NORTH CENTRAL
REGIONAL AQUACULTURE CENTER

ANNUAL PROGRESS REPORT

December 1994

ANNUAL PROGRESS REPORT

For the Period
September 1, 1993 to August 31, 1994

December 1994

North Central Regional Aquaculture Center
13 Natural Resources Building
Michigan State University
East Lansing, MI 48824-1222
Telephone: (517) 353-1962 FAX: (517) 353-7181

TABLE OF CONTENTS

INTRODUCTION

The U.S. aquaculture industry continues to be one of the fastest growing sectors within U.S. agriculture, although at a lesser rate than what occurred during the 1980s. Production in 1990 reached 861 million pounds and generated approximately $762 million for producers. The impact of U.S. aquaculture in 1990 was substantial: final sales value totalled $4.75 billion; direct and indirect economic impact was estimated to be $8.0 billion. Yet, anticipated growth in the industry, both in magnitude and in species diversity, continues to fall short of expectations.

Much of what is known about aquaculture science is a result of institutional attention given to our traditional capture of wild fisheries with the goal of releasing cultured fishes into public waters for enhancement of declining public stocks. Despite extensive efforts to manage wild populations for a sustained yield, as a nation we consume substantially greater amounts than we produce. Much of the United States' demand for seafood has been met by imports. The U.S. imports over 40% of its fish and shellfish and, after Japan, is the world's second largest importer of seafood. Fisheries imports---some $10.6 billion per year---are the largest contributor to the U.S. trade deficit among agricultural products, and third largest overall after petroleum and autos. The value of imported fisheries products more than doubled during the 1980s. In 1993, the trade deficit was $3.7 billion for all fisheries products, $2.8 billion of which was for edible fish and shellfish. In fact, foreign-grown aquaculture products constitute some $800 million of our fisheries imports.

Landings for most commercial capture fisheries species and recreational fisheries of the United States have been relatively stable during the last decade, with many fish stocks being overexploited. In this situation, aquaculture provides an opportunity to reduce the trade deficit and meet the rising U.S. demand for fish products. A strong domestic aquaculture industry is needed to increase U.S. production of fish and shellfish. This can be achieved by a partnership among the Federal Government, State and local public institutions, and the private sector with expertise in aquaculture development.

Congress recognized the opportunity for making significant progress in aquaculture development in 1980 by passage of the National Aquaculture Act (P.L. 96-362). Congress amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (P.L. 95-113) in Title XIV of the Agriculture and Food Act of 1981 (P.L. 97-98) by granting authority to establish aquaculture research, development, and demonstration centers in the United States in association with colleges and universities, State Departments of Agriculture, Federal facilities, and non-profit private research institutions. Five such centers have been established: one in each of the northeastern, north central, southern, western, and tropical/subtropical Pacific regions of the country. The 1990 Farm Bill (Food, Agriculture Conservation, and Trade Act of 1990 - P.L. 101-624) has reauthorized the Regional Aquaculture Center program at $7.5 million per annum. 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 U.S.

Department of Agriculture (USDA) 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 mission of the Regional Aquaculture Centers (RACs) is to support aquaculture research, development, demonstration, and extension education to enhance viable and profitable U.S. aquaculture production which will benefit consumers, producers, service industries, and the American economy.

The North Central Regional Aquaculture Center (NCRAC) was established in February 1988. It 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 for Aquaculture (NCC). The council is composed of the RAC directors and USDA aquaculture personnel.

ORGANIZATIONAL STRUCTURE

Michigan State University (MSU) and Iowa State University (ISU) work together to develop and administer programs of NCRAC through a memorandum of understanding. MSU is the prime contractor for the Center and has administrative responsibilities for its operation. The Director of NCRAC is located at MSU. ISU 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.

At the present time the staff of NCRAC at MSU includes Ted R. Batterson, Director and Liz Bartels, Executive Secretary. The Center Director has the following responsibilities:

- Serving as executive secretary to the Board of Directors, responsible for preparing agenda and minutes of Board meetings;
- Serving as an ex-officio (non-voting) member of the Technical Committee and Industry Advisory Council;
- Coordinating the development of research and extension plans, budgets, and proposals;
- Coordinating and facilitating interactions among the Administrative Center, Board of Directors, Industry Advisory Council, and Technical Committee;
- Monitoring research and extension activities;
- Arranging for review of proposals for technical and scientific merit, feasibility, and applicability to priority problems and preparing summary budgets and reports as required;
- Recruiting other Administrative Center staff as authorized by the Board of Directors;
- With assistance of the Economics and Marketing Work Group, Technical Committee, or others preparing a summary of regional aquaculture, including production statistics and sales, and identifying technical, financial, and institutional constraints to expanding production. The summary shall include sections addressing established industries, development industries, and opportunities for new product development, and recommended research needs;

- Maintaining liaison with other RACs; and
- Serving on the NCC.

At the present time the staff of NCRAC's Office for Publications and Extension Administration at ISU includes Joseph E. Morris, Associate Director and Glenda Dike, Secretary. The Associate Director has the following responsibilities:

- Serving as head of Publications for NCRAC, including editor of the *NCRAC Journal*, the newsletter of the Center;
- Serving as the NCRAC liaison with national aquaculture extension programs, including in particular, extension programs of the other four USDA RACs; and
- Serving as a member of NCRAC's Extension Executive Committee.

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 each 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 representatives to the TC/E. The TC/R has broad regional make-up and is composed of scientists from universities and state agencies with varied aquacultural expertise who are appointed by the BOD. 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.

ADMINISTRATIVE OPERATIONS

Since inception of NCRAC February 1, 1988, the role of the Administrative Center has been to provide all necessary support services to the BOD, IAC, TC, and project work groups for the North Central Region as well as representing the region on the NCC. As the scope of the NCRAC programs expand, this has entailed a greater work load and continued need for effective communication among all components of the Center and the aquaculture community.

The Center functions in the following manner.

- After BOD approval of Administrative Center costs, the Center submits a grant to USDA/CSREES/Awards Management Division for approval. To date the Center has received seven grants from USDA for FY88 (Grant #88-38500-3885), FY89 (Grant #89-38500-4319), FY90 (Grant #90-38500-5008), FY91 (Grant #91-38500-5900), FY92 (Grant #92-38500-6916), FY93 (Grant #93-38500-8392), and FY94 (Grant #94-38500-0048) with monies totalling $4,920,021. Currently, four grants are active (FY91-94); the first three grants (FY88-90) have terminated.

- The Center annually coordinates a program planning meeting which sets priorities for the next funding cycle and calls for regional workshops to develop project outlines to address priority problem areas.
- Work Groups, which are formed at the workshops, submit project outlines to the Center. The projects are peer reviewed by experts from both within and outside the region.
- The BOD, using reviewers' responses, decide which projects are to be approved and funding levels. The Center conveys BOD decisions to all Project Work Groups. 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 Plan of Work (POW) to USDA for approval.
- Once a POW is approved by USDA, 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 serve as fiscal agent for both receiving and disbursing of funds in accordance with all terms and provisions of the grants.

To date, the Center has funded or is funding 15 projects through 157 subcontracts from the seven grants received. Funding for all Center supported projects, except for Publications and a development of an Aquaculture Situation and Outlook Report, is summarized in Table 1 below (page 7).

During this reporting period, the Publications Office at ISU 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 Appendix under Extension.

Other areas of support by the Administrative Office during this reporting period included: monitoring research and extension activities and developing progress reports; preparing a compendium progress report for all five RACs; developing liaisons with appropriate institutions, agencies and clientele groups; preparing, in coordination with the other RACs, both written and oral testimony for the U.S. House Appropriations subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies hearing in Washington, D.C.; participating in the NCC; numerous oral and written presentations to both professional and lay audiences; and working with other fisheries and aquaculture programs throughout the North Central Region.

PROJECT DEVELOPMENT

A joint Program Planning meeting of the BOD, IAC, and TC is held every year in the early winter. The IAC, with input from the TC, generates a list of priority areas for consideration by the BOD. Using their recommendation as guidelines, the BOD then selects priority areas for which project outlines will be developed. The BOD also specifies a maximum funding level for each priority area. Problem statements and objectives are then developed for each priority area by IAC and TC members at the Program Planning meeting. For projects with more than one objective, the IAC ranks the objectives by priority. The problem statement and objective(s) are then included in a workshop announcement that is broadly distributed throughout the North Central Region. The workshops are one-day events to establish a work group that will develop a project outline over the summer months. Work group members will be those who have demonstrated that they have the expertise and facilities for undertaking the proposed work in regard to a particular objective or objectives. The proposed work cannot deviate from the objective or objectives included in the workshop announcement. The work group elects a chair and secretary. The chair is responsible for submitting the project outline to the NCRAC Director; the secretary is responsible for preparing minutes from the workshop that are distributed to all attendees. All project outlines are peer reviewed. The reviewers' comments are used by the BOD in making the final selection of projects and level of funding at the following year's annual Program Planning meeting. All work group members are apprised of the BOD decisions. Revisions of projects approved by the BOD are submitted by the work group chair to the NCRAC Director. The revised project outlines are then included in a POW that is submitted to USDA. Upon approval by USDA, the Center issues subcontracts to the funded work group members.

TIME FRAME

- Program Planning meeting: early winter.
- Workshops: late-spring, early summer.
- Project outlines developed over the summer by work group members who participated in the workshops. These project outlines are then submitted to the Center in the fall and peer reviewed.
- The Board of Directors at the following year's Program Planning meeting selects the projects to be funded.
- Project outline revised and submitted to the Center by May.
- Revised projects are then submitted in June as a POW to USDA for approval. Once approved by USDA subcontracts are let by the Center with a start date of September 1.

By following this procedure, it takes approximately 18 months from the time of identifying a priority area until inception of a project to address the issue in question.

WORKSHOPS

The purpose of the workshops is to bring together those who are best qualified to work on project objectives by virtue of a demonstrated record of expertise and access to facilities required in the project. These people form a work group for the purpose of writing a project outline to address the problem in question. The following criteria typically apply to those projects that are funded by NCRAC.

- Involves participation by two or more states in the North Central Region;
- requires more scientific manpower, equipment, and facilities than generally available at one location;
- approach is adaptable and particularly suitable for inter-institutional cooperation resulting in better use of limited resources and a saving of funds;
- will complement and enhance ongoing extension and research activities by participants, as well as offer potential for expanding these programs;
- is likely to attract additional support for the work which is not likely to occur through other programs and mechanisms;
- is sufficiently specific to promise significant accomplishments in a reasonable period to time (usually up to 2 years);
- can provide the solution to a problem of fundamental importance or fill an information gap;

- can be organized and conducted on a regional level, assuring coordinated and complementary contributions by all participants.

The NCRAC program pays no overhead to participating institutions nor tuition remission, has no brick-and-mortar money, and relies on in-place salaried personnel, equipment, and facilities to carry out the projects. Due to the collaborative and cooperative nature of these regional projects, no one individual or institution receives a significant portion of the total project funds.

PROJECT REPORTING

As indicated in Table 1, the Center has funded a number of projects for many of the project areas. For example, there have been four separately funded projects in regard to Extension and five for Walleye. Project outlines have been written for each separate project within an area, or the project area itself if only one project. These project outlines have been submitted in POWs or amendments to POWs for the grants as indicated in Table 1. Many times, the projects within a particular area are merely continuations of previously funded activities; while at other times they are addressing new objectives. Presented below are Progress or Termination Reports for all projects that were underway or completed during the period September 1, 1993 to August 31, 1994.

All publications, manuscripts, or papers for the different project areas are listed in the Appendix.

Table 1. North Central Regional Aquaculture Center funded projects.

Project Area	Project Number	Duration	Funding Level	Grant Number
Extension	1	5/1/89-4/30/91	$39,221	88-38500-3885
	2	3/17/90-8/31/91	$68,389	89-38500-4319
	3	9/1/91-8/31/93	$94,109	91-38500-5900
	4	9/1/93-8/31/95	$110,129	91-38500-5900
			$311,848	
Economics and Marketing	1	5/1/89-12/31/91	$127,338	88-38500-3885
			$34,350	89-38500-4319
	2	9/1/91-8/31/93	$53,300	91-38500-5900
	3	9/1/93-8/31/95	$40,000	93-38500-8392
			$254,988	
Yellow Perch	1	5/1/89-8/31/91	$76,957	88-38500-3885
			$85,723	89-38500-4319
	2	6/1/90-8/31/92	$92,108	90-38500-5008
	3	9/1/91-8/31/93	$99,997	91-38500-5900
	4	9/1/93-8/31/95	$150,000	93-38500-8392
			$504,785	
Hybrid Striped Bass	1	5/1/89-8/31/91	$68,296	88-38500-3885
			$68,114	89-38500-4319
	2	6/1/90-8/31/92	$101,000	90-38500-5008
	3	9/1/91-8/31/93	$96,550	91-38500-5900
	4	9/1/93-8/31/95	$168,000	93-38500-8392
			$501,960	
Walleye	1	5/1/89-8/31/91	$177,517	89-38500-4319
	2	6/1/90-8/31/92	$111,657	90-38500-5008
	3	9/1/91-8/31/92	$109,223	91-38500-5900
	4	9/1/92-8/31/93	$75,000	89-38500-4319
	5	9/1/93-8/31/95	$150,000	93-38500-8392
			$623,397	
Sunfish	1	6/1/90-8/31/92	$130,758	90-38500-5008
	2	9/1/92-8/31/94	$149,867	92-38500-6916
	3	9/1/94-8/31/96	$174,999	94-38500-0048
			$455,624	
Salmonids	1	6/1/90-8/31/92	$9,000	89-38500-4319
			$120,799	90-38500-5008
	2	9/1/92-8/31/94	$149,997	92-38500-6916
	3	9/1/94-8/31/96	$200,000	94-38500-0048
			$479,796	
NCR Aquaculture Conference	1	6/1/90-12/31/91	$7,000	90-38500-5008
National Aqua. Extension Workshop	1	10/1/91-9/30/92	$3,005	89-38500-4319
Crayfish	1	9/1/92-8/31/94	$50,000	92-38500-6916
Baitfish	1	9/1/92-8/31/94	$62,000	92-38500-6916
Effluents	1	9/1/92-8/31/94	$153,300	92-38500-6916
Aquaculture Drugs (INADs)	1	9/1/93-8/31/94	$2,000	89-38500-4319

PROJECT TERMINATION
OR
PROGRESS REPORTS

EXTENSION

Progress Report for the Period
May 1, 1989 to August 31, 1994

NCRAC FUNDING LEVEL: $311,848 (May 1, 1989 to August 31, 1995)

PARTICIPANTS:

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
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
David J. Landkamer	University of Minnesota	Minnesota
Joseph E. Morris	Iowa State University	Iowa
Kenneth E. Neils	Kansas State University	Kansas
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 development of 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: increased 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, e.g., walleye, hybrid striped bass, yellow perch, salmonids, and sunfish, through hands-on workshops and field demonstration projects; improved lines of communication between interstate aquaculture extension specialists and associated industry contacts; and enhanced legal and socioeconomic atmosphere for aquaculture in the NCR.

PROGRESS AND PRINCIPAL 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.

As with any organization, there have been changes in NCRAC extension personnel since the inception of the project. Landkamer was the primary aquaculture extension contact for Minnesota. However, he left the university and Kapuscinski became the primary contact person. Recently, Gunderson has assumed that responsibility. Two other individuals, who had served since the outset of the project as their state's aquaculture extension contact, have been replaced in 1994. In Kansas, Neils has replaced Henderson and in Illinois, Kohler has replaced Selock.

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 established to identify industry needs. Specific principal major actions have been as follows:

- 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), and 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), Missouri (Pierce), Nebraska (Kayes), Wisconsin (Binkowski), and Illinois, Indiana and Missouri (Kohler); fish diseases and commercial aquaculture recirculation systems in Ohio (Ebeling); aquaculture business planning in Nebraska (Kayes); crayfish culture in Minnesota (Gunderson); pond management in Illinois (Selock); yellow perch and hybrid striped bass culture in Ohio (Ebeling); and yellow perch and crawfish culture in Illinois and Indiana (Swann).
- Delivered in-service training programs to vocational agriculture and science teachers on basic aquaculture in Illinois (Kohler and Selock), Iowa (Morris), Michigan (Garling), and Wisconsin (Binkowski).
- Conducted hands-on training sessions and field site visits to aquaculture operations in Ohio, Indiana, Illinois and Michigan (Binkowski). Field tested a workshop on polyploid induction in sunfish for commercial fish producers in Michigan (Garling).
- 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-Carbondale (Selock), University of Nebraska-Lincoln (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 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.
- Planning began in 1994 for the 1995 North Central Aquaculture Conference. It is to be held in conjunction with the NCRAC Annual Meeting, Minnesota Aquaculture Conference, and the Great Lakes Fish Disease Control Committee meeting in Minneapolis, Minnesota. Participants on the steering committee include Gunderson (chair), Morris, Binkowski, and Kinnunen.
- Chaired a session entitled “Reservation Aquaculture Projects” at the Great Lakes Regional Native American Fish and Wildlife Conference held in Green Bay, Wisconsin as well as chaired the Program Committee for the 1994 Governor’s Conference on Agriculture:Wisconsin Aquaculture 1994 (Binkowski). Many NCRAC representatives participated in the conference including members of the Industry Advisory Council, Technical Committee, and Administrative office.
- Participated in the development of the United States Trout Farmers Association’s quality assurance program (HACCP) (Garling).
- Helped conduct a survey of crayfish producers in the NCR and completed a report on *Orconectes immunis* for inclusion in the Crayfish Work Group report (Gunderson).
- Produced script for a videotape for novice fish farmers on the basics of marketing aquaculture products in the NCR (Henderson).
- Provided NCRAC Economics and

Marketing Work Group with information relevant to the work group's efforts to develop cost of production budgets and expected revenues for the commercial production of food-sized hybrid striped bass, walleye, and yellow perch in the NCR (Kayes, Morris, Garling, Swann).

- Provided copies of videotape "Investing in Freshwater Aquaculture: A Reprise" to Extension Work Group chairperson for distribution to all NCR State Extension contacts. Videotape, produced and edited by University of Nebraska-Lincoln, is an adaptation of the first national interactive teleconference on aquaculture.
- Assisted in writing and developing the NCRAC Walleye Culture Manual (Gunderson, Garling, Kayes, Kinnunen and Morris) which is being edited by Bob Summerfelt of Iowa State University.
- Developed "Missouri Aquaculture Directory" and "Aquaculture in Missouri" newsletter to enhance aquaculture educational programs and development in Missouri (Pierce).
- Developing materials for aquaculture handbooks, which will be distributed to each NCRAC designated extension specialist, and selected CES and Sea Grant field staff (Swann).
- Completed 14 bulletins and fact sheets and two videos that were provided to all members of the extension network.

WORK PLANNED

At least one Extension Work Group member has been assigned to work with each funded NCRAC research project to: (1) provide ongoing needs assessment, (2) provide input for design and prioritization of future research projects, and (3) identify results that would be useful in extension programs.

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 participants will focus their program efforts on the following:

- Hybrid Striped Bass Workshop Proceedings (Team: Kohler [leader], Morris, Swann, and Kayes). This workshop is scheduled for fall 1995.
- Walleye Culture Manual/Workshop (Team: Morris, Kinnunen, Gunderson, Bob Summerfelt [leader] (Iowa State University), Jeff Malison (University of Wisconsin-Madison), and John Ringle (industry representative). Completion of the Walleye Culture Manual is scheduled for July 1995. A Walleye Culture Workshop is scheduled for February 1995 in conjunction with the North Central Aquaculture Conference '95 in Minnesota. Gunderson will coordinate the workshop.
- Yellow Perch Culture Guide/Videos (Team: Kayes [leader], Garling, extension liaisons, and work group researchers). Kayes will be developing extension publications on: (1) an overview of yellow perch aquaculture, sex identification, brood stock management and spawning, and artificial propagation techniques (May 1995 completion) and (2) egg incubation and hatching techniques, and pond fingerling production methods (September 1995 completion). Kayes is also involved in the production of the following videotapes: (1) yellow perch spawning and artificial propagation techniques (February 1995 completion), (2) egg incubation and hatching techniques (September 1995 completion), and (3) pond fingerling production methods (September 1995 completion).

- Sunfish Production Guide/Videos (Team: Morris [leader], Garling, and Kayes).
- Marketing Aquaculture Products Video (Team: Neils [leader], Henderson, Pierce, Kayes, industry and university members, and Economics and Marketing Work Group members).

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.

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, Gunderson 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 pressing problems. The development of aquaculture education programs for the NCR provides "hands-on" opportunities for prospective and experienced producers.

Approximately 4,200 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.

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) is often used to provide clients with initial information about aquaculture, while species specific publications on walleye (Harding et al.), catfish (Morris) and trout (Cain and Garling) have been used in numerous regional meetings and have been requested by clients from throughout the United States. Publications on organizational structure for aquaculture businesses (Kohler and Selock), transportation of fish in bags (Swann), and others are beneficial to both new and established aquaculturists. In a 1994 survey, NCRAC extension contacts estimated that NCRAC publications were used to address approximately 15,000 client questions annually.

NCRAC extension efforts have helped increase the number of aquaculture operations within the region. For example, the number of aquaculture licenses in Illinois increased an average of 20% annually for three years to a total of 96 license holders in 1992. Most NCRAC Extension contacts serve 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. For example, Ohio State University assisted in the passage of an amendment through the state legislature that acknowledges aquaculture as an agricultural activity, exempts it from Ohio Department of Natural Resources rules on size limitations, and sets up a list of approved species and an optional experimental list. In its final form early next year (1995), the legislation is expected to stimulate new interest in aquaculture in Ohio.

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.

Since the 1980's farm crisis and the inception of NCRAC in 1988, the number of purported and actual fish farmers in the NCR has probably declined due to a shake out of marginal operators who failed because of poor location, an inability or unwillingness to apply proven aquaculture practices, or inadequate financing, entrepreneurial initiative or business acumen. Despite this, the prospects for development of a major aquaculture industry in the NCR are better now than they were six years ago, first, because the surviving producers are more sophisticated and generally better financed, second, because more people in the NCR are better informed about the economic potential and technical aspects of aquaculture, and third, because certain state and local leaders and leadership groups are becoming better informed and more engaged in fostering aquaculture development. To a large extent, these three general outcomes have been due to NCRAC extension outreach activities.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED
See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1989-90	$39,221	$66,992				$66,992	$106,213
1990-91	$68,389	$70,065				$70,065	$138,454
1991-93	$94,109	$152,952				$152,952	$247,061
1993-95	$110,129	$198,099				$198,099	$308,228
TOTAL	$311,848	$488,108				$488,108	$799,956

EXTENSION

ECONOMICS AND MARKETING

Progress Report for the Period
September 1, 1993 to August 31, 1994

NCRAC FUNDING LEVEL: $40,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Susan B. Kohler	Southern Illinois University-Carbondale	Illinois
Marshall A. Martin	Purdue University	Indiana
Patrick D. O'Rourke	Illinois State University	Illinois
LaDon Swann	Purdue University	Indiana/Illinois
Extension Liasons:		
Donald L. Garling	Michigan State University	Michigan
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
LaDon Swann	Purdue University	Indiana

PROJECT OBJECTIVE

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 North Central Region (NCR).

ANTICIPATED BENEFITS

The overall goal of this collaborative project is to enhance walleye, yellow perch and hybrid striped bass production by developing enterprise budgets for production of these species in the NCR. This supports the mission of NCRAC, especially by conducting research "for the enhancement of viable and profitable commercial aquacultural production in the United States for the benefit of producers, consumers, and the American economy."

This project will benefit the aquaculture industry in the NCR in several ways, even though there are some limitations of these budgets given the "emerging" status of the industry and given the nature of budgets. First, the cost of production or budgeting components of this project offers the potential to help in identifying production systems for walleye, yellow perch and hybrid striped bass most likely to be commercially viable. Information on production costs is quite limited for these species, especially walleye and yellow perch. Second, a little bit of good-quality cost information is better than bad or no information. These budgets will give producers an idea of how enterprise budgets should be organized, what types of data need to be collected, and why good record keeping is essential. The production values and relationships upon which the cost structure is based, while not standardized in the industry, should serve as a rough rule-of-thumb by which aquacultural producers can gauge their management skills. Third, enterprise budgets are an excellent management tool for producers. Enterprise budgets will enable producers to assess the needed budget items and related costs for comparison with their own current, contemplated or expanded operations costs in light of reasonable price expectations. If the publication of these budgets stimulates potential and current aquacultural producers to put together budgets that reflect their unique enterprises, then the industry will be much better off. Fourth, enterprise budgets are the cornerstone for several different types of financial analysis related to aquaculture operations. The budgets will allow more economic research into financial aspects of aquaculture and enable those producers who are spurred on to put together budgets to push on into their own financial analysis (another management tool). Fifth, enterprise budgets are also the cornerstone for sensitivity analysis (yet another management tool). Undertaking sensitivity analysis will enable economists and producers to better understand the relative importance of cost and production items in the budget and to explore the boundaries of enterprise profitability. Finally, realizing that the budgets produced under the auspices of this project will not be the final, definitive budgets for aquaculture production in the NCR, they will serve as a solid starting base from which to update information and expand into alternative species, production systems, life stages, etc.

In a more indirect way, the enterprise budgets will accomplish two other important things. One, the budgets should help guide research and extension decisions by NCRAC work group participants, the Industry Advisory Council, the Board of Directors, and the supporting committees. Second, it will provide an opportunity for the economists and other personnel developing the budgets to interact with aquaculture producers, researchers, and extension personnel in the NCR. This type of interdisciplinary interaction is vital for the improved understanding and communication of all vital aspects of aquaculture in the NCR.

Economic feasibility analysis will help producers evaluate technical advances in fish production. This contribution is critical as a guide to future research funding in the various species and production systems suitable for commercial production. The distribution of research results from this project through the publications of the Economics and Marketing Work Group and through the Extension liaisons using computer budget software will provide a structured and informed dissemination system which is credible with producers, financial institutions and others.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

HYBRID STRIPED BASS

Kohler has compiled a review of the literature on hybrid striped bass (HSB) production and production costs. The literature is being summarized in an annotated bibliography. This bibliography will be available to anyone needing the information. A mailing list of 56 producers of phase III HSB both within and outside the NCR was compiled. Aquaculture Extension personnel from the 12 states within the NCR were contacted for a list of HSB producers in their state. Information on additional producers was obtained from the 1994-1995 Striped Bass Growers Association Directory and from producers listed in the 1994 Aquaculture Magazine Buyer's Guide. A mail survey was sent to these 56 producers to obtain data on production costs. The response rate was low due to a hesitation on the part of producers to reveal this information.

Two large fish farms in Arkansas (Malone's and Keo) and one in Missouri (Osage

Catfisheries) were visited to discuss HSB production and gather production information. In all cases, other species in addition to HSB are produced so species-specific production figures were not available. Both farms in Arkansas indicated that the information may be available in early 1995.

WALLEYE
O'Rourke and Illinois State University (ISU) graduate students have completed an extensive walleye production/culture literature review. For the first year of the current project they focused on fingerling production. The primary focus of the literature review was to discover any research findings that might be useful in ascertaining the cost of production for walleye under intensive and extensive culture regimes. Very little economic research was found and even less was found that was explained well enough to be useful.

The second source of information used was research experts and hatchery personnel familiar with walleye culture. The ISU investigators were surprised that many of the "experts" were as reluctant to share information as were the entrepreneurs/producers. The experts were selected and queried using a modified Delphi approach. This stage of the research will be completed in 1995 with additional follow-up questions and identification of a broader group of "experts."

Work has advanced on identifying and analyzing the cost of production for advanced walleye fingerlings in intensive and extensive culture systems. The first study, to be completed in December 1994, is an economic feasibility analysis of a tank based, intensive walleye fingerling production system.

YELLOW PERCH
A good enterprise budget is based on sound production information with data for all the production relationships involved in a production cycle. Knowing the number of commercial producers of yellow perch to be very small, Riepe conducted a literature review in early 1993 to determine whether any data on the production requirements for yellow perch were available. Unfortunately, most research on yellow perch has been limited to attempts to spawn them out of season and successfully culture and harvest eggs, fry, and eventually fingerlings habituated to commercial diets. Riepe then rejected the historical method for developing enterprise budgets and decided to use the economic engineering approach.

At this point, Riepe then considered alternatives for obtaining the needed production-related information upon which the budgets must be based, and came up with two methods. The first method may or may not be of use during this project. Riepe developed a record keeping sheet for the non-funded collaborators involved in the yellow perch project who are testing the commercial scale feasibility of food-size yellow perch production systems. The record keeping sheets ask for the itemization of all costs and inputs into the production process and also provides a weekly record keeping sheet that could be used on an ongoing basis by the collaborators. Depending upon how well the collaborators' trials turn out and on what kind of job they do keeping records, Riepe may or may not be able to use the information they provide to guide this set of budgets.

Riepe developed, for the second method, a Delphi approach to obtaining the expert opinions of NCRAC researchers on the production relationships which are needed to underpin the yellow perch production cost budgets. Expert opinions were solicited from the researchers and extension persons involved in the NCRAC Yellow Perch Work Group during 1994. The opinion data were entered into a spreadsheet to average the responses and then re-submitted to the researchers. Also, budget assumptions were clarified so that all researchers were thinking of production relationships relating to a similar set of assumptions. Subsequently, some of the NCRAC personnel revised some of their original production values. Expert opinions were solicited for several types of related production values (death loss, feed conversion, fingerling size, harvest size, etc.) for a producer with average skill under average conditions and then for minimum and maximum values representing above and below average skills and conditions.

Since it was not possible to model all life stages in all production systems at all sizes of production, Riepe met with Marshall Martin, Paul Brown, and LaDon Swann of Purdue University in late winter to discuss and come to a consensus on how to prioritize alternative budgets. In addition, the membership of the Indiana Aquaculture Association was surveyed by Riepe in October of 1993 to solicit their views on budget priorities. This input was provided to all parties before the meeting. The decision was made that the budgets to be modeled include the life stage of advanced fingerling growout; the production in cage, constructed fish pond, and recirculating tank systems; and two levels of annual production: 2,268 kg (5,000 lb) and 22,680 kg (50,000 lb).

Riepe is almost finished with the cage culture budgets, has completed a fair amount of background work on the pond culture budgets, and has not yet started on the tank culture budgets. Riepe also spent some time contacting alternative suppliers of feed and fingerlings since these two items typically account for a majority of the costs associated with an aquaculture enterprise.

WORK PLANNED

Kohler will submit the annotated bibliography on HSB for publication. Producers who did not respond to the initial mail survey will be contacted. Additional farms in the NCR will be visited to obtain production costs and to discuss production of HSB. Production costs received via the mail survey and farm visits will be incorporated into a model by the work group chair. O'Rourke will continue economic analysis of fingerling production systems and begin examining likely food size walleye production systems. Riepe plans to complete as many of the alternative budgets for yellow perch stated above as her funding and work schedule will allow. Results will be published through NCRAC publications and professional presentations and journals (although the latter is the slowest method for the release of timely information).

IMPACTS

This project has already benefited the aquaculture industry in the NCR, even though the production cost budgets are not yet completed. Primarily this is because the funding has allowed more economists in the NCR to spend time on applied aquaculture research. As a result, these economists have been able to give presentations on economic issues in aquaculture production to current and potential aquacultural producers that may have reduced the impacts of uninformed investment decisions by current and potential aquaculture entrepreneurs.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$22,104	$35,829				$35,829	$57,933
1994-95	$17,896						$17,896
TOTAL	$40,000	$35,829				$35,829	$75,829

YELLOW PERCH

Progress Report for the Period
September 1, 1993 to August 31, 1994

NCRAC FUNDING LEVEL: $150,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Paul B. Brown	Purdue University	Illinois
Konrad Dabrowski	Ohio State University	Ohio
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Extension Liaison:		
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Non-funded Collaborators:		
Byron Bezdek	Aquatic Management, Inc., Lisbon	Ohio
Harlan Bradt, etc.	Coolwater Farms, LLC, Cambridge	Wisconsin
Dave Gerholt	Red Hook Fisheries, David City	Nebraska
William Hahle	Pleasant Valley Fish Farm, McCook	Nebraska
John Hyink/John Wolf	Alpine Farms/Glacier Springs Trout Hatchery	Wisconsin
George Matousek	Perch Research International, Inc., Bentley	Michigan
Dave Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Michael Wyatt	Sandhills Aquafarm, Keystone	Nebraska

PROJECT OBJECTIVES

(1) Determine the commercial scale feasibility and improve on the best intensive tank and pond culture practices for the production of yellow perch fingerlings.

(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.

ANTICIPATED BENEFITS

At the 1992 Program Planning Meeting of the North Central Regional Aquaculture Center (NCRAC), the NCRAC Industry Advisory Council advanced the position that the primary emphasis of research projects proposed for the 1993-1995 funding period should be on the demonstration of commercial-scale feasibility of the best available research-based production technologies, working in collaboration with private fish producers. The NCRAC Board of Directors supported that position, and the NCRAC Yellow Perch Work Group responded by developing a project centered largely on conducting such demonstrations. This project is aimed at providing much needed information on the practical feasibility and costs of employing, on a commercial-scale, selected fingerling production and grow-out strategies that were initially developed and/or tested on a small (laboratory) scale. In addition, this project will develop improved technologies for certain key facets of yellow perch aquaculture. Finally, the results of experiments incorporated into this proposal will immediately help fish farmers improve the production efficiency of both fingerling and food-size yellow perch.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

As an integral component of much of this project, private producers were to provide the requisite facilities, fish, feed, day-to-day husbandry, and routine data collection. At its inception, this project included the participation of eight different private fish farms in various parts of the North Central Region. Participating university researchers were to provide project oversight on experimental design, advice or direct assistance with the technical set-up of any specialized experimental systems, supervision and assistance on critical end-point data collection, and analyses of results.

In Year 1 of the project (September 1, 1993 to August 31, 1994), significant progress was made at certain sites at testing selected research-based production technologies. Accordingly, from an extension perspective, the project is successfully building and/or expanding working relationships between NCRAC researchers and certain regional fish farmers, testing various research-based technologies under practical production conditions, transferring knowledge from academia to the private sector, and identifying private producers who are both capable and willing to sustain a collaborative technology evaluation and demonstration effort. Several of the original private-sector collaborators have either met or have worked hard to meet their project commitments, including Pleasant Valley Fish Farm, Sandhills Aquafarm, and Coolwater Farms, LLC.

However, from the research perspective, the likelihood of the project generating significant amounts of comprehensive feasibility-assessment data that will be publishable in peer-reviewed journals seems low, based on Year 1 results. One primary reason for this development is that several private-sector collaborators who had initially agreed to participate in the project have either partially or totally pulled back from their original commitments. The reasons for these pullbacks range from initially exaggerated claims of facility and other resource capabilities, to lack of sufficient technical competence or experience, to a belated realization of the potential risks involved. To deal with this problem, in some instances alternate private sector collaborators are being sought for studies to be conducted in Year 2 (September 1, 1994 to August 31, 1995), and in other cases feasibility assessments will be conducted under laboratory conditions rather than under field conditions as originally proposed.

OBJECTIVE 1

Researchers at the University of Wisconsin-Milwaukee (UW-Milwaukee) calculated the labor, supplies and utility costs for the commercial-scale, intensive culture of yellow perch fingerlings in tanks at the Aquaculture Institute University of Wisconsin System Great Lakes Research Facility. Based on this information, the cost for intensively culturing yellow perch from sac fry to 74 d posthatch in tanks was $0.0842 per fingerling. These costs did not include capital expenses or depreciation for facilities and equipment.

UW-Milwaukee investigators made several modifications to their procedures to improve hatching success and survival. First, reductions in *Saprolegnia* growth on eggs and subsequent increases in egg survival were achieved by increasing water temperature during incubation by 1.5°C/d (as opposed to 1°C every other day). Second, the use of vigorous aeration was used to force-hatch fully developed embryos that failed to hatch on their own. Third, a drip feeder system was developed to provide a constant (24 h/d) supply of food to the yellow perch, and as a result there were no visible signs of cannibalism in any production tanks, and the habituation time to commercial starter diet was reduced to 25 d posthatch. Cumulatively, survival of perch from egg to 74 d posthatch was 41.6%.

Studies on pond fingerling production by the University of Wisconsin-Madison (UW-Madison) are being conducted using ponds of various sizes at Coolwater Farms, LLC and the Lake Mills State Fish Hatchery. These studies are evaluating the use of: (1) selected high fry stocking densities and early pond harvest to maximize pond fingerling production, and (2) underwater lights and vibrating feeders to habituate perch fingerlings to formulated feeds while they remain in ponds. To date, fingerling production from ponds not equipped with automatic feeders and stocked at 1,000,000 fry/hectare has averaged 375,000 fingerlings/ha (N = 2), and the fingerling size at harvest has ranged from 17-24 mm total length (TL). Fingerling production from ponds equipped with lights and automatic feeders and stocked at 2,000,000 fry/ha has averaged 324,000 fingerlings/ha (N = 5), and the fingerling size at harvest has ranged from 24-44 mm TL. Other fry stocking densities have not yet been tested with a sufficient number of replicates to reach any meaningful conclusions. In general, pond fingerling production has been highly variable, ranging from 0-610,000/ha. All indications are that this high variability has been due to extreme variations in zooplankton populations that have occurred despite extensive efforts at monitoring zooplankton and using fertilization and aeration to maximize pond productivity.

UW-Madison investigators also evaluated the effect of fingerling size at harvest (from ponds not equipped with lights and feeders) on the subsequent habituation of fingerlings to formulated feeds in tanks. Their results showed that habituation rates of ~ 60% could be achieved with fingerlings as small as 14.8 mm TL at harvest.

In another study, UW-Madison researchers found that fingerlings harvested from ponds equipped with lights and feeders and stocked into tanks had habituation rates of >95%. This result, however, does not necessarily imply that >95% of the fingerlings were habituated to formulated feeds while they were still in ponds. In fact, other results (e.g., see the studies conducted in Nebraska described below, in which bi- or multi-modal populations of perch were harvested from ponds equipped with lights and automatic feeders) suggest that feeding methods and strategies may have a profound effect on the number or percentage of perch fingerlings that can be habituated to formulated feeds while still in ponds.

Studies in Nebraska on Objective 1 were conducted at Pleasant Valley Fish Farm in two 0.08-ha × 1.5-m-deep rectangular ponds which are drainable and supplied with groundwater. Both ponds were aerated, fertilized and stocked with about 200,000 eyed-eggs (2,500,000/ha). An effort was also made to conduct a perch fingerling production trial in two new ponds at Red Hook Fisheries. However, these ponds failed to yield any fish after stocking, because construction on the ponds was not completed until a few weeks beforehand and a forage base could not be established.

On April 27-28, 1994 Nebraska was hit by a major cold front that resulted in freezing temperatures, a 30-cm snowfall, and a 3-d electric power outage at Pleasant Valley Fish Farm. The direct effects of this cold front on fry survival could not be determined. However, the effect on the zooplankton forage base was a significant pauperization that lasted for several weeks. To help offset this reduction in forage, both ponds were supplementally fed Silver Cup trout starter feed (Sterling H. Nelson and Sons, Inc., Murray, Utah) beginning about 3 weeks after stocking, and the planned duration of the pond production trial was expanded from 6-8 weeks to the entire summer. Standard water chemistry parameters and water temperatures were measured routinely, and zooplankton and fish samples were collected weekly. Water temperatures in the ponds from mid-May to mid-September ranged from 20-26°C, with the highest temperatures occurring in July. Under these conditions, the perch reached an average TL of about 20 mm in slightly over 5 weeks, and about 50 mm TL in 10-11 weeks. Field trials to habituate perch fingerlings to formulated feed and raise them intensively in tanks were not conducted in Year 1 at either Pleasant Valley Fish Farm or Red Hook Fisheries because of facility limitations. This situation should be rectified at Pleasant Valley Fish Farm by the spring of Year 2 of the project.

The perch in both ponds at Pleasant Valley Fish Farm were harvested on September 22, 1994. Estimated percent survival from the two ponds was 13% and 8.3%, and the average weight per fish was 7.58 g and 8.79 g. Perhaps the most significant finding of this field trial was that supplemental feeding produced two or three populations of perch of markedly different average body size, a result that was probably dependent on their level of acceptance of formulated feed. For example, in one pond approximately 25% of the perch harvested averaged 34.5 g, 15% averaged 8.2 g and the remainder weighed 1.4 g.

Two experiments conducted by Ohio State University (OSU) researchers evaluated mass rearing of yellow perch in ponds and intensively reared perch fry in tanks. In one study yellow perch embryos (prior to hatch) were stocked into six 0.1 ha research ponds at 1,000,000/ha. The ponds were fertilized weekly to stimulate and maintain algae and zooplankton production. Two of the ponds were equipped with automatic feeders and high intensity flood lamps to attract the fingerling perch to the vicinity of the feeders. On several occasions, yellow perch fry were seen actively swimming under the lights and consuming feed. Overall survival averaged about 7.5% for the best three ponds, and was 1.5, 2.5, and 0% for the other ponds. Of the two ponds with automatic feeders, one had poor survival (2.3%) but large fry at harvest (5.5 gm), and the other had survival (7.5%) and mean fish size (1.77 g) that was similar to those of unfed control ponds.

In a second experiment, pond-reared yellow perch were transferred indoors into 12 40-L flat bottomed flow-through tanks (21°C) with automatic feeders at a density of 15 fish/L. Six tanks were stocked with perch at 11-13 mm TL, three with perch at 13-15 mm TL and three with perch at 15-17 mm TL. The fry were fed Ziegler Bros. Inc., Salmon Starter Crumbles #1 every half-hour for 16 h/d and every hour for the remaining 8 h. This experiment was terminated after 28 d. Survival for the smallest size group (11-13 mm TL) was only about 4%, and in most instances larger fry were observed cannibalizing smaller fry. Similar results were obtained in the 13-15 mm TL size group, and mean survival was 22%. The largest size group (15-17 mm TL) showed uniform growth and a final mean weight of from 0.33 g. These findings suggest that the best initial size for habituation of yellow perch to intensive tank rearing using conventional starter feeds would be larger than 15 mm TL.

OBJECTIVE 2

Studies to determine the commercial-scale feasibility of raising food-size yellow perch in different types of production systems while comparing the best available formulated diets were initiated in open ponds at Pleasant Valley Fish Farm, in raceways at Sandhills Aquafarm, and in large net-pens at Red Hook Fisheries. The main thrust of the Year 1 effort was to compare the growth and performance of perch fed a standard commercially available trout diet (Silver Cup, Sterling H. Nelson and Sons, Inc.) with that of perch fed a diet specifically formulated for perch. This latter diet was developed cooperatively with, and subsequently manufactured by, Hubbard Milling Company of Mankato, Minnesota. In Year 1 of the project, the three Nebraska cooperators apparently experienced delays in obtaining the Hubbard perch diet, and were further delayed in starting their feeding trials by concerns over the quality and utility of the perch diet delivered.

Problems reported with the Hubbard diet included: (1) an unacceptably high level of feed fines (i.e., 20-25%), which would not be consumed and could have significant deleterious effects on water quality; (2) poor pellet size uniformity, which made the use of automatic or demand feeders difficult and necessitated feeding almost entirely by hand; (3) intact feed pellets generally too large to be readily consumed by the size perch being fed; and (4) the integrity of the pellets in water tended to be poor, resulting in their falling apart after hitting the water surface. Because of such difficulties, Sandhills Aquafarm and Red Hook Fisheries soon abandoned their efforts to feed the Hubbard diet, and fed the trout diet exclusively. Pleasant Valley Fish Farm, however, completed a 54-d comparison of the two diets fed to perch in ponds, but scaled down the comparison in terms of size and numbers of ponds and numbers of fish committed to the feeding trial.

The feeding trial at Pleasant Valley Fish Farm was initiated on August 10 and terminated on October 4, 1994. Age-1 perch with an average length and weight of about 143 mm TL and 29.1 g, respectively, which had previously been fed Silver Cup trout diet, were stocked into a 10.7-m-square × 1.2-m-deep pond (1,020 fish stocked) and a 24.4-m-square × 1.2-m-deep pond (2,831 fish stocked). Both ponds were supplied with pumped groundwater to maintain water quality and to moderate water temperature, and the smaller pond was aerated. Water temperatures and dissolved oxygen levels in the two ponds were generally about equal and sufficient for good growth. The Hubbard perch diet was fed to the fish in the small pond; Silver Cup trout diet was fed to the perch in the larger pond. The fish in both ponds were fed approximately to satiation once daily in the afternoon. Production figures at harvest for perch fed the Hubbard and Silver Cup diets, respectively, were as follows: estimated percent survival, 87.9% and 90.4%; average final length per fish, 157 mm and 163 mm TL; average final weight per fish, 48.2 g and 59.8 g; and estimated feed conversion ratio, 1.62 and 1.06. As yet, these figures have not been subjected to statistical analyses.

The Objective 2 field trials conducted at Sandhills Aquafarm and attempted at Red Hook Fisheries failed to produce substantive results. Sandhills Aquafarm was built downstream of a major spring field and began operating in 1989 as a modern trout production facility. From late spring through mid-autumn, water temperatures in the raceways can vary between 13 and 22°C, but more typically range between 16 and 20°C. Because of these comparatively high temperatures, which during the daytime are sufficient to promote good growth in yellow perch, it was postulated that Sandhills Aquafarm could potentially diversify its operations into perch as well as trout production. To test this possibility, 28,000 feed-trained age-1 perch fingerlings were procured from Pleasant Valley Fish Farm in late May 1994, and stocked at 14,000 fish per raceway in similar-size sections at the head ends of two raceways. After an initial outbreak of Columnaris disease, which was quickly brought under control, the perch at Sandhills Aquafarm remained healthy and consumed feed, but ultimately failed to exhibit significant growth between early June and the end of September. The exact reason for this lack of growth is unknown. However, the tentative conclusion drawn by both Sandhills Aquafarm and Kayes of the University of Nebraska-Lincoln (UN-L) is that the wide diurnal temperature fluctuations and low nighttime temperatures of the raceway waters effectively precluded significant perch growth. Consequently, field trials will not be conducted at Sandhills Aquafarm in Year 2 of the project. During Year 1, Red Hook Fisheries also reported problems with the Hubbard perch diet, claims to have raised a number of perch in large net-pens, but in the opinion of the UN-L has operated in a manner that is inconsistent with the intent or effective conduct of the project. Accordingly, field trials involving UN-L personnel will not be attempted at Red Hook Fisheries in Year 2 of the project.

WORK PLANNED

OBJECTIVE 1

UW-Milwaukee will work in collaboration with Alpine Farms, a commercial fish farm, to evaluate the intensive culture of yellow perch using a recirculating system and establish the production costs for this type of rearing unit. As outlined in the original proposal, UW-Madison researchers will continue to test various fry stocking densities, from 1-6 million fry/ha, for their effect on the production of fingerling perch reared in ponds with and without underwater lights and automatic feeders. In 1995, UN-L efforts on the project will be focused on field trials to be conducted at Pleasant Valley Fish Farm. For work under this objective, particular emphasis will be placed on improving the commercial-scale production of yellow perch fry and early fingerlings in ponds, and the habituation to formulated feed and intensive culture of early to advanced fingerlings in tanks. At OSU the studies conducted in 1994 will be repeated in 1995 with improved accuracy gained from this year's experiences. In addition, a new feeding and lighting system will be tried out for pond habituation to dry diets.

OBJECTIVE 2

A controlled laboratory study will be conducted at Purdue University to examine acceptability and responses of advanced fingerling perch fed a variety of experimental and practical diets. That study and a follow-up study will be conducted under controlled, near-optimal environmental conditions for perch. Also in 1995, Purdue University researchers will collaborate in a field study involving the same private sector collaborators who participated in 1994, and possibly two others. UN-L efforts on this objective will focus on the grow-out of age-1 fingerlings to market size in aerated ponds supplied with groundwater to maintain water quality and moderate pond water temperature. At least two different formulated diets will also be compared for their effects on perch growth and performance in ponds, following consultation with Brown of Purdue University.

IMPACTS

The preparation of a summary of production cost information by UW-Milwaukee investigators for the intensive culture of yellow perch fingerlings in tanks will provide the necessary framework for writing a business plan for private sector producers who intend on using this fingerling production strategy. In addition, the continual refinement of intensive fry culture protocols will improve the production efficiency of this method.

Studies on pond fingerling production by UW-Madison, UN-L and OSU researchers have shown that research-based production strategies can be used on a commercial scale to produce large numbers of perch fingerlings at a relatively low cost. The most promising of these strategies include the use of high fry stocking densities coupled with either: (1) early pond harvest, for the subsequent habituation of fingerlings to formulated feeds in tanks; or (2) systems using lights and automatic feeders for habituating fingerlings to formulated feeds while they remain in ponds.

Studies evaluating the grow-out of yellow perch in ponds in Nebraska have shown that excellent growth rates (>0.5 g/d) for perch can be obtained using this culture strategy, if environmental and nutritional factors are kept at or near optimal. At the conclusion of these studies a significant amount of information will have been generated to help producers select relatively high performing and/or least cost feeds for yellow perch.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$75,000	$87,240	$30,000	$10,000[a]		$127,240	$202,240
1994-95	$75,000						$75,000
TOTAL	$150,000	$87,240	$30,000	$10,000		$127,240	$277,240

[a]Wisconsin Sea Grant/USDC/NOAA

HYBRID STRIPED BASS

Project Component Termination Report for the Period
May 1, 1989 to August 31, 1994

NCRAC FUNDING LEVEL: $333,960 (May 1, 1989 to August 31, 1993)

PARTICIPANTS:

Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa

PROJECT OBJECTIVES

(1) Obtain and maintain (in captivity) populations of spawning size white 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 brood stock.

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 three 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/photoperiod 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. Average hatching rates have also been improved from 25% to 50%. These findings represent major steps toward the development of domesticated white bass brood stocks 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.

Annual rhythms of serum levels of estradiol-17β and testosterone, as well as gonadal growth and histology of the wild and the three captive populations of white bass were documented and correlated with actual spawning events.

IMPACTS

DOMESTICATION

The development of a protocol to habituate adult white bass to captivity, including training to dry formulated feeds, allows for developing domesticated brood stock. Domesticated brood stock is clearly advantageous by:

- obviating need to collect brood stock from wild,
- resolving numerous regulatory issues regarding collection and hauling of wild brood stock,
- allowing for brood stock selection programs, and
- ensuring availability of brood stock when needed.

OUT-OF-SEASON SPAWNING

The development of efficacious procedures to manipulate sexual maturation and induce out-of-season spawning is important for optimal management of brood stock. It leads to:

- greater predictability of gamete production,
- reduced incidence of failed spawnings,
- reduced incidences of brood stock losses due to toxemia, and
- production of fertilized eggs and fry at predetermined times throughout the year.

HATCHING RATES

Improvements in hatching rates allows for increased hatchery production or reduction in brood stock needs.

hCG DOSAGES

Determination of the most efficacious hCG dosages not only improves spawning performance, but these data have positive implications toward eventual regulatory approval of hCG by the FDA for spawning *Morone* species. As a direct consequence of this work:

- standard dosages of hCG are being tested for efficacy in a multi-state Investigational New Animal Drug (INAD) application being administered by Auburn University through sponsorship of Intervet Inc.,
- hCG will be tested for animal safety by SIU-C under sponsorship of Intervet Inc., and
- these projects will collectively provide FDA with necessary information to make a determination for approval of hCG for broodfish.

RECOMMENDED FOLLOW-UP ACTIVITIES

NCRAC is currently funding a follow-up study that is focused on developing procedures to intensively rear white bass larvae to a stage when they will consume formulated feed (see next Progress Report). A proposed study for the next NCRAC funding cycle will, among other topics, compare three strains of white bass in yield trials. Collectively, the results from these studies should pave the way to undertake a white bass brood stock selection program.

PUBLICATIONS, MANUSCRIPTS,

AND PAPERS PRESENTED See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1989-91	$136,410	$93,436				$93,436	$229,846
1990-92	$101,000	$94,000				$94,000	$195,000
1991-93	$96,550	$54,317				$54,317	$150,867
TOTAL	$333,960	$241,753				$241,753	$575,713

HYBRID STRIPED BASS

Progress Report for the Period
September 1, 1993 to August 31, 1994

NCRAC FUNDING LEVEL: $168,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
George G. Brown	Iowa State University	Iowa
Paul B. Brown	Purdue University	Indiana
Konrad Dabrowski	Ohio State University	Ohio
James E. Ebeling	Ohio State University	Ohio
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Jeffrey A. Malison	University of Wisconsin	Wisconsin
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
R. Melvin White	Purdue University	Indiana
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborator:		
Fred Barrows	U.S. Fish and Wildlife Service	Montana

PROJECT OBJECTIVES

(1) Develop intensive hatchery production techniques for white bass and to "domesticate" white bass by producing brood stock originating from induced spawns.

(2) Perfect cryopreservation techniques for white bass/striped bass semen and to demonstrate feasibility of hybrid striped bass production using "stored" semen in industry-type settings.

ANTICIPATED BENEFITS

The development of intensive larval culture techniques for white bass 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.

Conversion of larval fish to formulated feeds is one of the most difficult aspects of hybrid striped bass culture. Typically, high mortality and nonuniform acceptance of feed results. Thus, if flavor additives can be identified that entice consumption of feed, conversion to formulated feeds would be more uniform and lead to higher survival rates. Higher survival rates would result in higher profits for aquaculturists.

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 will 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 brood stock 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

In a previously funded NCRAC project, an objective was to develop larval diets and economically feasible techniques to convert hybrid striped bass young from their natural prey, zooplankton, to artificial diets. Researchers at Southern Illinois University-Carbondale (SIU-C) found that both hybrid striped bass crosses at a 2-5 g size range readily convert from zooplankton to formulated feed. Associated with this objective and Objective 1 of this project, research at Purdue University was designed to formulate and mix dry dietary ingredients, and facilitate manufacturing small pellets with the help of colleagues at the U.S. Fish and Wildlife Service, Fish Technology Center, Bozeman, Montana. Three diets were formulated in the first year of this project that contained two distinctive flavor additives that would be considered legal to use. That task was accomplished and diets were sent to colleagues at SIU-C and the University of Wisconsin-Milwaukee (UW-Milwaukee).

Facilities to intensively rear larval white bass were established at Ohio State University (OSU), SIU-C, and UW-Milwaukee. White bass larvae from two separate spawning trials were shipped overnight to OSU and UW-Milwaukee. Larvae arrived in good shape at Wisconsin, but were in stressed condition upon arrival at Ohio. Attempts to rear larval white bass were minimally successful--about 5% in Wisconsin and Illinois studies after 30 d, and approximately 1% in Ohio after 14 d.

Past studies at Iowa State University (ISU) and SIU-C allied with Objective 2 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 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.

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.

WORK PLANNED

Research planned for next year is a duplication of this year's work using two additional flavor additives. Again, dry ingredients will be mixed at Purdue University, then shipped to Bozeman, Montana for pelleting. Finished diets will be shipped to SIU-C and UW-Milwaukee for feeding. Upon termination of studies at SIU-C and UW-Milwaukee, fish will be shipped back to Purdue University for histopathological evaluation. Additional larval rearing trials will be conducted at OSU.

Based on fertility tests with freeze-stored semen, cryopreservation procedures developed by ISU and SIU-C have been fairly successful. Methodologies that 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.

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 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

The potential impacts of intensive larval rearing and larval diet research are increased profitability. If flavor additives can be identified, a higher percentage of larvae can be trained to accept the feed and more juveniles can enter the food fish production cycle.

Related to this domestication of brood stock is the availability of suitable gametes for successful fish reproduction. Because 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.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$81,000	$58,679				$58,679	$139,679
1994-95	$87,000	$60,761				$60,761	$147,761
TOTAL	$168,000	$119,440				$119,440	$287,440

WALLEYE

Progress Report for the Period
September 1, 1993 to August 31, 1994

NCRAC FUNDING LEVEL: $150,000 (September 1, 1993 to August 31, 1995)

PARTICIPANTS:

Terence B. Barry	University of Wisconsin-Madison	Wisconsin
Tom Harder	Max McGraw Wildlife Foundation	Illinois
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Robert C. Summerfelt	Iowa State University	Iowa
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan
Non-funded Collaborators:		
Gene P. Hanson	Aurora-Aqua, Inc., Kandiyohi	Minnesota
Nebraska Game & Parks Commission	North Platte State Fish Hatchery, North Platte	Nebraska
Nebraska Game & Parks Commssion	Calamus State Fish Hatchery, Burwell	Nebraska

PROJECT OBJECTIVES

(1) Measure genetic parameters required for efficient combined selection of sub-adult and adult traits, using a pedigreed population of walleye.

(2) Compare performance (survival, growth, feed conversion) of walleye hybrids produced from different parental stocks reared under intensive and the tandem extensive-intensive culture systems.

(3) Conduct field trials that compare effectiveness and costs of different pond and tank culture strategies for producing advanced fingerlings.

ANTICIPATED BENEFITS

For commercial walleye aquaculture to be profitable, many aspects of the production process require further research, and field trials are needed to evaluate the technology transfer, and effectiveness and comparative economics of alternative production strategies. The present study concerned a small set of problems identified by representatives of the aquaculture community in the North Central Region (NCR) as constraints to development and expansion of a commercial walleye food fish aquaculture industry.

A major constraint to private aquaculture is the lack of domesticated brood stock, and biological and economic data on intensive and extensive methods for rearing of fingerlings. In addition, there is need for additional biological information on comparative performance of walleye and its hybrid, a cross between a female walleye and male sauger.

The focus of the proposed project is on: (1) selective breeding based on family selection; (2) performance comparisons of purebred and hybrid walleye; and (3) field trials comparing the effectiveness and costs of different strategies for producing advanced fingerling walleye.

OBJECTIVE 1

Lack of a domesticated, selected line of brood stock is a major impediment to the development of walleye aquaculture. The success of commercial trout and catfish industries are related to the availability of domesticated, selectively bred brood stock. Integration of rationally designed and long-term selective breeding programs into aquaculture operations is an essential mean for improving the performance of culture 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 profit. The goal of the present genetic study is to measure genetic parameters required for efficient combined selection on sub-adult and adult traits using a pedigreed population of walleye derived from a previous NCRAC study. Completion of this objective will allow consideration of a long-term selective breeding program by application of combined selection on the parent generation. Following that, the response to selection in the progeny generation can be determined and practical guidelines for commercial-scale selection in future generations may be undertaken.

OBJECTIVE 2

Although information is limited, it seems that development and expansion of a commercial walleye food fish industry may be constrained by the relatively slow growth of walleye when reared from advanced fingerlings to food-size fish in intensive culture on formulated feed. In this culture environment, an attribute that may be responsible for their slow growth is that walleye are very excitable and easily disturbed. In addition to development of a culture environment that is less stressful (i.e., low light intensity or in-tank lighting), interspecies crossbreeding of walleye with sauger has resulted in hybrids having behavioral and growth characteristics better suited for intensive culture than those of purebred species. This strategy has been successful for other species, for example, striped bass × white bass hybrid. The striped bass hybrid accepts formulated feed more readily and they are more easily acclimated to intensive culture conditions. Hybrid striped bass also grow faster than either parental species, at least during the first few years of life. The improved performance resulting from hybridization is one of the factors responsible for the rapid growth of the hybrid striped bass aquaculture industry over the last several years. Previous studies by the principle investigators have demonstrated that hybrid walleye (saugeye: walleye female × sauger male) reared in intensive culture conditions are more tractable than purebred walleye and the hybrids also have faster growth than either parental species, at least during the first year of life. Additional studies are needed, however, to determine the extent to which the performance advantages of juvenile hybrid walleyes continue in fish reared from advanced fingerlings to food-size and to identify specific stocks of walleye and sauger that produce hybrid walleyes having the greatest performance improvements.

OBJECTIVE 3

Field trials are needed to compare effectiveness and costs of pond and tank culture strategies for producing advanced fingerlings, and to demonstrate technology transfer for mass culture of larval walleye on formulated feed. Field trials include studies to compare production costs for intensive walleye culture with that of the tandem system that begins with pond culture of fingerlings followed by training pond-reared fingerlings to formulated feed in an intensive culture system. Producers can maximize the number of fingerlings that can be produced in ponds, thereby minimizing production costs if fingerlings can be harvested at a smaller size. Studies will be undertaken to identify the minimum size at which pond-reared walleye can be harvested and habituated (trained) to intensive culture conditions on formulated feed.

Field trials were conducted at three sites: northern Illinois (Max McGraw Wildlife Foundation), south-central Wisconsin (Lake Mills State Fish Hatchery), and western Nebraska (North Platte State Fish Hatchery).

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

University of Minnesota (UM) investigators and Aurora Aqua, Inc., a commercial walleye aquaculture enterprise, reared pedigreed families of walleye that are to be used as the parent generation to develop a domesticated line of walleye selected for high performance in different indoor systems for food-fish production. Benefits of improved performance of such a selected walleye strain will include reduced operating costs, harvest of a better quality product, and prevention of adverse environmental impacts. UM is rearing 2,000 walleye derived from 12 full-sib families nested within 4 half-sib families. Length, weight and mortality data were collected monthly for the first eight months and subsequently on alternate months. Walleye at UM have been tagged with passive integrated transponder (PIT) tags, and walleye at Aurora Aqua, Inc. were tagged with visible implant tags (VIT tags). The tagging was done to enable collection of individual growth records which facilitate implementing the most effective selection scheme at the time these fish are bred in the spring of 1995.

A test for differences in aggressiveness of the different genetic families of walleye was developed. The test quantified aggressiveness by measurements of strike rates on fathead minnows. Observations on a subsample of nine full-sib families revealed an order of magnitude difference between two of three half-sib families tested. However, due to large variation within half-sib families, no significant differences were found between half-sib families. Expanded studies might show there is a genetic component in determining aggression in walleye. Previous NCRAC studies have shown that cannibalism of larval walleye was much higher in a northern Minnesota stock than that seen in six other stocks from the NCR.

OBJECTIVE 2

Iowa State University (ISU) and University of Wisconsin-Madison (UW-Madison) investigators undertook comparison of the performance of purebred and hybrid walleyes produced from several stocks of walleye. Three populations of hybrid walleye were made by crossing male sauger collected from the Mississippi River near Genoa, Wisconsin with female walleye collected from the Mississippi River near Genoa, Wisconsin; Spirit Lake, Iowa; and Rock Lake, Wisconsin. In addition, a control group of walleye was produced using eggs from the same Rock Lake, Wisconsin females used to make the hybrids, and male Rock Lake walleye. The four groups are referred to as Rock Lake walleye (RLW), Rock Lake hybrids (RLH), Spirit Lake hybrids (SLH), and Genoa hybrids (GH). Fertilized eggs of all four groups were incubated and hatched at the ISU fish culture laboratory. The resulting fry were cultured intensively at ISU for 74 d when the average size was 87 mm. At that time 1,360 (340 fish from each group) fingerlings were transported by ISU personnel to the UW-Madison fish culture site at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin where the fingerlings are to be reared to food size by personnel from UW-Madison.

Tank culture of hybrid walleye was conducted at ISU in 157-L cuboidal tanks with a circular flow pattern. Three replicate tanks were used for each hybrid group and the walleye control group. Samples of 25 fish were taken from each tank at 7, 14, 21, 30, 44, 58, and 74 d posthatch to determine mean total length (TL) and weight; gas bladder inflation and acceptance of feed was determined at 7, 14, 21, and 30 d. Fry survival was determined at 30 d posthatch by removing and counting all fish from each tank. Statistically significant differences in survival and growth (TL and weight) were observed at 30 d posthatch; the mean lengths of all hybrid groups were significantly greater than that of the RLW. Survival from 30 to 58 d posthatch was 28.6% for walleye, but 61 to 72% for the hybrids; the Spirit Lake hybrid (SLH) had 72% survival. At the 30, 44, and 58 d posthatch sampling times, the SLH were significantly longer and heavier than any other group. At 74 d posthatch, the average TL of all tank-reared fingerlings that were transported to the Lake Mills State Fish Hatchery was 86 mm (3.4-inches), with a range from 72 to 109 mm, and the average fish weight was 5.8 g (78 fish-to-the-pound).

Through August, investigators at UW-Madison found that all three groups of the walleye hybrids are growing faster than the purebreds, and indications are that differences between hybrids produced from different walleye stocks will be significant.

OBJECTIVE 3

Field trials at the Max McGraw Foundation were undertaken to demonstrate transfer of the intensive fry rearing technology developed at ISU and the Iowa Department of Natural Resources Rathbun State Fish Hatchery, and to obtain biological and production costs for intensive (tank) and pond-culture methods to produce 30 d old and advanced (150 mm) fingerling walleye. In the spring of 1994, walleye eggs were obtained from lakes on the Foundation's property and purchased from a private Wisconsin hatchery. Two-day old, 7.7 mm long, fry were stocked into six circular tanks at a density of 20 fry/L. A clay solution was injected into the tank every 20 min to maintain a low level of turbidity, a technique that ISU has found to reduce clinging of the fry to the sidewalls of the tanks and to substantially enhance growth and survival. The fry were fed every 5 min, 22 hours a day.

After 6 d in intensive culture, fry averaged 10.1 mm, and 91% of the fry had food particles in their stomachs. By the 11th d posthatch, fry had grown to 13 mm, 95% of the fry had food in their stomachs and 94% had fully inflated gas bladders. By the 17th d gas bladder inflation was 98%. Thus, the culture techniques were successful in getting fry on feed and inflating their gas bladder. Unfortunately, however, when fry were 17-20 d posthatch, bacterial infections, possibly bacterial gill disease, occurred within 8 d of each other causing nearly 100% mortality.

Pond (i.e., extensive) culture of walleye fry at the McGraw Foundation was undertaken concurrent to the tank culture to obtain comparative costs for the two types of culture. Two 0.4 ha ponds were stocked with 2-4 d-old fry at the rate of 275,000 per hectare. Initial and periodic applications of alfalfa pellets and soybean meal were used to develop and sustain zooplankton populations. When zooplankton populations declined, a light-harvesting technique was used to harvest fish for the tank study. Fingerlings harvested over five nights represented 36% and 46% of the two ponds' fingerling populations that were harvested by final draining and seining. Of the initial number stocked into each pond, 22% and 24%, respectively, were harvested as 40-44 mm fingerlings.

McGraw Foundation personnel trained some of the pond-reared walleye to formulated feed in 1.2 and 1.5 m diameter circular tanks. Fingerlings were stocked in all tanks at a density of two fingerlings per L of water. Of the 12 tanks, seven had black interior walls and five had light blue walls. Light intensity at the water surface was maintained within the range of 4 to 47 lux, and initial water flow was 12-14 L/min in the small and large tanks, respectively. Fish were fed at 5 min intervals for 22 h/d. Survival to harvest, when most fish were greater than the 150-mm TL target size, was 22.5% and fish density averaged about 0.45 fish/L (15-16 g/L). However, fish reared in the 1.2 m diameter tanks had final lengths and weights that were 12 mm and 7.9 g greater than fish reared in the larger tanks. At harvest, 90% of the fish in the smaller tanks were >150 mm. By contrast, only 55% of the stock in large tanks were target size. Feed conversion was 1.7 in the small tanks and 1.4 in the large tanks. Tanks with black side-walls had a higher final density at harvest (18 g/L) than tanks with blue side-walls, and the fish reared in black tanks were somewhat larger, a higher percent of them were greater than the 150 mm target size (72%), and they exhibited better feed conversions (1.3) than fish reared in the tanks with blue side-walls.

University of Nebraska-Lincoln (UN-L) investigators evaluated pond aeration, fertilization, and fry stocking density in ponds at the North Platte State Fish Hatchery, North Platte, Nebraska. In one 7-week study, employing 17 0.4 ha × 1-m-deep ponds, the effects of no aeration and continuous "Quad-Air" diffuser aeration were compared, as well as two different fertilization rates (150 or 225 kg/ha per week of alfalfa pellets, supplemented with liquid phosphoric acid), and stocking rates of 405,000 and 607,000 fry/ha (rather than a normal stocking rate of 250,000 fry/ha). This study revealed consistently high levels of dissolved oxygen (DO) in all ponds and no appreciable aeration, fertilization, or stocking-rate effects on survival (71-81%) or on the size (37-44 mm TL) of fish harvested.

In a second UN-L study, the effects of stocking rate and continuous aeration on walleye fingerling production in 18 heavily fertilized 0.4-ha × 1-m-deep ponds were investigated. Walleye fry were stocked at rates of 405,000, 607,500, and 800,600 fry/ha. All ponds were fertilized at a similar rate (340 kg/ha per week of alfalfa pellets, supplemented with liquid phosphoric acid). During the 6.5 week study, DO levels typically remained near saturation levels and rarely went below 5 mg/L, irrespective of aeration. At harvest, fish stocked at 405,000/ha were significantly longer (40 mm TL) and heavier (0.47 g) than those stocked at either 607,500/ha (35 mm TL, 0.31 g), or 800,600 fry/ha (34 mm TL, 0.28 g). The size at harvest of fish stocked at the two higher densities did not differ significantly. Neither stocking rate nor aeration had a significant effect on survival (69-79%), or the total biomass of fish harvested per pond (126-166 kg/ha).

Collectively, these results suggest that walleye culture ponds in the region are being operated at far below their production potential in terms of harvestable numbers of fingerlings, and that at the tested rates of fertilization, which were comparatively high, the need for supplemental aeration in the Great Plains states of the NCR, except for emergency applications, may be minimal because of the climatically normal windy conditions.

To date, UN-L investigators have demonstrated that (using appropriate pond stocking, fertilization, and harvesting strategies) the number of walleye fingerlings that can be produced per unit of pond surface area (ha or acre) can be increased by a factor of 1.6-3.2 above presently established standards, with no significant detrimental effect on survival and only a comparatively small reduction in fish size. The success of this approach depends on harvesting within 6-7 weeks of stocking, when walleye typically are about 34-44 mm TL, before depletion of the forage base and high summer water temperatures become a problem. Walleye in this size range and smaller can be readily habituated in tanks to conventional starter diets. Greatly increasing the number of fry stocked per unit of surface area and reducing the size at which fingerlings are harvested should significantly increase the economic efficiency and reduce the cost of producing walleye fingerlings initially in ponds, then to larger sizes in tanks or other culture systems.

A study by UW-Madison workers, however, found that walleyes harvested from ponds at 20 mm TL and habituated to intensive culture conditions and formulated feeds had higher mortalities than those harvested at 30 mm TL. In a separate study, UW-Madison researchers conducted a preliminary evaluation of a system to feed-train fingerling fish to formulated feeds in ponds. They used vibrating feeders with underwater lights. The system relies on the photopositive response of many small fingerling fishes, and has been used very successfully with yellow perch. Initial observations suggest that walleye fingerlings exhibited a positive response to feed-training in ponds using this system.

WORK PLANNED

OBJECTIVE 1

Performance data on walleye families will be analyzed to determine heritabilities and genetic correlations of measured traits and to make selection decisions for a selective breeding scheme planned for the spring of 1995. In November 1994 the fish will be placed under simulated ambient temperatures and photoperiods to experience an "environmentally" normal winter. These conditions should stimulate the onset of normal biorhythms for gonadal growth and development. In the spring of 1995, Malison of UW-Madison will assist UM personnel to induce spawning of the 2 year old fish. If none of the fish have completed vitellogenesis by the end of year 2, the fish will be held under ambient conditions for a third year, and hormonal induction of spawning will be delayed until the following spring. Based on results obtained for trait heritabilities and genetic correlations, and consultations with walleye producers in the region (facilitated by liaisons of the NCRAC Extension and Economics and Marketing Work Groups), a selection index will be formulated in order to impose efficient selection on a few traits at a time. The best individuals within the best families will be mated to produce the progeny generation. Gametes will be collected from sexually mature individuals and reared at each testing facility. Early life history information will be collected on the resulting crosses.

OBJECTIVE 2

ISU investigators will produce three groups of half-sib hybrid walleye by fertilizing eggs of walleye from Rock Lake, Wisconsin with sauger semen obtained from three geographic locations, preferably from the Ohio River, Mississippi River and Missouri River. Parental stock from Rock Lake will be used as the control. Fry will be reared intensively on formulated feed at ISU and in ponds at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. ISU will rear fingerlings in an intensive culture environment to an average size >75 mm TL, then transfer about 1,200 of these fingerlings to Rock Lake State Fish Hatchery, where personnel of UW-Madison will culture the fish to food size with support from a continuation grant from NCRAC for the next two years. UW-Madison investigators will also continue to collect performance data on the four groups of walleye purebreds and hybrids produced in 1994 that are currently being raised to food-size.

OBJECTIVE 3

In 1995, McGraw Foundation personnel will spawn eggs from brood fish collected from lakes on the foundation property. After hatching, fry will be reared intensively and others extensively to obtain comparative data on performance and production costs to rear a 50 mm TL fingerling by intensive and extensive technologies. In 1995, however, as the fry get larger, less Kyowa feed and more walleye grower feed will be used to decrease feed costs. The harvesting techniques for the ponds will be modified slightly by changing the light harvesting equipment. Training of pond-reared fingerlings will be evaluated in a 2 × 2 factorial experiment to compare production in large and small (1.2 and 1.5 m diameter) tanks and tanks with black and blue side-walls .

UW-Madison investigators will continue evaluating the influence of fish size at harvest on the habituation of walleye to intensive culture conditions and formulated feeds, and these studies will also compare fish raised in ponds with and without vibrating feeders and underwater lights.

In 1995, UN-L will place particular emphasis on: (1) improving and testing a low-cost system recently developed for the large-scale low-stress harvest of small walleye fingerlings (18-30 mm TL) from production ponds at high densities (400,000-600,000 fry/ha); and (2) evaluating the growth and production efficiency of rearing these fish to advanced-fingerling size (100-150 mm TL) by intensive tank-culture techniques using conventional formulated diets, compared to extensive culture in ponds restocked with 12,000-15,000 small fingerlings/ha (a traditional approach to rearing advanced walleye fingerlings).

IMPACTS

OBJECTIVE 1

A selective breeding program for walleye is being developed from data collected under laboratory and commercial rearing conditions. Selection programs in salmonids have improved the performance of desirable traits for aquaculture by as much as 14-30% per generation. Selective breeding programs developed for walleye should lower operating costs and improve the final product. Future brood stock created in this study will be available to coolwater aquaculturists through UM and Aurora Aqua, Inc. Aurora Aqua, Inc. has invested three times what they had originally committed to support their portion of the project. This cooperator, a leader in intensive culture of walleye, will also learn how to develop a selective breeding program.

OBJECTIVE 2
The investigators believe that this research will benefit producers because it will provide information on optional production practices for rearing walleye and hybrid walleye to food size under different types of production practices, and it will serve to identify sources of brood fish for producing hybrid crosses having superior performance traits. These studies will provide further evidence for evaluating the potential for hybrid walleye and provide information on techniques for rearing fingerling walleye and hybrids.

OBJECTIVE 3
Technology transfer of the ISU-Rathbun State Fish Hatchery techniques to the Max McGraw Foundation facility for intensive culture walleye fry was demonstrated. Tank culture of fry was successful until an epizootic killed all of the fish. The spray bar technique was effective for obtaining gas bladder inflation in walleye. Training pond-reared walleye was more successful in 1.2 m than in 1.5 m diameter circular tanks. Both length and weight of fingerlings, and the higher percentage of target-sized fish (150 mm) were obtained in the smaller tanks (90% of the stock were equal to or larger than the 150 mm target size in the 1.2-m tanks). The cost of feed and labor per fingerling reared first in ponds then in tanks averaged $0.17. Production costs, however, were higher in the small tanks; $0.22 in the 1.2-m tanks compared with $0.12 in large tanks, and $0.18 in black tanks compared to $0.13 in blue tanks.

The average estimated number of 25-50 mm TL walleye fingerlings produced per annum by the Nebraska Game and Park Commission at the North Platte State Fish Hatchery and statewide for the 3-year period 1990-1992 was over 1.3 million/year (the North Platte Hatchery was essentially the state's sole producer of walleye fingerlings). In 1994, the estimated numbers of these size fish at the North Platte Hatchery and statewide were 3.4 and 4.3 million, respectively. The over two-fold increase in production at the North Platte Hatchery was directly attributable to UN-L's research efforts there. Of the statewide overall increase in walleye fingerling production in 1994, compared to the 1990-1992 average, about 71% was attributable to UN-L's research at the North Platte Hatchery while the remaining 29% was due to production at the Calamus State Fish Hatchery. That hatchery had cost $8.6 million and began operation in 1991.

At the conclusion of these studies, investigators will have obtained comparative performance information on pond and tank culture techniques and identified least-cost methods for producing advanced walleye fingerlings.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED
See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$72,725	$111,029	$11,250[a]	$11,000[b]	$57,420[c]	$190,699	$263,424
1994-95	$77,275						$77,275
TOTAL	$150,000	$111,029	$11,250	$11,000	$57,420	$190,699	$340,699

[a]Aurora Aqua, Inc.
[b]Wisconsin Sea Grant/USDC/NOAA
[c]Max McGraw Wildlife Foundation ($14,900), Minnesota Department of Natural Resources ($820), Nebraska Game and Parks Department ($41,700)

SUNFISH

Progress Report for the Period
June 1, 1990 to August 31, 1994

NCRAC FUNDING LEVEL: $280,625 (June 1, 1990 to August 31, 1994)

PARTICIPANTS:

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:		
Joseph E. Morris	Iowa State University	Iowa

PROJECT OBJECTIVES

(1) Production and evaluation of polyploid sunfish.

(2) Determinations of optimum stocking densities and relationships between temperature and growth for sunfish, sunfish hybrids, and triploid sunfish.

(3) Development of low cost, high performance sunfish diets.

ANTICIPATED BENEFITS

Several factors are slowing the progress towards commercialization of bluegill food fish production. The first factor is that sunfish often reach sexual maturity before they reach market size. This results in slow and inefficient growth during grow out and uncontrolled reproduction in culture ponds. Induced triploidy, which creates sterility, could potentially overcome this problem. Triploidy in other species has resulted in reduced gonadal development, higher vitality, and delayed sexual maturation. Pressure shocking techniques to induce 100% triploidy have been developed. However, the production rate of triploids using direct induction techniques may be limited. The development of efficient production protocols for tetraploid bluegill could overcome the limitations of using direct induction methods. Other triploid fishes have been generated from crosses of tetraploids and diploids which exhibited higher survival and viability than triploids created by direct induction techniques. Additionally, tetraploid × diploid crosses could significantly improve production rates of triploids and eliminate the need for triploid verification procedures.

Studies are currently underway to determine which of the sunfishes, e.g., bluegill, green sunfish, black and white crappie, sunfish hybrids, and/or triploids, are most suitable for aquacultural production in the North Central Region (NCR). Species suitability for aquaculture is based on several considerations, including survival, growth performance in relation to temperature, and tolerance to crowding.

Lysine is generally considered the first-limiting essential amino acid in fish artificial diets. Thus, if the combination of feed ingredients used to manufacture a feed meets the requirement for lysine, other essential amino acid requirements should be met. Further, once one essential amino acid requirement is establishied, others can be predicted by analyzing whole fish. This can be considered the first step in establishing optional dietary needs for this potential new aquaculture crop.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

An evaluation of both cold and pressure shocks of varying magnitudes, initiation times (time after mixing egg and sperm), and durations to determine the optimum treatments to produce tetraploid bluegill has been completed at Michigan State University (MSU). Tetraploidy was induced in five of the 16 cold shock treatments tested. Maximum induction rates of 40% are comparable to those achieved in other species. Of the 10 pressure treatments examined, none were successful in producing tetraploids. Relative survival ranged from <1 to 34% for bluegill exposed to cold shock treatments or pressure shock treatments, respectively.

In spring 1994, 0.4 ha ponds at the Illinois Natural History Survey's (INHS) Sam Parr Biological Station were drained and hybrid, pure stock white and pure stock black crappies (85 - 100 mm total length [TL]) were transported to Pittsburgh State University (PSU), Pittsburgh, Kansas (*N* = 1,300 - 1,500 of each stock) and to Southern Illinois University-Carbondale (SIU-C) (*N* = 400 - 500 of each stock).

Pure stock white, diploid F_1 hybrid and triploid F_1 hybrid crappies were produced at the Sam Parr Biological Station by INHS personnel during spring 1994, with assistance from personnel from SIU-C. To produce F_1 crappie fry, ripe white crappie brood fish were collected from Forbes Lake, Illinois and ripe black crappie brood fish were collected from Ridge Lake, Illinois and were transported to the INHS laboratory. Eggs from ripe female crappies were fertilized in vitro and incubated in recirculating systems in Heath™ spawning trays modified with 52 × 52-twill saran cloth screens at 21°C . Half-sibling diploid 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. Triploid F_1 hybrid crappies were produced by pressure shock.

Hatching occurred 36 - 48 h postfertilization for all three genetic stocks. Fry were removed from the Heath™ trays 5 d posthatch and were counted into transport containers. Fry were then stocked into grow-out ponds at SIU-C. To ensure the genetic integrity of the fry, vertical starch-gel electrophoresis of all brood fish is in progress. In early summer 1994, 0.4 ha ponds were drained and hybrid and pure stock black crappie (100 - 150 mm TL) were transported to SIU-C (*N* = 300 - 400 of each stock).

White crappie, which survived transport-related mortalities early in the summer of 1993, were placed into 2-m^3 cages during July 1993 at PSU. Each cage initially contained 2.2 kg of fish/m^3, with 104 individuals in one cage and 106 fish in the second cage. Fish were fed BioDiet™ at 3% of their body weight divided into twice daily feedings. Feeding behavior was noted and any mortalities counted at feeding time. This trial was terminated

November 1993 as water temperatures approached 9°C and feeding activity ceased.

Survival over the 104 d feeding trial was 77% and 81% for each of the two cages. Using Amspacker's (1991) criterion for white crappie feeders (condition factor [K] >0.90), less than half of the fish had converted to the artificial diet. Those that did convert exhibited a significant ($P < 0.01$) weight increase; mean weights increased from 25.8 g to 46.7 g. These fish were then moved indoors to a closed loop system for further feeding trials and fish density determinations.

Black crappie were obtained from a commercial fish farm in October 1993 for a short trial at PSU. Fish were hauled at a very low density (1.1 fish/3.8 L), with oxygen provided via an airstone and 0.5% NaCl added to transport water. Fish were loaded at dusk and unloaded into two 1-m^3 aquaculture cages after dark. These fish had a posttransport mortality of 17% within the first five d, with a total mortality of 27.8% after 13 d. After fifteen days in the cages, fish were weighed and measured into two cages, with 39 fish/cage and densities of 1.8 and 1.9 kg/m^3, respectively. Fish were fed BioDiet™ at 3% of their body weight divided into twice daily feedings. As with the white crappie, feeding continued until November 1993, when water temperatures reached 9°C. Fish were overwintered in the cages without supplemental feeding. During April 1994, the 61 remaining fish were weighed and measured and placed in a cylindrical cage at a density of 2.6 kg/m^3. Fish were again fed BioDiet™ at 3% of their body weight, divided into twice daily feedings.

Some of the fish converted readily to the diet and fed actively at the water surface, but mortalities occurred beginning in early May, peaking in late May, and tapering off by mid-June. Dead fish appeared to be non-feeders, with hollow bellies and K factors <0.90. As of August 31, 1994, total mortality was 75%, with remaining fish feeding actively. The trial will be terminated in October and final growth rates determined.

In spring 1994, black, white and F_1 hybrid crappie (85 - 100 mm TL) were obtained from the INHS Sam Parr Biological Station for the feeding trial at PSU. Because of the long distance between the two locations, significant effort was made to decrease stress. These efforts included: (1) additives, 0.5% NaCl, PolyAqua™, and AmQuel™, (2) supplemental oxygen, and (3) transportation at night. White crappie were hauled at a density of 5 fish/3.7 L, and blacks and hybrids were hauled at 9 fish/3.7 L. All fish arrived in excellent shape, with no transport-related mortalities within the first two weeks. This was a great improvement from the results of 1993 trials, and it is not known whether the excellent survivability was due to the hardiness of the stock, hauling at night, or a combination of factors. Fish were weighed and measured using Finquel™ over six dates from April 19 to May 8, 1994. Four replicates for each species were used, utilizing 1-m^3 cages. Initial densities averaged 5.2 kg/m^3 (350 fish/cage) for each of four cages of black crappie, 4.0 kg/m^3 (318 fish/cage) for each hybrid crappie cage, and 4.1 kg/m^3 (338 fish/cage) for each cage of white crappie. Cages were split into four groups, containing one cage each of each type, and were anchored with groups approximately 20 m apart in the deepest part of the strip pit lake (4.5 to 5.5 m depths). Fish were fed BioDiet™ from the time of arrival and were fed at 3% of their body weight divided into twice daily feedings throughout the summer.

Mortalities peaked at different times for the different species, regardless of cage location. The peak mortality rates for fish were: hybrid white crappie mortalities (18 to 22°C), white crappie (24 to 28°C), and black crappie (26 to 30°C). As of August 15, 1994, total observed mortalities were 18% for hybrid white crappie, 25% for white crappie, and 32% for black crappie. Dead fish appeared to be non-feeders, with mean K values of 0.70 and an emaciated appearance. Feeding activity was consistently highest for the black crappie, intermediate for hybrid white crappie, and lowest for white crappie. Black crappie would congregate near the surface at feeding time, and splash vigorously as feed was provided. A small subsample taken August 1994, indicated black crappie had the best growth performance, followed by white crappie, with hybrid white crappie showing the poorest growth rates.

Growth trials are underway at SIU-C evaluating black crappie, white crappie, hybrid crappie, and triploid white crappie at five water temperatures. Similar studies with *Lepomis* showed that triploid hybrids grow well across a broad temperature range, and as well or better than the other tested *Lepomis* spp.

In general, crappie have proven to be much less tolerant to handling, more difficult to train for prepared diet acceptance, and more susceptible to disease-related mortalities than have all the *Lepomis* spp. evaluated in a similar manner. However, black crappie have, in general, survived better and been more easily trained to accept prepared feeds than white crappie, with the hybrid performing intermediately. Also, SIU-C reseachers have been unable to develop triploid induction methods for crappie that provide both high survival and high rates of triploidy, unlike the success which was accomplished with *Lepomis* spp.

SIU-C researchers have been unable to make a sufficient number of fingerling triploid *Lepomis* to conduct the cage-culture growth trials. Several ponds were stocked with triploid larvae, but survival to fingerling size has been extremely poor. It is not known at this time if the poor survival was due to reduced tolerance of triploids to pond conditions or to other factors. Hence, the cage-culture study has been postponed until summer 1995.

Research at Purdue University has been focused on establishing the dietary lysine requirement of hybrid bluegill. To date, three separate studies have been conducted in this area using three different experimental diets. In the most recent study, dry mixes were sent to Ron Hardy, National Marine Fisheries Service Laboratory in Seattle, Washington for pelleting. Small particle extruded diets that contained approximately 20% moisture were manufactured. Through six weeks of feeding, growth and feed efficiency indicated a dietary requirement for 1.2-1.4% of the dry diet with juvenile fish (approximately 3-5 g initial weight). Using that value, other essential amino acid requirements have been predicted and are available for preliminary diet formulation.

WORK PLANNED

MSU researchers plan to have completed scientific and extension publications based on the findings of this project by June 1995.

Researchers at SIU-C plan to complete growth trials at five temperatures for black and white crappie, hybrid crappie, and triploid crappie. Cage culture trials with triploid sunfish are planned for summer 1995. A draft of an SIU-C dissertation describing growth of *Lepomis* species, hybrid, and triploid hybrids in relation to temperature and genetic sex-determination mechanisms in bluegill has been completed. The final draft is anticipated in fall 1994. Publications on these topics will be derived from the dissertation. SIU-C is also evaluating triploid sunfish in recreational fishing ponds in a study funded by the American Fishing Tackle Manufacturers Association (AFTMA).

Work planned for next year at Purdue University will focus on additional nutrient requirements considered critical to developing a diet for hybrid bluegill. Those studies will utilize juvenile fish reared in a controlled situation and fed purified diets containing graded levels of phosphorus and varyng ratios of lipid and carbohydrate. Establishing the dietary phosphorus requirement will result in diets that meet, but do not exceed, the requirement, which will be beneficial in meeting effluent discharge regulations in the NCR. A precise understanding of the optimum lipid to carbohydrate ratio will be an important dietary formulation restriction and provide information on manufacturing techniques necessary for diets fed to hybrid bluegill.

IMPACTS

Research at MSU and SIU-C provided regional producers with the information and the techniques to produce a new aquacultural product; namely, triploid sunfish. The specific aquacultural impacts of this work are as follows:

- Techniques to produce triploid and tetraploid bluegill have been developed. These techniques have been demonstrated to commercial sunfish growers in Michigan.
- Coupled with the NCRAC sponsored development of improved intensive larval sunfish culture techniques at Iowa State University under the direction of Joe Morris (Bryan et al., 1994), commercial fish farmers have the tools to establish stocks of polyploid sunfishes.
- Growth of triploid *Lepomis* is as good or better than that of diploids, but triploids will not reproduce in culture units.
- NCRAC funding permitted SIU-C to leverage funding from the AFTMA to evaluate benefits of triploid sunfish in recreational fishing ponds. The supply of triploids to recreational fisheries could provide a new market for regional producers.
- Developing diets specifically for targeted species results in maximum performance at the lowest possible cost. Feeds are 30-60% of production costs in aquaculture operations, depending on production system. This, the work at Purdue University directed at minimizing costs of feeds will result in maximizing profit to the producer.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-92	$130,758	$96,710				$96,710	$227,468
1992-94	$149,867	$313,330	$3,200[a]		$29,830[b]	$346,360	$496,227
TOTAL	$280,625	$410,040	$3,200		$29,830	$443,070	$723,695

[a]American Fishing Tackle Manufacturing Association
[b]Illinois Natural History Survey

SALMONIDS

Progress Report for the Period
June 1, 1990 to August 31, 1994

NCRAC FUNDING LEVEL: $279,796 (June 1, 1990 to August 31, 1994)

PARTICIPANTS:

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 Liaisons:		
James E. Ebeling	Ohio State University	Ohio
Ronald E. Kinnunen	Michigan State University	Michigan

PROJECT OBJECTIVES

(1) Evaluate all-female diploid, all-female triploids, and mixed-sex diploids through sexual maturity and use brood stock 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

Midwestern producers have developed a market for 2-3 kg rainbow trout, but losses and reduced growth through sexual maturity continue to be problematic. Triploids, especially females, do not become sexually mature and should continue rapid growth through adulthood. Also, triploids in general show reduced gonadal tissue growth, which could possibly improve dressout and feed conversion efficiency. Monosex culture may reduce agonistic behaviors and further improve feed conversion efficiency. Thus, research at Southern Illinois University-Carbondale (SIU-C) should benefit regional trout culturists by developing lines of all-female fish that are available, and providing important information regarding growth rates and feed conversion ratios.

The production of salmonids at the Platte River

Hatchery in Michigan was decreased substantially in order to reduce the level of phosphorus in the hatchery effluent as mandated by court order. Similar restrictions could be placed on private aquaculturists. Phosphorus must be supplied in the diet to meet the requirements of the animal for maximum growth, but excess phosphorus can result in eutrophication (pollution). Research at Purdue and Michigan State Universities was designed to provide baseline effluent values for private aquaculturists who may be facing effluent permitting requirements. Further, nutritional research was designed to provide a proven method of predicting phosphorus in effluents by way of a mass-balance approach and providing the necessary information to feed manufacturers that will allow formulation of diets based on availability of nutrients.

Rearing density, loading, and water turnover rates are interrelated factors, all of which have major direct effects on the production capacity and cost efficiency of flow-through salmonid hatcheries and farms. These factors also indirectly affect productivity by their impacts on the growth, performance, and stress responses of fish. Researchers at the University of Wisconsin-Madison (UW-Madison) and the University of Nebraska-Lincoln (UN-L) are developing a thorough understanding of how rearing density and loading influence growth, performance, and stress and should allow established producers to increase the numbers of fish raised in a given amount of water, and help novice fish farmers develop realistic business plans.

All research funded through the salmonid project was designed to provide better-quality fish for production and the necessary information for intensifying production in the same amount of rearing space and water. This coordinated effort should help existing culturists as well as those seeking detailed information for development of business plans.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This project is designed to improve regional production in salmonid aquaculture through an interdisciplinary research approach. Major initiatives include work on: (1) genetics and development of regional brood stock; (2) improved diet formulations that will reduce pollution from aquaculture facilities; and (3) defining the maximum loading density trout will tolerate.

Triploid all-female fish attained a mean size of 857 g (1.9 lb) by the end of 320 days, compared to 609 g (1.34 lb) and 642 g (1.4 lb) for the mixed-sex diploid and all-female diploid trout, respectively. Further, at 17°C, the all-female trout showed substantially lowered activity. Mean daily activity for mixed-sex diploids was about 3.3 times that of all-female diploids. However, temperature affected relative activity levels between the two genetic treatments. All-female trout were more active than mixed-sex trout below about 12.7°C, whereas mixed-sex trout were more active than triploids above 12.7°C.

Heat shocks produced 100% triploids in rainbow trout. However, only 60% and 80% of the putative triploids were indeed triploids in the chinook and coho tests, respectively.

Survival for diploid and triploid rainbow trout did not differ. However, triploid coho salmon and chinook salmon died significantly faster than their diploid counterparts in stress tests. Triploid coho and chinook have not survived as well as diploids during hauling, but no differences in survival have been seen between diploid and triploid rainbow trout during hauls.

Researchers at Michigan State University (MSU) completed collection of chinook and coho salmon, feces and feeds from the Platte River Hatchery (Honor, Michigan) in June 1994. Phosphorus (P) analysis of the samples was completed in late August 1994.

An attempt was also made to measure phosphorus digestibility in the feeds used at the Platte River Hatchery using acid-insoluble ash (AIA) as the marker. This method was chosen because AIA is present naturally in the diet. However, since AIA was found in very small quantities in the feeds, this method was not practical for digestibility studies on very small fish where only minute quantities of fecal matter can be collected by dissection.

Researchers at Purdue University completed analyses from the first salmonid project and found that both apparent and true availability of phosphorus from feedstuffs fed to rainbow trout was higher when fed feedstuffs of animal origin (fish meals) than plant protein feedstuffs. Addition of phytase as a dietary additive significantly increased absorption of phosphorus from plant feedstuffs. However, phosphorus absorption was not additive; that is, when mixtures of ingredients were fed to trout, the absorption of phosphorus was not equal to the sum of the individual ingredients.

All samples have been collected from rainbow trout and Atlantic salmon from the second project and data are being analyzed

WORK PLANNED

A more complete analysis of data obtained in SIU-C studies is in progress. The results will be presented in the form of a project termination report.

Work at MSU will be completed by mid-October. The quantity of P of hatchery origin will be calculated using the nutritional mass balance model. This result will be compared to hatchery water quality data to evaluate the accuracy of the water testing method for measuring P loading by the hatchery using a chemical model.

Work at Purdue University will be completed by December 1994. Apparent and true absorption of phosphorus from feedstuffs fed to Atlantic salmon will be compared to similar values from rainbow trout. Additionally, absorption of crude protein from multi-ingredient (compounded) diets will allow evaluation of associative effects.

Work at UW-Madison will be completed by December 1994. Density and loadings from those studies will be compared to existing published values.

All pertinent data collected by UN-L investigators will be fully analyzed and compared with UW-Madison findings. Final results and conclusions will be submitted in a termination report.

All results from these studies will be published in reputable scientific journals and transferred to NCRAC's Technical Committee/Extension for further dissemination.

IMPACTS

The immediate impacts of these studies include:

- all-female triploid rainbow trout grow more rapidly from 180 to 250 d posthatch than all-female diploids;
- all-female trout were less active at temperatures greater than 12.7°C;
- absorption of P was higher from fish meals than from plant feedstuffs, but higher from plant feedstuffs with added phytase;
- absorption of P from multi-ingredient diets was not additive; that is, P absorption did not equal the sum of P absorption from individual feedstuffs; and,

- trout rearing densities can be increased above current recommendations without loss of weight gain.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-92	$129,799	$184,843	$30,000[a]			$214,843	$344,642
1992-94	$149,997	$170,793			$126,300[b]	$297,093	$447,090
TOTAL	$279,796	$355,636	$30,000		$126,300	$511,936	$791,732

[a]ALKO Biotechnology
[b]Monsanto Agricultural Group and Feed Flavors, Inc. ($59,600) and Nebraska Game and Parks Commission ($66,700)

CRAYFISH

Progress Report for the Period
September 1, 1992 to August 31, 1994

NCRAC FUNDING LEVEL: $50,000 (September 1, 1992 to August 31, 1994)

PARTICIPANTS:

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
Non-Funded Collaborators:		
Carl Richards	University of Minnesota	Minnesota
Robert Wilkinson	Southwest Missouri State University	Missouri

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

Crayfish culture in the NCR of the United States is a potential new aquaculture industry that could supply crayfish tail meat during naturally low production periods from traditional areas such as Louisiana, Texas and Arkansas. However, there are very few data on any aspect of crayfish culture in the North Central states. Species with market potential, adequate growth rates, and other biological characteristics suitable for aquaculture need to be identified. Identification of appropriate species, as well as other problems such as the high cost of harvest using baited traps, control over species composition in culture ponds, and poor water quality during summer and winter months, could be immediate impediments to development of sufficient information for successful production.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Extension specialists in the region were contacted and asked to provide the names of individuals within their state who grow or harvest crayfish; 73 individuals were identified. Questionnaires were developed and sent to all individuals. A second mailing was sent after two months to those who did not respond to the first. From the two mailings, fourteen surveys were returned (19.2%) to Gunderson and results from those were tabulated and are summarized below.

Production in the region: Approximately 6,045 kg (13,300 lb) of crayfish are grown in the NCR with gross sales of $53,500. Species grown were divided among *Orconectes virilis, O. immunis, O. nais* and *O. rusticus*. Because of incomplete surveys, it was not possible to specifically divide production among the various species. Based on personal knowledge of the work group members, these figures are underestimations of total regional production.

Monoculture or polyculture with fish: 71.4% of respondents indicated they grew crayfish in polyculture situations with fish, while 28.6% indicated monoculture production systems. Most of those who indicated polyculture were growing crayfish in the same systems with fathead minnows (55.5%). Other combinations included crayfish and: (1) bluegill, red ear and channel catfish (11.1%); (2) golden shiner (11.1%); (3) catfish and fathead minnows (11.1%); and, (4) golden shiners and goldfish (11.1%). Of those polyculture systems, only 22.2% of respondents indicated crayfish were the primary species.

Markets: 11 of the 14 respondents (78.6%) listed their market as hard shell crayfish for the bait market, 2 listed soft shell bait, 5 listed human food, 1 listed shedding stock for soft shell producers, 5 listed pond stocking and 1 listed other. Clearly, most of the crayfish were going to the hard-shell bait market.

Potential for expansion: Producers were asked to rank the crayfish market form with the greatest potential for expansion within the North Central Region. Producers felt that bait markets for both hard and soft crayfish and human markets for hard shells and tail meat offered the best potential for expansion.

Economic return: Producers were asked to rank the crayfish market form that represented the best potential for economic return. Respondents felt that tail meat for human consumption and hard shell crayfish for bait offered the best potential for economic return on investment.

Prioritized problem areas: Producers were asked to prioritize a list of problem areas in need of research efforts. Crayfish markets and growth rates were the problem areas ranked most important. Choice of species, water quality management, feeds, culture techniques, legal constraints, reproduction and harvest techniques were problem areas ranked as important. Only diseases was ranked low on the list of priorities.

OBJECTIVE 2

Most of the indigenous crayfish species reports have been completed and transmitted to the work group chair. They are being collated into a single document that will be available by the end of the year.

OBJECTIVE 3

Research at Purdue University was designed to evaluate pond culture of native species. Juveniles of several species were obtained in spring 1993 and raised through November 1993 in replicated pools that mimicked an earthen pond culture system. Species evaluated in the first year included *Orconectes virilis, O. rusticus*, two distinct populations of *O. immunis* and *Procambarus acutus*. The *O. immunis* were from either a stream population in southern Indiana or a mine pit that had been in place since the 1950s. Wheat straw was used as a supplemental source of nutrients.

Growth of all four species was similar, ranging from an average of 13-15 g per individual. Yield ranged from a high of 505 kg/ha for *O. virilis* to lows of 280 and 290 kg/ha for the stream population of *O. immunis* and *P. acutus*, respectively. Yield of *O. rusticus* averaged 422 kg/ha and yield of *O. immunis* which came from the mine pit lake averaged 350 kg/ha.

After harvest in November, all species were restocked to evaluate reproductive ability of females that were one year old. All species produced apparently good-quality eggs in the spring of 1994.

Species stocked as juveniles in 1994 included *O. virilis, O. longidigitus,* and *O. propinquus.* Each was stocked at two densities to evaluate density effects. Those pools will be harvested in November 1994.

At Kansas State University (KSU), growth and survival of *Orconectes nais* were evaluated in three farm ponds with a surface area of 0.20 ha (0.5 acre). No supplemental feed was added and the ponds were not aerated.

At the end of the 1993 growing season, crayfish in Pond B averaged 41 mm carapace length (CL) and the population estimate was 4,037 ± 444, which was a 78% summer survival. The end of season CLs for Ponds D and S were 26 mm and 23 mm, respectively, and their population estimates were 3,948 ± 408 and 23,611 ± 1,866, respectively.

During June of 1994, all three ponds were intensively trapped over a two week period. The total amount caught from Pond B was 175 kg/ha. By number, this is 16% of the fall population. The catch was 100% of edible size individuals, 78% were in the jumbo category. The total catch from pond D was 122 kg/ha (109 lb/acre). This was 55% of the fall population by number. Only 8% of the catch was edible size. The total amount removed from Pond S was 123 kg/ha (109 lb/acre). This was only 3% of the fall population, the number of edible size was 82%. The pond with the largest crayfish (B) trapped out the fastest. After 10 trappings, 97% of the total removed had been trapped already.

In mid-July 1994, the three ponds were restocked with small young-of-the-year (YOY) crayfish from other ponds at 3/m^2. They grew well and by the end of August average CLs were 35, 29, and 29 mm for Ponds B, D, and S, respectively. Additional data are being collected from ponds at KSU and those will be summarized in the termination report.

P. acutus, *O. virilis*, and *O. immunis* were evaluated in a polyculture situation at Southern Illinois University-Carbondale (SIU-C). Three management strategies were examined. Feeding prepared diets and artificial aeration/destratification was compared to feeding alone during the 1993 growing season. Seining was used for harvest. During the 1994 growing season, feeding and aeration/destratification in ponds left filled over the winter was compared to a production method similar to that employed in the South; namely, fall-winter draining, planting of a cover crop (winter wheat and wild rice in the spring), spring flooding, and harvest via trapping. The latter water-level management scheme was expected to influence population dynamics in the polyculture crayfish community.

A complete harvest of research ponds was conducted in the fall prior to both production years. YOY were stocked into all ponds in the spring of each production year to supplement natural production. Three replicate ponds for each experimental condition were used in 1993, but replication was increased to four in 1994.

There was no significant difference in yield of harvestable-size YOY crayfish between the aerated/destratified ponds (mean = 267 kg/ha, range 147 to 332) and ponds that were not aerated (mean = 213 kg/ha, range 175 to 256) in the 1993 study. However, mean survival, growth rate, and water quality (dissolved oxygen) were all significantly better in the aerated/destratified ponds. Consequently, the aeration/destratification, feeding, and seining production technique was used to compare to the fall draining, cover-crop production, and harvest by trapping technique in 1994.

Four ponds were drained in October 1993 and allowed to dry. The ponds were tilled in March and planted with winter wheat (12 kg seed/ha). These ponds were then filled on May 25, 1994, at which time the wheat crop covered the ponds and was 12 to 15 cm tall. Wild rice (300,000 seeds/ha) was planted in mid-June to supplement the wheat crop.

The 1994 harvest of YOY crayfish has not yet been completed. However, harvest to date has been ten times greater in the aerated/destratified ponds than in the cover-crop ponds.

WORK PLANNED

A second crayfish project has not been approved. Thus, the only formal work planned is completion of the objectives originally outlined.

Research at Purdue will be completed this winter when pools are harvested. We anticipate restocking to assess reproductive success of age-1 female crayfish.

At KSU the crayfish in three farm ponds will continue to be monitored. In fall population estimates will be made to determine the summer survival. During June of 1995 the surviving crayfish will be intensively trapped with the individuals grouped into size groups. This will have completed two years of production and survival data so the project will be terminated.

IMPACTS

The impacts from this research effort are:

- Identification of preferred species raised by current culturists and prioritized areas in need of research efforts.
- YOY crayfish can be successfully acquired from wild populations, transported and stocked into culture ponds.
- Low density crayfish can grow very fast, some reaching edible size at the end of their first growing season and many reaching jumbo size the following spring.
- The large crayfish can be harvested quickly and efficiently by trapping in less than two weeks.
- Cover crop production in the NCR may not be the best approach to producing and harvesting crayfish from outdoor ponds.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1990-95					$61,960[a]	$61,960	$61,960
1992-93	$25,000	$29,439				$29,439	$54,439
1993-94	$25,000	$28,610				$28,610	$53,610
TOTAL	$50,000	$58,049	$0	$0	$61,960	$120,009	$170,009

[a]State of Indiana, Business Modernization and Technology Center, through the Purdue University New Crops Center

BAITFISH

Project Termination Report for the Period
September 1, 1992 to August 31, 1994

NCRAC FUNDING LEVEL: $62,000 (September 1, 1992 to August 31, 1994)

PARTICIPANTS:

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 Liaisons:		
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
Joseph E. Morris	Iowa State University	Iowa
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 baitfish 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 baitfish 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.

PROJECT ACCOMPLISHMENTS

OBJECTIVE 1

The many species and sizes used were identified; the most important baitfish was the fathead minnow and non-fish bait was the night crawler. About two-thirds of baitfish were harvested from the wild; the rest were cultured. Non-fish bait was above 50:50 wild vs. cultured. Availability varied seasonally and shortages were identified. Values of various fish and non-fish baits were estimated; baitfish composed 64%, and non-fish bait, 36% of the estimated value of bait. Bait mortality was a problem for 50% or more of wholesalers and retailers. Better temperature control and handling and transport would probably reduce mortality.

OBJECTIVE 2
The 107 respondents who reported growing baitfish on the 1990 survey of fish growers in the Economics and Marketing project were resurveyed about their baitfish enterprises, the sales of baitfish, and the costs of producing those baitfish during 1993. After three mailings and numerous follow-up telephone calls, a total of 33 surveys were completed, of which only 10 were useable. The remaining respondents were no longer in the baitfish business or handled only wild-caught species. Even for the 10 useable responses, the data provided was not sufficient for detailed budget analysis. Four of 10 reported sales of less than $10,000 during 1993 while only one reported baitfish sales in excess of $40,000. Nearly all operations could reach break even, i.e., cover their reported costs, within the sales class they reported.

OBJECTIVE 3
The value of the industry was estimated in six state economies. For all six combined, the total minimum estimated value in 1992 was about $165 million for baitfish and $92 million for non-fish bait.

OBJECTIVE 4
A list of rules and regulations affecting the bait industry was assembled for the 12 states in the NCR.

OBJECTIVE 5
Several species of important baitfish that are harvested from the wild were identified for investigation of potential for fish culture. At least one, the emerald shiner, will be studied with funding from another source.

IMPACTS
- Identification of the most important baitfish species, fathead minnows, and non-bait, night crawlers, was accomplished. Protection and research may be needed in the future.
- Identification of supply shortages indicates species for which increasing the supply would aid the industry. Baits commonly in short supply include: fathead minnows, lake shiners, golden shiners, night crawlers, leeches, and crayfish.
- Identification of disease and handling problems indicates areas for fruitful future research and extension efforts.
- Estimates of economic value, $165 million for baitfish and $92 million for non-fish bait for six states, emphasize the importance of the industry to those state economies.
- Inconsistent state regulations identified as problematic to the industry.
- Study has generated more than 50 inquiries on baitfish culture and markets.
- Aquaculture shortcourse offered, March 1993.
- Copes served as moderator of afternoon session of the Governor's Conference on Agriculture: Wisconsin Aquaculture 1994, University of Wisconsin-Stevens Point, February 1994.

RECOMMENDED FOLLOW-UP ACTIVITIES
- Study problems identified by the survey respondents and increase extension educational information on proper bait handling procedures.
- Investigate culture methods for important non-propagated species and potentially valuable unused species.
- Study ways to alleviate supply shortages.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED
See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93	$31,000	$13,800	$1,000[a]	$8,066[b]		$22,866	$53,866
1993-94	$31,000	$14,550	$1,000[a]	$8,066[b]		$23,616	$54,616
TOTAL	$62,000	$28,350	$2,000	$16,132		$46,482	$108,482

[a]Various bait dealers
[b]U.S. Fish and Wildlife Service and National Biological Service (Wisconsin Cooperative Fishery Resarch Unit)

EFFLUENTS

Progress Report for the Period
September 1, 1992 to August 31, 1994

NCRAC FUNDING LEVEL: $153,300 (September 1, 1992 to August 31, 1994)

PARTICIPANTS:

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	Nebraska
Ronald R. Rosati	Illinois State University	Iowa
Extension Liaison:		
LaDon Swann	Purdue University	Illinois/Indiana
Non-Funded Collaborators:		
John Hyink	Glacier Springs Trout Hatchery/Alpine Farms	Wisconsin
Iowa DNR	Rathbun and Fairport State Fish Hatcheries	Iowa
Myron Kloubec	Kloubec's Fish Farm	Iowa
Dave Smith	Freshwater Farms of Ohio, Inc.	Ohio
John Wolf	Glacier Springs Trout Hatchery/Alpine Farms	Wisconsin
Michael Wyatt	Sandhills Aquafarms	Nebraska

PROJECT OBJECTIVES

(1) Characterize aquaculture effluents from four types 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 results of these investigations provide a reference source that is useful to aquaculturists and regulatory agencies concerned with assessment of aquaculture effluents and their potential ecological impacts. Fish farmers in the region have become aware of the potential impacts of these effluents upon the environment and, subsequently, are more proactive in managing these effluents. These investigations provide information that is being used to develop best management practices (BMPs) for handling effluent generated from aquaculture facilities. The results from this study will help to educate regulatory agencies as to the ecological impacts of aquaculture effluents.

Copies of the information from these investigations will be forwarded to regional regulatory agencies. These studies should be helpful to such agencies in relation to providing reasonable judgments concerning National Pollutant Discharge and Elimination System (NPDES) permits.

In addition, these data will serve as useful baseline information for future studies on the effectiveness of different BMPs and diet regimes on aquaculture effluent and resulting water quality.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

POND PRODUCTION SYSTEMS

Fairport Fish Hatchery

Water quality was monitored in four culture ponds stocked with channel catfish, *Ictalurus punctatus*, fingerlings at Fairport Fish Hatchery near Muscatine, Iowa during 1993. Data were collected during the culture season and at harvest to analyze pond and effluent water quality. During the course of the growing season, water temperature, nitrates, and total suspended solids levels decreased while dissolved oxygen, ammonia, un-ionized ammonia and 5-day carbonaceous (organic) biological oxygen demand ($CBOD_5$) increased.

Analysis of data collected at harvest revealed that total phosphorus and total solid levels increased substantially in the pond effluents compared to those within the ponds. Towards the latter stages of fish harvest, $CBOD_5$ levels significantly increased within the ponds; effluent quality significantly deteriorated, having increased levels of total phosphorus, total nitrogen, $CBOD_5$ total solids, and total suspended solids. Fish biomass was a positive influence on $CBOD_5$.

Rathbun Hatchery

The effects of a flow-through aquaculture facility, Rathbun Fish Hatchery, Iowa, were assessed in 1993. Significant differences (P = 0.10) were determined in both water quality and invertebrate parameters at the six sample sites. Sites closest to the culture facility had elevated levels of several nitrogenous and phosphorus compounds compared to sites at the water intake and Chariton River. Main production factors influencing water quality parameters at sites were those taking place within the main hatchery building (flow, fish biomass, feed quantity and quality). Invertebrate groups, both zooplankton and macroinvertebrates, did not differ between the upstream and down-river stations.

The overall conclusion concerning this data set is that the effects of aquaculture effluents from this hatchery are minimal at best on both chemical and biological factors. High flows resulting from flood conditions caused increased dilution of aquacultural effluents. The 1993 field season had the worst flooding in the state's history. Thus, data collected during this period may not be representative of a typical year where some hatchery effects may have been seen under more normal conditions.

Kloubec Fish Farm

Samples were obtained during October 1993. At this time, two ponds had elevated levels of nitrites and three ponds had elevated levels of nitrates compared to earlier sampling periods. However, $CBOD_5$ levels have decreased in all ponds during this sampling period. The two ponds with the highest levels of $CBOD_5$ at this time had been harvested the previous month. The act of seining probably resulted in direct increase in $CBOD_5$ levels compared to those ponds that have not been harvested.

RACEWAY PRODUCTION SYSTEMS

Sandhills Aquafarms

The goal of the University of Nebraska-Lincoln (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 ft × 110 ft)-raceways, with total flows of 23.5 m^3/min (6,200 gpm) and annual production rates of rainbow trout of 77,100 kg/yr (170,000 lb/yr). Four sites were established above the facility and four below to obtain reliable, representative physicochemical measurements and water samples for laboratory analyses.

It was clear that several water quality parameters continued to differ consistently above versus below the aquaculture facility, particularly dissolved oxygen, pH, ammonium-nitrogen, total nitrogen, orthophosphate, and total phosphorus. Total suspended solids and turbidity showed no consistent trends. While temperature and biochemical oxygen demand (BOD) appeared to exhibit relatively little difference above and below the facility (although even these differences were consistent), downstream decreases in dissolved oxygen and pH, and increases in ammonium-nitrogen, total nitrogen, total phosphorus, and ortho-phosphate were evident . These data clearly indicate that water quality was altered downstream from the facility in both 1993 and 1994. It is anticipated that these differences will also be reflected in qualitative changes in the algal flora and invertebrate fauna, which have been collected and are presently being enumerated.

<u>Rushing Waters</u>

Rushing Waters is one of the most productive commercial rainbow trout hatcheries in Wisconsin. It has earthen raceways and ponds with a total flow approximately half that of the Sandhills Nebraska operation. As such it is representative of the more typically sized private trout production facilities in the North Central Region. This facility is supplied by groundwater wells and springs of moderate conductivity (between 400-600 µS) and is located at the head of a small creek that is a tributary to Blue Springs Creek in Jefferson County, Wisconsin.

Alterations in water quality occurred in the effluents of the three chains of raceways as compared to the source waters entering at the head of each raceway chain, and the water quality of the combined effluent in the creek leaving the property. Increases in BOD, total suspended solids, total ammonia nitrogen, nitrite-nitrogen, soluble reactive phosphorus, and total phosphorus were evident. Under typical production conditions these changes were slight, but on at least one occasion raceway cleaning activities created more elevated conditions of total suspended solids and total phosphorus in the creek leaving the property.

The effluents from the earthen production raceways had slightly lowered levels of nitrate-nitrogen compared to the source waters. It seems reasonable that the natural primary and secondary productivity in the earthen bottomed rearing units would utilize nitrate. Dissolved oxygen levels in the groundwater well sources tended to be slightly lower than in the effluents from the raceways. Use of aerating devices in the rearing units kept dissolved oxygen levels high, and the level in the newly pumped well water probably had not yet had enough contact with the atmosphere to reach full saturation before sampling. Source water samples were taken from an open reservoir rather than from groundwater wells, and water from this reservoir had slightly higher levels of solids, ammonia, and phosphorus than the well water sources. This difference was slight, however, in comparison to the general differences between the source waters and the effluents.

CAGE CULTURE PRODUCTION SYSTEMS
Trout Culture
Freshwater Farms of Ohio's trout cage culture facility is located near Urbana, Ohio in an abandoned quarry. The site consists of four separate quarry lakes, two of which discharge into a third, which together with the fourth, discharge into the Mad River. A total of ten sampling sites were monitored, including spring inflow into two lakes, the cage culture site at two depths, the discharge from the production lake into a settling lake, the discharge into the Mad River from the settling pond, discharge from an unused lake into the Mad River, and the Mad River upstream and downstream from the discharges.

For all measured parameters, there was no significant difference. There was no negative impact of Freshwater Farms of Ohio's trout cage culture operation on the water quality of the quarry lakes or the receiving water of the discharge. In fact, in most cases, significant improvement occurred due to the diluting effect of the quarry discharges.

Channel Catfish Culture
The Piketon Research and Extension Center (PREC-OSU) has a small demonstration cage culture operation in a 1.8 ha (4.5 acre) reservoir located at the facility. The cage culture operation reflects what a small farmer could easily build in a farm pond for the production of channel catfish and for trout growout in the winter months. The system was lightly stocked over the spring months with trout and yellow perch fingerlings and then heavily stocked with catfish (850 kg) in mid-summer.

The impact of the small scale cage catfish cage culture operation at PREC-OSU is not as easily characterized due to the input from the Center's wastewater treatment plant. Still most water quality parameters were typical of catfish production ponds.

RECYCLING SYSTEMS
Illinois State University (ISU) reports that a complete analysis has been conducted on the effluent from a second commercial-scale recirculating system. This report is currently being written and a final draft is expected in early November 1994.

OBJECTIVE 2
Data and descriptive statistics from each production site that has been investigated will be tabulated in a standard format showing the core water quality and production related fish and food parameters. Categories of sampling site and date will also be included. Tables from last year's progress report will be updated and combined with this year's results. These combined data sets will provide a single source overview of effluent water quality from representative regional aquaculture production facilities. This database in printed and electronic form will be made available for copying and distribution through NCRAC extension channels.

WORK PLANNED
Data from all investigators will be tabulated into a standard format for use as a reference database and final analyses will be incorporated into a final project termination report.

Several manuscripts have been prepared for publication based on these investigations. Others are anticipated once final analysis and gathering of pertinent production information has been finalized.

For the pond system investigation, two articles for the Progressive Fish-Culturist have been developed and will be submitted this year. In addition, one extension publication has been submitted to the NCRAC Publications Office for consideration as a NCRAC Fact Sheet.

IMPACTS

Regional regulatory agencies are already beginning to use information from these investigations to assist in decisions concerning aquaculture effluents and the environment.

Iowa Department of Natural Resources used NCRAC generated data in the plans for enlarging the Rathbun Hatchery. This study and others will be used as a database to support applications for NPDES Permits from Ohio Environmental Protection Agency and to provide a scientific database to answer questions.

With the use of the data set, NCRAC Extension specialists are informing aquaculturists about developing BMPs to reduce the negative impact of aquaculture effluents on the environment.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93	$77,064	$54,427	$15,000[a]			$69,427	$146,491
1993-94	$76,236	$43,261	$20,000[a]			$63,261	$139,497
TOTAL	$153,300	$97,688	$35,000			$132,688	$285,988

[a]Glacial Springs Hatcheries

AQUACULTURE DRUGS (INADs)

Progress Report for the Period
September 1, 1992 to August 31, 1994

NCRAC FUNDING LEVEL: $2,000 (September 1, 1993 to August 31, 1994)

PARTICIPANTS:

Robert K. Ringer	Michigan State University	Michigan
Ted R. Batterson	Michigan State University	Michigan
Henry S. Parker	USDA/CSREES	Washington, DC

PROJECT OBJECTIVES

(1) Ensure effective communications among groups involved with Investigational New Animal Drug (INAD) applications, including liaison with Canada.

(2) Serve as an information conduit between INAD applicants and the U.S. Food and Drug Administration/Center for Veterinary Medicine (FDA/CVM).

(3) Champion preparation and submission of INAD applications by affected groups.

(4) Seek opportunities for and encourage grouping of applications.

(5) Function as an information source for INAD applications.

(6) Coordinate educational efforts as appropriate.

(7) Identify potential funding sources for INAD activities.

ANTICIPATED BENEFITS

Investigation and approval of safe therapeutic drugs for use by the aquaculture industry is one of the highest priorities currently facing the industry. At present, only a few approved compounds are available to the industry and further development of the aquaculture industry is severely constrained by a lack of approved drugs essential for treating over 50 known aquaculture diseases. The FDA/CVM has afforded the aquaculture industry throughout the U.S. with a "window of opportunity" to seek approval of legal drugs to be used in their production practices. The need for additional drugs is great, but securing data necessary to satisfy the requirement of FDA/CVM for drug approval is time consuming, costly, and procedures are rigorous. The obtaining of drugs for legal use through the INAD process is one method the industry can provide FDA/CVM with data on efficacy and also aid producers in their production practices.

Educating potential INAD applicants will save time and effort for both the industry and FDA/CVM. A National Coordinator for Aquaculture INADs would serve as a conduit between an INAD applicant and the FDA/CVM. The Coordinator would help to alleviate time demands on FDA staff, thus allowing more time to process a greater number of applications as well as increasing the breadth of research endeavors within the industry. The grouping of INAD applicants should help to alleviate redundancy, amalgamate efforts, and increase the amount of efficacy data, all of which should result in greater progress toward developing available, approved therapeutic drugs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS
In September 1992, Ringer, Professor Emeritus of Michigan State University, was hired on a part-time basis as National Coordinator for Aquaculture INAD Applications. He served in that capacity through August 31, 1994. He also serves as the National Coordinator for USDA's National Research Support Project No. 7 (NRSP-7) for Minor Use Animal Drugs.

As National Coordinator for Aquaculture INADs he participated with FDA/CVM in educational workshops on INAD procedures and requirements. These workshops were conducted throughout the U.S. and attended by several hundred within the aquaculture community. This included workshops held in conjunction with the U.S. Trout Farmers Association, Boston Seafood Show, and Aquaculture Expo V in New Orleans. The workshop at the Boston Seafood Show was videotaped and is now available on cassette from the Northeastern Regional Aquaculture Center. In addition to the workshops, talks were presented on aquaculture drugs at the request of several organizations, including the World Aquaculture Society.

Ringer also helped in the preparation of a letter that FDA/CVM used in requesting disclosure information from those holding aquaculture INADs. By law, FDA/CVM cannot release any information about an INAD without such permission. As of September 1994, 70 disclosure permissions had been granted. A table containing information about these disclosures was recently made available to the general public. This included the names and addresses of the INAD holders as well as the drug and species of fish intended for use of the drug. It is intended that this table will be periodically updated after additional disclosure permissions have been obtained.

Every effort was made by the National Coordinator to encourage applicant grouping. The Coordinator also provided to INAD applicants specific instructions on proper procedures and requirements for submitting applications to FDA.

It was repeatedly stressed to the aquaculture community that aquaculture INADs are merely a stop-gap measure and efforts must be undertaken to support approval of new animal drugs.

WORK PLANNED
Dependent upon adequate financial resources, efforts during the next year will focus on New Animal Drug Applications (NADAs) for aquaculture. A National NADA Coordinator will be hired if the position can be supported at a minimum of a half-time level.

IMPACTS
Establishment of the National Coordinator for Aquaculture INAD applications has broadened awareness not only of INAD procedures and requirements but also of the need to carry investigations beyond the INAD to gain approval of new animal drugs for aquaculture.

As a result of this broadened awareness, the NRSP-7 and FDA sponsored a two-day national workshop, "Drugs in Aquaculture: Current Status - Future Goals." This workshop was held in Bethesda, Maryland September 29-30, 1994. Published proceedings of the workshop are forthcoming.

Because of limited funds, this position was only supported on a part-time basis (less than 15%). Therefore, not all intended aspects of coordination were accomplished. The Joint Subcommittee on Aquaculture, Working Group on Quality Assurance in Aquaculture Production, which established the position, has realized the benefits of a National Coordinator for aquaculture drugs. That group is making every effort to establish the position on a full-time basis in the future.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED
See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93				$17,000[a]		$17,000	$17,000
1993-94	$2,000			$12,180[b]	$4,000[c]	$16,180	$18,180
TOTAL	$2,000			$29,180	$4,000	$33,180	$35,180

[a]USDA funding through a Cooperative Agreement with NCRAC
[b]USDA funding through a Cooperative Agreement with NCRAC ($8,500) and FDA's Office of Seafood Safety ($3,680)
[c]Northeastern Regional Aquaculture Center ($2,000) and Southern Regional Aquaculture Center ($2,000)

APPENDIX

EXTENSION

NCRAC Extension Fact Sheet Series

Garling, D.L. 1992. Making plans for commercial aquaculture in the North Central Region. NCRAC Fact Sheet Series #101, NCRAC Publications Office, 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, NCRAC Publications Office, Iowa State University, Ames.

Kohler, S.T., and D.A. Selock. 1992. Choosing an organizational structure for your aquaculture business. NCRAC Fact Sheet Series #103, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. Transport of fish in bags. NCRAC Fact Sheet Series #104, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. Use and application of salt in aquaculture. NCRAC Fact Sheet Series #105, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E. 1993. Pond culture of channel catfish in the North Central Region. NCRAC Fact Sheet Series #106, NCRAC Publications Office, Iowa State University, Ames.

Morris, J.E. In review. Pond culture of hybrid striped bass. NCRAC Fact Sheet Series #107, NCRAC Publications Office, Iowa State University, Ames.

Cain, K., and D. Garling. 1993. Trout culture in the North Central Region. NCRAC Fact Sheet Series #108, NCRAC Publications Office, Iowa State University, Ames.

Mittelmark, J. In review. Fish health management. NCRAC Fact Sheet Series #109, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., J. Morris, and D. Selock. In press. Cage culture in the midwest. NCRAC Fact Sheet Series #110, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Technical Bulletin Series

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, NCRAC Publications Office, Iowa State University, Ames.

Swann, L. 1992. A basic overview of aquaculture: history, water quality, types of aquaculture, production methods. NCRAC Technical Bulletin Series #102, NCRAC Publications Office, Iowa State University, Ames.

Kinnunen, R.E. 1992. North Central Regional 1990 salmonid egg and fingerling purchases, production, and sales. NCRAC Technical Bulletin Series #103, NCRAC Publications Office, Iowa State University, Ames.

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, NCRAC Publications Office, Iowa State University, Ames.

Lichtkoppler, F.P. 1993. Factors to consider in establishing a successful aquaculture business in the North Central Region. NCRAC Technical Bulletin Series #106, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., and J.R. Riepe. 1994. Niche marketing your aquaculture products. NCRAC Technical Bulletin Series #107, NCRAC Publications Office, Iowa State University, Ames.

NCRAC Video Series

Swann, L. 1992. Something fishy: hybrid striped bass in cages. NCRAC Video Series #101, NCRAC Publications Office, Iowa State University, Ames.

Swann, L., editor. 1993. Investing in freshwater aquaculture. NCRAC Video Series #103, NCRAC Publications Office, Iowa State University, Ames.

Other Videos

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part I). Videorecording, VHS format, 38 min. Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Kayes, T.B., and K. Mathiesen, editors. 1994. Investing in freshwater aquaculture: a reprise (part II). Videorecording, VHS format, 41 min. Cooperative Extension. Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Situation and Outlook Report

Hushak, L.J. 1993. North Central Regional aquaculture industry situation and outlook report, volume 1 (revised October 1993). NCRAC Publications Office, Iowa State University, Ames.

ECONOMICS AND MARKETING

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 (revised October 1993). NCRAC Publications Office, Iowa State University, Ames.

Hushak, L., C. Cole, and D. Gleckler. 1993. Survey of wholesale and retail buyers in the six southern states of the North Central Region. NCRAC Technical Bulletin Series #104, NCRAC Publications Office, 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 5:3-5.

Robinson, M., D. Zepponi, 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.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, NCRAC Publications Office, Iowa State University, Ames.

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.

Manuscripts

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

Papers Presented

Foley, P., R. Rosati, P.D. O'Rourke, K. Tudor. 1994. Combining equipment components into an efficient, reliable and economical commercial recirculating aquaculture system. 25th Annual Meeting of the World Aquaculture Society Silver Anniversary Meeting, New Orleans, Louisiana, January 12-18, 1994.

O'Rourke, P. D., K. Tudor, R. Rosati. 1994. The selection and use of economic tools in the aquacultural engineering decision making process to determine the comparative costs of alternate technical solutions. 25th Annual Meeting of the World Aquaculture Society Silver Anniversary Meeting, New Orleans, Louisiana, January 12-18, 1994.

O'Rourke, P. D., K. Tudor, R. Rosati. 1994. Economic risk analysis of production of tilapia (*Oreochromis niloticus*) in a modified Red Ewald-style recirculating system operated under commercial conditions. 25th Annual Meeting of the World Aquaculture Society Silver Anniversary Meeting, New Orleans, Louisiana, January 12-18, 1994.

Riepe, J.R. 1994. Production economics of species cultured in the north central region. Animal Science, AS-495, one-week summer course "Aquaculture in the Midwest," Purdue University, West Lafayette, Indiana, June 13-17, 1994.

Riepe, J.R. 1994. Getting started in commercial aquaculture: economics. Workshop on Getting Started in Commercial Aquaculture Raising Crayfish and Yellow Perch, Jasper, Indiana, October 14-15, 1994.

Rosati, R., P. D. O'Rourke, K. Tudor, P.

Foley. 1994. Production of tilapia (*Oreochromis niloticus*) in a modified Red Ewald-style recirculating system when operated under commercial conditions. 25th Annual Meeting of the World Aquaculture Society Silver Anniversary Meeting, New Orleans, Louisiana, January 12-18, 1994.

Rosati, R., P. D. O'Rourke, K. Tudor, P. Foley. 1994. Technical and economical considerations for the selection of oxygen incorporation devices in a recirculating aquaculture system. 25th Annual Meeting of the World Aquaculture Society Silver Anniversary Meeting, New Orleans, Louisiana, January 12-18, 1994.

Tudor, K., R. Rosati, P. D. O'Rourke, Y. V. Wu, D. Sessa, P. Brown. 1994. Technical and economical feasibility of on-farm fish feed production using fishmeal analogs. 25th Annual Meeting of the World Aquaculture Society Silver Anniversary Meeting, New Orleans, Louisiana, January 12-18, 1994.

YELLOW PERCH

Publications in Print

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

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

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, 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 × *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., 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., 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.

HYBRID STRIPED BASS

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.

Kohler, C.C., R.J. Sheehan, C. Habicht, J.A. Malison, and T.B. Kayes. 1994. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society 123:964-974.

Manuscripts

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.

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.

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. Acclimization to captivity and out-of-season spawning of white bass. Aquaculture '92, 23nd Annual Meeting of the World Aquaculture Society, Orlando, Florida, May 21-25, 1992.

Kohler, C.C., R.J. Sheehan, C. Habicht, V.

Sanchez, J. Finck, J.A. Malison, and T.B. Kayes. 1991. Domestication and out-of-season spawning of white bass. 53rd Midwest Fish and Wildlife Conference, Des Moines, Iowa.

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

Kohler, C.C., R.J. Sheehan, and T.B. Kayes. 1989. Advancing hybrid striped bass culture in the Midwestern United States. 51st Midwest Fish and Wildlife Conference, Springfield, Illinois.

Kohler, C.C., R.J. Sheehan, C. Habicht, V. Sanchez, J.A. Malison, and T.B. Kayes. 1992. Collection, acclimation to captivity, and out-of-season spawning of white bass. American Fisheries Society Annual Meeting, Rapid City, South Dakota.

Kohler, C.C., R.J. Sheehan, V. Sanchez, and A. Suresh. 1994. Evaluation of various dosages of hCG to induce final oocyte maturation and ovulation in white bass. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-18, 1994.

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")

WALLEYE

Publications in Print

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, NCRAC Publications Office, 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.

Summerfelt, R.C., C.P. Clouse, and L.M. Harding. 1993. Pond production of fingerling walleye, *Stizostedion vitreum,* in the northern Great Plains. Journal of Applied Aquaculture 2(3/4):33-58.

Vargas, G. 1994. A behavioral study of feeding agression in walleye (*Stizostedion vitreum*). Report for the Minnesota Biological Sciences Summer Research

Program, University of Minnesota, Department of Fisheries and Wildlife, St. Paul.

Manuscripts

Barry, T.P., A.F. Lapp, L.S. Procarione, and J.A. Malison. Submitted. 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. Submitted. Genetic variation in candidate walleye brood stocks for use in aquaculture. Aquaculture.

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

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

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

Kapuscinski, A.R., R.C. Summerfelt, M.C. Hove, B.T. Bristow, E.W. Sell, R.C. Acomb, and D.J. Brister. In preparation. Heritability estimates for early life history traits in walleye. Aquaculture.

Summerfelt, R.C., C.P. Clouse, and L.M. Harding. In preparation. 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, Florida, May 21-25, 1992. Also presented at the Midwestern Regional Endocrinology Conference, Illinois State University, Normal, 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. Fifth International Symposium on Genetics in Aquaculture, Halifax, Nova Scotia, June 19-25, 1994.

Malison, J.A., T.B. Kayes, L.S. Procarione, J.F. Hansen, and J.A. Held. 1994. Induction of out-of-season spawning in walleye (*Stizostedion vitreum*). 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January

12-18, 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*). 23th Annual Meeting of the World Aquaculture Society, Orlando, Florida, May 21-25, 1992. Also presented at the Endocrinology Reproductive Physiology Program Research Symposium, Madison, Wisconsin, September 10, 1992.

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.

SUNFISH

Publications in Print

Bryan, M.D., J.E. Morris, and G.J. Atchison. 1994. Methods for culturing bluegill in the laboratory. Progressive Fish-Culturist 56:217-221.

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 buegill sunfish (*Lepomis macrochirus*) using cold and pressure shocks. M.S. thesis. Michigan State University, East Lansing.

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. In press. Pressure induced triploidy in *Lepomis*. Journal of the World Aquaculture Society.

Papers Presented

Sheehan, R.J., J.M. Paret, P.S. Wills, S.D. Cherck, 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 paper)

Brown, P.B., and K. Wilson. 1994. Experimental and practical diet evaluations with hybrid bluegill. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-16, 1994.

SALMONIDS

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. Submitted. 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. Submitted. Pretreatment of salmonid diets with phytase to reduce phosphorus concentrations in hatchery effluents. Progressive Fish-Culturist.

Procarione, L.S., and J.A. Malison. In preparation. Effects of rearing density and loading on the growth and stress response of rainbow trout. Aquaculture.

Riche, M., and P.B. Brown. In preparation. Absorption of phosphorus from feedstuffs fed to rainbow trout. Aquaculture.

Riche, M., M.R. White, and P.B. Brown. In review. Barium carbonate as an alternative indicator to chromic oxide for use in digestibility studies with rainbow trout. Nutrition Research.

Papers Presented

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.

Brown, P.B. 1993. Slamonid aquaculture in the North Central Region. Seventh Annual Minnesota Aquaculture Conference, Alexandria, Minnesota, March 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.

Riche, M., M.E. Griffin, and P.B. Brown. 1994. Effect of dietary phytase pretreatment on phosphorus leaching from rainbow trout feces. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-16, 1994.

CRAYFISH

Paper Presented

Brown, P.B. 1994. Pond production of crayfish. Workshop on Getting Started in Commercial Aquaculture Raising Crayfish and Yellow Perch, Jasper, Indiana, October 14-15, 1994.

BAITFISH

Publication in Print

Meronek, T. G. 1994. Status of the bait industry in the North Central Region of the United States. Master's thesis. University of Wisconsin, Stevens Point.

Manuscript

Meronek, T. G., F. A. Copes, and D. W. Coble. In preparation. Bait regulations in the north central United States. Fisheries.

Papers Presented

Copes, F.A. Aquaculture Shortcourse. Sponsored by University of Wisconsin-Sea Grant and Wisconsin Department of Agriculture, Greenwood, Wisconsin, March 1993.

Copes, F.A. 1995. Baitfish aquaculture. North Central Aquaculture Conference/Ninth Annual Minnesota Aquaculture Conference, St. Paul, Minnesota, February 1995.

Meronek, T.G. Survey of the bait industry in the north central United States. Annual Meeting of the Michigan Fish Farmers Association, Cadillac, Michigan, February 1993.

Meronek, T. G. Survey of the bait industry in the north central United States. Seventh Annual Minnesota Aquaculture Conference, Alexandria, Minnesota, March 1993.

Meronek, T. G. Survey of the bait industry in the north central United States. Illinois Fish Farmers Association, Pana, Illinois, March 1993.

Meronek, T. G. Status of the bait industry in the north central region. Annual Meeting of the Wisconsin Chapter of the American Fisheries Society, Marinette, Wisconsin, January 1994.

Meronek, T. G. Baitfish aquaculture and production. Governor's Conference: Wisconsin Aquaculture '94. University of Wisconsin, Stevens Point, February 1994.

EFFLUENTS

Manuscripts

Smydra, T.M., and J.E. Morris. In review. Alternative methods for aquaculture effluents. North Central Regional Aquaculture Center Extension Publication.

Smydra, T.S., and J.E. Morris. In review. Characterization of aquaculture effluents from an Iowa Hatchery. Progressive Fish-Culturist.

Smydra, T.S., and J.E. Morris. In review. Effects of agricultural effluents upon water quality and lotic invertebrate biota. Progressive Fish-Culturist.

Papers Presented

Hinrichs, D., J. Webb, R. Rosati, and P. Foley. 1994. Effluent characterization from the production of *Oreochromis niloticus* in a modified Red Ewald-style recirculating system. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-16, 1994.

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.

Rosati, R., D. Hinrichs, and J. Webb. 1994.

Biofilter performance during the production of *Oreochromis niloticus* in a modified Red Ewald-style recirculating system. American Fisheries Society Annual Meeting, Halifax, Nova Scotia.

Smydra, T.M., and J.E. Morris. 1994. Characterization of aquaculture effluents from two Iowa hatcheries. American Fisheries Society, Iowa Chapter, Council Bluffs, Iowa.

AQUACULTURE DRUGS (INADs)

Papers Presented

Ringer, R.K. 1993. Workshop on INADs, NADAs, and the IR-4 Project. California Aquaculture Association, Oakland, October 11, 1993.

Ringer, R.K. 1993. INAD workshop: proper drug and chemical use in aquaculture. 9th Annual Florida Aquaculture Association Conference, Fort Pierce, November 6, 1993.

Ringer, R.K. 1994. National INAD Coordinator's role in aquaculture. Aquaculture Expo VII/Annual World Aquaculture Society Meeting, New Orleans, January 13, 1994.

Ringer, R.K. 1994. State of current USDA regulations on drug, therapeutic, and chemical use. North Carolina Aquaculture Development Conference, New Bern, February 5, 1994.

Ringer, R.K. 1994. Investigational New Animal Drugs Workshop. Tropical and Subtropical Regional Aquaculture Center Industry Advisory Council Meeting, Honolulu, Hawaii, March 14, 1994.