), transportation of fish in bags (Swann, Indiana), and others are beneficial to both new and established aquaculturists.

NCRAC extension efforts have helped increase the number of aquaculture operations within the region. For example, the number of aquaculture licenses in Illinois has increased by an average of 20% annually for the last three years to a total of 96 license holders in 1992. Most NCRAC Extension Work Group members participate on state aquaculture planning committees designed to facilitate aquaculture development. New or improved operations have been facilitated in most NCR states with NCRAC extension assistance. These activities will continue to enhance the development of aquaculture in the region.

Approximately 700 participants viewed the teleconference program "Investing in Freshwater Aquaculture." Overall, the program accomplished the stated objectives. Sixty-one percent of the individuals who responded to the evaluations were participating in their first aquaculture program. These individuals overwhelmingly felt the program was good to excellent. However, a majority of the respondents would have preferred a workshop or seminar over the teleconference.

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B. Aquaculture Economics, Marketing and Policy for the North Central Region

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$254,988

WORK GROUP MEMBERS:

Mary E. Gerlow	Ohio State University	Ohio
Leroy J. Hushak	Ohio State University	Ohio
Jeffrey Mittelmark	University of Minnesota	Minnesota
Bruce J. Sherrick	University of Illinois	Illinois
Extension Liaison:		
Frank R. Lichtkoppler	Ohio State University	Ohio

PROJECT OBJECTIVES

The objectives of this project have been to:

- (1) Identify existing and needed economic data; develop statistical reporting methods; design an information management system and prototype annual situation/outlook report on the North Central Region (NCR) aquaculture industry; begin collecting and compiling a regional database; and prepare a situation/outlook report.
- (2) Develop and implement an extension program designed to educate current and potential aquaculture producers on the need to provide accurate economic information on their operations.
- (3) Investigate economic production and marketing feasibility for selected species currently produced in the NCR and other species which offer commercial potential.
- (4) Identify existing policy impediments and incentives for expanded aquaculture development in each participating state within the NCR.

During this reporting period activities of the Work Group focused on objectives (1) and (3).

ANTICIPATED BENEFITS

The implications of the economics, marketing and policy project for the future of fish production in NCR have further emerged during 1992-93. The Situation and Outlook Report will provide a widely distributed report of the state of aquaculture in the NCR.

The benefits of the cost of production budgets are two. First, for the first time, budgets using North Central trout and catfish producer data are available for use by regional producers and by North Central Regional Aquaculture Center (NCRAC) Extension agents in assisting producers and others to assess the profitability of existing and proposed fish enterprises. These budgets will also be useful in helping producers assess the feasibility of growing other species in the region.

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Second, these budgets provide an educational tool in the hands of Extension agents to teach fish growers how to improve cost accounting and budgeting procedures on their operations. Improved cost accounting will make producers better managers and assist regional researchers in assessing the feasibility of growing particular species under varying conditions.

Incorporation of cost of production budget parameters into budget software will give current or potential fish producers, financial institutions and policy makers regional results about the feasibility of producing trout and catfish in various locations of the NCR. In addition, the data on some costs such as water and facilities will be transferable to other species of interest.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This project seeks to understand the economics, marketing and policy issues of aquaculture in the NCR. It is a multidisciplinary effort involving personnel from three institutions in three states, combining the disciplines of agricultural economics and cooperative extension.

Trout and catfish cost of production budgets were developed. Based on the 1990 NCRAC survey of producers, these two species are the largest revenue generators for this region's growers.

There were 65 trout producers who grew trout and sold in excess of \$1,000 during 1990. Twenty-nine of these producers were chosen for the cost of production study to reflect differences in sizes of operations. Nineteen of the facilities were visited in person; the remaining ten were sent a questionnaire and then interviewed by telephone. The initial 19 were also contacted by telephone, as needed, to clarify initial responses when questions arose. Of the ten participants who were not visited, five did not respond to the telephone survey. Three questionnaires were not used because the data provided was too incomplete to develop budgets. The remaining 21 producer surveys provided the data base for the trout study. The level of cooperation received from trout growers in completing a very lengthy and difficult questionnaire was a very pleasant surprise.

Data were collected for the calendar year 1991. Producers were asked to provide information about variable and fixed operating costs of raising trout, the prices of variable and fixed inputs for which producers would have price data, type(s) of fish stocked, stocking size, market size, food conversion rate, and physical relationships such as water temperature and flow rates.

The 21 producers were divided into three groups. The small group contained nine producers with gross sales of \$1,250 to \$45,000, with average sales of \$20,039. These producers sold an average of 8,845 kg (19,500 lbs) live weight. The medium group contains seven producers with sales ranging from \$92,178 to \$130,000, and averaging \$108,220. Output averaged 278,671 kg (61,005 lbs) live weight. The large group contains five producers who averaged \$324,184 in sales and 72,746 kg (160,378 lbs) live weight in output. The smallest of this group sold \$225,000 during 1991.

Variable plus fixed operating costs were \$21,140 for the average small producer resulting in negative operating revenues of \$1,101; so there was a negative balance before any allocation to the operator's labor, management and investment. The medium and large groups had variable plus fixed costs of \$95,927 and \$239,510, respectively, leaving returns of \$12,293 and \$84,674, respectively, available for operator's labor, management and investment.

The cost and revenue data were of questionable validity at best. Most of the trout producers interviewed have very weak cost accounting skills, and, therefore, have limited ability to evaluate whether their trout operations are profitable or not. In addition, trout operations as a group are very complex when compared to other agricultural production enterprises because of the number of growing ranges for the fish (hatching eggs, selling or buying fingerlings, selling or buying stockers, selling food size fish). Also, there are a large variety of production facilities, i.e., ponds, raceways, cages, etc. and all possible combinations of these facilities, plus variations in the costs of obtaining water. Experience suggests that very basic educational programs in management, cost accounting, and budgeting would be highly beneficial to these producers in NCR.

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PUBLICATIONS AND MANUSCRIPTS

Publications in print:

- Brown, G.J., and L.J. Hushak. 1991. The NCRAC producers survey and what we have learned: an interim report. Pages 69-71 in *Proceedings of the North Central Aquaculture Conference*, Kalamazoo, Michigan, March 18-21, 1991.
- Floyd, D.W., and R.M. Sullivan. 1990. Natural resources and aquaculture: the policy environment in the North Central states. *Proceedings of the Third Symposium on Social Science and Resource Management*. Texas A&M University, College Station, Texas.
- Floyd, D.W., R.M. Sullivan, R.L. Vertrees, and C.F. Cole. 1991. Natural resources and aquaculture: Emerging policy issues in the North Central states. *Society and Natural Resources* 4:123-131.
- Gleckler, D.P. 1991. Distribution channels for wild-caught and farm-raised fish and seafood: a survey of wholesale and retail buyers in six states of the North Central Region. M.S. thesis. Ohio State University, Columbus.
- Gleckler, D.P., L.J. Hushak, and M.E. Gerlow. 1991. Distribution channels for wild-caught and farm-raised fish and seafood. Pages 77-81 in *Proceedings of the North Central Aquaculture Conference*, Kalamazoo, Michigan, March 18-21, 1991.
- Hushak, L.J. 1993. North Central Regional Aquaculture Industry Situation and Outlook Report. Volume 1. North Central Regional Aquaculture Center Publications Office, Department of Animal Ecology, Iowa State University, Ames.
- Hushak, L.J., D.W. Floyd, and R.L. Vertrees. 1992. Aquaculture: a competitive industry in North Central states? *Ohio's Challenge* 5(1):3-5.
- Hushak, L.J., C.F. Cole, and D.P. Gleckler. 1993. Survey of wholesale and retail buyers in the six southern states of the North Central Region. NCRAC Technical Bulletin Series #104. North Central Regional Aquaculture Center Publications Office, Department of Animal Ecology, Iowa State University, Ames.
- Robinson, M., D. Zeponi, and B.J. Sherrick. 1991. Assessing market potential for new and existing species in the North Central Region. Pages 72-76 in *Proceedings of the North Central Aquaculture Conference*, Kalamazoo, Michigan, March 18-21, 1991.
- Thomas, S.K. 1991. Industry association influence upon state aquaculture policy: a comparative analysis in the North Central Region. M.S. thesis. Ohio State University, Columbus.
- Thomas, S.K., R.L. Vertrees, and D.W. Floyd. 1991. Association influence upon state aquaculture policy--a comparative analysis in the North Central Region. *The Ohio Journal of Science* 91(2):54.
- Thomas, S.K., R.M. Sullivan, R.L. Vertrees, and D.W. Floyd. 1992. Aquaculture law in the North Central states: a digest of state statutes pertaining to the production and marketing of aquacultural products. NCRAC Technical Bulletin Series #101, North Central Regional Aquaculture Center Publications Office, Department of Animal Ecology, Iowa State University, Ames.

Manuscripts:

- Brown, G.J. In press. Cost of production budgets for trout in North Central states. M.S. thesis. Ohio State University, Columbus.

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WORK PLANNED FOR NEXT YEAR

The current Work Group members will complete unfinished activities on a no-cost basis. A new Work Group will begin to develop cost of production budgets and expected revenues for the raising of food-sized walleye, yellow perch, and hybrid striped bass on farms in the NCR.

IMPACTS

1. The marketing study showed that the primary species cultured by North Central producers are highly marketable.
2. The cost of production budgets provide, for the first time, budgets based on actual production units in the NCR.

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C. Advancement of Yellow Perch Aquaculture

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$504,785

WORK GROUP MEMBERS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Illinois
David A. Culver	Ohio State University	Ohio
Konrad Dabrowski	Ohio State University	Ohio
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois

Extension Liaison:

Donald L. Garling	Michigan State University	Michigan
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PROJECT OBJECTIVES

This is the final annual report of a 4-year project, the funding on which began May 1, 1989 and ended August 31, 1993. The project's objectives were to:

- (1) Compare the survival, growth, feed conversion, and proximate composition of offspring from selected northern, southern, and Great Plains stocks of yellow perch, at different life history stages and at different temperatures.
- (2) Evaluate the survival, growth, and feed conversion of yellow perch raised at various loadings or rearing densities in selected flow-through and pond culture systems.
- (3) Evaluate and improve the efficiency of various methods of inducing triploidy in yellow perch, and compare the survival and growth to market size of the triploids produced with that of normal diploids.
- (4) Compare pond and intensive culture methods for the production of yellow perch fingerlings.

Most of the research findings on these four objectives were generated in the first three years of the project and are summarized in the North Central Regional Aquaculture Center (NCRAC) "ANNUAL PROGRESS REPORT" dated December 1992. The 1991-92 report fully summarizes all of the research done by the Work Group on Objectives 1 and 2. This report describes the final research completed on Objectives 3 and 4 from September 1, 1992 to August 31, 1993, as well as special accomplishments before that period and plans for future activity.

ANTICIPATED BENEFITS

The principal goal of this project, as stated in the initial 1989 proposal, has been to "develop practical strategies for commercial yellow perch aquaculture under the diverse environmental conditions that exist in the North Central Region." Much of this goal has been realized. During its 4-year history, the project examined: (1) the suitability of selected wild perch broodstocks obtained from different geographic locales as candidates for potential broodstock development; (2) the applicability of selected conventional production technologies to perch aquaculture; (3) the

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potential of using chromosomal triploidy induction to enhance growth; and (4) the relative merits of pond versus intensive culture methods for the production of perch fingerlings, and the nutrient composition of live-food organisms versus perch fry raised to different sizes (stages of development) under different culture conditions (different pond sites and laboratories, pond versus intensive culture). The anticipated benefits of the project, in large part, reflect the principal findings and conclusions that can be drawn from the research that was done.

With respect to Objective 1, studies at the University of Wisconsin-Milwaukee (UW-Milwaukee) found variations in percentage of survival and swim bladder inflation between perch fry from different stocks, and research at Purdue University (Purdue) identified significant differences in the growth of perch fingerlings from these same stocks at various rearing temperatures. In overview, these variations and differences appeared to be primarily reflective of the geographic locales from which the brood fish and fertilized eggs of the different stocks were selected, which is a factor that should be considered when selecting broodstock for the production of perch. Thus, producers in the northern and southern parts of the North Central Region (NCR) should probably use broodstock from their own respective parts of the region, and not expend undue time and resources seeking "super" perch from stocks with presumed superior performance traits that have not been documented by properly controlled experimental procedures.

As part of Objective 2, Michigan State University (MSU) and University of Wisconsin-Madison (UW-Madison) researchers unequivocally demonstrated that perch can be raised to market size using conventional aquaculture production technologies in a time frame similar to that of such important commercially cultured species as channel catfish. The demonstration of this fact is perhaps one of the project's most important practical benefits, because it underscores the importance of matching species selection for aquaculture development with climatic conditions and available resources. This research effort was also important because it helps refute the notion that, except for salmon and trout, finfish aquaculture in the North, owing to the shorter growing season, cannot be competitive with aquaculture production at southern or tropical latitudes. The temperature requirements of perch for successful reproduction and optimum growth make the commercial culture of this species in the principal catfish producing states of the South highly unlikely.

Regarding Objective 2, MSU investigators, working with Bay Port Aquaculture Inc. of Port Sheldon, Michigan, have demonstrated that perch can be raised on a commercial scale at high densities in flow-through tanks, using research-based procedures for estimating carrying capacity based on the dissolved oxygen requirements and ammonia tolerance limits of perch. Such an approach to perch aquaculture, employing intensive procedures similar to those used in commercial trout production, should be particularly applicable to situations where an inexpensive, abundant source of high-quality temperate (i.e., 18-24 °C) water is or can be made available for "grow out" - from natural springs, wells, and/or the utilization of dependable waste heat or clean cooling water from such providers as electric power generating stations.

Using a different approach, UW-Madison researchers, working with Coolwater Farms of Dousman, Wisconsin, have demonstrated that the commercial-scale culture of perch in ponds can be feasible, if sufficient quantities of inexpensive groundwater (which ranges between about 8 and 14 °C across the NCR) is available to moderate pond water temperature highs during the summer and ice formation during the winter. Such groundwater addition also helps maintain elevated dissolved oxygen concentrations, and facilitates ice control during the winter to provide access for management and feeding and to prevent equipment damage. The benefit of this approach is that it provides a ready means of producing commercial quantities of perch in those parts of the region where pond construction is feasible and groundwater is abundant and available at a reasonable cost.

Studies by researchers at the UW-Madison and Southern Illinois University at Carbondale (SIU-C) on Objective 3 have shown that while direct triploidy induction in fertilized eggs produces perch that exhibit retarded gonadal development and somewhat higher fillet yields than is observed in normal diploid fish, direct triploidy induction does not significantly enhance growth. Investigators at the UW-Madison have developed effective procedures to induce triploidy in perch either by heat or hydrostatic pressure shocks, but have shown that such shocks exert a negative influence on growth independent of ploidy change. Accordingly, unless perch can be marketed on the basis of fillet yield or lack of reproductive competence, instead of total body weight, it is difficult to envision how direct triploidy

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induction can benefit commercial perch aquaculture. Researchers at the UW-Madison have also developed procedures for producing tetraploid brood perch, which presumably can be backcrossed with diploid fish to produce triploid eggs via natural fertilization, rather than by using physical or chemical shock treatments. Triploid perch produced by crossing tetraploid and diploids may grow faster than diploids, but this potential benefit has not yet been tested either experimentally or in practice.

Researchers at the UW-Madison and UW-Milwaukee, working collaboratively on Objective 4, have clearly demonstrated that with recently developed "best available" techniques, fry and early-fingerlings perch raised in ponds exhibit better survival and growth and far fewer problems with swim bladder inflation and spinal deformities than perch reared intensively in tanks since hatching. Furthermore, after habituation to formulated feed and intensive culture conditions, pond-reared perch often continue to out-grow fish reared entirely by intensive methods. Over the years, UW-Madison investigators have continued to develop improved procedures for incubating and hatching perch eggs, rearing and harvesting ever-increasing numbers of perch fingerlings from ponds (up to 1,000,000 per surface hectare), and habituating early-fingerlings (16-18 mm total length) to formulated feed and intensive culture conditions using internal tank lighting. The development of these procedures represents another one of the project's most important practical benefits, because they provide fish farmers with a ready means of producing large number of perch fingerlings that are habituated to formulated feed and ready for "grow out" to market size.

After three years of research on Objective 4, UW-Madison and UW-Milwaukee investigators have found that despite significant improvements in procedures and fry survival, problems with swim bladder inflation and cannibalism continue to be serious impediments to the large-scale intensive production of perch fingerlings. UW-Milwaukee researchers demonstrated that problems with early development and habituation of fry to intensive culture conditions were not as serious with perch originating from the Prquimans River in North Carolina, as with perch fry originating from other locales. Ohio State University (OSU) investigators discovered no significant differences in the amino acid compositions of young perch from Wisconsin and Ohio, suggesting similar nutritional needs across perch stocks. Researchers from OSU also found suggestive evidence, but no causal or clear-cut functional linkages, that dietary ascorbic acid deficiencies may be responsible for the high incidence of spinal deformities often observed in perch larvae reared under intensive culture conditions, and that certain long-chain fatty acids may be important in the diets of young perch.

The importance of these UW-Milwaukee and OSU investigations on Objective 4 is that they demonstrate that considerable additional research will probably be required to develop the procedures and diets necessary to successfully culture perch larvae intensively in tanks on a large scale. Based on experience with other species with small larvae, a long-term investment in selective breeding or in research on perch larval diet development might make such intensive culture technically feasible. Whether or not it would be commercially competitive with the improved methods developed in recent years for culturing young perch in ponds is unclear, particularly considering that continued improvements in the latter approach are likely.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

As noted previously, the Work Group's principal accomplishments on Objectives 1 and 2 are fully summarized in the NCRAC "ANNUAL PROGRESS REPORT" for 1991-92. Regarding Objective 1, observations before 1991 on the survival and development of young perch from different geographic locales revealed little clear-cut variation between stocks, using a standardized rearing scheme at the UW-Milwaukee and fish from Lake Mendota, Wisconsin as controls. In 1991, perch from the Prquimans River in North Carolina performed far better than previously examined stocks in terms of survival and swim bladder inflation. Perch in 1992 from the Valentine National Wildlife Refuge in Nebraska performed intermediately between the Lake Mendota controls and the Prquimans River fish examined in 1991. Studies done at Purdue demonstrated significant variations in the growth of juvenile perch from stocks from different geographic locales, primarily at the experimental temperature extremes of 16 and 28 °C. In contrast, the Prquimans River fingerlings grew better than the Lake Mendota controls at all experimental temperatures, including the reported optimum growth temperature of 22 °C.

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Research done by MSU investigators on Objective 2 using small-scale flow-through systems revealed that: (1) the optimum loading rate for intensive culture of perch is between 1.1 and 1.4 kg of fish/L per min of water flow, (2) about 3.5 mg/L of dissolved oxygen is necessary to maintain optimal perch growth, and (3) the mean metabolic rate during feeding periods for perch of 135-155 mm total length (TL) fed about 1.4% of body weight is about 173 mg O₂/kg per hour at 20 °C. Although maximum rearing density has not been identified, perch of 110-150 mm TL can be reared at a density of at least 85 kg/m³ without significant reductions in performance. In 1991-92, MSU investigators demonstrated that perch can be reared in large-scale flow-through systems at flow indices of 1.18 kg/L/min/mm fish length (2.5 lbs/gpm/in) without a reduction in growth, if oxygen levels are maintained at or above 3 mg/L.

Studies done by UW-Madison researchers on Objective 2 demonstrated that age-0 and age-1 perch can be successfully raised in net-pens in small (0.1-0.4 hectare) ponds. The addition of a small amount of groundwater to ponds (enough to replace total pond volume one to two times monthly) moderated mid-summer maximum temperature extremes and elevated dissolved oxygen levels, resulting in significant increases in fish survival and growth. In winter, groundwater addition greatly reduced ice formation, making fish husbandry easier and preventing damage to equipment located in the ponds. Throughout the project, all groups of perch reared in net-pens grew slower than fish reared in the ponds but not confined to net-pens. The poorer growth of perch in net-pens may have been partly due to their small size (1.2-m × 1.2-m × 1.8-m deep), or may reflect an inherent disadvantage to raising perch in net-pens. Perch overwintered indoors at groundwater temperatures of 9-10°C gained about 10% in body weight, while perch overwintered in net-pens in ponds at ambient temperatures lost about 10% of their weight, despite being regularly fed. For three years in succession, the ponds at Coolwater Farms (Wisconsin) that were provided with groundwater addition produced about 11,200 kg/surface hectare (10,000 lbs/surface acre) per year of market-size perch.

Research done on Objective 3 by UW-Madison investigators demonstrated that triploid perch can be produced by subjecting perch eggs to heat shocks of 28-30 °C, initiated 5 min after fertilization and lasting 10 or 25 min, or by hydrostatic pressure shocks of 9,000 or 11,000 psi, initiated 5 min after fertilization and lasting 12 min. They also found that tetraploid perch can be produced by subjecting eggs to pressure shocks of 9,000 psi, initiated 192 min after fertilization and lasting 24 min. Experiments by UW-Madison and SIU-C researchers revealed that triploid perch produced by heat or pressure shock techniques do not grow faster than diploid fish. However, SIU-C workers found that adult-size (heat-shocked) triploid females had relatively smaller gonads and higher fillet yields than diploid females. Researchers at the UW-Madison have repeatedly demonstrated that either heat shocking or pressure shocking perch eggs exerts a detrimental influence on growth, independent of any effect on ploidy.

Investigators at the UW-Madison recently completed a series of studies that compared the growth and reproductive biology of unshocked diploid perch with that of shocked triploids and shocked diploids, under simulated ambient water temperature and photoperiod conditions for southern Wisconsin, and under near-optimal rearing conditions (21 °C, 16 h light/8 h dark photoperiod), over a period of 270 d. The principal findings of these studies were as follows (under both environmental conditions): (1) the females in all treatment groups grew faster than the males, (2) the triploids of both sexes were functionally sterile, (3) levels of serum estradiol-17β were lower in triploid than in diploid females, and (4) levels of serum testosterone in triploid and diploid males did not differ. Under the simulated ambient, but not optimal, environmental conditions, (1) triploid males (but not females) gained more weight (but not length) than diploids, (2) the triploids of both sexes exhibited retarded gonadal development and correspondingly higher fillet yields than diploids, and (3) the females in all treatment groups had relatively larger gonads and correspondingly lower fillet yields than males.

Because of their potential importance to the future direction of research on perch aquaculture, most of the principal accomplishments on Objective 4 prior to the 1992-93 funding year are described under "ANTICIPATED BENEFITS." In 1992, UW-Madison researchers conducted a study to compare the survival and growth of 40-d old pond-reared and intensively-reared perch fingerlings over an 80-d period in 110-L flow-through tanks equipped with internal tank lighting and automatic feeders, and supplied with tempered water (19 ± 0.5 °C) and airstone aeration. Cumulative survival was not different between the pond-reared and intensively-reared perch. However, the primary cause of mortality among the former was starvation, and among the latter was cannibalism, which suggests that present

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methods of intensively culturing perch fry may select for cannibalism. At the end of the study, the pond-reared perch were both longer and heavier than the fish that had been intensively reared as fry. Scoliosis was observed in 17.5% of the latter, but in less than 1% of the pond-reared fish.

In 1992-93, UW-Madison investigators did research to improve procedures for habituating perch fingerlings to formulated feed while still in ponds. This involved the use of lights to attract the highly photopositive young fish to the vicinity of automatic (vibrating) feeders. Initial observations indicate that more than 625,000 fish/surface hectare (250,000 fish/surface acre) can be produced that are habituated to formulated feed.

Researchers from OSU working on Objective 4 found that between ages of 2 and 7 weeks in pond-reared perch, n-3 family fatty acids in the polar lipid fraction of the young fish exhibited a downward trend, while n-6 family fatty acids increased significantly. Changes in the neutral lipid fraction of perch were highly significant during early growth. Such findings suggest that fatty acids play an important role in the early development and growth of perch and might be important in perch nutrition.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

Publications in print:

Dabrowski, K., and D.A. Culver. 1991. The physiology of larval fish: digestive tract and formulation of starter diets. *Aquaculture Magazine* 17(2):49-61.

Garling, D.L. 1991. NCRAC research programs to enhance the potential of yellow perch culture in the North Central Region. Pages 253-255 in *Proceedings of the North Central Regional Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.*

Glass, R.J. 1991. The optimum loading and density for yellow perch (*Perca flavescens*) raised in a single pass, flow-through system. M.S. thesis. Michigan State University, East Lansing.

Malison, J.A., and J.A. Held. 1992. Effects of fish size at harvest, initial stocking density and tank lighting conditions on the habituation of pond-reared yellow perch (*Perca flavescens*) to intensive culture conditions. *Aquaculture* 104:67-78.

Malison, J.A., T.B. Kayes, J.A. Held, T.B. Barry, and C.H. Amundson. 1993. Manipulation of ploidy in yellow perch (*Perca flavescens*) by heat shock, hydrostatic pressure shock, and spermatozoa inactivation. *Aquaculture* 110:229-242.

Malison, J.A., L.S. Procarione, J.A. Held, T.B. Kayes, and C.H. Amundson. 1993. The influence of triploidy and heat and hydrostatic pressure shocks on the growth and reproductive development of juvenile yellow perch (*Perca flavescens*). *Aquaculture* 116:121-133.

Williams, F., and C. Starr. 1991. The path to yellow perch profit through planned development. Pages 49-50 in *Proceedings of the North Central Regional Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.*

Manuscripts:

Dabrowski, K., D.A. Culver, C.L. Brooks, A.C. Voss, H. Sprecher, F.P. Binkowski, S.E. Yeo, and A.M. Balogun. In press. Biochemical aspects of the early life history of yellow perch (*Perca flavescens*). *Proceedings of the International Fish Nutrition Symposium, Biarritz, France, June 25-27, 1991.*

Papers presented:

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- Brown, P.B., K. Wilson, J. Wetzel, J. Mays, F. Binkowski, and S. Yeo. 1994. Culture characteristics of juvenile yellow perch (*Perca flavescens*) from different geographical locales grown at three temperatures. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-18, 1994.
- Crane, P., G. Miller, J. Seeb, and R. Sheehan. 1991. Growth performance of diploid and triploid yellow perch at the onset of sexual maturation. 53rd Midwest Fish and Wildlife Conference, Des Moines, Iowa, November 30 - December 4, 1991.
- Malison, J.A., J.A. Held, L.S. Procarione, T.B. Kayes, and C.H. Amundson. 1991. The influence on juvenile growth of heat and hydrostatic pressure shocks used to induce triploidy in yellow perch. 1991 Annual Meeting of the American Fisheries Society, San Antonio, Texas, September 8-12, 1991.
- Malison, J.A., J.A. Held, and C.H. Amundson. 1991. Factors affecting the habituation of pond-reared yellow perch (*Perca flavescens*), walleye (*Stizostedion vitreum*), and walleye-sauger hybrids (*S. vitreum* female x *S. canadense* male) to intensive culture conditions. 22nd Annual Meeting of the World Aquaculture Society, San Juan, Puerto Rico, June 16-20, 1991.
- Malison, J.A., D.L. Northey, J.A. Held, and T.E. Kuczynski. 1994. Habituation of yellow perch (*Perca flavescens*) fingerlings to formulated feed in ponds using lights and vibrating feeders. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-18, 1994.

WORK PLANNED FOR NEXT YEAR

The findings by the investigators that participated in this completed NCRAC project have or soon will be analyzed, and manuscripts will continue to be prepared and submitted for publication. Researchers at the UW-Madison have indicated that they will continue to work on the potential benefits of triploidy and tetraploidy in perch, irrespective of NCRAC funding. Over the next year, the Work Group chair and extension liaison will encourage the other Work Group members to make appropriate findings and data available for, and if possible help prepare, a much needed series of extension publications on yellow perch aquaculture.

Building on the results of the completed project, NCRAC provided funding for a new yellow perch project also entitled "Advancement of Yellow Perch Aquaculture," which began on September 1, 1993, and will run for two years. The objectives of this new project are to: (1) determine the commercial scale feasibility and improve on the best intensive tank and pond culture practices for the production of yellow perch fingerlings, and (2) determine the commercial scale feasibility of raising food-size yellow perch in flow-through raceways or tanks, open ponds, and large net-pens, comparing the best available formulated diets. A number of commercial fish farmers in the NCR have been named as major participants in this new project; many aspects of which will not be possible without their full cooperation and support.

IMPACTS

The principal impacts of the completed NCRAC yellow perch project have been the development and/or expansion of two of the NCR's leading commercial perch aquaculture operations, the actual or planned start up of several new commercial perch aquaculture ventures, the utilization of the project's newly developed knowledge and production procedures by a number of fish farmers, and the training of numerous graduate and undergraduate students at the participating institutions.

Specific Examples:

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The research done by MSU on the intensive flow-through culture of perch in tanks (Objective 2) played a key role in the development and expansion of Bay Port Aquaculture Inc. of Sheldon, Michigan. Similarly, all of the perch net-pen and pond production research (Objective 2) and many of the perch fingerling production studies (Objective 4) reported by the UW-Madison were done at Coolwater Farms of Dousman, Wisconsin, and directly involved Coolwater Farms' personnel in these investigations. As a consequence, Coolwater Farms has greatly expanded both the scope and efficiency of its operations.

Private producers that are actually known to have recently started culturing perch largely as a consequence of the project, or who have made significant investments to soon start, include one in Iowa, three in Indiana, one in Michigan, two in Nebraska, two in Ohio, and two in Wisconsin. Other perch aquaculture ventures in the region may have recently started or may soon become operational, but this cannot be presently documented.

The UW-Madison has reported that several "aquaculture endeavors in Iowa, Indiana and Michigan have based their business plans on the pond culture of perch," that one in Iowa "is evaluating the use of net-pens," that "at least three commercial fish farms (one each in Wisconsin, Michigan and Ohio) have begun to rear all-female perch," and that "at least three commercial perch aquaculture operations in the upper Midwest" have or are implementing the "egg hatching and fingerling production and training methods developed" during the project. The UW-Milwaukee has reported training fish farmers in its procedures for producing perch fingerlings intensively in tanks.

Purdue has indicated the partial training of two graduate students and three undergraduates, as part of the project; MSU reported training two graduate and several undergraduate students. In overview, all of the principal investigators and technical staff of the various laboratories and institutional programs participating in the project gained tremendous insights and new knowledge about the culture and biology of the yellow perch, and a better appreciation of the benefits of regional and inter-institutional collaboration.

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D. Advancing Hybrid Striped Bass Culture

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$501,960

WORK GROUP MEMBERS:

George G. Brown	Iowa State University	Iowa
Terrence B. Kayes	University of Nebraska	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois

Extension Liaison:

Joseph E. Morris	Iowa State University	Iowa
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PROJECT OBJECTIVES

- (1) Obtain and maintain (in captivity) populations of spawning size white bass and striped bass.
- (2) Define reproductive development in wild and captive white bass by characterizing seasonal changes in hormone titers and gonadal histology.
- (3) Evaluate the effects of selected photoperiod/temperature and hormonal manipulations on gonadal development and spawning in white bass broodstock.
- (4) Improve methods for storage and transport of striped bass and white bass gametes.
- (5) Develop larval diets and economically feasible techniques to convert hybrid striped bass young from zooplankton to artificial diets.

ANTICIPATED BENEFITS

The overall goal of this collaborative project is to enhance hybrid striped bass aquaculture in the North Central Region (NCR). The development of effective procedures to manipulate sexual maturation and induce out-of-season spawning is an important component of optimal broodstock management. The potential benefits of such procedures include: (1) greater predictability of gamete production; (2) reduced incidence of failed spawnings, gamete resorption and subsequent brood fish losses; and (3) the production of fertilized eggs and fry at predetermined times throughout the year. The availability of fertilized eggs outside the normal spawning season would greatly facilitate research on the intensive culture of *Morone* species. On a larger scale, the production of fertilized eggs out-of-season could facilitate a fuller, more efficient use of culture facilities and equipment, and might allow such innovative techniques as double- or triple-cropping of fry in rearing ponds.

The development of intensive larval culture techniques for this species will allow for its full domestication, and will preclude the initial need for outdoor ponds. Because reciprocal cross hybrid striped bass are the same size as white bass at the swim-up stage, the results of this work will be directly applicable to their culture.

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Development of efficient and reliable techniques to store, cryopreserve, and transport gametes (eggs and sperm) would improve breeding and production capabilities for culture technology of hybrid striped bass. Specifically, the development of these techniques would allow: (1) a continuous supply of gametes, (2) year-round production, (3) facilitation of selective breeding, and (4) more efficient use of available gametes. Although such methods need to be perfected for both semen and eggs, it is more likely that studies on semen will result in rapid development of technology for use in the aquaculture industry.

By working closely with a commercial producer in the region, it is hoped to directly transfer the developed semen storage technologies to the private sector, as well as satisfy future research objectives. This work, coupled with the out-of-season spawning work being conducted in our region and elsewhere, should greatly assist commercial producers to economically produce their own seed stock. Commercial producers would only need to maintain female broodstock of one of the species used in the cross. Sperm from the other species could be obtained elsewhere, stored until needed, and then used.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Southern Illinois University-Carbondale (SIU-C) researchers have successfully captured adult white bass, acclimated them to tank culture conditions, and trained them to accept formulated feed. Some fish have been held in captivity for over two years. This level of domestication is not known to have been achieved with white bass in any other laboratory or commercial enterprise.

Considerable numbers of white bass spawns have been accomplished using various hormonal/temperature/photo-period manipulations over the course of this project. Fish have been accelerated to spawn as early as January, and have had their spawning delayed to as late as October. Accordingly, techniques have been developed that allow successful spawning of white bass any season of the year. Moreover, female white bass that successfully spawned in October 1992 were successfully induced to spawn again in April 1993. Thus, it was demonstrated that white bass can be successfully spawned twice in a 7-month period. It was also shown that male white bass held at or above spawning temperatures (15 °C) produced viable sperm for at least two months. Hatching rates have also been improved from 25% to 50% on average. These findings represent major steps toward the development of domesticated white bass broodstocks to be used for hatchery production of hybrid striped bass.

Injection levels of a synthetic luteinizing hormone-releasing hormone analogue (LhRha) and human chorionic gonadotropin (HCG) have been identified that greatly improve upon previous results at SIU-C, and elsewhere, with respect to controlled spawning of white bass. Data indicate that HCG dosages considerably less than that traditionally used to induce final egg maturation are more useful in white bass. In addition to providing guidance for improved spawning performance, these data have positive implications toward eventual regulatory approval of HCG by FDA for spawning *Morone* species.

Past studies at Iowa State University (ISU) and SIU-C have allowed for evaluations of a number of semen extender and cryoprotectant solutions, and freezing and thawing methods. It was found that cryopreserved sperm showed promise for providing a cost-effective method for striped bass culturists to obtain seed stock. Studies at SIU-C with white bass and striped bass males, using best technologies developed jointly by ISU and SIU-C, showed that good fertility can be achieved in white bass eggs using cryopreserved spermatozoa.

Average fertility in several tests using white bass eggs fertilized with cryopreserved white bass sperm ranged from 22 to 48% of fertility with fresh, control semen. However, fertility was highly variable, and considerable motility was lost upon thawing in frozen spermatozoa. Results with frozen striped bass spermatozoa and white bass eggs were better, but were also variable; average fertility for frozen striped bass spermatozoa ranged from 45 to 100% of control values.

Although no new funding was available over the past year, studies were conducted at SIU-C to determine whether increasing the ratio of cryopreserved sperm to eggs would increase fertility and/or decrease variability. Replicate

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batches of eggs from four white bass out-of-season spawns were fertilized at SIU-C with either: (1) fresh white bass spermatozoa, (2) a roughly equivalent number of frozen spermatozoa, (3) twice as many frozen spermatozoa, or (4) three times as many spermatozoa. No benefits were derived from increasing the ratio of frozen sperm to eggs, and the results indicated that fertility remains highly variable with frozen white bass sperm.

Studies were also conducted at ISU using white bass semen collected and cryopreserved at SIU-C to determine the effects of the freeze-thaw process on sperm motility and morphology. This work suggests that improvements in freezing and thawing techniques, rather than developing methods for freeze-storage of larger volumes of semen need to be emphasized.

Studies of sperm morphology at ISU indicated that some cryopreserved seminal samples (about 20% of those evaluated) showed clumping. Samples which exhibited clumping and adhesion showed no motility upon thawing, whereas samples where sperm morphology was normal and no clumping occurred became motile upon thawing. These results could explain much of the variability that has been observed in fertility tests, but it cannot be explained at this time why some samples undergo these adverse changes while others do not.

Studies at ISU also showed that best motility was routinely obtained when samples were activated with water prior to being completely thawed. This agrees with the results of fertility tests conducted at SIU-C; better fertility has routinely been obtained when cryopreserved semen is only partially thawed when combined with eggs.

Researchers at SIU-C found that both hybrid striped bass crosses at a 2-5 g size range readily convert from zooplankton to formulated feed. Over 90% of the fish converted to formulated feed within two days as compared to 70-85% after seven days for largemouth bass which were trained in a "side-by-side" study. A master's thesis is currently being conducted by a SIU-C graduate student to determine the relative age and size in which both hybrid crosses switch from zooplankton to prepared feed. Preliminary results indicate that white bass and reciprocal-cross hybrids are equivalent in this regard and can make the switch between day 21 and 28 after hatch. Original cross hybrids can generally be switched at day 7 after hatch.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

Publications in print:

Kohler, C.C., and R.J. Sheehan. 1991. Hybrid striped bass culture in the North Central Region. Pages 207-209 in Proceedings of North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.

Manuscripts:

Kohler, C.C., R.J. Sheehan, C. Habicht, J.A. Malison, and T.B. Kayes. In review. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society

Woods, L.C., C.C. Kohler, R.J. Sheehan, and C.V. Sullivan. Submitted. Volitional tank spawning of female striped bass with male white bass produces hybrid offspring. Transactions of the American Fisheries Society.

A manuscript describing striped bass semen cryopreservation has been completed for submission to the Journal of the World Aquaculture Society. Another manuscript describing work with white bass cryopreservation is currently in preparation for submission to the same journal.

Papers presented:

Habicht, C., R.J. Sheehan, C.C. Kohler, G.G. Brown, and L. Koutnik. 1991. Routine collection, storage, and shipping of white bass sperm. 29th Annual Meeting Illinois Chapter of the American Fisheries Society, Champaign, Illinois.

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Kohler C.C. 1993. The farm fish of the future: hybrid stripers. AQUA '93: 7th Annual Minnesota Aquaculture Conference. Alexandria, Minnesota, March 5-6, 1993 (Invited paper)

Kohler, C.C., R.J. Sheehan, C. Habicht, J.A. Malison, and T. B. Kayes. 1992. Acclimation to captivity and out-of-season spawning of white bass. Aquaculture '92, 23rd Annual Meeting of the World Aquaculture Society, Orlando, Florida, May 21-25, 1992.

Kohler, C.C., R.J. Sheehan, C. Habicht, V. Sanchez, J.A. Malison, and T.B. Kayes. 1993. Development of white bass broodstock and spawning protocol. U.S. Chapter World Aquaculture Society Annual Meeting. Hilton Head Island, South Carolina, January 1993 (Invited paper)

Koutnik, L.A., R.J. Sheehan, C.C. Kohler, C. Habicht, and G.G. Brown. 1992. Motility and fertility of extended and cryopreserved *Morone* sperm: when is cryopreservation the best option? Annual Meeting, Illinois/Wisconsin Chapters of the American Fisheries Society, Waukegan, Illinois. (Awarded "Best Student Paper")

WORK PLANNED FOR NEXT YEAR

Many of the original objectives in this project have been completed with manuscripts developed for or submitted to appropriate journals. Additional adult white bass will be collected and trained to formulated feeds to meet other objectives. Researchers at SIU-C will continue to send blood samples to UW-Madison to determine spawning condition of fish based on hormone levels.

Also, researchers at SIU-C will be continuing spawning trials to meet objectives for the next phase of the research which is directed at larval rearing of white bass. Refinements in hormonal regimes will be undertaken.

Based on fertility tests with freeze-stored semen, cryopreservation procedures developed by ISU and SIU-C have been fairly successful. Methodologies which have potential under practical fish-culture conditions will be attempted. The goals of future work will be to (1) optimize the use of available gametes by improving fertility, (2) reduce the variability in fertilization rates, and (3) adapt current laboratory procedures to commercial-scale aquaculture. Changes in sperm morphology and sperm adhesion, as well as motility, can now be used to evaluate the effectiveness of changes in cryopreservation procedures.

Findings to date suggest directions for improving techniques and addressing the needs of commercial-scale aquaculture. It has been noted that frozen sperm become motile during thawing, prior to activation. This suggests that thawing rate may be critical, and that achieving uniform thawing rates throughout large cryopreservation containers will be important. Also, duration and intensity of swimming upon activation of the sperm are decreased after thawing, as compared to that of activated fresh semen, and some samples show no motility, sperm adhesion, and changes in semen morphology. This suggests that improvements in semen collection, freezing medium, freeze-temperature regime, or all three are also needed.

To improve laboratory-scale cryopreservation techniques, the following is proposed. Several concentrations of the cryoprotectant with the best cumulative success will be evaluated. In an attempt to reduce premature activation, the use of ice water for thawing will be evaluated. Finally, the use of cryoprotectants for long term storage will be evaluated for long-term storage of semen.

To adapt these procedures to commercial-scale aquaculture, the following will be evaluated: (1) use of larger, 4.5 mL straws to freeze semen; (2) reducing the amount of cryogenic medium used to dilute the semen; and (3) the potential for storing samples on dry ice rather than liquid nitrogen. Storage on dry ice would be much more practical in an industry site.

In the second year of funding for this project, a protocol(s) that appear(s) to be most suitable for practical applications, based on results of work in the first year, will be chosen and refined. These protocol(s) will then be tested under

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practical fish culture conditions by enlisting the cooperation *of* at least one commercial producer in the region. The goal of this second year of work will be to produce an entire crop of hybrid striped bass using cryopreserved sperm.

IMPACTS

Since one of the first steps in establishing a commercial aquaculture enterprise is the domestication of broodstock, it is important to note that wild adult white bass have been acclimated to tank culture conditions and trained to consume formulated feed (some have been held in captivity for over two years). This level of domestication is not known to have been achieved with white bass in any other laboratory or commercial enterprise.

Related to this domestication of broodstock, is the availability of suitable gametes for successful fish reproduction. Since striped bass are typically difficult to obtain, it would be highly advantageous for the aquaculturist to have access to gametes without the difficulty of collecting or transporting the parent fish. The successful induction of white bass spawns and subsequent storage and transportation of *Morone* species gametes should go far in advancing the hybrid striped bass industry in the NCR. These technological advancements, combined with the cooperation of a regional commercial producer, will be transferred to the private sector in the form of fact sheets, videos, and workshops.

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E. Culture Technology of Walleye

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$623,397

WORK GROUP MEMBERS:

Thomas G. Bell	Michigan State University	Michigan
Neil Billington	Southern Illinois University-Carbondale	Illinois
David E. Hinton	University of California-Davis	California
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Robert C. Summerfelt	Iowa State University	Iowa
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois

Extension Liaison:

Joseph E. Morris	Iowa State University	Iowa
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PROJECT OBJECTIVES

The objectives of this project have been to:

- (1) Control and manipulate the reproductive cycle.
- (2) Manage fingerling production ponds.
- (3) Determine the etiology of non-inflation of the gas bladder in indoor intensive culture systems.
- (4) Develop captive, domesticated broodstock.

During this reporting period activities of the Work Group focused on objectives (1) and (4).

ANTICIPATED BENEFITS

The overall goal of this project is to overcome the biological and technological constraints on the development and expansion of a commercial walleye food fish aquaculture industry. Primary constraints in this regard include (1) the lack of procedures for manipulating reproduction and controlling spawning in walleye, (2) the unreliability of pond management and harvesting strategies for fingerling production, (3) non-inflation of the gas bladder in intensively cultured walleye fry, and (4) the lack of captive, domesticated broodstock. Many aspects of the production process need further study to facilitate the development of a commercial aquaculture industry based on sound scientific principles. Work on the reproductive cycle should greatly improve the predictability of walleye egg production, and functionally extend the annual walleye spawning season by several weeks or months. Increased availability of walleye eggs will, in turn, lead to more efficient use of culture facilities, especially fingerling production ponds, and facilitate research and development of intensive walleye fry culture techniques. The ability to predictably produce walleye fingerlings in large quantities in ponds is one of the most important problems in the culture of coolwater fishes. Development of effective and predictable pond culture practices would greatly enhance walleye production. Overcoming the problem of non-inflation of the gas bladder (NGB) will allow for increased production of intensively

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cultured larval walleye. Implementation of rationally designed and long-term selective breeding programs into aquaculture operations is an essential means of improving the performance of cultured organisms. The major benefits of selective breeding to commercial aquaculture operations are improvements in product quality and cost-effectiveness, and increases in harvestable yields and profits.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This report describes the activities of a cooperative regional research project on the culture technology of walleye. The project has been conducted by the investigators and at the institutions listed above, with the assistance of the following public fisheries management agencies: the Iowa, Minnesota, Ohio, and Wisconsin Departments of Natural Resources, the Kansas Department of Fish and Game, the Nebraska Game and Parks Commission, and the U.S. Fish and Wildlife Service.

This report describes the progress of the Work Group from September 1, 1992 to August 31, 1993. Information regarding data collected prior to this time period is noted when such information was not available in previous North Central Regional Aquaculture Center (NCRAC) reports.

Studies on the endocrine and gonadal changes during the annual reproductive cycle of walleye were conducted collaboratively by investigators from Southern Illinois University-Carbondale (SIU-C), the University of Minnesota (UM) and the University of Wisconsin-Madison (UW-Madison). SIU-C and the UM researchers were responsible for collecting blood and tissue samples from pond-held and wild adult walleye, respectively. The UW-Madison researchers were responsible for the analysis of blood and tissue samples and interpretation of endocrinological and histological data. After three years of collection, a large set of samples was obtained that can be used to describe for the first time the natural reproductive cycle of walleye.

No evidence was obtained that indicated holding wild walleye in ponds exerted any negative effects on their reproductive development. Cumulatively, findings suggest that wild male and female walleye are nearing reproductive maturity as early as January, and that successful induction of spawning in walleye from January through April may be accomplished using relatively simple spawning induction techniques.

Studies on the development of methods to manipulate the annual reproductive cycle of walleye and induce out-of-season spawning were conducted collaboratively by investigators from the University of Nebraska-Lincoln (UN-L) and the UW-Madison. Investigators from the UN-L were responsible for collecting wild adult walleye, maintaining captive walleye in culture ponds, and egg fertilization and sampling. Personnel from the UW-Madison were responsible for the injection of steroid hormones, analysis of blood samples and interpretation of endocrinological data.

Over 100 adult walleye were captured in autumn from Nebraska reservoirs and the Mississippi River, and overwintered under ambient environmental conditions in ponds at the Gavins Point National Fish Hatchery, Yankton, South Dakota. In late January, February, and March (approximately 10, 6, and 3 weeks prior to natural spawning), 16-20 female and 4-8 male walleye were removed from the ponds and transferred to indoor tanks, where they were warmed over 5 days to 10 °C and illuminated using a 12-h light/12-h dark photoperiod. Females were individually tagged and randomly subjected to one of four injection regimes. The results from these investigations show that appropriate hormone and environmental treatments can be successfully used to induce spawning in walleye from late January through March, the most effective hormone treatment being human chorionic gonadotropin (HCG).

Recent findings at Iowa State University (ISU) and the Iowa DNR's Rathbun Fish Hatchery demonstrate that gas bladder inflation can be substantially increased by use of a tank design with a circular flow that prevents resuspension of decomposed feed, and equipping tanks with an inexpensive surface spray that clears the surface of oil, bacteria and other debris with each pass of the water under the spray. Gas bladder inflation of fish reared in circular flow tanks with a surface spray is now typically 80 to 100% of the fish harvested.

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Neil Billington of SIU-C directed the genetic analyses that were conducted on four walleye populations (Genoa, Kansas, Ohio, and Spirit Lake). These populations were potential candidates for providing broodstock from which fish could be taken for future selective breeding experiments.

A study involving comparisons of offspring from selected walleye broodstock was carried out by SIU-C and ISU. SIU-C used a tandem pond-tank rearing system and ISU reared walleye from hatch through 21 days exclusively in indoor intensive (tank) culture conditions on formulated feed. In 1992, as in 1991, the Mississippi River stock performed better than the other stocks tested. High mortality of the other stocks occurred in the post-hatching and pond-stocking phase. Premature hatching of eyed-eggs shipped by overnight express service may have negatively influenced the post-stocking survival of fry. Virtually no fish survived from the Ohio and Pennsylvania stocks. There was poor survival (0 and 2%) in the northern Wisconsin stock during the pond rearing phase, and the trainability of these fish was only 0.8%.

Trainability of the Mississippi River stock varied with the initial size of the fish. Lower trainability of the medium-size group may have been due to lack of optimally-sized feed for the initial training process. At the end of the 30-day training period, the lengths and weights of the small-size group exceeded that of the medium-size group.

Researchers from UM and ISU measured genetic parameters used in selecting fry and fingerling traits involving pedigreed families (fish of known parentage). Based on performance and genetic diversity analyses conducted under the previous study, it was determined that the walleye population suited for this study was that of the Mississippi River at Genoa, Wisconsin.

Significant differences were observed among the 12 full-sib family groups in hatchability and incidence of cannibalism. Mean hatchability of the four family groups ranged from 40 to 80%, and incidence of cannibalism ranged from 1 to 2.4% of the initial number stocked. Differences among family groups in gas bladder inflation, survival to 21 days, and length or weight were not statistically different at 21 days. Between 21 and 126 days post-hatch, significant differences in growth rates were found within full-sib families in two of the four half-sib family groups. Growth rates ranged from 1.1 to 1.3 mm/d and from 0.14 to 0.22 mg/d.

USEFULNESS OF FINDINGS

These studies provided the basic knowledge of the reproductive cycle of walleye that was needed to begin efforts at controlling reproduction in walleye. Egg and sperm formation in walleye nears completion as early as mid-winter. Investigators at UW-Madison also succeeded in inducing spawning of walleye two weeks ahead of the normal spawning period using injections of HCG (500 IU/kg) and a synthetic luteinizing hormone-releasing hormone analogue (LhRha) (100 µg/kg).

These studies demonstrated that appropriate hormone and environmental treatments can be successfully used to induce spawning in walleye from late January through March. The most effective hormone in this regard was HCG. These methods can now be used to produce walleye fry for over three months of the year. The availability of walleye fry during this interval should: (1) increase the efficiency of existing intensive fry culture systems (e.g., by allowing double- or triple- cropping of these systems); (2) aid public and private hatcheries in their efforts to produce larger walleyes for stocking; and (3) facilitate research on the intensive culture of walleye fry. Additional benefits of using procedures developed in these studies include greater predictability of gamete production and reduced incidence of failed spawning, gamete resorption and subsequent brood fish losses.

Field studies on clam shrimp ecology, and the effects of clam shrimp on primary production, zooplankton and yield of fingerling walleye were completed in the 1992 culture season at the Garrison Dam National Fish Hatchery (GDNFH). Investigators found that clam shrimp were not observed in the new ponds in the first year of use at a hatchery that had a chronic problem with clam shrimp. The absence of clam shrimp in new ponds suggests that clam shrimp problems may not develop until pond basins develop a large population of resting eggs. To reduce clam shrimp

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problems in the walleye culture season, care should be taken to make sure that the ponds are thoroughly dried before refilling.

The findings of the nature and cause of non-inflation of the gas bladder (NGB) are of major importance to the intensive culture of larval walleye. These findings demonstrate the need for tank design and husbandry techniques that will prevent accumulating debris and bacteria on the surface. Findings at ISU and the Iowa DNR's Rathbun Fish Hatchery demonstrate that gas bladder inflation can be increased to 100% when fish are reared in tanks having both a circular flow that reduces the suspension of decomposed feed, and a vertically directed surface spray that clears the surface of oil, bacteria and other debris with each pass of the water under the spray.

Population genetic data are necessary to recognize and maintain pure strains for aquaculture. In addition, such data provide genetic diversity estimates useful for identifying suitable strains for selective breeding programs. Strains which have little or no genetic variation have little potential for positive gains in commercially important performance traits through selective breeding programs. Thus, when choosing a candidate strain for selective improvement it is important to choose one with high genetic diversity. Such selective breeding programs in Atlantic salmon have achieved responses of 14-30% gain per generation. If gains similar to those achieved in salmon can be realized in walleye this will have a profound beneficial impact on the industry.

The genetic data showed that the Genoa population exhibited a high level of genetic diversity. This diversity, coupled with performance information obtained from other objectives of this project, was used to make the decision that the Genoa population would be used in the NCRAC-funded selective breeding program on walleye that is currently underway. Stock performance evaluations provided important information on the variability of performance traits of selected walleye stocks. Cannibalism in tank-reared walleye was highest in a Minnesota stock and lowest in a semi-domesticated stock from the London, Ohio DNR hatchery. This suggests that cannibalism may be reduced by domestication.

Evaluation of pedigreed families will be used to estimate heritability and other genetic parameters for early life performance traits. In turn, these genetic estimates will guide selective breeding when these families reach sexual maturation. Having these genetic estimates in hand before imposing selection on the adults ensures cost-effective selection and predictable responses (improvements) to selection.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

Publications in print and/or in press:

Billington, N., R.J. Barrette, and P.D.N. Hebert. 1992. Management implications of mitochondrial DNA variation in walleye stocks. *North American Journal of Fisheries Management* 12:276-284.

Bristow, B.T. 1993. Comparison of larval walleye stocks in intensive culture. M.S. thesis. Iowa State University, Ames.

Clouse, C.P. 1991. Evaluation of zooplankton inoculation and organic fertilization for pond-rearing walleye fry to fingerlings. M.S. thesis. Iowa State University, Ames.

Harding, L.M., C.P. Clouse, R.C. Summerfelt, and J.E. Morris. 1992. Pond culture of walleye fingerlings. NCRAC Fact Sheet Series #102, North Central Regional Aquaculture Center Publications Office, Department of Animal Ecology, Iowa State University, Ames.

Luzier, J.M. 1993. The ecology of clam shrimp in fish culture ponds. M.S. thesis. Iowa State University, Ames.

Luzier, J.M., and R.C. Summerfelt. 1993. A review of the ecology and life history of clam shrimp (Order Spinicaudata, Laevicaudata, Formerly Order Conchostraca: Branchiopoda). *Prairie Naturalist* 25:55-64.

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Summerfelt, R.C., C.P. Clouse, and L.M. Harding. 1993. In press. Pond production of fingerling walleye in the northern Great Plains. *Journal of Applied Aquaculture* 2 (3/4).

Manuscripts:

Barry, T.P., A.F. Lapp, L.S. Procarione, and J.A. Malison. Effects of selected hormones on steroid production, final oocyte maturation and ovulation in walleye (*Stizostedion vitreum*). *General and Comparative Endocrinology*.

Billington, N., Banerjee, M., and Jiang, R. Genetic variation in candidate walleye broodstocks for use in aquaculture. *Aquaculture*.

Luzier, J.M., and R.C. Summerfelt. Effects of clam shrimp on production of walleye and northern pike.

Malison, J.A., L.S. Procarione, A.R. Kapuscinski, and T.B. Kayes. Endocrine and gonadal changes during the annual reproductive cycle of walleye (*Stizostedion vitreum*). *General and Comparative Endocrinology*.

Malison, J.A., T.B. Kayes, L.S. Procarione, J. Hansen, and J.A. Held. Induction of out of season spawning in walleye (*Stizostedion vitreum*).

Summerfelt, R.C., C.P. Clouse, and L.M. Harding. Pond production of fingerling walleye in the northern Great Plains.

Papers presented:

Barry, T.P., L.S. Procarione, A.F. Lapp, and J.A. Malison. 1992. Induced final oocyte maturation and spawning in walleye (*Stizostedion vitreum*). Presented at the World Aquaculture Society Annual Meeting, Orlando, FL, May 21-25, 1992. Also presented at the Midwestern Regional Endocrinology Conference, Illinois State University, Normal Illinois, May 15-16, 1992, and the Endocrinology Reproductive Physiology Program Research Symposium, Madison, Wisconsin, September 10, 1992.

Bristow, B., and R.C. Summerfelt. 1993. The timing of critical events in the early development of larval walleye reared on formulated feed. Joint meeting, 31st annual meeting of the Illinois Chapter and 25th annual meeting of the Iowa Chapter of the American Fisheries Society, Bettendorf, Iowa, February 16-18, 1993.

Clouse, C., and R.C. Summerfelt. 1991. Evaluation of zooplankton inoculation and organic fertilization as management strategies for pond-rearing walleye fry to fingerlings. Coolwater Fish Culture Workshop, Springfield, Missouri, January 7-9, 1991.

Kapuscinski, A.R., R.C. Summerfelt, B. Bristow, and M.C. Hove. 1994. Genetic components of early performance traits of intensively cultured walleye. To be presented at the Fifth International Symposium on Genetics in Aquaculture, Halifax, Nova Scotia, June 19-25, 1994.

Malison, J.A., L.S. Procarione, A.R. Kapuscinski, and T.B. Kayes. 1992. Endocrine and gonadal changes during the annual reproductive cycle of walleye (*Stizostedion vitreum*). Presented at the World Aquaculture Society Annual Meeting, Orlando, Florida, May 21-25, 1992. Also presented at the Endocrinology Reproductive Physiology Program Research Symposium, Madison, Wisconsin, September 10, 1992.

Malison, J.A., T.B. Kayes, L.S. Procarione, J.F. Hansen, and J.A. Held. Induction of out-of- season spawning in walleye (*Stizostedion vitreum*). To be presented at the World Aquaculture Society Annual Meeting, New Orleans, Louisiana, January 12-18, 1994.

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Summerfelt, R.C. 1991. Walleye culture research sponsored by the North Central Regional Aquaculture Center (NCRAC). Walleye Technical Committee, North Central Division, American Fisheries Society, Work Group Meeting, Dubuque, Iowa, July 15-17, 1991.

Summerfelt, R.C. 1992. Overview of walleye culture. AQUA '92, 6th Annual Minnesota Aquaculture Conference, Duluth, Minnesota, March 6-7, 1992.

Summerfelt, R.C. 1993. Production of fingerling walleye in drainable ponds. AQUA '93, 7th Annual Minnesota Aquaculture Conference, Alexandria, Minnesota, March 5-6, 1993.

WORK PLANNED FOR NEXT YEAR

Many of the original objectives of this project have been completed and manuscripts have either been submitted or being prepared for submission to suitable scientific journals.

Additional analyses will include re-running the genetic analyses samples extracted from frozen muscle tissue. A final report for the NCRAC and a manuscript for publication in a scientific journal will be prepared once statistical analyses have been completed.

Using data collected in year one, estimates of heritability and related genetic parameters will be calculated for early performance traits. Similar estimates will be determined for sub-adult traits, as data collection on them proceeds. An abstract of the 1993 findings has been prepared for presentation at an international genetics conference and a manuscript is planned.

The genetic selection project will continue by retaining the 12 best full-sib families, based on survival rates and other early performance traits. These families will become the base for a combined selection, to be imposed when fish become sexually mature. Pedigreed families currently at the UM will be split, half will be sent to Aurora Aqua, Inc., a Minnesota-based aquaculture company, and then raised under similar conditions at both facilities to sexual maturity.

IMPACTS

Techniques for controlling reproduction and inducing out-of-season spawning have already been used to provide walleye fry outside of the normal spawning season to ISU, the Iowa DNR, and the U.S. Fish and Wildlife Service Hatchery at Valley City, North Dakota. These fry were used to greatly extend the period of time during which larval walleye could be reared intensively, thereby increasing the efficiency of intensive fry culture systems and facilitating research on the intensive culture of walleye fry. The techniques developed as a result of these studies are also useful for synchronizing spawning in walleye, and may be used by at least one private walleye producer in Wisconsin in 1994 to increase the efficiency and reliability of their walleye propagation efforts.

Studies of clam shrimp ecology and life history are important to understand the reasons for clam shrimp success in fish culture ponds, and provide insight into strategies for control. Clam shrimp survive over winter in dry ponds because they have a "resting" egg that is highly resistant to drying and freezing. To reduce clam shrimp problems in the walleye culture season, care should be taken to make sure that the ponds are thoroughly dried before filling ponds for walleye culture. The degree to which clam shrimp are a nuisance problem in walleye culture varies from year to year and is dependent on a large carryover of juvenile clam shrimp that grow to a size that will clog the screens. Clam shrimp effects on fish production is variable, but when it occurs, it is probably the result of competitive interaction between clam shrimp and zooplankton for algae and particulate organic matter.

A tank culture system was designed for larval walleyes that does not result in major losses from non-inflation of the gas bladder. Such a system allows intensive culture to be used to rear larval walleye in industry and state and federal hatcheries. The Iowa DNR has expanded their experimental tank culture facility to production scale tanks, and they are rapidly moving ahead with using this option as a major production system for fingerling walleye. Overcoming

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the gas bladder problem allows researchers to concentrate experimental efforts on genetic selection, nutrition and other important needs.

The information gathered during this project was used to choose the stock of brood fish which are being used in a genetic selection program. Selection programs in salmonids have improved the performance of desirable traits for aquaculture by as much as 14-30% per generation. However, it is only possible to conduct such a program with maximum efficiency, while minimizing the effects of inbreeding, if good baseline data on genetic variability, such as collected in this study, are available.

Evaluation of pedigreed families has benefited both private and public sectors to date; a genetic selection program for walleye has begun. As a part of this program, plans and a written agreement for future collaboration between UM researchers and Aurora-Aqua, Inc., a Minnesota-based aquaculture company, were completed. Walleye fingerlings reared at ISU were transferred to pond sites in northeast Iowa for use in a USDA-sponsored net-pen research project on walleye that is being conducted by the Resource Conservation and Development for Northeast Iowa, Inc., Postville, Iowa.

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F. Culture of Bluegill and Crappie for Food Fish

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$501,960

WORK GROUP MEMBERS:

Paul B. Brown	Purdue University	Indiana
Donald L. Garling	Michigan State University	Michigan
Michael L. Hooe	Illinois Natural History Survey	Illinois
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Bruce L. Tetzlaff	Southern Illinois University-Carbondale	Illinois
James R. Triplett	Pittsburgh State University	Kansas
David H. Wahl	Illinois Natural History Survey	Illinois
Extension Liaison:		
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin

PROJECT OBJECTIVES

- (1) Determine the mechanisms of sex control in sunfish and to produce and evaluate polyploid sunfish and hybrids.
- (2) Determine optimum stocking densities and relationships between temperature and growth for sunfish, sunfish hybrids, and triploid sunfish.
- (3) Develop low cost, high performance sunfish diets.

ANTICIPATED BENEFITS

The development of a sunfish food fish production industry has been impeded because sexual maturation in sunfish species occurs prior to attainment of market size. This leads to slow and inefficient growth during growout and uncontrolled reproduction in culture ponds. Induced triploidy could greatly enhance development of sunfish food fish production in the North Central Region (NCR). Induced triploidy in other species has resulted in individuals with reduced gonadal development and delayed sexual maturation. If triploid sunfish show similar characteristics, then the problems associated with the onset of sexual maturation before attaining market size will be diminished.

There is little specific information available to culturists regarding successful production techniques. Even basic information, such as how many sunfish to stock in a given culture unit, is lacking. Identification of optimal stocking densities will provide basic information for regional aquaculturists to improve production methods or initiate production trials. Determinations of the temperature range for growth and temperatures where good growth and feed conversion are obtained for sunfish species, hybrids, and triploid sunfish is essential for determining the economics of regional sunfish production and for selecting sunfish suitable for production under the various temperature regimes found in the region.

The work on formulation of feeds that will minimize production costs and maximize performance, will allow sunfish producers in the NCR the same advantages that culturists of other species, such as rainbow trout and channel catfish, in other regions have enjoyed for years.

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PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Despite many desirable attributes, several factors have slowed progress towards widespread commercialization of sunfish for food fish production. Sexual maturation in sunfish species occurs prior to the attainment of market size. This leads to slow and inefficient growth during grow-out and uncontrolled reproduction in culture ponds. In addition little information is available concerning culture techniques of sunfish during grow-out. Feeds specifically designed for sunfish have not been developed, and suitable stocking densities and feeding rates are not known.

The primary goal of this research is to facilitate commercial aquaculture of sunfish within the NCR. The Bluegill and Crappie Work Group consists of an interdisciplinary team of seven scientists from five institutions and four states.

Scientists at Michigan State University (MSU) under the direction of Don Garling conducted experiments to enhance the protocols for producing triploid *Lepomis macrochirus* and to develop the protocols for the production of tetraploid sunfish. Pressure shock experiments concentrated on two intensities, three duration periods and a continuous time block from 20 to 45 minutes after fertilization. Of the pressure treatments completed, none have produced tetraploids. Many of the shock treatments had low survival. Shocks of 7000 psi for 10 minutes had higher survival rates than shocks of higher intensities and durations.

During the previous year, Southern Illinois University-Carbondale (SIU-C) researchers completed tests with 27 different pressure shocks that determined an optimum pressure shock for *Lepomis* hybrids. Several pressure shock treatments yielded 100% triploidy and a number of treatments yielded high survival. Ploidy has now been tested in more than 90 individuals from the 4 min, 7,000 psi shock (initiated 2 min after fertilization); all have proven to be triploids, indicating that a reliable method for obtaining good survival and 100% triploidy has been found. A manuscript based on this work was submitted to the Journal of the World Aquaculture Society during this fiscal year. SIU-C researchers also tested several hydrostatic pressure shocks in attempts to induce triploidy in black crappie x white crappie hybrids. This work was conducted in cooperation with the Illinois Natural History Survey (INHS) researchers, Michael Hooe and David Wahl. John Cassani of the Lee County Hyacinth Control District, Fort Myers, Florida, conducted the flow-cytometric ploidy analysis of the test larvae. Best results for hybrid crappie were obtained with a five-minute shock at 6,000 psi initiated five minutes after fertilization; it yielded 89% triploids. Several of the other shock treatments induced more than 50% triploidy, but SIU-C researchers do not believe that an optimum pressure shock for *Pomoxis* has been identified at this time.

Growth trials at temperatures from 8 to 28 °C in duplicate tanks at 5 °C intervals with three taxa, green sunfish, green sunfish female x bluegill male diploid hybrids, and bluegill female x green sunfish male triploid hybrids, were completed by Robert Sheehan at SIU-C. Survival over the 235-day trial ranged from 93-95% and did not differ (ANOVA, $p > 0.05$) between the taxa.

The results of the SIU-C growth trials were highly encouraging for culturists in the NCR. Growth occurred at all temperatures, and best growth and feed conversion were at 18 °C. All of the *Lepomis* taxa generally produced a pound of flesh for each pound of food fed at all tested temperatures, and only about 1.3 pounds of feed were required to produce a pound of *Lepomis* at 18 °C. This compares very favorably with other cultured species, and feed conversion should improve once diets specifically designed for *Lepomis* are developed.

SIU-C researchers continue to evaluate genetic determination mechanisms in sunfish and methods for production of all female stocks. Slow growth has hampered evaluation of sex in bluegill gynogens produced by the combined techniques of hydrostatic shock on eggs fertilized with irradiated sperm. A small subsample (7) of those that have grown large enough to sex by inspection is encouraging since all were females.

Six repeated attempts to field collect white crappie (3000 - 4000) and acclimatize them to six one cubic meter aquaculture cages, at Pittsburgh State University (PSU), Kansas, have encountered high mortality due to stress and disease when trap netting was employed, despite the use of salt, terramycin and anesthetic in some cases. Electrofishing as an alternative collection method produced too few fish to be practical, even though these fish

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exhibited higher survival. Currently 210 remaining fish have been acclimated to the cages and are being converted to artificial diet.

Hybrid and pure stock crappies were produced by Mike Hooe and David Wall of INHS at the Sam Parr Biological Station during spring 1993 for work at PSU and SIU-C during the next fiscal year. Half-sibling hybrid and white crappies were produced by dividing the eggs from each female white crappie into two groups of approximately equal numbers and fertilizing half with sperm from a white crappie and half with sperm from a black crappie.

Fry were stocked into grow-out ponds at the Sam Parr Biological Station and SIU-C 5 days post-hatching. Fry of each genetic type were stocked in separate 0.4 and 0.13 hectare ponds at the Sam Parr Biological Station and in 0.04 hectare ponds at SIU-C. Stocking rates for all three genetic stocks ranged from 7,500 to 13,870 per hectare. To produce triploid F₁ hybrid crappie, ripe female white crappie and male black crappie were collected and transported to the Sam Parr Biological Station as described previously. Triploid hybrid crappies produced by personnel from SIU-C by pressure shock were incubated at the Sam Parr Biological Station until the fry became free-swimming, at which time they were transferred to ponds at SIU-C.

USEFULNESS OF FINDINGS

Using the optimum pressure shock treatment identified by this project, it is now possible to routinely produce triploid sunfish. Further strategies of tetraploid production will further enhance the reliability of triploid production.

These fish have the advantage of overcoming problems of overpopulation and stunting due to unwanted reproduction. This allows greater control of fish densities in either aquaculture or recreational stocking situations. The sterility of triploids could also be useful in situations where contamination of wild stocks is a concern.

Findings concerning growth in relation to temperature and optimum stocking densities of *Lepomis* sunfish and their hybrids indicate that they are very good candidates for foodfish culture in our region. Best growth and food conversion occur at the relatively low 18 °C water temperature but excellent growth and conversion extend over a broad range of suitable regional temperatures.

Findings concerning crappie, so far, indicate that culturists will have to overcome problems with handling and capture of these fish when habituating them to culture situations. The conversion of a limited number of fish to commercial feed is somewhat encouraging; once initial handling and transport problems are overcome, these species may adapt to aquaculture conditions.

Findings regarding sunfish growth and available commercial feeds indicate that these feeds are adequate, but do need improvement. Additional work is needed to develop low cost high performance sunfish feeds.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

Publications in print:

Montes-Brunner, Y. 1992. Study of the developmental stages of bluegill (*Lepomis macrochirus*) eggs using selected histological techniques. M.S. thesis. Michigan State University, East Lansing.

Tetzlaff, B., and P. Wills. 1991. Current trends in the culture of hybrid sunfish. Pages 214-218 in Proceedings of North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.

Westmas, A.R. 1992. Polyploidy induction in bluegill sunfish (*Lepomis macrochirus*) using cold and pressure shocks. M.S. thesis. Michigan State University, East Lansing.

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Westmaas, A.R., W. Young, and D. Garling. 1991. Induction of polyploids in bluegills and chinook salmon. Pages 110-112 in Proceedings of North Central Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991.

Manuscripts:

Wills, P.S., J.M. Paret, and R.J. Sheehan. Pressure induced triploidy in *Lepomis*. Journal of the World Aquaculture Society.

Papers presented:

Sheehan, R.J., J.M. Paret, P.S. Wills, S.D. Scherck, and J.E. Seeb. 1993. Triploid induction and growth performance of *Lepomis* sunfish parental species, hybrid, and triploid hybrid at five temperatures. Presented at the Prospects for Polyploid Fish in Fisheries Management Symposium, 123rd Annual Meeting of the American Fisheries Society, Portland, Oregon, August 29 - September 2, 1993. (Invited presentation)

Brown, P.B. and K. Wilson. 1994. Experimental and practical diet evaluations with hybrid bluegill. To be presented at the Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-16, 1994.

WORK PLANNED FOR NEXT YEAR

Continued research at MSU will focus on a variety of tasks: (1) out of season spawning will be attempted on fish captured throughout the summer, fall and winter; (2) if spawning is successfully induced, these fish will be used to further define effective treatments; and (3) construction and initial trials of a cold shocking unit will be completed during the summer of 1994.

Research at SIU-C will continue tests to optimize pressure shocks for inducing triploidy in crappie. Temperature shocks will also be tried. Attempts will be made to obtain crappie prior to the spawning season for the INHS fish so that an optimum shock will be available prior to mass production of triploid hybrid crappie.

Fingerlings of black and white crappie and their hybrid obtained from INHS are being prepared at SIU-C for growth studies of these taxa in relation to water temperature. Mortality as of this writing has been substantial (up to 30%) for fingerlings of the parental species since stocking them into tanks, and it has not abated. The mortality appears to be related to stress associated with harvest, hauling, and stocking into tanks, and it parallels the difficulties PSU has had handling these species. In contrast, mortality in the hybrid has been substantially lower thus far.

Although the homogametic sex in bluegills appears to be the female, this may not be the case in other *Lepomis* species. Hybridization between tilapia species such *Oreochromis niloticus* and *O. aureas* has resulted in predominantly male progeny. The female is the homogametic (XX) sex in *O. niloticus*, but the female is heterogametic (WZ) in *O. aureas*. Thus, such differences in genetic sex determination mechanisms between species could also explain why *Lepomis* hybrid progeny are generally males. SIU-C researchers are currently planning to induce gynogenesis in green sunfish to determine whether the WZ system is operative in this species.

In the fall of 1993, a small number of pond-raised black crappie will be obtained by PSU from a private fish farm for a short growing season in the cubic meter cages. During the winter, indoor trials in a closed loop system at PSU will continue to try to answer questions about trainability and growth of crappie in confinement and on artificial diets. Indoor trials will attempt to determine preferred densities for cultured crappie.

The interspecific comparison at PSU will be conducted during the summer of 1994 with stocks specifically bred for this project by INHS. Hybrid and pure stock crappies will be produced again in 1994 by INHS using procedures outlined above.

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In October a feeding study at Purdue University was initiated with juvenile hybrid bluegill. That study is designed to quantify the dietary lysine requirement for this potential new food fish. Using that piece of information and whole-body analysis of hybrid bluegill, the dietary essential amino acid pattern can be accurately predicted. These data will allow for rapid development of diets for this hybrid and facilitate economic viability of sunfish production.

IMPACTS

The work funded by NCRAC on ploidy manipulation and performance of triploids received national exposure when Sheehan and colleagues presented an invited paper in the "Prospects for Polyploid Fish in Fisheries Management" symposium at the 1993 Annual Meeting of the American Fisheries Society in Portland, Oregon.

The SIU-C studies have stimulated producers in the region to consider sunfish foodfish production. One producer in Iowa intends to start raising hybrid sunfish in cages beginning in 1994. Other producers have indicated a great deal of interest in the findings from this Work Group.

Because *Lepomis* species grow across a much broader range of temperatures than channel catfish and rainbow trout, they should grow well during much of the year in the NCR. In contrast, rainbow trout will die in many ponds during the summer in this region while channel catfish require warmer water temperatures for maximum growth than do *Lepomis* species (18 °C versus 25 °C). Thus, sunfish species appear to be excellent candidates for foodfish production in this region; however, continued work is still needed on improving growth rates.

The PSU project has served to substantially increase the awareness and interest of the Kansas commercial fish growers in the NCRAC program. Data on crappie behavior, feeding, trainability, and growth will aid in determination of the suitability of crappie for aquaculture.

Both SIU-C and PSU studies have contributed to the support and training of students in aquaculture. A graduate student and one undergraduate student have been supported at PSU while an additional graduate student and three undergraduate students have benefitted from exposure to this project.

Since feed costs typically comprise 50% of annual variable production costs in most aquaculture operations, development of diets specifically formulated for sunfish should improve economic viability in the NCR. Further, research studies of this nature typically stimulate manufacturing of diets for target species in proximity to production sites.

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G. Culture Technology of Salmonids

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$279,796

WORK GROUP MEMBERS:

Terence P. Barry	University of Wisconsin-Madison	Wisconsin
Paul B. Brown	Purdue University	Indiana
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois

Extension Liaison:

Ronald E. Kinnunen	Michigan State University	Michigan
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PROJECT OBJECTIVES

- (1) Evaluate all-female diploid, all-female triploids, and mixed-sex diploids through sexual maturity and to use broodstock developed in the region to produce all-female diploid and all-female triploid trout populations.
- (2) Develop diets that are less polluting by:
 - a. quantifying absorption of crude protein in rainbow trout fed commonly-available feedstuffs substituted at varying levels in the diet (evaluation of associative effects);
 - b. developing baseline effluent values from several types of salmonid aquaculture facilities located in the region;
 - c. developing and field testing a mass balance method to estimate phosphorus levels from feed sources in hatchery effluents; and
 - d. quantifying phosphorus absorption from common feedstuffs fed to Atlantic salmon.
- (3) Determine the practical limits on rearing density of juvenile rainbow trout by examining the effects of selected high rearing densities on trout stress responses, survival and growth in both experimental tanks and production raceways.

ANTICIPATED BENEFITS

The overall goal of this collaborative project is to enhance salmonid aquaculture in the North Central Region (NCR). The identified objectives are not intimately linked, but are necessary for continued growth and development. Improved feed conversion, less agonistic behavior, and alleviation of the concerns regarding shipment of eggs across state lines may be some of the results of transferring the information necessary to produce triploid and monosex salmonids. Knowledge of the amounts of phosphorus and nitrogen absorbed by salmonids will help reduce the levels of those nutrients in effluents, thereby improving the regulatory atmosphere and possibly reducing feed costs. A better understanding of maximum stocking densities may allow current producers to increase the numbers of fish raised in a given amount of water and will help novice aquaculturists develop realistic business plans.

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PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This project is designed to improve regional competitiveness in salmonid aquaculture through an interdisciplinary research approach. Major initiatives include work on: genetics and development of regional broodstocks; an improved understanding of dietary formulations that will reduce the pollution associated with aquaculture effluents; estimating levels of phosphorus in effluents from different types of hatcheries; and defining the practical limits of loading rate and rearing density for rainbow trout through the evaluation of stress and performance responses.

Work conducted at Southern Illinois University-Carbondale (SIU-C) prior to September 1992 showed that growth and feed conversion did not differ between all-female diploid, all-female triploid, and mixed-sex rainbow trout through 250 d of age. Growth in all three genetic treatments continues to be excellent, and several more months of study will be required before full growth to market size is achieved and the genetic treatment effects can be analyzed.

Researchers at Purdue University (Purdue) have completed the determination of phosphorus absorption from common feedstuffs fed to rainbow trout. Phosphorus (P) absorption values for feedstuffs from animal origin were generally positive and reflected a higher percentage of P in the form of inorganic sources; while the relatively low values for plant feedstuffs indicated the presence of P in the form of phytic acid, which is poorly absorbed by fish. The addition of phytase significantly improved the absorption of P from plant feedstuffs. Also, the combination of plant feedstuffs with menhaden fish meal improved P absorption over either feedstuff alone, indicating positive associative effects.

Diets from Michigan State University (MSU), containing deflourinated rock phosphate (DFP) with and without phytase, contained a basal diet comprised mainly of plant feedstuffs. While the DFP supplemented diet would normally have a high P absorption value, removal of the inorganic DFP and supplementation with phytase resulted in the highest P absorption value.

Researchers at Purdue and MSU have begun work at public fish hatcheries in their respective states, to estimate levels of P in hatchery effluents. Their findings thus far indicate better oxidation of nitrogenous waste products in a partial recirculating situation than in a flow-through system, without excessive increases in nitrite- or nitrate-nitrogen. Estimates of P in effluents from hatchery origin are not yet available, and the possibility of predicting P levels in hatchery effluents from laboratory-based measurements will be evaluated.

Investigators from the University of Wisconsin-Madison (UW-Madison) and the University of Nebraska-Lincoln (UN-L), working to define the practical limits of loading rate and rearing density for rainbow trout, found that significantly elevated rearing densities had a negative effect on growth and feed conversion, independent of water flow. In a detailed laboratory investigation by UW-Madison researchers employing multifactorial experimental procedures, trout raised at a low rearing density exhibited a stronger overall stress response than fish grown at higher densities; and in the size range of fish tested, loading rate had no effect on the stress response.

Because of the importance of key water chemistry parameters to rainbow trout production under practical conditions, UN-L investigators performed an assessment which revealed that at the Calamus State Fish Hatchery in Nebraska, the well-water pH is somewhat lower (7.4 vs. 7.7), the total alkalinity significantly lower (124 vs. 300 mg/L), and the total hardness higher (204 vs. 155 mg/L), than at the UW-Madison wet-laboratory facilities. These data, plus information on past production loading rates and rearing densities employed in raceways at the Calamus hatchery, are being used to conduct experiments that are similar (but simpler in design) to those performed by the UW-Madison, using cylindrical-shaped tanks of approximately the same size and volume.

These comparison UW-Madison and UN-L experiments are being done to evaluate the effects of site and water chemistry differences on the stress and performance responses of rainbow trout to various loading rates and rearing densities. The UN-L experiments are also being used as pilot tests, run in advance of much larger trials to evaluate the effects of various rearing densities in production raceways. In the first year of the project, UN-L investigators also gained familiarity with and began evaluating various organismic indicators of general health and condition - and potentially stress status.

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USEFULNESS OF FINDINGS

Phosphorus and nitrogen containing wastes in effluents from private and government fish production facilities have been identified as sources of pollution in many parts of the world. The P absorption values identified by the Purdue and MSU studies provide the basis for formulating diets on an available P basis - that is, maximizing P absorption, thereby minimizing P in effluents. These P absorption values will be provided to fish feed manufacturers for their use. Improved diets should enhance the regulatory and economic climate for aquaculture, and facilitate expansion of the industry in an environmentally friendly manner. Further, establishment of these baseline dietary values will allow assessment of modified hatchery designs in the future and provide important information for business plans for new operations.

Loading rates of up to 0.75 kg/L per min did not alter the stress or performance responses of rainbow trout grown at the chemistry of the water provided at the UW-Madison wet-laboratory facilities. Under such water chemistry conditions, juvenile trout can be raised at density indices of up to 1.35 (compared to the 0.5 value often recommended) with no adverse effects on survival or incidence of disease. Fish reared at high rearing densities did, however, exhibit reduced growth and feed conversion, even at high water flows. Paradoxically, trout raised at a low density had elevated overall stress responses compared to fish reared at higher densities. Of particular importance, UW-Madison data suggest that water turnover rate through rearing tanks, independent of loading rate, may affect un-ionized ammonia concentration in such a way as to be a critical factor in determining production capacity.

Preliminary indications from UN-L work to date confirm earlier observations that water chemistry is an important factor in determining maximum loading rate, and that rainbow trout cannot be raised at "ultra-high" rearing densities, even when dissolved oxygen rates are adequate and waste metabolites are being removed by high rates of flushing. Combined with the findings of the detailed laboratory experiments conducted at the UW-Madison, these UN-L observations indicate that from the practical perspective, the new technology of pure oxygen supplementation cannot be used to produce trout at rearing densities above certain limits, which at present are not known. Further research is underway, and more will probably be needed in the future, to determine exactly what the rearing density limits of rainbow trout are in different types of culture systems and under different practical rearing conditions.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

Publications in print:

Riche, M. 1993. Phosphorus absorption coefficients for rainbow trout (*Oncorhynchus mykiss*) fed commercial sources of protein. M.S. thesis. Purdue University, West Lafayette, Indiana.

Manuscripts:

Barry, T.P., T.B. Kayes, T.E. Kuczynski, A.F. Lapp, L.S. Procarione, and J.A. Malison. Effects of high rearing density and low-level gas supersaturation on the growth and stress responses of rainbow and lake trout. Transactions of the American Fisheries Society.

Cain, K.D., and D.L. Garling. Pretreatment of salmonid diets with phytase to reduce phosphorus concentrations in hatchery effluents. Progressive Fish-Culturist.

Papers presented:

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Barry, T.P., T.B. Kayes, T.E. Kuczynski, A.F. Lapp, L.S. Procarione, and J.A. Malison. 1993. Effects of high rearing density and low-level gas supersaturation on the growth and stress responses of lake trout (*Salvelinus namaycush*). 123rd Annual Meeting of the American Fisheries Society, Portland, Oregon, August 28 - September 3, 1993.

Riche, M., and P.B. Brown. 1993. Apparent phosphorus absorption coefficients for rainbow trout fed common feedstuffs. 24th Annual Meeting of the World Aquaculture Society, Torremolinos, Spain, May 26-28, 1993.

WORK PLANNED FOR NEXT YEAR

Researchers at Purdue will complete their studies on nutrient absorption in rainbow trout and Atlantic salmon in 1993-94, and will continue monitoring the two hatcheries in Indiana. Additional Atlantic salmon eggs will be obtained from New York for broodstock development at Purdue in each of the next 3-5 years. Collaborators at MSU will complete the collection of the biological samples and analyses necessary to perfect a mass balance equation for salmonids. The collaborating Purdue and MSU groups will also collect profiles of hatchery effluents over time and under known loading rates.

In the autumn of 1993, UW-Madison investigators will conduct an experiment designed to elucidate the reason(s) for the surprising observation that rainbow trout raised at a low density had greater measured stress responses than trout reared at higher densities. A second experiment will examine the time course of changes in measured stress responses after introducing trout to chronic high density rearing conditions. Subsequent long-term experiments will be conducted to more tightly define the interrelationships between rearing density, loading rate and turnover rate, and their effects on the performance and stress responses of trout.

In the second year of the project, UN-L investigators will complete the small pilot-scale tests to evaluate the effects of water chemistry differences between sites on the loading rate and rearing density findings generated by the earlier UW-Madison experiments. Following that, one or more full-scale raceway trials will be conducted at the Calamus hatchery in Nebraska to examine the effects of a minimum of two different rearing densities on the stress and performance responses of rainbow trout. The number of trials run and rearing densities examined will depend on time and the availability of fish and other resources. Throughout this second year, considerable emphasis will be placed on evaluating organismic indicators of general health and condition, and correlating these indicators with the general physiological stress response, particularly following a standardized acute stress challenge (as described in the original proposal).

IMPACTS

Studies conducted at SIU-C have been done in association with regional producers of trout and salmon since the inception of the salmonid project. Those studies have demonstrated the technology of genetic manipulations to practicing fish culturists, and have placed the fish necessary to produce improved lines of progeny in the hands of regional producers. Two graduate students have been trained with funds provided by the project, and collaborative relationships with colleagues in Alaska have been developed.

The initial salmonid project of the North Central Regional Aquaculture Center (NCRAC) was instrumental in Purdue and MSU collaborators obtaining an additional grant of \$30,000 from ALKO, Ltd., Finland, for the evaluation of phytase in diets fed to trout. Additional grants in the amount of \$28,000 have been acquired by Purdue collaborators to conduct studies on the use of plant feedstuffs in diets fed to trout and salmon (from Central Soya and Monsanto). Both Purdue and MSU have used NCRAC funds to train one M.S.-level graduate student each, as well as four undergraduate students who helped with the various aspects of the initial project. Additional graduate students are being trained as part of the ongoing project. Two new producers of trout and salmon will attempt winter culture in Indiana this year.

Studies conducted at the UW-Madison will have commercial applications during and after the second year of the project. Funding by NCRAC has also allowed UW-Madison to expand work on an ongoing University of Wisconsin

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Sea Grant project studying stress physiology in trout (\$142,730). The NCRAC project is providing funds to train one graduate student, who is a Fulbright Scholar, and one undergraduate student.

The UN-L component of the project has provided for the training of one technician and one M.S.-level graduate student in the procedures needed to measure physiological stress indicators in rainbow trout (e.g., blood serum osmolarity and glucose and chloride titers), and in the use of organismic indicators to assess general health and condition. By the end of the second year of the project, the State Hatchery Biologist and the principal salmonid culturist at the Calamus hatchery will also be proficient in these techniques, and fairly close estimates of the maximum rearing density at which rainbow trout can be produced in raceways under water chemistry conditions similar to those at the Calamus hatchery should be available.

Once available, this information can be extended to the private sector. Nebraska's three largest commercial salmonid producers are continuing to expand, and two have their own processing plants - one of which was added in the past year and accepts fish from other trout producers. Many of these producers have water sources with a chemistry similar to that of the Calamus hatchery and should be able to benefit directly from the finding generated there.

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H. Culture of Crayfish in the North Central Region

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$50,000

WORK GROUP MEMBERS:

Paul B. Brown	Purdue University	Indiana
Harold E. Klaassen	Kansas State University	Kansas
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois

Extension Liaison:

Jeffrey L. Gunderson	University of Minnesota	Minnesota
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NON-FUNDED COLLABORATORS:

Robert Wilkinson	Southwest Missouri State University	Missouri
Carl Richards	University of Minnesota	Minnesota

PROJECT OBJECTIVES

- (1) Complete a study of the status of the crayfish industry in the north central states, relative to its extent, culture operations in use, market characteristics, and problems which need to be addressed by research.
- (2) Complete a report on indigenous crayfish species appropriate for culture in the North Central Region (NCR), to include species life histories, ranges of distribution, economic assessment of appropriate culture production systems, a bibliography of pertinent literature, and a summary of critical information gaps.
- (3) Conduct preliminary trials evaluating the performance of several promising indigenous species in pond culture.

ANTICIPATED BENEFITS

Results of this cooperative project will serve as an important initial step in exploring the feasibility of crayfish aquaculture in the NCR. Work has been designed to collate existing information on species and culture practices in use in the region that will help new aquaculturists and identify future research needs. In addition to the potential of producing crayfish for the human food market, there is considerable potential for producing crayfish for the bait market in the midwest. The survey of current producers should provide some quantification of the baitfish segment of the crayfish industry and current methods in practice. Results from the performance trials will: (1) simultaneously compare potential species in the same culture situation; (2) continue the investigation of farm-pond culture of *Orconectes nais*; and, (3) continue the evaluation of polyculture of selected species. Extension publications resulting from the first two objectives will be made available and fill an important gap in the ability to respond to queries from potential crayfish aquaculturists. Additionally, results from the performance trials will help define optimal culture conditions and species for the region.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This project utilizes an interdisciplinary team of scientists from five states that have been involved in research or extension activities with crayfish. Three institutions: Purdue University (Purdue), Kansas State University (KSU),

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and Southern Illinois University-Carbondale (SIU-C) receive funding to carry out the identified Work Group objectives. Two other institutions (Southwest Missouri State University and the University of Minnesota) are non-funded collaborators.

The survey of existing crayfish producers was developed with input from all the collaborators and the Extension liaison. The survey was mailed to 73 producers in the region from Purdue. It included a self-addressed, stamped return envelope. Non-respondents will be sent a follow-up survey. Survey results will be compiled by the Extension liaison. The primary accomplishment to date was just getting names and addresses of current producers. This proved difficult in some states where crayfish producers are not licensed or well known.

Progress on the descriptive analysis of the regions indigenous crayfish species is being made. Each member of the Work Group has been assigned one to three species for summarization of existing information and for analysis of the potential for aquaculture. A bibliography of pertinent information is also being developed and, together with the survey results, will be used to summarize information gaps and research needs related to commercial crayfish aquaculture.

Significant progress relative to performance trials of selected species has been made, but as of this writing (October) much of the 1993 growing season production either remains unharvested or has not yet been analyzed. A clearer picture of the progress made toward fulfilling the goal of this project will be available shortly. The following is a brief summary of the progress to date at each of the three institutions funded to study crayfish culture.

At SIU-C, eight 0.6 hectare ponds were stocked with an average of 8,340 young of the year crayfish (139,000 per hectare). Although three species of crayfish were to be stocked in the ponds, horizontal starch gel electrophoresis tests indicated that only *Orconectes immunis* and *O. virilis* were stocked. They were stocked at a ratio of seven to one, respectively. *Procambarus acutus* was not cultured during the 1993 growing season. Four of the eight ponds were aerated to examine the effects of aeration on growth, yield and survival. All crayfish ponds received 25 kg/ha of sinking catfish food (32% protein) four times per week beginning July 6.

As of this writing, data from six of the eight SIU-C ponds have been collected (three aerated and three non-aerated). There was little thermal stratification in any of the ponds from July to September. Although dissolved oxygen (DO) levels were similar between aerated and non-aerated ponds at the surface, DO was generally 1.5 mg/L lower in midwater and bottom samples in the non-aerated ponds. DO declined to marginal levels (1 mg/L) at the bottom in non-aerated ponds at times. Since crayfish are generally restricted to bottom areas of the pond, aeration appeared to be beneficial in these ponds receiving prepared feed. Growth and yield were greater in aerated than in non-aerated ponds. Survival, however, was not significantly different. *O. immunis* and *O. virilis* averaged 13.4 and 13.5 g, respectively, in aerated ponds at harvest but only 10.3 and 8.2 g, respectively, in non-aerated ponds. Average yield of crayfish was 284 kg/ha (range 195 - 324) in aerated ponds and 217 kg/ha (range 176 - 272) in non-aerated ponds. Survival rate for *O. virilis* and *O. immunis* averaged 23% and 12%, respectively.

At KSU, three ponds were prepared for the 1993 growing season. Due to cold and wet weather, only one of the three ponds was poisoned to remove existing crayfish. Crayfish in the other two ponds were, however, intensively trapped and seined prior to the study. Intensive trapping in one of the latter ponds indicated that 90+% of crayfish adults can be removed in spring with 10 trappings. After detoxification, the poisoned pond was stocked with young of the year crayfish at a rate of 3/m². Stocking in the other two ponds proceeded with their existing populations reduced by trapping and seining. By the end of August, average carapace length of crayfish in the pond that had been poisoned and then restocked was 35.6 mm, while in the other two ponds the average carapace length were 21.2 mm and 22.6 mm. End of the season data was not available, as of this writing.

Research at Purdue focused on comparison of growth, yield, and survival of four crayfish species cultured in small pools during the 1993 growing season. Young of the year *O. virilis*, *O. rusticus*, two distinct groups of *O. immunis*, and *P. acutus* were collected in Indiana in the spring and stocked in the pools at densities of 3/m². Crayfish had not been harvested from the pools as of this writing.

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USEFULNESS OF FINDINGS

Preliminary results indicate useful findings in four areas; culture potential, aeration, harvest, and pond stocking. Because many of the research ponds and pools were not harvested as of this writing, the results reported here are incomplete and preliminary.

Culture Potential. Young of the year crayfish of two native species (*O. immunis* and *O. virilis*) at SIU-C reached harvestable size and produced yields that show promise for commercial application. It is anticipated that production can be increased above the average 284 kg/Ha with increased stocking density that will likely occur from natural reproduction during the 1994 growing season.

Aeration. Aeration appeared to be beneficial in study ponds at SIU-C. Growth and yield were better in aerated ponds, and dissolved oxygen depletions in bottom waters (where crayfish generally reside) only occurred in non-aerated ponds.

Harvest. Results of trapping efforts during preparation for the KSU study demonstrated that *O. nias* can be effectively trapped out of a pond in less than two weeks during the spring. This high rate of trapability indicates suitability for commercial harvest and offers pond management options that may increase growth, yield, or survival of young of the year crayfish.

Pond Stocking. It was demonstrated at all locations that young of the year crayfish can be successfully harvested, transported and stocked into ponds. This offers potentially important pond management options that may have commercial application.

WORK PLANNED FOR NEXT YEAR

The survey of producers will be completed and summarized in a report or fact sheet. The report evaluating the culture potential of NCR indigenous crayfish species will also be completed; it will include information regarding life history, distribution, economic assessment of culture systems and a bibliography of pertinent literature. In addition, data from the first production year for several promising indigenous species will be analyzed and compiled.

During the 1994 production season, two crayfish production systems will be evaluated at the SIU-C facility using the same three species targeted for 1993. The first system will use artificial destratification/aeration, use of prepared feeds, perpetually filled ponds, and seining as the harvest method. The second system will use a fall-winter drawdown with winter cover crop establishment, spring flood-up, and harvest by baited traps. Broodstock of two of the three species has been established in the ponds, but supplemental stocking will also be employed to ensure appropriate culture densities for all species.

At KSU, researchers will continue to collect crayfish (*O. nias*) growth data and water quality parameters into the fall of 1993 and spring 1994. Mark and recapture population estimates will be made in fall 1993. During the following May to June period, ponds will be intensively trapped to evaluate winter survival and trapping effectiveness. Ponds will then be poisoned to remove all crayfish and restocked with young of the year crayfish. Growth, yield and water quality data will be collected during the 1994 growing season.

Research pools at Purdue will be harvested to analyze growth, yield, and survival of four species (including two stains of *O. immunis*) cultured during the 1993 growing season. During the 1994 growing season, *O. longidigitus*, *O. propinquus*, and *O. gracilis* will be cultured in the experimental pools. One or two species from the 1993 growing season will be cultured again to serve as a comparison between years and between species.

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IMPACTS

The impacts of this study thus far have been the financial assistance and aquaculture related educational experiences for two undergraduate students at KSU, SIU-C and Purdue. Additionally, grants from the state of Indiana through the Purdue University New Crops Center (\$42,000) were acquired that will allow further evaluation of feeding strategies and appropriate feeds for native species of crayfish.

North Central Regional Aquaculture Center

I. Status of the Bait Industry in the North Central Region

for the period
September 1, 1992 to August 31, 1993

TOTAL FUNDS COMMITTED: \$62,000

WORK GROUP MEMBERS:

Fred Copes	University of Wisconsin-Stevens Point	Wisconsin
Daniel W. Coble	University of Wisconsin-Stevens Point	Wisconsin
Leroy J. Hushak	Ohio State University	Ohio

Extension Liaison:

Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
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NON-FUNDED COLLABORATORS:

Charles Berry, Jr	South Dakota Coop. Fishery & Wildlife Unit	South Dakota
Carl Gollon	Gollon Brothers Fish Farm	Wisconsin
Dirk Peterson	Minnesota Department of Natural Resources	Minnesota
Charles Rabeni	Missouri Cooperative Fishery & Wildlife Unit	Missouri

PROJECT OBJECTIVES

- (1) Conduct a comprehensive survey of the status of the bait fish industry in selected North Central states to determine: a. species used; b. sizes of species marketed; c. sources of species; d. seasonal availability; e. shortfalls in supplies; f. relative value of various fish and nonfish species; and g. common problems of the industry that may need to be addressed by research.
- (2) Estimate the costs of culturing bait species commonly used in the North Central Region (NCR) in selected types of production facilities, e.g., extensive and intensive pond culture, tanks, raceways.
- (3) Estimate the economic contribution (output, employment, income) generated by the bait industry to selected state economies.
- (4) Assemble a list of rules and regulations for each state affecting the bait fish culture industry.
- (5) As time permits, summarize biological life cycle information for several underused or unused species that have culture potential and which may match needs of the regional industry.

ANTICIPATED BENEFITS

The survey will provide the groundwork for future decisions on investments and study of the bait industry in the NCR by describing the industry's structure and how it functions, estimating its economic value, and identifying important problems. The information obtained will be communicated through technical/scientific publications, presentations at industry and professional meetings as appropriate, and extension education communications as determined by the Extension Liaison.

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PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

The primary goal of the first year of research was to conduct a survey of the bait industry in six NCR states: Illinois, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin. The survey was done by mail and personal interviews of bait retailers, wholesalers, and producers. Lists of these groups in the selected states were obtained from state licensing agencies, fisheries management agencies, and cooperators. Fish producer associations were also contacted and informal talks given to explain the survey and seek their cooperation.

Survey forms were mailed to a random sample of live bait retailers and all identified live bait wholesalers and producers in the six states. Two forms were used, one for retailers and one for wholesalers and producers. The survey was designed to determine the volume, prices, and sizes of bait species marketed; the importance of wild versus farm raised bait fish; seasonal availability and shortfalls in supplies; the relative value of various fish and non-fish species; bait fish mortality; and problems in the industry. Of the 420 retailer surveys mailed, 40% have been returned, with 34% usable. Of 482 wholesaler/producer surveys mailed, 44% have been returned, with 23% usable. Data from the retailer survey have been entered into a computer database. Data from the wholesaler/producer survey are currently being entered into a database.

In June, July, and August of 1993, members of the Work Group traveled across the six states to interview 21 wholesalers selected from those who had returned their surveys. The purpose of the interviews was to obtain additional information on species and sizes sold, and retail and wholesale bait values. Interview arrangements were made only if they agreed to participate. Attempts were not made to contact retailers who returned survey forms; however, random stops were made for additional information at retailers while traveling through the six states.

Preliminary survey results indicate that in 1992, the fathead minnow (*Pimephales promelas*), was the bait fish most important to retail sales in the six states evaluated with 12,130 gallons¹ reported sold. Lake shiners (*Notropis atherinoides*, *N. hudsonius*, and *N. ludibundus*), followed with 3,497 gallons, white suckers (*Catostomus commersoni*), with 3,258 gallons, golden shiner (*Notemigonus crysoleucas*), with 1,622 gallons, and chubs (*Nocomis biguttatus* and *Semotilus atromaculatus*), with 1,003 gallons reported sold. Night crawlers were the non-fish bait most important to retail sales with 8 million reported sold, followed by grubs (waxworms, spikes, mousies, eurolarvae) with 3.4 million and leeches with 2.3 million reported sold. Retail price ranges and average price per dozen, according to bait fish size categories, have been summarized for the eight most commonly sold species.

A list of bait producers responding to the mail survey was sent to Leroy Hushak at Ohio State University. Hushak will use the list to gather information on the cost of culturing bait species in the NCR.

Agencies in all 12 NCR states were contacted; agency personnel, in turn, submitted copies of their regulations affecting the live bait industry. Information concerning licenses and fees required, legal and illegal species, permissible waters and methods of capture, state import and export laws, inspection/certification programs, and reporting requirements was collected by the Work Group.

A few bait fish species have been selected for biological investigation to determine their culture potential in the NCR. The hornyhead chub (*Nocomis biguttatus*), emerald shiner (*Notropis atherinoides*), river shiner (*Notropis blennius*), and spottail shiner (*Notropis hudsonius*) have been selected because they are important wild-harvested bait fish. The longnose sucker (*Catostomus catostomus*), spotfin shiner (*Cyprinella spiloptera*), and pearl dace (*Margariscus margarita*) have been selected because their physical characteristics are similar to important wild-harvested species.

¹Typically metric units are reported but bait is sold by the gallon; 1 U.S. gallon (liquid) = 3.785 liters.

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USEFULNESS OF FINDINGS

Bait fish and non-fish live bait sales volumes and prices provide an estimate of the economic contribution of the bait industry to the NCR. Governmental officials and agencies, as well as private sector entrepreneurs, can make sound decisions from this specific data, which was previously unavailable.

Our survey results provide vital information for future investments in bait fish aquaculture. By knowing wholesale and retail bait prices, which species and sizes generate the most sales, and when shortages occur, aquaculturists can focus on filling the supply gaps. Underused or unused minnow species with culture potential may also meet bait industry needs in times of shortages.

Important wild-harvest information for fisheries resource management agencies was collected (seasonal demand, river, lake, or stream sources, restrictions, etc.). Their stewardship activities to protect, enhance, and insure the wise use of natural resources could benefit from this data. Summaries of the survey results will be sent to all participants.

WORK PLANNED FOR NEXT YEAR

During the second year of this two year project, using the species and volume data on the surveys, the relative importance of wild versus farm raised bait will be determined. The months of specific shortages in supply will also be further defined. Also, survey results will identify other industry problems such as: access to wild-harvest areas, holding mortality, diseases, and concerns about state agency policies.

Leroy Hushak will estimate the costs of culturing common bait species in the region. Selected types of production facilities, such as extensive and intensive pond culture, tanks, and raceways, will be examined. Current and new aquaculturists may then project annual operating expenditures based on the volumes they produce. Income and employment generated by the bait industry in this region will also be estimated.

A publication summarizing the rules and regulations affecting the bait industry across the NCR would be beneficial to all involved. Bait dealers indicated that such a publication would enable them to operate more efficiently and with less anxiety.

As time permits, life cycle information on certain bait fish species will be summarized. Underused and/or unused species may offer additional aquaculture opportunities.

IMPACTS

At this time, three new commercial operations are being planned due to some of the information generated by this North Central Regional Aquaculture Center funded activity. Two commercial operations, already in existence, have shown an interest to expand by raising some of the species listed in this study.

A portion of the bait fish budget has been used to provide a graduate research assistantship at the University of Wisconsin-Stevens Point and has generated support for an undergraduate student. The undergraduate is funded through a biology coop-student program for 2.5 semesters.

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J. Characterization of Aquaculture Effluents from Four Types of Production Systems

For the period
September 1, 1992 through August 31, 1993

TOTAL FUNDS COMMITTED: \$153,300

WORK GROUP MEMBERS

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James M. Ebeling	Ohio State University	Ohio
Konrad Dabrowski	Ohio State University	Ohio
Reginald D. Henry	Illinois State University	Illinois
Kyle D. Hoagland	University of Nebraska-Lincoln	Nebraska
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Joseph E. Morris	Iowa State University	Iowa
Ronald R. Rosati	Illinois State University	Illinois

Extension Liaison:

LaDon Swann	Purdue University	Indiana
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NON-FUNDED COLLABORATORS:

John Hyink and John Wolf	Glacier Springs Trout Hatchery/Alpine Farms	Wisconsin
Myron Kloubec	Kloubec's Fish Farm	Iowa
Iowa DNR	Rathbun and Fairport State Fish Hatcheries	Iowa
Dave Smith	Freshwater Farms of Ohio, Inc.	Ohio
Michael Wyatt	Sandhills Aquafarms	Nebraska

PROJECT OBJECTIVES

- (1) Characterize aquaculture effluents from four type of aquaculture production systems: pond culture; flow through culture (raceway); cage culture, and; recirculating systems.
- (2) Generate a data base from these four types of production systems, to help promote a reasonable choice of effluent discharge regulations by government agencies.

ANTICIPATED BENEFITS

The proposed work will clarify the nature of aquacultural effluents and its potential impact on receiving waters, and help answer questions as to whether aquacultural wastes are uniquely different or essentially similar to municipal or agricultural wastes generated by terrestrial animals.

Also, this work will provide a more accurate and complete data base on the variety, quality and scale of wastes produced by the diverse aquaculture production strategies examined. Problematic aspects of the various production techniques will be identified. Through understanding of the relationships of species cultured and production practices to the amount and type of effluent produced, aquaculturists will know what approaches can reasonably be used to control effluent. Further research could then be more effectively aimed at solving the identified problem areas, benefiting the advancement of design solutions to the reduction of aquaculture waste loads.

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Armed with this information aquaculturists and regional aquaculture federations will be able to take a proactive stance in formulating realistic effluent standards with environmental regulatory agencies. Without this type of information regulators have little choice other than relying on established information which may not be representative of the actual aquaculture situation. The ability to take such a stance could improve the public perception of aquaculture that is now viewed somewhat suspiciously as potential source of water quality degradation. This will assist the protection of the quality of water resources to the benefit of all users public and private including aquaculturists who will require abundance sources of high quality water to develop and operate their production systems.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This report describes activities of a cooperative regional research project characterizing effluents from four types of production systems, which are representative of those in use in the North Central Region (NCR). Pond production system effluents are being examined by Iowa State University (ISU). Flow-through production system effluents are being examined by the University of Nebraska-Lincoln (UN-L) and the University of Wisconsin-Milwaukee (UW-Milwaukee). Cage culture system effluents are being examined by Ohio State University (OSU) and recirculating system effluents are being examined by Illinois State University (ILSU). These commercial production systems are either made available to the Work Group investigators through the cooperation of private aquaculturists or are large scale demonstration projects.

This North Central Regional Aquaculture Center (NCRAC) project is in support of a broader based interregional initiative to answer the need for a proactive stance concerning effluent regulations, by providing realistic information on actual aquaculture effluents rather than generalizing from information on other domestic and agricultural waste discharges.

Pond Production Systems

Personnel from ISU are currently investigating aquaculture effluents associated with two state fish hatcheries (Rathbun and Fairport) and one private hatchery (Kloubec's Fish Farm) in Iowa. During Fall 1992, an analytical lab was developed on the ISU campus to do the chemical analyses for this project. Since the work in Iowa entails warmwater fishes, field work did not begin until Spring 1993. At all stations, a duplicate water sample at one site was randomly chosen for each date to provide an estimation of sampling error.

Rathbun Hatchery

This intensively managed hatchery was dedicated in 1977 and is located in south central Iowa. Its water supply is from the Rathbun Reservoir. This hatchery employs a flow-through system and has an annual production of 68,000 kg of fish such as channel catfish (*Ictalurus punctatus*), walleye (*Stizostedion vitreum*) and largemouth bass (*Micropterus salmoides*). Effluents from the hatchery and outside ponds first pass through a 2-stage lagoon system and then into the Chariton River via a drainage canal. This river is classified as a significant warmwater stream capable of supporting a variety of fish and aquatic communities.

Six sampling sites were established at this hatchery: (1) at the entrance of the reservoir water into the hatchery, (2) at the point where effluent water is leaving the 2-stage lagoon into the drainage canal, (3) at the point where effluent water is leaving the drainage canal and entering the Chariton River, (4) 0.25 km above the hatchery outflow on the Chariton River, while (5) and (6) are located 0.25 and 0.5 km, respectively, downstream from the outflow. From May to October 1993, bimonthly samples were obtained; monthly samples will be taken November 1993 to December 1993.

Fairport Hatchery

This hatchery is a warmwater, extensively managed state hatchery located along the Mississippi River. Fairport was a federal hatchery until it was given to the state of Iowa 1973. Three ponds have been selected for this study. All three ponds are currently stocked with young-of-year channel catfish.

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Kloubec's Fish Farm

Myron Kloubec has the largest private fish farm in the state of Iowa and is located in east central part of the state. The earthen ponds empty into one another and ultimately into the Iowa River. Water sources are wells and surface runoff.

This private operation has approximately 32-ha of production waters that range in size from 0.04 to 0.81-ha. Six ponds have been selected for study. Three ponds are used for channel catfish culture and three ponds for hybrid sunfish culture (*Lepomis macrochirus* x *L. canales*).

Flow Through Systems

UN-L/Sandhills Aquafarms

The goal of the UN-L research has been to monitor key water quality parameters above and below Sandhills Aquafarms, a modern trout production facility on Whitetail Creek in western Nebraska. Whitetail Creek is a spring-fed, first order stream with relatively constant flow and good water quality. Sandhills Aquafarms consists of twelve 2.44 × 33.5 m (8' × 110') raceways, with total flows of 23.5 m³/min. (6,200 gpm) and annual production rates of rainbow trout of 77,100 kg/yr (170,000 lbs/yr). Four sites were established above the facility and four below, to obtain reliable, representative physicochemical measurements and water samples for laboratory analyses. The following parameters were measured monthly (or in some instances bimonthly) from November 1992 to May 1993, then biweekly from June 1993 to present: temperature, dissolved oxygen (DO), pH, turbidity, total suspended solids (TSS), biochemical oxygen demand (BOD), total nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, total phosphorus, and dissolved reactive phosphorus.

UW-Milwaukee/Glacier Springs Hatchery Renovation

Personnel from the UW-Milwaukee Aquaculture Institute are conducting a before and after investigation of flow through system effluents associated with the renovation of an abandoned fish hatchery, formerly Glacier Springs Hatchery at Lyndon, Sheboygan County, Wisconsin. This site consists of small flow through ponds and earthen raceways, supplied by groundwater springs. Commercial fish production at this site will not commence until debris and sediment can be removed from the ponds. However, currently there are populations of feral fish in these ponds, but no supplemental feeding is done. Renovation of the ponds will start at the source ponds at the head of the "A" and "B" chains of ponds and progress to ponds further down stream. Removal of debris and sediment from the upper ponds is anticipated to occur through Fall 1993.

From September 1992 through August 1993, sampling at this site has concentrated on establishing a before-renovation characterization of the water quality. Eight sampling stations were established including: the two major springwater source ponds, intermediate effluents along the two major pond chains, a station containing the combined effluent of all the ponds intended for redevelopment, and sites on the receiving water (Mill Creek) above and below the combined discharge.

Seasonal variation in temperature, and dissolved oxygen have indicated that the presence of ice cover and groundwater flow in the upper ponds may depress oxygen content during the winter months. The temperature of the effluent water from the small headwater source ponds is influenced by the incoming groundwater flow, while the larger downstream ponds are more influenced by seasonal environmental conditions and are more variable than those of Mill Creek.

UW-Milwaukee/Alpine Farms Whitefish and Yellow Perch Effluents

The second site, Alpine Farms, involves the characterization of the effluent associated with the flow through tank production of yellow perch (*Perca flavescens*) and lake whitefish (*Coregonus clupeaformis*). The water supply and effluent from duplicate flow-through tanks of lake whitefish and duplicate tanks of yellow perch were sampled from December 1992 through August 1993. Water temperature, flow, DO, pH, specific conductance, TSS, total dried residue, settleable solids, BOD, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphorus, and dissolved reactive phosphorus have been determined.

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Cage Culture

Freshwater Farms of Ohio

Personnel from OSU are investigating effluents from Freshwater Farm's cage culture operation, located in Urbana, Ohio. Ten sampling stations were established. These sites included the inflow point of spring water, two depths at the cage site, the discharge into a small receiving pond, the discharge into the receiving stream and locations upstream and downstream. Dissolved oxygen and temperature were measured in situ at the time of sampling. Samples for other parameters were stored in the dark on ice and returned to OSU's Piketon Research facility for analysis. Sampling was done predominantly between March and early June 1993, corresponding to the time of maximum feeding of the rainbow trout. In addition, a water quality system was installed in late March to monitor temperature, DO, and pH at several depths beneath the cage operation.

Recycle Systems

ILSU Recirculating system

Wastewater has been collected daily since early September 1992 from a recirculating aquaculture system located on the campus of ILSU. The system consists of a 18,500 liter (5,000 gallon) fiberglass raceway and a vertical screen biofilter and particle filter stocked with an all-male population of Nile tilapia (*Oreochromis niloticus*) and operated under commercial conditions. Data has been collected on the following effluent parameters: volume, temperature, DO, pH, total dried residue, settleable solids, BOD, total Kjeldahl nitrogen, un-ionized ammonia, total ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, total phosphorus, total reactive phosphorus, hardness, carbon dioxide, and salinity. Data has also been collected on system production parameters for determination of trends in effluent characteristics when compared to fish loading rates, feed input rates, system biomass, and volume of water added.

Data Base

Varying degrees of progress have been made in collection of the core set of effluent quality parameters by Work Group participants on each of the production systems. The core set of parameters includes: temperature; DO; pH; settleable solids, total solids, and TSS; BOD; total Kjeldahl nitrogen, ammonia nitrogen, nitrate nitrogen and nitrite nitrogen; total phosphorus and total reactive phosphorus. Interlaboratory standards for several of the core parameters will be circulated by UW-Milwaukee to other Work Group members in the coming months.

USEFULNESS OF FINDINGS

The data base generated from these investigations will help to answer questions as to whether aquaculture wastes are uniquely different from or essentially similar to municipal or other agricultural wastes. They will also define differences in effluent quality of a broad variety of production systems and fish species that are used, some exclusively, in the NCR. In addition these data could also serve as useful baseline information for future studies on the effectiveness of different diet regimes on aquaculture effluents and resulting water quality.

Armed with this information aquaculturists and regional federations will be able to take a proactive stance in formulating realistic effluent standards with environmental regulatory agencies. Some of the findings already have practical significance for the operators of the cooperating private facilities. For example the low oxygen levels in the head water ponds at Glacier Springs Hatchery during winter months with ice cover has been identified as a potential problem which the owners will have to overcome, and the difference in nutrient levels depending on the source water used as compared to Alpine Farms is also useful information.

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PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

Papers Presented:

Rosati, R., P.D. O'Rourke, K. Tudor, and R.D. Henry. 1993. Performance of a raceway and vertical screen filter while growing *Tilapia nilotica* under commercial conditions. *In* Techniques for modern aquaculture, American Society of Agricultural Engineering, St. Joseph, Michigan.

Rosati, R., J. Webb, D. Hinrichs, and P. Foley. 1993. Characteristics of the effluent from a recirculating aquaculture system. Proceedings of the 1993 annual meeting of the U.S. Chapter of the World Aquaculture Society, Hilton Head, South Carolina, January 29, 1993.

Abstract Accepted for Presentation:

Hinrichs, D., J. Webb, R. Rosati, and P. Foley. Effluent characterization from the production of *Oreochromis niloticus* in a modified Red Ewald style recirculating system. World Aquaculture Society Meeting. New Orleans, Louisiana, January 12-16, 1994.

WORK PLANNED FOR NEXT YEAR

Pond Production Systems

Additional samples will be taken at all three sites. Effort will be made to obtain samples during significant occurrences at each site, e.g., harvests and pond drawdowns. Besides the chemical analyses for the three sites, biotic parameters will be collected and analyzed at Rathbun Hatchery. The benefit of this addition to the project will be to help determine the biotic effects of aquaculture effluents upon the aquatic communities that they enter.

Flow Through Systems

Analyses completed by UN-L thus far have demonstrated that the Sandhills Aquafarms is altering several water quality parameters in Whitetail Creek. Important questions remain, however, including: (a) what are the associated biological impacts if any (this will be addressed in year two), and (b) how far downstream are these effects detectable (this is currently being addressed with samples collected several kilometers downstream)?

As the pond renovation at Glacier Springs Hatchery proceeds UW-Milwaukee will continue to monitor the eight sampling stations to detect changes due to renovation and to reinstatement of higher levels of fish production. Whitefish production at Alpine farms will be terminated by the owners during September 1993. UW-Milwaukee will, however, collect more data on effluents associated with flow through yellow perch production at either the Milwaukee County House of Correction fish hatchery or from large scale perch rearing tanks at the Great Lakes Research Facility. There is also the possibility of obtaining access to Rushing Waters Fish Hatchery, one of the most productive private operations in Wisconsin, as an additional example of flow through production effluents.

Cage Culture

Due to lower than anticipated production at Freshwater Farms over the last year, plans are being made to move some of the monitoring to a cage system in a 1.82 hectare (4.5 acre) reservoir at the OSU Piketon Research facility.

Recycle Systems

A 12.2 m × 24.4 m (40' × 80') commercial aquaculture building is scheduled for completion at the ILSU aquaculture center in September, 1993. This building will contain approximately 132.5 m³ (35,000 gallons) of production capacity

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which will be allocated solely to the production of Nile tilapia under commercial culture conditions. All tanks are scheduled for stocking in late March 1994. Effluent data will be collected from the systems in this building.

Data Base

As the data on the core effluent quality parameters is received from the Work Group cooperators, it will be further assembled and tabulated at UW-Milwaukee. The format will be further standardized. In addition, the data will be compiled in printed and electronic spreadsheet or database formats and made available for circulation to interested individuals either through mailing or perhaps through extension and communication networks such as the Internet system.

IMPACTS

This project is still principally in an information gathering phase; full impact on the regional aquaculture industry will occur when this information is placed within the broader context of participation in the inter regional initiative. However, data from the recirculating-system study has already been used by a private sector aquaculturist to developing a new large recirculating system that meets EPA compliance. It is anticipated that eventually this data base will be made available to the industry so that many more actual applications will occur.

This project has already had impact on the cooperating institutions by providing working experience for undergraduates (2) and graduate students (5) through employment in connection with the sampling and chemical analysis. These students are gaining practical experience in monitoring actual aquaculture effluents; this developing pool of experienced workers will potentially benefit the industry.

Funding of these investigations has also benefited the aquaculture recirculating system program at ILSU by providing leverage for additional funding. These leveraged funds total \$262,910 and include the following:

<u>Source of Funds</u>	<u>Amount</u>	<u>Activity or Explanation</u>
Archer Daniel Midland	\$10,000	aquaculture production
NCRAC (pending)	\$49,000	New salmonid project looking at feeds research with Purdue University
USDA/CSRS	\$189,110	co-solicitor with Pat O'Rourke
ILSU Research Grant Program	\$6,800	aquaculture feeds with Tudor
ILSU Research Release Time Grant	\$8,000	indoor aquaculture research