NORTH CENTRAL
REGIONAL AQUACULTURE CENTER

ANNUAL PROGRESS REPORT 2000-01

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ANNUAL PROGRESS REPORT

For the Period
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A table of commonly used abbreviations and acronyms can be found inside the back cover.

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INTRODUCTION

The U.S. aquaculture industry is an important sector of U.S. agriculture. Production in 1999 reached about 842 million pounds and generated approximately $987 million for producers. 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 value of imported fisheries products more than doubled during the 1980s and continued to increase through 2000. In fact, the $19.0 billion value for 2000 was a record. In 2000, the trade deficit was $8.1 billion for all fisheries products, $7.1 billion of which was for edible fish and shellfish.

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 over exploited. 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 1996 Federal Agriculture Improvement and Reform Act (FAIR) (P.L. 104-127) otherwise known as the Farm Bill, 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:

- Developing and submitting proposals to USDA Cooperative State Research, Education and Extension Service (USDA/CSREES) which, upon approval, becomes a grant to the Center;
- Developing appropriate agreements (sub-contracts) with other parties, including ISU for the Associate Director's office, for purposes of transferring funds for implementation of all projects approved under the grants;
- 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;
- Maintaining liaison with other RACs; and
- Serving on the NCC.

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

- Coordinating, facilitating, and executing regional aquaculture extension program activities;
- Serving as head of Publications for NCRAC, including editor of the fact sheet, technical bulletin, culture manual, and video series as well as of the NCRAC Newsletter;
- Serving as the NCRAC liaison with national aquaculture extension programs, including in particular, extension programs of the other four USDA Regional Aquaculture Centers; 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 four persons from the IAC, a representative from the region's State Agricultural Experiment Stations and Cooperative Extension Services, a member from a non-land grant university, representatives from the two universities responsible for the center: Michigan State and Iowa State, and chairs of the two subcommittees of the Center's Technical Committee. 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 sub-committee 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 a member of the BOD.

NCRAC functions in accordance with its *Operations 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/Grants Management Branch for approval. To date the Center has received 14 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), FY94 (Grant #94-38500-0048), FY95 (Grant #95-38500-1410), FY96 (Grant #96-38500-2631), FY97 (#97-38500-3957), FY98 (#98-38500-5863), FY99 (#99-38500-7376), FY00 (#00-38500-8984), and FY2001 (#2001-38500-10369) with monies totaling $10,198,934. Currently, five grants are active (FY97-01); the first nine grants (FY88-96) have terminated.
- The Center annually coordinates a program planning meeting which typically sets priorities for the next funding cycle and calls for development of project outlines to address priority problem areas.
- Work Groups are formed which submit project outlines to the Center. The projects are peer reviewed by experts from both within and outside the region and a Project Review Committee.
- The BOD, using the Project Review Committee's recommendation and reviewers' responses, decides 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, Project Review Committee, 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 agents for both receiving and disbursing funds in accordance with all terms and provisions of the grants.

Through August 31, 2001, the Center has funded or is funding 56 projects through 291 subcontracts from the first 13 grants received. Funding for these Center supported projects is summarized in Table 1 below (pages 6-7). Information about funded projects is also available at the Center's Web site (http://ag.ansc.purdue.edu/aquanic/ncrac).

During this reporting period, the Publications Office at ISU produced and distributed a number of publications including fact sheets, technical bulletins, videos, and the Center's newsletter. 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; developing liaisons with appropriate institutions, agencies and clientele groups; soliciting, in coordination with the other RACs, written testimony for the U.S. House Appropriations Subcommittee on Agriculture, Rural Development, Food and Drug Administration, and Related Agencies and the U.S. Senate Appropriations Subcommittee on Agriculture, Rural Development, and Related Agencies; participating in the NCC; numerous oral and written presentations to both professional and lay audiences; working with other fisheries and aquaculture programs throughout the North Central Region; and in conjunction with the Aquaculture Network Information Center (AquaNIC) maintaining the NCRAC Web site.

PROJECT REPORTING

As indicated in Table 1, NCRAC has funded a number of projects for many of the project areas it has selected for research and extension activities. For example, there have been seven separately funded projects in regard to Extension and 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 continuations of previously funded activities while at other times they are addressing new objectives. Presented below are Progress or Termination Reports mostly for projects that were underway or completed during the period September 1, 2000 to August 31, 2001. Projects, or Project components, that terminated prior to September 1, 2000 have been reported on in earlier documents (e.g., 1989-1996 Compendium Report and other Annual Progress Reports).

A cumulative list of all publications, manuscripts, papers presented, or other outputs for all funded NCRAC project areas is contained in the Appendix.

Table 1. North Central Regional Aquaculture Center funded projects.

Project Area	Project Number	Proposed Duration Period	Funding Level	Grant Number
Extension	1	5/1/89-4/30/91	$39,221	88-38500-3885
			$37,089	89-38500-4319
	2	3/17/90-8/31/91	$31,300	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
	5	9/1/95-8/31/97	$10,813	92-38500-6916
			$20,391	95-38500-1410
	6	9/1/97-8/31/99	$39,000	97-38500-3957
		9/1/99-8/31/01	$94,000	99-38500-7376
	7		$476,052	
Economics and Marketing	1	5/1/89-12/31/91	$127,338	88-38500-3885
			$34,350	89-38500-4319
	2	9/1/91-8/31/92	$53,300	91-38500-5900
	3	9/1/93-8/31/95	$40,000	93-38500-8392
	4	9/1/99-8/31/01	$48,000	97-38500-3957
			$302,988	
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
	5	9/1/95-8/31/97	$199,507	95-38500-1410
	6	9/1/97-8/31/99	$185,600	97-38500-3957
	7	9/1/98-8/31/00	$92,370	98-38500-5863
			$982,262	
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
	5	9/1/95-8/31/97	$150,000	95-38500-1410
	6	6/1/99-5/31/00	$15,000	96-38500-2631
			$666,960	
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
	6	9/1/95-8/31/97	$117,395	94-38500-0048
			$59,835	95-38500-1410
	7	9/1/99-6/30/02	$127,000	98-38500-5863
			$927,627	
Sunfish	1	6/1/90-8/31/92	$130,758	90-38500-5008
	2	9/1/92-8/31/94	$149,799	92-38500-6916
	3	9/1/94-8/31/96	$173,562	94-38500-0048
	4	9/1/96-9/31/98	$199,921	96-38500-2631
	5	9/1/99-8/31/01	$200,000	99-38500-7376
			$854,040	

Project Area	Project Number	Proposed Duration Period	Funding Level	Grant Number
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	$199,290	94-38500-0048
	4	9/1/97-8/31/99	$158,656	97-38500-3957
			$637,742	
NCR Aquaculture Conference	1	6/1/90-3/31/91	$7,000	90-38500-5008
	2	12/9/98-6/30/99	$3,000	96-38500-2631
			$10,000	
National Aquaculture Extension Workshop/Conference	1	10/1/91-9/30/92	$3,005	89-38500-4319
	2	12/1/96-11/30/97	$3,700	95-38500-1410
			$6,705	
Crayfish	1	9/1/92-8/31/94	$49,677	92-38500-6916
Baitfish	1	9/1/92-8/31/94	$61,973	92-38500-6916
Wastes/Effluents	1	9/1/92-8/31/94	$153,300	92-38500-6916
	2	9/1/96-8/31/98	$100,000	96-38500-2631
			$253,300	
National Aquaculture INAD/NADA Coordinator	1	9/1/93-8/31/94	$2,000	89-38500-4319
		5/15/95-5/14/96	$5,000	94-38500-0048
		5/15/96-5/14/97	$6,669	92-38500-6916
			$3,331	95-38500-1410
		5/15/97-5/14/98	$15,000	96-38500-2631
		5/15/98-5/14/99	$13,241	94-38500-0048
		5/15/99-5/14/00	$10,000	95-38500-1410
			$55,241	
Tilapia	1	9/1/96-8/31/98	$118,791	96-38500-2631
	2	9/1/98-5/14/00	$150,000	98-38500-5863
			$268,791	
Aquaculture Drugs	1	7/1/96-6/30/97	$27,000	95-38500-1410
	2	12/1/96-11/30/97	$950	95-38500-1410
	3	10/1/99-9/30/00	$16,615	97-38500-3957
			$44,565	
White Papers	1	7/1/98-12/31/98	$5,000	96-38500-2631
	2	9/1/99-12/31/99	$17,500	97-38500-3957
			$22,500	

PROJECT TERMINATION
OR
PROGRESS REPORTS

EXTENSION[1]

Progress Report for the Period
May 1, 1989 to August 31, 2001

NCRAC FUNDING LEVEL: $476,052 (May 1, 1989 to August 31, 2001)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
James M. Ebeling	Ohio State University	Ohio
Robert D. Espeseth	University of Illinois	Illinois
Donald L. Garling	Michigan State University	Michigan
Jeffrey L. Gunderson	University of Minnesota-Duluth	Minnesota
F. Robert Henderson	Kansas State University	Kansas
John N. Hochheimer	Ohio State University	Ohio
Paul B. Jarvis	North Dakota State University	North Dakota
Anne R. Kapuscinski	University of Minnesota	Minnesota
Terrence B. Kayes	University of Nebraska-Lincoln	Nebraska
David L. Klinkebiel	North Dakota State University	North Dakota
Ronald E. Kinnunen	Michigan State University	Michigan
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
David J. Landkamer	University of Minnesota	Minnesota
Charles D. Lee	Kansas State University	Kansas
Frank R. Lichtkoppler	Ohio State University	Ohio
Terry A. Messmer	North Dakota State University	North Dakota
Jeff Mittlemark	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
Shawn H. Sanders	North Dakota State University	North Dakota
Daniel A. Selock	Southern Illinois University-Carbondale	Illinois
John P. Slusher	University of Missouri	Missouri
Fred L. Snyder	Ohio State University	Ohio
Brian R. Stange	North Dakota State University	North Dakota
LaDon Swann	Purdue University	Indiana/Illinois
Laura G.Tiu	Ohio State University	Ohio

PROJECT OBJECTIVES

(1) Strengthen linkages between North Central Regional Aquaculture Center (NCRAC) Research and Extension Work Groups.

[1]NCRAC has funded seven Extension projects. The first three were chaired by Donald L. Garling, the fourth project was chaired by Fred P. Binkowski, and the fifth, sixth, and seventh projects are chaired by Joseph E. Morris. A Project Component Termination Report for one of the objectives of the fifth Extension project is contained in the 1997-98 Annual Progress Report. The seventh project is a 2-year project that began September 1, 1999.

(2) Enhance the NCRAC extension network for aquaculture information transfer.

(3) Provide in-service training for Cooperative Extension Service, Sea Grant Advisory Service, and other landowner assistance personnel.

(4) Develop and implement aquaculture educational programs for the North Central Region (NCR).

(5) Develop aquaculture materials for the NCR including extension fact sheets, bulletins, manuals/guides, and instructional video tapes.

ANTICIPATED BENEFITS

Members of the NCRAC Extension Work Group have promoted and advanced 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;
- Access to information by the aquaculture industry through 24-hour access to worldwide aquaculture information (i.e., photographs, slide sets, and publications); and
- An enhanced legal and socioeconomic atmosphere for aquaculture in the NCR.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Aquaculture Extension Work Group members have:

- Served as extension liaison, if not an active researcher, for every NCRAC-funded project.
- Assisted in developing, writing, and editing of several culture manuals, e.g., Walleye Culture Manual, Sunfish Culture Guide, and Yellow Perch Culture Manual.
- Assisted with the planning, promotion, and implementation of hybrid striped bass, walleye, and yellow perch workshops held throughout the region.
- Provided the NCRAC Economics and Marketing Work Group with information relevant to that group's efforts to develop production budgets and expected revenues for the commercial production of food fish.
- Participated as Steering Committee members for a regional public forum regarding revision of the National Aquaculture Development Plan and three National Aquaculture Extension Workshops/Conferences.
- Participated as Steering Committee members for the past four North Central Regional Aquaculture Conferences.
- Served as writers and reviewers of several white papers for the Center.
- Served as Steering Committee members of state-specific aquaculture conferences as well as state aquaculture coordinating councils.

OBJECTIVE 2

The demand for aquaculture extension education programs cannot be met by the few specialists in the NCR (currently less than 3.0 full time equivalents). A NCRAC white paper on extension presents several strategies to address this concern.

Networking of specialists and Cooperative Extension Service (CES)-designated contacts has maximized efficiency of education programs and minimized duplication. Individual state extension contacts often respond to 10–15 calls per month from outside their respective state as well as interacting with colleagues with mutual concerns related to developing aquaculture activities. Many of these requests have been met by providing fact sheets, technical bulletins, bibliographies, maintenance of list servers, and detailed responses to both generalized and specialized questions. This extension network is critical to being able to match specific aquaculture questions with the best source of information, e.g., crawfish and leech information with Gunderson.

The Aquaculture Network Information Center (AquaNIC [http://aquanic.org/]) was established at Purdue University in 1994 through funds from USDA's Cooperative State Research, Education, and Extension Service and the Illinois-Indiana Sea Grant Program. AquaNIC hardware is housed in the Department of Animal Sciences at Purdue University and is coordinated by the Mississippi-Alabama Sea Grant Consortium, the Alabama Cooperative Extension System, and the Illinois-Indiana Sea Grant College Program.

AquaNIC was the first U.S. aquaculture Web site and is globally one of the most widely accessed and cited aquaculture Web sites. More than 1,000 individual, educational, commercial, and governmental Web sites link to AquaNIC as a source of online aquaculture information. An online aquaculture course has also been developed (http://ag.ansc.purdue.edu/courses/aq448/index.htm).

Aquaculture handbooks have been developed and distributed to each NCRAC-designated aquaculture extension contact and selected CES and Sea Grant field staff members.

As with any organization, there have been changes in NCRAC extension personnel since the inception of the project. For instance, Landkamer was the primary aquaculture extension contact for Minnesota. In the intervening years, he has been replaced by Kapuscinski and then by Gunderson. Two other individuals were replaced in 1994. In Kansas, Neils replaced Henderson and in Illinois, Kohler replaced Selock. Lee replaced Neils in Kansas in 1996. Hochheimer, who replaced Ebeling in Ohio, left Ohio State University; Tiu was appointed as the aquaculture extension specialist for Ohio in 1998. Sanders replaced Klinkebiel as the extension contact for North Dakota in 1998, resigned the following year; Brian Stange followed who was replaced by Paul Jarvis in 1999. Jerry Mills is now the appointed NCRAC Extension contact for South Dakota. As of 1999, Kayes is no longer with Nebraska Extension; to date no replacement has been designated. In 2000, Swann resigned from Indiana/Illinois Sea Grant; that position is currently open.

OBJECTIVE 3

In-service training for CES and Sea Grant personnel and other landowner assistance personnel have been held in most of the states in the region. Training has been in the areas of basic aquaculture, species-specific technologies, e.g., yellow perch, and safe seafood handling including Hazard Analysis Critical Control Point (HACCP). Many of these individuals have, in turn, trained industry representatives in respective subject matter.

To help prevent the spread of aquatic nuisance species (ANS) via cultured fish and baitfish, and to provide the industry

with a tool to demonstrate to natural resource agencies that private fish culturists can provide an ANS-free product, the ANS-HACCP approach was developed by Gunderson and Kinnunen. Developed materials include a manual and video for use in the training sessions as well as a related poster use in for retail outlets.

OBJECTIVE 4

A number of workshops, conferences, videos, field-site visits, hands-on training sessions, and other educational programs have been developed and implemented. There have been workshops on general aquaculture, fish diseases, commercial recirculation systems, leach and baitfish culture, aquaculture business planning, crayfish culture, pond management, yellow perch and hybrid striped bass culture, rainbow trout production, in-service training for high school vocational-agricultural teachers, and polyploid induction in sunfish held in the region. Depending on the workshop, the number in attendance often exceeded 100.

Four North Central Regional Aquaculture Conferences have been held. The first in Kalamazoo, Michigan was held in March 1991; the second was held in February 1995 in Minneapolis, Minnesota; the third conference was held in Indianapolis, Indiana; and the fourth was held February 1999 in Columbia, Missouri. These regional meetings were attended by hundreds of individuals including persons from Canada.

On April 10, 1993, over 700 viewers from 35 states and Canada watched the first national interactive teleconference on aquaculture, "Investing in Freshwater Aquaculture," that was broadcast from Purdue University. It was a televised satellite broadcast for potential fish farmers. The program consisted of 10 five- to seven-minute video tape segments that addressed production aspects of channel catfish, crayfish, rainbow trout, hybrid striped bass, tilapia, yellow perch, baitfish, and sportfish.

A Yellow Perch Producers' Forum was conducted in Hudson, Wisconsin on January 21-22, 2000. NCRAC extension contacts helped design the forum, the goals of which were to: (1) increase profitability and sustainability of existing perch producers, (2) increase cooperation between and among producers, researchers, and extension personnel, and (3) identify yellow perch research and extension needs. A summary of research and extension needs identified by the producers was compiled.

Kinnunen was instrumental in developing and compiling support for the "Environmental Strategies for Aquaculture Symposium." This two-day meeting took place during the 62nd Midwest Fish and Wildlife Conference in Minneapolis, Minnesota, December 3-6, 2000. The symposium provided a forum where industry, resource management agencies, and environmental/conservation organizations could discuss the scientific information available and/or needed to make reasoned decisions regarding aquaculture development. Several NCRAC state aquaculture extension contacts, i.e., Gunderson, Kinnunen, Morris, and Tiu, participated in the planning of or made presentations at this symposium.

In 2000, a workshop, entitled "Organic Aquaculture Standards Workshop" was developed and supported by Minnesota extension contacts. With support from the USDA's Agricultural Marketing Service, Packard Foundation, and the University of Minnesota's Extension Service, 43 national and international participants came together to address issues of concern regarding the National Organic Standards Board's organic aquaculture standards.

NCRAC extension contacts have served as editors for regional aquaculture newsletters as well as in-state aquaculture associations; served on state aquaculture advisory councils and state aquaculture task forces; and assisted in the planning and implementation of state aquaculture association meetings.

In support of extension activities being funded through research projects, i.e., hybrid striped bass and sunfish research projects, extension specialists have completed fact sheets, book chapters, and videos. These extension materials, arising from the combined efforts of both extension specialists and researchers, will help to address many questions concerning aquaculture in the NCR.

In addition to the previously mentioned areas, NCRAC extension contacts have been instrumental in fostering the continued growth of the aquaculture industry in the region. For example, Pierce created the Cooperative Extension Aquaculture and Marketing Educational Program to facilitate the development and implementation of aquaculture educational programs in Missouri. Tiu has also worked to revitalize the Ohio Aquaculture Association (OAA). She has continued to coordinate monthly OAA board meetings and edit the OAA newsletter. Gunderson has worked to distribute information about the Environmental Assessment Tool for Land-based Aquaculture developed by Kapuscinski under contract by the Great Lakes Fisheries Commission. This instrument has the ability to impact aquaculture development in much of the NCR. Lee has worked with the Kansas Aquaculture Association to develop and fund a current directory of Kansas fish producers.

Many of the NCRAC extension contacts have worked with industry and governmental representatives to produce state aquaculture plans and improved governmental regulations. Binkowski has worked with the Wisconsin Department of Agriculture, Trade and Consumer Protection in the production of A Wisconsin Aquaculture Industry Profile Processor Survey 1998 and 1998 Wisconsin Aquaculture Directory.

All fish processors, including those who handle aquaculture products, are now required by law to process their fish following HACCP guidelines. Kinnunen has conducted numerous HACCP training workshops throughout the NCR. These workshops served to train fish processors on the principles of HACCP and to give them knowledge on how to develop and implement a HACCP plan for their specific facility.

NCRAC extension contacts have been responsive to arising issues for the NCR aquaculture industry. For instance, the aquaculture industry is accused of being an important vector for the spread of exotic species like zebra mussels, Eurasian watermilfoil, round goby, and others because water and organisms are moved from one water body to another. Minnesota and Michigan extension contacts worked with other aquaculture and exotic species specialists from around the region to address this issue important to many fish farmers in the NCR, especially people raising fish for stocking or baitfish. To better identify the risks of spreading exotic species and to reduce those risks, a HACCP approach was used. Extension specialists in Illinois/Indiana, Michigan, Minnesota, and Ohio are participating in this project. The project is designed to identify critical control points and to develop guidelines for controlling the spread of exotic species

while not overburdening the industry with unnecessary regulations.

In-service training of secondary teachers has taken placed in a number of states. For instance, teachers in Iowa, Ohio, and Wisconsin have received instruction in aquaculture which they can use in their vocational agriculture courses.

Several states have on-site facilities that are used for extension programming. For instance, the Northern Aquaculture Center operated by North Dakota State University is used to inform the public about aquaculture as well as foster grass root support for this agriculture enterprise. The Piketon facilities operated by Ohio State University have also been used in a similar fashion.

The National Catfish Information Database has proceeded with Swann serving on the planning committee as well as serving as a lead editor. The Aquaculture Business Plan Guide has been delayed due to Swann's departure from Purdue University.

OBJECTIVE 5
Numerous fact sheets, technical bulletins, and videos have been written or produced by various participants of the Extension Work Group. These are listed in the Appendix.

WORK PLANNED
Efforts will continue in regard to strengthening linkages between research and extension work groups as well as enhancing the network for aquaculture information transfer. Participants will also continue to provide in-service training for CES, Sea Grant, and other land owner assistance personnel.

Educational programs and materials will be developed and implemented. This includes final publication of the Sunfish Culture Guide and development of the Yellow Perch Culture Manual and videos, and a Hybrid Striped Bass Culture Guide.

Future HACCP workshops will be planned as needed in the NCR. Any 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.

The Aquaculture Business Plan Guide will be completed by Southern Illinois University-Carbondale contacts in 2002.

IMPACTS
- In-service training for CES and Sea Grant personnel has enabled those professionals to respond to initial, routine aquaculture questions from the general public.
- Development of aquaculture education programs for the NCR has provided "hands-on" opportunities for prospective and experienced producers. More than 5,000 individuals have attended workshops or conferences organized and delivered by the NCRAC Extension Work Group.
- Fact sheets, technical bulletins, and videos have served to inform a variety of clients about numerous aquaculture practices for the NCR. For instance, "Making Plans for Commercial Aquaculture in the North Central Region" is often used to provide clients with initial information about aquaculture, while species-specific publications on walleye, trout, and catfish 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, transportation of fish in

bags, 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 outreach activities have helped to foster a better understanding and awareness for the future development of aquaculture in the region.
- AquaNIC has become an entry point for many people searching for aquaculture information on the Web. AquaNIC's home page now averages more than 3,000 visits per month by people from more than 50 countries.
- The 4-H Guide for Aquaculture will offer a tremendous opportunity to teach math, biology, and chemistry using experiential learning. Incorporating aquaculture into 4-H Youth programs is not limited to rural farming communities; the curriculum could also be used in urban and inner city schools.
- Fish processors who have attended NCRAC-sponsored HACCP Training Workshops have learned the principles of HACCP with regards to its importance in insuring the production of a safe fishery product. HACCP Plans have now been implemented by workshop attendees who are now keeping records of their daily processing and Sanitation Standard Operating Procedures. About 200 fish processors and/or aquaculturists have attended HACCP Training Workshops.
- In Ohio, an organized OAA has given producers the forum necessary to encourage appropriate legislation necessary for the success of the aquaculture industry in that state.

PUBLICATIONS, MANUSCRIPTS, WORKSHOPS, AND CONFERENCES

See the Appendix for a cumulative output for all NCRAC-funded Extension activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1989-91	$107,610	$237,107				$237,107	$344,717
1991-93	$94,109	$152,952				$152,952	$247,061
1993-95	$110,129	$198,099		$250,000	$55,000	$503,099	$613,228
1995-97	$31,204	$149,325	$5,000	$84,000		$238,325	$269,529
1997-99	$39,000	$110,559				$110,559	$149,559
1999-01	$94,000	$108,124				$120,816	$215,816
TOTAL	$476,052	$956,166	$5,000	$334,000	$55,000	$1,362,858	$1,839,910

ECONOMICS AND MARKETING[2]

Progress Report for the Period
September 1, 1999 to August 31, 2001

NCRAC FUNDING LEVEL: $48,000 (September 1, 1999 to August 31, 2001)

PARTICIPANTS:

Ronald E. Kinnunen	Michigan State University	Michigan
Edward M. Mahoney	Michigan State University	Michigan
William C. Nelson	North Dakota State University	North Dakota
Patrick D. O'Rourke	Illinois State University	Illinois
Industry Advisory Council Liaisons:		
Curtis Harrison	Harrison Fish Farm, Hurdsville	Missouri
David A. Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan

PROJECT OBJECTIVE

Evaluate the potential "supply" and "market" for hybrid walleye (female walleye × male sauger) and sunfish (female green sunfish × male bluegill) fillets relative to comparable fish.

Sub-objectives:

(1) To analyze information on the consumption and "supply" of comparable fish in the U.S. and the North Central Region.

(2) To provide a technical comparison of the qualities and attributes of hybrid walleye (female walleye × male sauger) and sunfish (female green sunfish × male bluegill) fillets with those of substitute fish.

(3) Assess consumer (supermarket/ consumers and restaurant/consumers) perceptions and likelihood of purchasing hybrid sunfish and walleye fillets relative to substitute fish.

(4) Evaluate the likelihood (and conditions, e.g., supply available, fillet sizes, price) that wholesaler, institutional buyers, and major fish retailers will add hybrid walleye and sunfish to their product lines.

(5) Assess the potential interest and perceived barriers to the commercial production of hybrid sunfish and walleye.

(6) Estimate the "supply" and "demand" for hybrid walleye and sunfish fillets.

ANTICIPATED BENEFITS

Markets are made, not born, and the successful introduction of aquaculture

[2]NCRAC has funded four Extension and Marketing projects. Termination reports for the first two projects are contained in the 1989-1996 Compendium Report; a termination report for the third project is contained in the 1996-97 Annual Progress Report. The first project was chaired by Donald W. Floyd; the second was chaired by Leroy J. Hushak; and the third was chaired by Patric D. O'Rourke. This progress report is for the fourth project which began September 1, 1999 and is chaired by Edward M. Mahoney.

produced walleye and sunfish will require focused and coordinated marketing strategies. The four "Ps" of marketing, "product" positioning, "pricing," "promotion," and "place" (distribution systems) are essential components of developing a market plan for any differentiated product. Much of the information to be gathered and analyzed in this project is intended to do more than provide estimates of market potential. It also provides guidance for developing marketing mixes to competitively position the new products in wholesaler, buyer, and consumer markets. The comparisons will provide potential producers and wholesalers with preferences and evaluations against other (substitute) fish to guide their "entry" marketing strategies. The information will also be useful for potential operators who may need to secure outside financing to be able to produce these species.

The study will also identify real and perceived potential barriers to commercial production and successful introduction of farm-raised sunfish and walleye hybrids. This information will be useful in designing educational materials and technical assistance aimed at producers and marketing channels. The purpose is to provide market indicators that would-be sunfish and walleye hybrid producers can incorporate as part of their feasibility assessments.

The first benefit will be to provide current producers with necessary information on markets for hybrid walleye and sunfish. Specifically, information will be provided on desired and undesirable attributes of fillets in comparison to competitor species, and the characteristics of the markets. The principal benefit will be to provide market information to potential producers of hybrid walleye and sunfish in order that they may make informed decisions on investment in producing these species, operation in terms of desired attributes, and market entry strategies.

The survey of wholesalers and buyers will produce information that will be synthesized with other information to evaluate that wholesaler, institutional buyers, and major fish retailers will add hybrid walleye and sunfish to their product lines and estimate the "supply" and "demand" for hybrid walleye and sunfish fillets. The compiled list of buyers and wholesalers along with descriptive information on their operations will be useful as a stand-alone product and will be useful in marketing hybrid and walleye. The results from the buyer and wholesaler survey will also be needed to develop the survey to assess the potential interest and perceived barriers to the commercial production of hybrid sunfish and walleye.

Obtaining accurate estimates of the market for these products will provide growers with one-half of the information necessary to evaluate whether these species will be profitable for their operation. The other necessary information pertains to the cost of production, processing, and marketing the product to the consumer. This market information will include quality comparisons to competitive species, consumer reactions and perceptions, and an analysis of general market conditions.

University researchers, extension specialists, and industry leaders agree that there is a need for more scientific, analytical, and integrated approaches to assessing "feasibility" of aquaculturally-raised fish. The approach and methods that will be employed in this study will be evaluated for potential application with other "new" aquaculturally-raised fish. The integration of market (product) tests, results from the production tests, and supplier interest in these products could provide a framework for use with other aquaculturally-raised fish.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

SUB-OBJECTIVE 1

Most of the data and information on the U.S. fish industry has been gathered by North Dakota State University (NDSU). This was accomplished by searching public and private sources of information and statistics, i.e., government statistics, professional aquaculture association Web pages, commercial aquaculture Web pages and a literature review of journals, other media, and proceedings of conferences. Substantial progress on the regional, national, and global markets (production, consumption, and trade flows) has been made in 2001. This is projected to be completed by December 31, 2001.

SUB-OBJECTIVE 2

A preliminary consumer blind taste-testing of wild-caught walleye and sunfish was conducted at the annual meeting of the Minnesota Aquaculture Association. Based upon preliminary surveys of behavior and taste-testing, walleye exhibits great potential demand. Walleye is a preferred species in the region and possesses characteristics demanded by fish consumers. Sunfish, although a sought after fish by anglers, was not received favorably by consumers in the taste-testing experiments. No further consumer survey work was conducted as fillets of hybrid walleye and sunfish were not available until summer (walleye) and fall (sunfish) 2001. Due to the timing of fillet availability, a request to extend the marketing project to May 15, 2002 was made and has been approved.

SUB-OBJECTIVE 3

A preliminary taste-testing survey was conducted by NDSU at one location. The taste-testing portion was limited to wild-caught walleye, which were purchased commercially, and wild-caught sunfish obtained from fishermen. This limited the taste-testing to one site, the annual meeting of the Minnesota Aquaculture Association in February 2000. It was an opportunity to inform the association members about the project and about the North Central Regional Aquaculture Center. These results, which are not based upon hybrid walleye and sunfish, will provide a limited baseline of comparison with future analyses of hybrid species.

The preliminary general consumer survey was conducted at four sites: the Minnesota Aquaculture Association in February 2000 (51 surveys completed); the Wisconsin Aquaculture Association in March 2000 (46 surveys completed); the Indoor Aquaculture Field Day, Vandalia, Illinois in March 2000 (22 surveys completed); and a Hazard Analysis Critical Control Point (HACCP) training program conducted by Kinnunen in August 2000 (20 surveys completed). A total of 139 surveys were completed in 2000. There was substantial difference in consumer behavior within the region with Indiana and Michigan being similar and Minnesota and Wisconsin consumers having similar patterns of consumption behavior.

SUB-OBJECTIVES 4 AND 6

During Year 1 of the study Michigan State University (MSU) took the lead in regard to the wholesaler and buyer analysis. MSU completed a literature review of previous studies that collected information from seafood wholesalers and buyers. This included obtaining survey instruments used to collect information from these and similar businesses. The literature review provided a conceptual basis for development of a draft survey instrument to be used to collect information from “seafood” brokers and distributors, institutional buyers, and major fish retailers in the seafood business.

The draft survey collects information on: (1) gross fish purchases, (2) cost of all fish

bought/brokered, (3) species of fish bought or sold, (4) percentage of fish they buy or sell that are wild-harvested saltwater fish, wild-harvested freshwater fish, and farm-raised fish, (5) percentage of fish that they buy or sell that are fresh whole, fresh fillet/steaked, frozen whole, frozen fillet/steaked, and live, (6) the importance of different attributes in deciding whether or not to buy or carry a particular finfish product, (7) whether they purchase/sell or have purchased/sold wild-harvested walleye, farm-raised walleye, wild-harvested sunfish, or farm-raised sunfish, (8) for which fish species would farm-raised walleye and sunfish be a substitute, and (9) what, if any, are the potential barriers to introducing farm-raised walleye and sunfish into their markets. The survey instrument collects information about the seafood brokers and distributors, institutional buyers, and major fish retailers that will have uses beyond the objectives of this study including regular monitoring of these businesses as it relates to purchase and sale of aquaculturally-raised fish.

MSU also evaluated different approaches for collecting information from businesses including food processors. The review of different methods (e.g., mail survey, fax surveys, telephone surveys, and personal interviews) resulted in a decision to utilize a mail/fax-telephone approach. Brokers and distributors, institutional buyers, and major fish retailers will be mailed and faxed a questionnaire and given the option of completing it and returning it by fax or mail or though a telephone interview. A telephone interview will be used to assess and correct for possible biases introduced by non-response. Non-response bias could be a major concern in studies such as these.

The draft survey was circulated by MSU to cooperators from Illinois State University (ISU) and NDSU for comment and recommended changes.

MSU developed a list of seafood brokers and distributors, institutional buyers, and major fish retailers. The list was developed by combining a list previously developed by NDSU, businesses listed in the yellow pages, and in a National Fisheries Institute publication. MSU collected telephone and fax numbers, and the names of key contact persons for 88 seafood brokers and distributors, seven major grocery retail chains, and 20 institutional buyers which were identified. The other two participants who are to develop similar lists for their market areas will use a similar approach. These lists were utilized as a sampling frame for the survey of brokers and distributors, institutional buyers, and major fish retailers in the seafood business questionnaires and also to later conduct product testing.

A fax and telephone survey was administered by MSU to fish wholesalers, fish retailers, and institutional buyers. The survey collected data about the types of fish (species, wild, aquacultured) sold and/or purchased, source (suppliers) of fish, attributes important in deciding what fish to handle, and their potential interest in purchasing and/or selling hybrid walleye. Seventeen large wholesalers of fish were identified. Of these, three were identified as being out of business. Ten (71%) of the remaining 14 wholesalers completed a survey. Fourteen (66%) of 21 small wholesalers that were identified completed a survey. Four of the five large fish retailers that were identified were successfully interviewed as well as three (of five) large institutional buyers of fish. The overall response rate for large and small wholesalers, retailers, and institutional buyers was 68%. Preliminary results indicate a very strong interest in fish that have the same attributes as hybrid walleye. Wholesalers and retailers exhibit no concern regarding their ability to market a new fish. Wholesalers and retailers indicate that there is strong consumer demand for fish with similar size and attributes as hybrid walleye.

They indicate that they increasingly encounter problems acquiring enough similar fish to meet this demand. A number of the wholesalers indicated that they are eager to sample the hybrid walleye. The only potential concern would be the price that wholesalers would be willing to pay aquaculture operators for the hybrid walleye. The data from the surveys has been coded and data analysis is now in process.

Forty-eight firms that bought or brokered fish in Illinois returned questionnaires that were distributed by ISU. A large number of questionnaires were returned unopened due to changes of address or an undeliverable address, indicating that several firms had ceased operations or moved out of the state. There was no attempt to determine if these firms had been replaced by newly established businesses. Among the 48 respondents, nine firms reported that they brokered fish, 25 firms reported that they carried out wholesaler/distributor operations, and 26 firms or individuals reported that they bought fish for retail establishments. The gross fish purchases of the firms in the year 2000 were $9,324,406 ± $6,241,016 (mean ± S.E; $N = 32$). For those firms that brokered fish or carried out wholesaler/distributor operations, 35.3 ± 8.1% of their business was conducted with wholesalers/distributors; 8.0 ± 4.7% was conducted with institutional buyers; 32.3 ± 7.3% was conducted with restaurants; 12.7 ± 4.4% was conducted with retailers other than restaurants; 11.2 ± 5.7% was conducted with consumers; and 0.3 ± 0.3% was conducted with other unspecified types of businesses. Of those firms that reported buying for retailers or institutions, 14 were buyers for restaurants, 16 were buyers for retailers other than restaurants, and four were institutional buyers.

ISU researchers found that with regard to the types of fish handled or brokered, the firms reported that 42.3 ± 4.8% of their transactions were related to wild-harvested saltwater fish, 26.7 ± 4.4% of their transactions were related to wild-harvested freshwater fish, and 32.4 ± 4.4% of their transactions were related to farm-raised fish. The following figures reflect the number of firms that handled or brokered various species of farm-raised fish: catfish, 36; salmon, 30; tilapia, 30; trout, 25; striped bass, 14; walleye, 8; yellow perch, 5; sunfishes, 3; and other unspecified species, 2. The firms reported the following distribution of farm-raised fish sales: salmon, 34.1 ± 5.4%; catfish, 31.7 ± 5.7%; tilapia, 20.8 ± 5.1%; trout, 7.2 ± 1.7%; striped bass, 2.1 ± 0.7%; yellow perch, 1.7 ± 0.9%; walleye, 1.6 ± 0.9%; sunfishes, 0.5 ± 0.3%; and other unspecified species, 0.3 ± 0.3%.

The ISU questionnaire revealed 29 firms reporting transactions involving wild harvested walleye over the past 22.4 ± 3.8 years. They rated their overall experience with wild-harvested walleye at 8.0 ± 0.4 (0 = unacceptable, 10 = positive). Nine firms reported transactions involving wild-harvested sunfishes over the past 30.7 ± 8.8 years. They rated their overall experience with wild-harvested sunfishes at 6.9 ± 0.5 (0 = unacceptable, 10 = positive). Transactions involving farm-raised walleye were reported by four firms, and transactions involving farm-raised sunfishes were reported by one firm. Twelve firms rated the food quality of farm-raised walleye, based upon experience, perception, or both at 7.8 ± 0.5 (0 = unacceptable, 10 = positive). Six firms rated the food quality of farm-raised sunfishes, based upon experience, perception, or both, at 8.2 ± 0.5 (0 = unacceptable, 10 = positive). Respondents were asked to rate 15 attributes that could potentially influence whether they would buy or sell a particular finfish product. The highest rating was assigned to “consistent

quality of supplied fish" (9.6 ± 0.1), and the lowest rating was assigned to "low price" (6.7 ± 0.4). Respondents were also asked to provide information about the various forms of fish that they purchased or brokered.

The information collected from the questionnaires indicates that there are potential markets for farm-raised walleye and sunfishes in Illinois, although the support for walleye appears to be stronger than the support for sunfishes. Walleye, and to a limited degree, sunfishes are possible substitutes for a number of saltwater and freshwater species that are currently being marketed in Illinois. Keys to successful market development appear to be consistent high quality with emphasis on taste and appearance, guaranteed year-round supplies, competitive pricing, and strategically placed product promotion. Product forms most commonly used by Illinois fish buyers include fresh whole, fresh fillet, and frozen fillet.

SUB-OBJECTIVE 5
MSU has identified existing aquaculture operations, including but not limited to, those that produce and market species similar to hybrid walleye and sunfish. They have also begun to conceptualize the development of a format for a survey instrument that will incorporate findings from the survey of seafood brokers and distributors, institutional buyers, and major fish retailers.

WORK PLANNED
SUB-OBJECTIVE 1
Completion is projected for December 31, 2001, and will be published as a separate report.

SUB-OBJECTIVE 2
The technical comparison of fillets will be completed by December 31, 2001.

SUB-OBJECTIVE 3
The consumer perception surveys will be initiated in November 2001 and be completed by March 2002.

SUB-OBJECTIVES 4 AND 6
The analysis of the survey results will be completed in November 2001. The results, along with information on the historical trends of finfish in the region and nation with an emphasis on comparable species, per capita consumption of fish by region, and fish consumption in the region, will be combined in a report to be completed in January 2002. Sub-Objective 6 will be completed and a report focusing on Sub-Objectives 2-6 will be completed by May 15, 2002.

Wholesalers, institutional buyers, and restaurant operators will participate in a product/sensory analysis to determine acceptance of hybrid walleye and sunfish relative to other fish. Participants will be asked to evaluate the fish on various attributes including color, flavor, mouth feel, and general acceptability of the fish. Following the tasting the panelists will be provided information on the walleye including potential supply and price range. They will participate in a focused discussion relating to the marketability of walleye, willingness to pay, and potential quantities that would be demanded.

SUB-OBJECTIVE 5
At the annual meeting of the Michigan Aquaculture Association a focus group will be held with operators. They will first be provided with: (1) findings from the wholesaler, retailer, and institutional buyer survey, (2) preliminary findings from product/sensory tests conducted by NDSU, and (3) technical information about raising hybrids. They will also be provided with a tasting of the fish. The focused discussions will emphasize: (1) producer awareness and

perceptions of hybrid sunfish and walleye including fish characteristics, e.g., ability to grow faster and easier to handle than their purebreds especially as it relates to walleye, (2) perceptions related to the requirements and technology needed to successfully raise these fish, (3) financial feasibility, (4) potential markets, marketability, and issues associated with marketing these products to wholesalers and institutional buyers, and (5) their opinions regarding the relative primary advantages and disadvantages associated with raising hybrids. These focus groups will be followed by more in-depth surveys of producers focusing on: interest in walleye, the price that they would have to charge wholesalers and restaurants for walleye filets, and the amount of the product that could be made available. The results of the focus group and survey of aquaculture operators will be completed by May 2002.

IMPACTS

Based upon preliminary surveys of behavior and taste-testing, walleye exhibits great potential demand. It is a preferred species in the region and possesses characteristics demanded by fish consumers. It appears that production problems and costs are the only limiting factors to a substantial increase in walleye production and sales.

Sunfish, although a sought after fish by anglers, was not received favorably by consumers in the taste testing experiments. It also was not one of the favored species in the survey of consumption behavior. Additional analysis of the hybrid sunfish needs to be undertaken prior to any firm conclusions or recommendations, however, based upon current information, sunfish will sell at a much lower price than walleye and will need to be produced at much lower cost per pound to be profitable.

The preliminary survey of wholesalers, retailers, and institutional buyers reveals that there is significant interest in hybrid walleye. Wholesalers and retailers are unable to acquire sufficient "similar" fish to meet current consumer demand. Wholesalers and retailers do not believe that "newness" would be a barrier to marketing the fish because walleye has significant positive name recognition. The process of conducting the survey created awareness and interest concerning hybrid walleye. A number of the wholesalers and retailers were interested in receiving more information including suppliers. Others expressed interest in taste and market testing of hybrid walleye. This implies that marketing the fish would not be difficult or costly.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Economics and Marketing activities.

SUPPORT

YEAR	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-00	$27,822	$53,777				$53,777	$81,599
2000-01	$20,178	$55,910				$55,910	$76,088
TOTAL	$48,000	$53,777				$109,687	$157,687

YELLOW PERCH[3]

Project Component Termination Report for the Period
September 1, 1997 to August 31, 2001

NCRAC FUNDING LEVEL: $185,600[4] (September 1, 1998 to August 31, 2001)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Donald L. Garling	Michigan State University	Michigan
Robert S. Hayward	University of Missouri-Columbia	Missouri
Jeffery A. Malison	University of Wisconsin-Madison	Wisconsin
Industry Advisory Council Liaison:		
Forrest Williams	Bay Port Aquaculture Systems, Inc., West Olive	Michigan
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-Funded Collaborators:		
Forrest Williams	Bay Port Aquaculture Systems, Inc., West Olive	Michigan

REASON FOR TERMINATION
Objective was completed.

PROJECT OBJECTIVE
Increase growth rates of yellow perch greater than 150 mm (6 in) by evaluating diets, feeding strategies, environmental manipulation, and mono-sex/bi-sex comparisons.

PRINCIPAL ACCOMPLISHMENTS
University of Wisconsin-Madison (UW-Madison) researchers published a manuscript describing the effects of genistein on the growth and reproductive development of yellow perch. Low levels (0.75 mg/g [parts per thousand] of diet) of genistein may have a positive effect on growth in yellow perch, but no apparent estrogenic effects on reproductive function. The effects of genistein on growth and reproductive development are highly dependent on dose.

Also at the UW-Madison, the growth of male and female yellow perch in ponds was compared using one pond in each year of the project. In both studies female yellow perch had greater weight and length gains than males when grown in ponds. Females were

[3]NCRAC has funded seven Yellow Perch projects. Termination reports for the first three projects are contained in the 1989-1996 Compendium Report; a termination report for the fourth and fifth projects is contained in the 1997-98 Annual Progress Report; a project component termination report for two objectives of the sixth project is contained in the 1999-00 Annual Progress Report. This project component termination report is for the third objective of the sixth Yellow Perch project, which was chaired by Jeffrey A. Malison. It was originally a 2-year study that began September 1, 1997. A termination report for the seventh Yellow Perch project is contained elsewhere in this Annual Progress Report.

[4]Total for all three objectives of the sixth Yellow Perch project.

larger at the beginning of each trial, and the difference in size between the males and females increased significantly as the studies progressed. At the conclusion of the two pond studies, females were 35 and 47% heavier, and 10 and 12% longer, respectively, than males. The growth of both males and females in these studies was relatively poor, most likely due to the tags used to identify individuals. Tag retention was very poor, and those individuals that did retain the tags showed a high incidence of ulcerated and necrotic tissue at the site of the tag.

Studies at the University of Missouri were designed to determine whether the tendency for dramatic growth slowing in yellow perch upon reaching 75–100 g (2.65–3.53 oz) could be negated by subjecting fish to feeding regimes that elicited compensatory growth. The expectation that compensatory growth feeding schedules might improve perch growth arises from previous North Central Regional Aquaculture Center (NCRAC)-funded studies where weight gain was doubled in hybrid sunfish (relative to controls fed ad libitum) in response to feeding schedules that elicited the compensatory growth response. This growing significantly beyond control weights through compensatory growth is now known as growth overcompensation, and was first identified through a NCRAC-funded study.

A first experiment sought to determine whether total weight gain by largely mature age-2 yellow perch could be increased over that of continuously fed controls by using compensatory growth feeding regimes. Five compensatory growth feeding regimes involving repeating cycles of no-feeding (for either 2, 7, 12, 17, or 22 days) followed by ad libitum feeding for as long as elevated feeding rates occurred, were evaluated over a 125-day experiment at 21°C (69.8°F). While episodes of compensatory growth did occur in all treatment groups when food was resupplied after the no-feeding periods, perch did not surpass control fish weights in any treatment group, unlike what occurred previously for hybrid sunfish. Point estimates of final weight did not reach that of the control group in any treatment group. A second experiment was run subsequently in an attempt to achieve greater weight gains through compensatory growth. In the second experiment, a compensatory growth feeding schedule similar to that in Experiment 1 involving 12-day periods of no feeding was used. However, 12-day periods of maintenance feeding were used rather than 12-day periods of no-feeding. Weights of perch exposed to this modified compensatory growth feeding schedule rapidly caught up to control fish (unlike in Experiment 1), but the rapid growth immediately ceased as soon as this group reached control fish weights.

Although study results indicate that compensatory growth feeding schedules cannot be used to increase growth of adult and maturing yellow perch beyond that of continuously fed controls, valuable insights relating to compensatory growth, growth overcompensation, and yellow perch aquaculture were provided by this work. Results indicated that an upper-weight limiting mechanism involving appetite suppression precluded the yellow perch undergoing rapid compensatory growth from surpassing control weights. This result was clearly different from that observed for hybrid sunfish where compensatory growth carried them well beyond control weights. Through comparisons with the hybrid sunfish studies, it is suggested that factors including fish age (or sexual maturity status), time-of-year, species-specific response, and hybrid vigor, are determinants of growth overcompensation capacity in fishes. In this study it was observed that

male and female yellow perch showed their most vigorous compensatory growth responses following food deprivation periods of different durations (after 2 days of food deprivation for males, and 12 days for females); causes for these differences are not yet apparent. Under conditions of unrestricted feeding in the control groups, growth rates and growth efficiency of female yellow perch exceeded those of males by up to two-fold. It was also indicated that substantial periods of restricted feeding can be imposed on yellow perch which, if followed by appropriate feed reprovisioning periods, will result in complete recovery of lost growth with no loss of food conversion ratio. This capacity may be of value in aquaculture in relation to feed and growth rate management. An article based on the results of this study has been published in the Journal of Fish Biology.

Research at Michigan State University was designed to compare gender-related growth rates of yellow perch greater than 150 mm (6 in) raised in single-gender or mixed-gender cohorts. Reliable external secondary sex characteristics could not be identified. Male and female stocks purchased from commercial yellow perch growers were randomly assigned (8/tank). Experiments were conducted in 110-L (29.1-gal) tanks. Water temperatures were maintained at 21°C (69.8°F) by a recirculation system. Each tank of fish was assigned to one of four feeding rates (0.5, 1.0, 2.0, and 3.0% of total tank wet body weight of fish per day) and fed a commercial diet for 16 weeks. There were three replicate tanks per feeding rate treatment. Fish were weighed every two weeks and feed levels adjusted accordingly. A mixed-gender analysis was not completed because the percentage of males in the mixed stock (66%) was not significantly different than the predominantly-male stock (71%). Gender-related metabolic differences between the all-female and predominantly-male stocks were determined using a saturation kinetics model developed by Mercer. Total proximate analysis (lipids, crude energy, crude protein, ash, and moisture) was done to determine general nutritional requirements. The all-female stock had a greater maximum growth rate (1.850 g [0.065 oz]/day/tank) than the predominately-male stock (1.112 g [0.039 oz]/day/tank). The optimal feeding level for the predominately-male stock was 0.76%/day and the maintenance level was 0.37%/day. The optimum feeding and maintenance levels for the all-female stock were similar to those determined for the predominantly-male stock at 0.78%/day and 0.37%/day, respectively. No metabolic parameters, excluding maximum growth rate, were statistically different between the two gender groups.

Work at Purdue University (Purdue) was designed to identify legal flavor additives for perch that will lead to increased consumption of feed. The original proposal indicated two genetic groups of fish would be raised at either 16, 22, or 28°C (60.8, 71.6, or 82.4°F) and offered one of three flavor additives: krill meal, squid meal, and betaine. An additional genetic group was obtained that had a proven record of rapid growth. The three genetic groups were all-female fish from Lake Mendota, mixed-sex fish from Lake Mendota, and mixed-sex fish from North Carolina. All groups of fish were obtained as juveniles and were raised to the appropriate size for experimentation.

Purdue researchers compared food consumption, weight gain, and feed conversion ratio in two different genetic groups of yellow perch fed one of three dietary flavor additives and reared at either 16, 22, or 28°C (60.8, 71.6, or 82.4°F). Consumption of feed was significantly

different at the three temperatures, increasing as temperature increased. Consumption of feed was not significantly different between all-female perch and mixed-sex perch, but weight gain and feed conversion ratio of all-female perch were significantly higher then the mixed-sex group of perch. Diets containing krill and squid meals as flavor additives were consumed significantly better than the control diet. The diet containing betaine as a flavor additive was consumed to the same degree as the control and the other two experimental diets.

Purdue researchers completed experiments to increase growth rates of yellow perch greater than 150 mm (6 in) by evaluating diets, feeding strategies, environmental manipulation, and mono-sex/bi-sex comparisons. Perch were obtained from two private producers. One group was all-female, the other mixed sex. Both groups originated from Lake Mendota, Wisconsin. Both groups of fish were obtained as juveniles, transported to Purdue, and grown for six months to the desired size. Both genetic groups were stocked into one of three experimental systems. All three systems were initially at 22°C (71.6°F). The temperature in one system was gradually lowered (1°C/day) and the temperature in another system was gradually increased (1°C/day). After achieving the desired temperatures of 16 and 28°C (60.8 and 82.4°F), respectively, all fish were acclimated for an additional two weeks. Four experimental diets, one a control and the other three with a flavor additive, were formulated based on the known nutritional requirements and recommendations for perch. All were practical diets. The three potential flavor compounds (krill meal, squid meal, and betaine) were added to the diets at 0.5% of the dry matter. All diets were offered to triplicate groups of fish in each temperature system as a satiation feeding regime. At the end of eight weeks, all fish were counted and weighed. Total consumption, weight gain, and feed conversion ratio were determined for each replicate. Feed consumption and weight gain were significantly affected by diet and temperature. Consumption increased as temperature increased from 16–28°C (60.8–82.4°F), but weight gain increased as temperature increased from 16 to 22°C (60.8 to 71.6°F), then declined at 28°C (82.4°F). All-female fish gained significantly more weight and converted feed more efficiently than the mixed-sex groups. There were no significant interactions among the variables. It seems clear that feed intake can be influenced in larger perch and additional weight gain can be realized. Several flavor additives were identified in this study that are readily available for use in diets. Diets containing flavor additives for grow out of yellow perch are recommended.

IMPACTS

This research has established methods for improving yellow perch growth as fish approach market size. Studies to date have shown that female perch out grow males, and accordingly the use of mono-sex female stocks may be a method for producers to increase growth rates of perch. Previous work has led to the development of methods for producing mono-sex female stocks of perch and this technology is currently being used by six regional perch producers under an Investigational New Animal Drug (INAD) exemption granted by the Food and Drug Administration. The establishment of optimum feed levels for perch will help producers minimize feed costs, which are one of the primary costs of aquaculture production. The development of methods to promote perch growth with naturally occurring dietary supplements may further improve the profitability of the culture of food-size yellow perch. There is significant

interest in moving toward regionally manufactured diets for perch, containing less fish meal and more regionally available ingredients. In this trend, diet acceptance becomes a critical issue. These data provide the framework for new dietary formulations that are accepted by perch. Together, the above strategies should provide the means for producers to reduce the cost of raising perch to market size.

RECOMMENDED FOLLOW-UP ACTIVITIES

This project was conducted to develop ways to increase growth rates of yellow perch greater than 150 mm (6 in) by evaluating diets, feeding strategies, environmental manipulation, and mono-sex/bi-sex comparisons. Research should be conducted on additional strategies for increasing the growth of male yellow perch or the use of all-female stocks. Additional research should be conducted on additional flavor additives as well as defining the minimum level of flavor additives required in diets containing high levels of plant protein sources.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Yellow Perch activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1997-98	$95,300	$98,565	$2,000			$100,565	$195,865
1998-00	$90,300	$94,335				$94,335	$184,655
2000-01		$45,000				$45,000	$45,000
TOTAL	$185,600	$237,900	$2,000			$239,900	$425,520

YELLOW PERCH[5]

Project Termination Report for the Period
September 1, 1998 to August 31, 2001

NCRAC FUNDING LEVEL: $92,370 (September 1, 1998 to August 31, 2001)

PARTICIPANTS:

Christopher Starr[2]	Bay Port Aquaculture Systems, Inc., West Olive	Michigan
Donald L. Garling	Michigan State University	Michigan
Michael D. Libbin[6]	Paragon Aquaculture, Oshkosh	Wisconsin
Harvey Hoven	University of Wisconsin-Superior Sea Grant Institute	Wisconsin
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan

REASON FOR TERMINATION
Objectives were completed or participants withdrew from the project.

PROJECT OBJECTIVES
(1) Evaluate recirculating aquaculture technology to optimize yellow perch growth, performance (survival, health, feed conversion), and water quality considering such factors as feed management, water replacement, flow rates, and density.

(2) Conduct "break-even analysis" for raising yellow perch in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

PRINCIPAL ACCOMPLISHMENTS
OBJECTIVE 1
Research at Bay Port Aquaculture (Bay Port), Paragon Aquaculture (Paragon), and Michigan State University (MSU) was

[5]NCRAC has funded seven Yellow Perch projects. Termination reports for the first three projects are contained in the 1989-1996 Compendium Report; a termination report for the fourth and fifth projects is contained in the 1997-98 Annual Progress Report; and a project component termination report for two objectives of the sixth project is contained in the 1999-00 Annual Progress Report. A project component termination report for the remainder of the sixth project, chaired by Jeffrey A. Malison, is contained elsewhere in this Annual Progress Report. This project termination report is for the seventh Yellow Perch project, which was chaired by Donald L. Garling. It was originally a 2-year study that began September 1, 1998.

[6]Paragon Aquaculture withdrew from the project after Year 1 because they lost all of the fish in their facility and went out of business. The loss of the fish was due to an unknown pathogen which also affected fish at other facilities as noted in the body of the report. Bay Port Aquaculture withdrew from the project in late 2000 because they lost all of the fish in their facility. The loss of fish was due to an accidental release of toxic levels of chlorine during a routine defouling treatment by Consumers Power Company which provided heated water for the Bay Port facility.

designed to evaluate the effects of multiple versus single-size cohort culture of yellow perch in recirculating systems using a common standardized protocol. Bay Port and Paragon were to have raised single-size and multiple-size cohorts in commercial-sized tanks, respectively. MSU research was designed to compare the growth of single- and multiple-sized cohorts of yellow perch in smaller replicated experimental tanks.

Bay Port was unable to begin their growth studies in 1998. An investor withdrew from the project which delayed construction of their recirculating aquaculture system, however, they provided fish for experiments at Paragon and MSU as called for in the common standardized protocol.

Paragon began their multiple cohort growth trials in October 1998. A cohort of 5,000 fish, approximately 50 mm (2.0 in) total length were marked with a left ventral fin clip at Bay Port so their growth rate in the multiple cohort system at Paragon could be followed throughout the project. The fish were transported to Paragon and stocked 10 days after marking.

MSU researchers visited Paragon in October 1998 and April 1999 to determine relative size distribution, ratio of marked to unmarked fish, and sex ratio in the culture tanks. Paragon provided bi-monthly survival data of marked and unmarked fish.

Paragon received a second cohort of fish in February 1999. Fish mortality was significantly higher than normal for the facility and continued throughout the first six months of the project. Eventually all of the fish in Paragon's facility died and soon thereafter (late summer 1999) the company went out of business.

The MSU recirculating system was designed and constructed during the fall of 1998. Yellow perch were obtained from Bay Port in January 1999. The fish experienced high mortality rates within days after stocking into a holding tank supplied with 12.5°C (54.5°F) well water. A second group of perch was obtained from Bay Port in February 1999 which also experienced high rates of mortality after transport and stocking into a holding tank at MSU.

The high level of mortality that occurred at MSU and Paragon in yellow perch that had been obtained from Bay Port also occurred at other yellow perch culture facilities which had received fish from Bay Port from the same stock of fish. Fish from MSU were sent to the MSU Animal Health Diagnostic Laboratory for evaluation. Necropsy, histopathology, bacteriology, and parasitology results were inconclusive. Fish from Paragon were evaluated by the Division of Animal Health by the State Aquaculture Veterinarian Dr. Myron J. Kebus and virology samples were submitted to Dr. Scott LaPatra, Clear Springs Foods, Idaho for diagnostics. Dr. Kebus also consulted with Dr. Michael Vander Klok (Michigan Department of Agriculture), Dr. Gerald Johnson (Atlantic Veterinary College Fish Diagnostic Laboratory), Dr. Fred Rommel (Pennsylvania Department of Agriculture Fish Diagnositic Lab), and Dr. Hamish Rogers (University of Pennsylvania Fish Diagnostic Lab). No definitive diagnosis was reported by any of the laboratories involved in performing diagnostics on the affected yellow perch from any of the locations that had been received from Bay Port.

Bay Port never experienced elevated levels of mortality at their facility of that stock of yellow perch which had served as the source of fish supplied to Paragon, MSU, and several other facilities. However, as a safeguard, Bay Port destroyed all of that remaining stock and sterilized all portions of their facility where those fish had been cultured.

Bay Port finally completed construction of its recirculating aquaculture system (RAS)

in May 2000. The system consisted of five, 18,100-L (4,782-gal) rearing tanks with associated filtration systems. They followed the original work plan to determine the growth and performance of yellow perch reared to market size (approximately 115 g; 4.1 oz) employing single-cohort management practices. Fish were stocked in the summer of 2000 but chemical contamination (chlorine) of Bay Port's source water (which is obtained from a power company along the shoreline of Lake Michigan) killed most of the fish in Bay Port's facility in mid-November. Any surviving fish, most of which were in the RAS, had to be sold to keep the company solvent, terminating the NCRAC-funded research. Eventually Bay Port brought a law suit against the power company for the loss of their fish but this did not preclude them from having to cease all operations, closing their facility, and terminating their employees at the beginning of 2001. Thus, the research that was planned for both Paragon and Bay Port was never completed.

As already mentioned, MSU experienced high levels of mortalities in their initial experiment, but completed a comparison of single- and mixed-size cohort rearing strategies in 2001. Nine tanks were randomly assigned one of the three cohorts: 20 small fish (average weight 8.9 g [0.31 oz] and length 9.4 cm [3.7 in]), 20 large fish (average weight 15.9 g [0.56 oz] and length 11.5 cm [4.5 in]), or 20 mixed-sized fish (10 small and 10 large fish). Each cohort was stocked in triplicate tanks receiving water from a common RAS of similar design to the RAS used at Bay Port. A feeding rate of 2% body weight per day divided into three feedings was assigned to match feeding rates used by the commercial cooperators. Fish were weighed and feeding rates were readjusted every four weeks. Results of the nine-month grow-out experiment indicated:

- Only a few fish reached market size by the end of the nine-month feeding trial, in part, because fish of the initial target size for large-size cohorts (16 cm; 6.3 in) were not available. Regression analysis of growth data indicated that the average size of large fish cohorts would have reached harvest size (20 cm [7.9 in] and 115 gm [4 oz]) in another 135 days assuming a continuous linear growth response .
- Females grew better than males in all cohorts.
- Large- and small-size female yellow perch reared in mixed-size cohorts grew at the same rates as large- and small-size females reared in single-size cohorts.
- Large-size male yellow perch reared in mixed-size cohorts grew at the same rate as large-size males reared in single-size cohorts.
- Small-size male yellow perch reared in mixed-size cohorts grew at a significantly higher rate than small-size males in single-size cohorts. The size of small males was not significantly different from the large-size males in the mixed-size cohort at the end of the grow-out period.

OBJECTIVE 2

This objective was designed to do the following:

- Develop a systematic method to collect monthly financial operating data from producers using commercial yellow perch recirculating systems.
- Collect and evaluate monthly financial data from four commercial producers/ growers of yellow perch in a recirculating system.
- Construct an annual financial operating statement of total operating revenues and expenses, and calculate a break-even financial operating level based on the expenses of production and the sales prices of the production for each cooperator.

Work was completed in the fall of 1998 by the University of Wisconsin-Superior Sea Grant Institute for a method and system to

collect financial operating data from active yellow perch commercial-scale producers. When the study was originally proposed and funded, four yellow perch commercial production facilities had agreed to cooperate by providing monthly financial operating data. Unfortunately, all of the original operators either terminated their operations or were unable to establish commercially-viable production levels. Both Paragon and Bay Port provided financial data but it was incomplete because no revenues were produced and, therefore, was not useful to conduct a break-even analysis. Hoven contacted other prospective or active RAS yellow perch producers seeking participation in the project. However, none were willing to become involved either because of insufficient size or unwillingness to participate.

IMPACTS

This research further demonstrated that female yellow perch grow at a faster rate than male perch. This research also demonstrated that females reared in mixed-size cohorts grew at the same rate as females reared in single-size cohorts. These preliminary results indicate that yellow perch aquaculturists using RAS may be able to use continuous loading, multiple-size cohort management strategies using an all-female stock of fish. However, if a mixed-gender stock is used, over time slower growing males may predominate the biomass. If the mechanism(s) causing the faster growth rate of the small-size male perch in the mixed-size cohort can be identified and used to increase the growth rate of all-male perch, culturists could use continuous loading, multiple-size cohort management strategies without obtaining an all-female stock.

RECOMMENDED FOLLOW-UP ACTIVITIES

The research objectives were developed to generate information to help aquaculturists using recirculating technology. Objective 1 was designed to compare the relative theoretical benefits of continuous loading (continuous harvest and utilization of the recirculating system near threshold design limits) against its potential drawbacks (reduced feed efficiency, increasing numbers/biomass of slow growing fish, and declining harvest rates over time).

Follow-up research should be conducted to determine the mechanism(s) causing small-size male perch in mixed-size cohorts to grow at a faster rate than their counterparts in single-size cohorts that was observed in the research system at MSU. A study to determine the effects of single- versus mixed-size cohorts should also be conducted with all-female stocks of yellow perch.

The calculation of break-even financial levels using actual costs of production and actual revenues received from product sales would have allowed current and prospective producers of yellow perch in a recirculating system to compare and forecast their financial results with some confidence. Each current or prospective producer could have compared their forecasted or actual production output, market prices received, and total operating costs against the actual financial results reported in this study. These studies should be conducted if commercial yellow perch aquaculturists using RAS who are willing to provide financial information can be identified.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Yellow Perch activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1998-01	$92,370	$82,496	$170,651[a,b]			$253,147	$345,517
TOTAL	$92,370	$82,496	$170,651[a,b]			$253,147	$345,517

[a]Paragon Aquaculture ($64,575); based on their original allocation for the project of $61,900 only $13,834 of which was actually expended.

[b]Bay Port Aquaculture Systems ($106,076); based on their original allocation for the project of $57,400 only $10,536 of which was actually expended.

HYBRID STRIPED BASS[7]

Project Termination Report for the Period
September 1, 1995 to August 31, 2001

NCRAC FUNDING LEVEL: $30,000 (September 1, 1995 to August 31, 2001)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Joseph E. Morris	Iowa State University	Iowa
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa

REASON FOR TERMINATION
The objectives were completed and funds terminated.

PROJECT OBJECTIVES
(1) Coordinate selection of various culture systems and implement field testing (fingerling to advanced fingerling to food size).

(2) Write an initial culture manual using information generated by all the hybrid striped bass research sponsored by the North Central Regional Aquaculture Center (NCRAC).

(3) Provide associated fact sheets, bulletins, and videos for hybrid striped bass research in the North Central Region (NCR).

(4) Conduct workshops presenting technologies developed through NCRAC-funded projects covering general methods of culturing this fish.

PRINCIPAL ACCOMPLISHMENTS
Coordination and implementation of field testing involving the grow out of fingerlings to advanced fingerlings and advanced fingerlings to food size was done in conjunction with several NCRAC aquaculture extension contacts.

Morris and Gibson T. Gaylor (post-doctoral fellow, Iowa State University) wrote "Hybrid Striped Bass Culture: Current Knowledge in the Industry." This manual provides an overview of previous hybrid striped bass culture manuals published in the 1980s ("Culture and Propagation of Striped Bass and Its Hybrids" produced by the American Fisheries Society and "Farming a New Fish: Hybrid Striped Bass" available from North Carolina Sea Grant) and as an update based on current information and that garnered from NCRAC-funded research activities, e.g., nutritional and gamete storage and transportation. The document has been reviewed by Kohler as well as four

[7]NCRAC has funded six Hybrid Striped Bass projects. Termination reports for the first four projects are contained in the 1989-1996 Compendium Report; a project component termination report for the two research objectives of the fifth project is contained in the 1997-98 Annual Progress Report. The first five projects were all chaired by Christopher C. Kohler. This termination report is for the remaining objective of the fifth project, which began September 1, 1995, as well as the objectives of the sixth project. The sixth project began June 1, 1999 and was chaired by Joseph E. Morris.

additional reviewers. Final publication is scheduled for Spring 2002 and will be NCRAC Culture Series #103.

A hybrid striped bass fact sheet that was developed by Morris and Kohler was published October 1999 (NCRAC Fact Sheet Series #107).

A video is being produced by Kohler using a combination of computer software, slides, and moving-video footage. It covers basic aspects of hybrid striped bass production and advances made by the various NCRAC Hybrid Striped Bass projects.

The first of two hybrid striped bass workshops was held in November 1995 in Champaign, Illinois. Workshop topics included larval culture, cage culture, brood stock management, and an industry perspective. The attendees were from Illinois, Indiana, Iowa, and Missouri. Speakers, who had been participants in various NCRAC-funded projects, included Chris Kohler, Sue Kohler, and Bob Sheehan of Southern Illinois University-Carbondale, George Brown and Joe Morris of Iowa State University, and LaDon Swann of Purdue University. Proceedings from this workshop are available from the NCRAC Publications Office at Iowa State University.

A second workshop will be held in St. Louis, Missouri in February 2002. It will also focus on presenting technologies developed through NCRAC-funded projects on hybrid striped bass. General methods used for culturing this important food fish will be fully covered. Speakers will include selected members of past NCRAC Hybrid Striped Bass Work Groups, as well as one or more guest speakers from the private sector. Workshop registrants will receive information packets covering important details of hybrid striped bass culture, i.e., NCRAC Fact Sheet #107. To obtain the greatest number of conference attendees, a workshop brochure will be developed, advertised, and distributed throughout the NCR using existing extension and research networks. It is anticipated that attendees will come from the NCR as well as other regions.

IMPACTS

The proceedings from the 1995 NCRAC hybrid striped bass workshop have been used in addressing many concerns and questions about hybrid striped bass culture. The 2002 workshop will build upon previous related outreach materials in bringing forth new information to the aquaculture industry.

RECOMMENDED FOLLOW-UP ACTIVITIES

Future extension programming, including materials and workshops, should use information garnered from this project as a base. In addition, new information from the newest (seventh) NCRAC Hybrid Striped Bass project should be included in any modifications to this information base.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Hybrid Striped Bass activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1995-97	$15,000	$16,968				$16,968	$31,968
1999-00	$15,000						$15,000
TOTAL	$30,000	$16,968				$16,968	$46,968

WALLEYE[8]

Progress Report for the Period
September 1, 1999 to August 31, 2001

NCRAC FUNDING LEVEL: $121,000 (September 1, 1999 August 31, 2001)

PARTICIPANTS:

Konrad Dabrowski	Ohio State University	Ohio
Robert S. Hayward	University of Missouri	Missouri
Ronald E. Kinnunen	Michigan State University	Michigan
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
David A. Smith	Freshwater Farms of Ohio, Inc.	Ohio
Industry Advisory Council Liaison:		
David A. Smith	Freshwater Farms of Ohio, Inc., Urbana	Ohio
Extension Liaison:		
Ronald E. Kinnunen	Michigan State University	Michigan

PROJECT OBJECTIVES

(1a) Carry out commercial-scale field trials for rearing hybrid walleye fingerlings to food size (25.4 cm; 10 in minimum) in tanks.

(1b) Carry out commercial-scale field trials for rearing hybrid walleye fingerlings to food size (25.4 cm; 10 in minimum) in ponds (at least three ponds at each site) at sites in the upper and lower portions of the North Central Region.

(2) Conduct producer training workshops on propagation of hybrid walleye.

ANTICIPATED BENEFITS

This project addresses priority needs identified by the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council for advancing hybrid walleye aquaculture in the North Central Region (NCR). One major constraint limiting development of hybrid walleye aquaculture is the lack of substantive information on the commercial feasibility of culturing hybrid walleye to food size. The proposed commercial field trials described will establish critical production parameters (including, but not limited to, fish growth rate, survival, and feed conversion) that can be expected for raising hybrid walleye commercially to food size in tanks and in ponds in the northern and southern parts of the NCR. In order to minimize costs, the ponds and tanks used for this study are near the minimum size needed to have commercial applicability. The trials will also generate detailed information that can be used to develop economic models outlining the production costs of producing food-size hybrid walleye with these different systems. The next logical step in this line of study will be for NCRAC to

[8]NCRAC has funded seven Walleye projects. Termination reports for the first, third, and Objective 1 of the fourth projects are contained in the 1989-1996 Compendium Report; a termination report for the second, fifth, sixth and the remainder of the fourth projects is contained in the 1996-97 Annual Progress Report. This progress report is for the seventh Walleye project, which is chaired by Konrad Dabrowski. It is a 3-year study that began September 1, 1999, however, the first objective was to be completed in two years as originally proposed.

employ economists to develop such models in a subsequent project.

In addition to providing field trial data, the grow-out studies at Freshwater Farms of Ohio (FFO), the University of Missouri (UM), and the University of Wisconsin-Madison (UW-Madison) will each test critical scientific hypotheses with an adequate number of replications to reach valid statistical conclusions. The studies at FFO and UM will determine the extent to which out-of-season spawning can improve the production efficiency of rearing hybrid walleye to food size in tanks and ponds in the southern part of the region. The studies at UW-Madison will determine the extent to which females outgrow males.

It is anticipated that the commercial rearing of hybrid walleye in indoor recirculating systems will benefit from multiple-spawning schedules to allow year-round production. The use of the commercial recirculating systems developed at FFO (WaterSmith Systems) for rearing rainbow trout may be found to be suitable for hybrid walleye culture. The construction and operation of these WaterSmith Systems are suitable for low-cost and farmer-friendly operations. No proprietary or patent restrictions are involved, and all materials are available from a variety of sources. The use of conical-bottom polyethylene tanks has allowed a drastic reduction in maintenance and solids removal. The use of the biofilter media (pea gravel) as the tank support structure also reduces construction costs significantly. The economic analysis of the operation of these commercial-scale systems will overcome the shortcomings of trying to estimate profitability based on small research-scale studies.

One of the greatest potential benefits of the workshops under Objective 2 will be that aquaculture producers will be made aware of a new species that can be cultured in the region that has potential for considerable economic returns. The study will also identify real and perceived potential barriers to the commercial production of hybrid walleye. This information will be useful in designing educational materials and technical assistance. In addition, aquaculture extension professionals are expected to be among the participants in these workshops, which could result in a significant "multiplier effect" in disseminating the knowledge presented. Another benefit of very visible commercial field trials will be to permit and encourage persons interested in raising hybrid walleye commercially to tour and inspect the facilities, thereby helping them assess the potential of raising hybrid walleye in different systems. Additional extension information will be disseminated in conjunction with the proposed economic models to be prepared subsequent to the conduct of the field trials of the present study.

This study will be closely linked to a related NCRAC study on the marketing of hybrid walleye. All of the collaborators of this project have agreed to provide samples of hybrid walleye at the end of the first and second years of this project that will be needed to conduct components of the marketing study. Ed Mahoney at Michigan State University is the leader of the marketing project and will serve as the contact person for this study should the need arise.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

During spring 2000, Ohio State University (OSU) researchers raised both out-of-season and regular season spawned hybrid walleye in an 800-L (211-gal) cylindrical-tank rearing system. The water flow was set at 4–5 L/min (1.1–1.3 gal/min) and there were two surface spray points supplying an

additional 750 mL/min (0.2 gal/min) each. The central stand pipe in each tank was covered with 500-µm mesh screen. Daily measurements of turbidity, temperature, and dissolved oxygen were recorded. Turbidity in the tanks was maintained at a level of 10–20 nephelometric turbidity units by a constant supply of clay solution to the system through inlet pipes using a peristaltic pump (Masterflex, model 7021-24, Cole Parmer Instruments, Vernon Hills, Illinois). Water temperature was maintained at approximately 19–20°C (66.2–68.0°F) in both experiments. Dissolved oxygen levels varied between 6.5 and 8 mg/L (ppm). Light intensity and photoperiod were kept at 150 lx and 12-h light/12-h dark, respectively.

Samples of 10–20 viable larvae or juveniles from each tank were collected every three to four days. Presence of food in the gut and swim bladder inflation was recorded. These same larvae were measured for caudal length and wet weight. Survival of hybrid walleye after both experiments was determined by counting all the viable fish remaining.

Survival, final length, and weight for out-of-season and regular-season hybrid walleye reared at OSU were as follows: (1) out-of-season—13.1 ± 2.4% survival, 24.6 ± 2.4 mm (0.97 ± 0.09 in) final length, 0.15 ± 0.05 g (0.005 ± 0.002 oz) final weight; (2) regular season—19.0 ± 1.7% survival, 30.6 ± 4.2 mm (1.20 ± 0.17 in) final length.

In the second year of study, OSU researchers were not able to produce sufficient numbers of 5–7.5 cm (2.0–3.0 in) feed-trained hybrid walleye juveniles for tank and pond rearing experiments. Wild parental stocks from Ohio had to be used.

On April 4, 2001, OSU researchers with the help of Ohio Department of Natural Resources personnel, collected walleye eggs from ovulating females caught by trap nets from the Maumee River, Ohio. Undiluted hybrid walleye sperm was transported on ice. The eggs were fertilized with sperm on the river bank for 3 min and washed three times with 400 mg/L (ppm) tannic acid solution for 2 min each washing. The fertilized eggs were then washed with river water to allow water hardening. The fertilized eggs were transported to the OSU Aquaculture Laboratory in oxygenated plastic bags. The time between fertilization and incubation of eggs in McDonald jars was about 4 h. Temperature of incubation was 14 ± 1°C (57.2 ± 1.8°F). Eggs were treated daily with 100 ppm formaldehyde starting four days after fertilization until one day before hatching to prevent fungal infection.

Hybrid walleye embryos hatched on April 17 and 18, 2001. Hatching rate was 70.4%. The newly-hatched embryos were stocked in 400-L (106-gal) circular tanks provided with flow-through water and allowed to absorb the yolk sac for three to four days. On April 21, 2001, newly-hatched embryos were placed in six oxygenated plastic bags (about 17,000 embryos per bag) and transported to OSU's Piketon Research and Extension Center (PREC). Fish from each of the six plastic bags were stocked into the same rearing system used in spring 2000. Temperature ranged from 16.7–19.8°C (62.1–67.6°F) and dissolved oxygen ranged from 7.7–8.2 ppm.

Fish were fed with dry diets Biokyowa B-400 and B-700. Fish (<11 mm [0.4 in] total length) were fed with 100% Biokyowa B-400 from April 24 to May 8. The high survival observed in tanks 1–5 during this period (78–100%) suggested the high palatability of this diet and suitability of the pellet size for hybrid walleye. On May 8, survival ranged from 78–81% in tanks 1–5, although a lower survival of 7.8% was recorded in tank 6. From May 9 to May 15, fish (11–13 mm [0.43–0.51 in] total length) were fed with 50% Biokyowa B-400 and 50% B-700. Survival in tanks 1–6 declined sharply (0.1–7.8%) on May 15. A lot of

uneaten food was observed at the bottom of the tank and fungus accumulated in the sidewalls of some tanks. Survival of fish in tanks 1–5 was similar during May 15-22 (3.7–7.8%).

The bimodal distribution of fish sizes was observed in tank 6: 12 and 26 mm (0.47 and 1.02 in) total length; hence, cannibalism had occurred. On May 15, the experiment in tank 6 was terminated because of the very few fish that remained ($N = 17$).

On June 14, 2001, 300 feed-trained hybrid walleye (23.2 ± 3.4 mm [0.91 ± 0.13 in] total length; 0.13 ± 0.04 g [0.005 ± 0.001 oz]) were transported in oxygenated plastic bags to FFO for further rearing. However, these fish died soon after transport due to pump failure in the small rearing system at FFO.

Stocking of the tanks at FFO was dependent on the number of fingerlings produced by OSU. It was anticipated that a total of 18,000 fingerlings would be available and an estimated 21,500 fish were provided to this phase of the project. These fish were not the 50 mm fingerlings that were anticipated for the demonstration of the commercial grow-out facility, but were 25 ± 2 and 31 ± 4 mm (0.98 ± 0.08 and 1.22 ± 0.16 in) in length, for early and regular season spawnings, respectively. Large mortalities occurred with these fish after transport and temporary facilities were provided in which they could be better adapted to new facilities (tank and feed). They were placed in a 4.9 m (16 ft) wooden trough in which the tank system water was passed through and in which a small 1.2 m (4 ft) section was made with small mesh dividers for the fish to occupy. In-tank lighting and an automatic feeder was installed in the center of this section to increase the likelihood of feeding and to decrease the level of stress by creating high schooling density. A semi-moist salmon diet as feed (Rangen, Buhl, Idaho) was successfully accepted by most of these fish.

The first batch of hybrid walleye juveniles was from out-of-season spawning and approximately 9,500 arrived at FFO on April 28, 2000. After 40 days the survivors numbered 3,350 and these were then transferred to the large tank system. As of the end of August, approximately 2,500 hybrid walleyes remained and averaged 13.4 cm (5.28 in), ranging from 12.1–15.2 cm (4.76–5.98 in). Average weight was 60 fish/kg (27 fish/lb) for a total of 48 kg (106 lb) in a 3,596-L (950-gal) tank. This rate of growth is as good or better than hybrid walleye raised in summertime under extensive pond culture conditions, and much better than that seen in other indoor laboratory studies in tank culture.

The second batch of hybrid walleye juveniles was from normal-season spawning and approximately 12,000 arrived on June 16. The juveniles were again stocked into a wooden trough that allowed system water to pass through. After 11 days, there were approximately 2,500 survivors. After 30 days, the 2,000 remaining fish were 6.35–10.2 cm (2.5–4.0 in). Unfortunately, just days before the planned transfer of fish from the trough to the large tank, a power outage occurred. While the rest of the system continued to operate after the backup system resumed flow in the main system, the brief shutdown produced an airlock in the water supply pipe to the temporary trough arrangement. This was not discovered until virtually all the fish were lost in the stagnant water of the trough.

FFO continued the rearing of hybrid walleye in the WaterSmith recirculation system for 521 days until October 1, 2001. The following data represents date of sampling, estimated number, and size at sampling: (1) April 28, 2000 (day 0), $N = 9{,}500$, 1.25 cm (0.49 in); (2) October 31, 2000 (day 186), $N = 1{,}600$, 80% at 15–20 cm (5.9–7.8 in), 19/kg (8.6/lb) and 20% at 10–15 cm (3.9–5.9 in), 55/kg (24.9/lb); (3) January 10, 2001 (day 257), $N = 1{,}579$, 80% at 19.7–22.3 cm (7.6–8.8 in), 13/kg (5.9/lb)

and 20% at 16.5–18.4 cm (6.5–7.4 in), 31/kg (14.1/lb); (4) March 12, 2001 (day 318), lost 812 fish due to mechanical failure over four days; (5) March 16, 2001 (day 322), *N* = 746, 80% at 22.9–27.9 cm (9.0–11.0 in), 9/kg (4.1/lb) and 20% at 15.2–20.3 cm (6.0–8.0 in), 18/kg (8.2/lb); (6) September 15, 2001 (day 505), *N* = 719, 75% at 27.9–35.6 cm (11.4–14.0 in), 3/kg (1.4/lb) and 25% at 22.9–27.9 cm (9.0–11.0 in), 9/kg (4.1/lb); (7) October 1, 2001 (day 521); *N* = 711.

The recirculating WaterSmith tank system has proven to be quite successful in rearing fingerling hybrid walleye to market size. There has been no problem with outbreaks of columnaris (*Flexibacter columnaris*) and bacterial gill disease (*Flavobacterium branchiophila*), and the fish in these round tanks appear to avoid the problems of physical injury. The use of in-tank lighting on a 24-h constant cycle has helped minimize the amount of stress in the hybrid walleye as noted in their aggressive feeding behavior. The collection and disposal of solid waste has proven to be easy in the conical-bottom tanks, and the activities of the fish have not interfered with the removal. The simple pea gravel system as biofilter has removed the ammonia produced by fish, and the temperature of the water in the system has been maintained through most of the year.

FFO personnel observed that the first month of feeding when the hybrid walleye were still quite small (<3 cm [1.2 in] in length) was very labor intensive using hand-feeding 4–6 times a day. An automatic feeder operating 24 h/day was also used. A combination of two starter diets produced by Rangen, Inc. was utilized. A 50/50 mix of #00 trout starter and 1/32 in semi-moist salmon starter diets was used in the first month. In the second and third month, feed sizes were gradually increased until a 50/50 mix of Rangen 1/16 in semi-moist and 1/8 in semi-moist diets was fed. It was during this time that the hybrid walleye were transferred into the large tanks of the WaterSmith recirculation systems, and most of the feeding was done by the automatic clock-sweep feeders. By the end of six months after arrival at FFO, the feed was switched to Rangen's 3/16 in sinking "Trout Production Diet." The delivered price for this diet in the NCR is usually $0.70/kg ($0.32/lb). Initially, a feeding rate of 0.9 kg (2 lb) per tank per day was dispensed from an automatic clock-sweep feeder over the central standpipe that housed the in-tank lighting system.

The amount of feed consumed by the fish that were weighed on August 31, 2001 at the end of the experiment was calculated to be 214.9 kg (473.8 lb). (This figure is corrected for fish lost on March 11, 2001 when approximately 50% were killed due to a mechanical failure. Installation of a water level alarm in the sump pump barrel would have prevented this loss of fish.) Therefore, the estimated feed/gain ratio for the surviving hybrid walleye (148.3 kg [327 lb]) was 1.45:1. This includes the feed consumed by other mortalities during the Phase II grow-out, because all other deaths were only 6.5% of the starting population, and were distributed evenly throughout the time of the experiment.

At FFO, ammonia levels were usually quite low, and were never above 1.1 ppm. Nitrite levels were measured during the summer of 2001 when ammonia levels were at their peak, but remained low (0.01–0.03 ppm), even after ammonia levels returned to normal levels of 0.4 ppm. Fish densities at the end of the experiment were 0.4 kg of fish/L of tank water or 0.33 lb/gal. Dissolved oxygen and carbon dioxide levels were always at normal levels. Three times during the course of the experiment the stainless steel aquaculture heaters failed and had to be replaced. These expensive ($250–$350) commercial units were sizes suggested by the manufacturer, and regular cleaning of the heater elements was necessary. Because of the failures, optimal

temperatures around 23°C (73.4°F) were not always maintained, and this probably slowed the growth of the hybrid walleye when water temperatures were below 20°C (68.0°F).

Two of the major problems with previous hybrid walleye culture efforts have been the stress factors due to light and sound disturbances, and the resulting incidence of diseases such as columnaris and secondary fungal infections. No incidence of disease was evident throughout this project. The use of larger round tanks, in-tank low-level light systems, partial tank covering with no overhead lighting, and 24 h constant-on light cycles all seemed to reduce apparent behavioral stress in the hybrid walleye. In addition, prophylactic levels of salinity were usually maintained between 0.15–0.25%, and this may have been important in preventing the columnaris outbreaks that are common in percids. Future controlled studies will be necessary to confirm this effect.

Another common problem with hybrid walleye culture has been cannibalism. Until most fish were over 10 cm (3.9 in) in length, a good deal of effort was involved in removal of larger cannibals during Phase I culture in the make-shift troughs. In the Phase II culture when the fish were in the large round tanks, the incidence of cannibalism was relatively minor. The use of automatic feeders that dropped pellets over a 24 h period may have helped reduce this problem.

Aeration of the WaterSmith Systems is provided by low-pressure, high-volume regenerative blowers, and these also provide air to operate air-lift pumps that move water from the ring filter sections to the pea gravel biofilter. One 1-HP blower is able to support the air needs of eight tanks in four modules. Each two-tank module also requires a submersible pump that lifts the water from the bottom of the gravel biofilter to the top of the fish tanks where it is directed at an angle to induce a circular flow pattern. A continuous-duty submersible pump manufactured by Little Giant, Co. was utilized (rated at 1/3 HP with a maximum zero-head lift at 2,500 gal/h [gph]). Measurements of energy consumption were taken and found to have an operating energy use of 10.25 amps at 115 VAC. With an expected power factor of 70%, this translates into 825 watts of power usage. Therefore, continuous operation of this pump at 19.8 KW/day would cost $1.64/day (assuming $0.08 per KWH). Later tests with other pumps found that a ½ HP pump manufactured by Tsurumi would be more economical, and would pump 3,500 gph using only 6.2 amps at 115 VAC, or $0.98 worth of electricity per day.

Daily labor requirements for the modules consists of cleaning overflow screens, checking water flows, loading the automatic feeders (with some supplemental hand-feeding), and flushing the solids from the collection basins at the bottoms of the conical tanks. These tasks typically require less than 2 min/day/module. The ring filters are cleaned twice a year, and this takes about 2 h of time. Normal monthly maintenance also includes removal of mineral deposits from the water heater elements, testing of alarm and backup systems, and checking fish for signs of disease or body condition factors (2–3 h/module/month). Water quality parameters may be measured weekly, biweekly, or as needed when fish behavior becomes suspicious (usually a change in feeding or swimming behavior). Based on 15 years of previous experience with the pea gravel biofilters, these require surface raking or tilling every 1–2 months, and gravel replacement every 8–10 years.

In total, the amount of time required for normal feeding, monitoring and maintenance labor would be 40 h/yr for each WaterSmith 2-tank module. The length of time that was required to raise fingerlings to market size was about one year. If average

farm labor and overhead is calculated at $8.00/h, then the total labor cost for 40 h/yr/module would be $320.

The estimated total operational costs per 454 kg (1,000 lb) fish (including labor costs) was estimated at $2.87/kg ($1.30/lb) fish or $2.23/kg ($1.01/lb) fish (excluding labor costs). These estimates do not include the cost of the WaterSmith Systems and the cost of fingerlings.

OBJECTIVE 1B

Pond studies conducted by UW-Madison researchers are nearing a conclusion. In May 2001, hybrid walleyes (20–80 g; 0.7–2.8 oz) produced in 2000 were stocked into four ponds to generate data on the economics and production characteristics of growing these fish to market size. Original plans called for two ponds to be stocked with monosex female fish and two ponds stocked with mixed-sex fish. Unfortunately, none of the groups of fingerlings produced were monosex females. Therefore, in lieu of comparing monosex and mixed-sex populations, the decision was made to compare the performance of fish fed sinking and floating feed (two ponds per treatment). UW-Madison researchers still plan to determine the difference in growth rate between the sexes by examining individual fish at the conclusion of the studies. Harvest of the four ponds will take place in early October 2001.

UW-Madison researchers observed a strong feeding response in all ponds during the late spring and early summer. However, the fish could only be observed feeding during low light levels. Accordingly, the bulk of feeding was conducted at dusk. In late July and early August a sharp decrease in feeding activity was observed. This decline was attributed to high pond temperatures (>28°C; 82.4°F) resulting from an unusually warm stretch of weather. A strong feeding response returned once water temperatures declined to less than 25°C (77.0°F).

In addition to the four primary ponds used for the study, two additional ponds were stocked in spring with larger (>100 g; 3.5 oz) Spirit Lake × Mississippi River strain hybrids. The harvest of these two ponds will be done in Fall 2001.

The hybrid walleye (mean length 3.8 cm; 1.5 in) received by UM researchers from OSU survived poorly in net pens anchored nearshore in production ponds at Flower's Aquaculture in Dexter, Missouri. Examination of fish guts indicated that the fish had gone off feed. None of these fish were released into the ponds. Delivery of a second batch of hybrid walleye was expected from OSU in 2000, however, these fish were not provided due to rearing problems at OSU's PREC. The UM investigators obtained 9,000 walleye from Iowa's Department of Natural Resources (IDNR) Spirit Lake Hatchery with the assistance of Andy Moore and other IDNR personnel. These fish (mean length of 7.4 cm; 2.9 in) were stocked into net pens in ponds at Flowers Aquaculture, fed a commercial diet by hand, and monitored carefully for approximately two weeks. Survival rates in net pens were judged to be low (mortality <10%) and fish were released into three ponds (N = 3,000 fish/pond) in August 2000.

Additional hybrid walleye were anticipated from OSU in 2001, however, these could not be provided. The IDNR Spirit Lake Hatchery provided 12,000 walleye (mean length approximately 8 cm; 3.1 in) in August 2001. These fish were stocked into four 0.2-ha (0.5-acre) production ponds at Harrison Fish Farm near Kirksville, Missouri. Their growth, size-structures, and ultimately survival will be monitored through 2002.

Results presented here are based on sampling of walleye stocked into three ponds at Flower's Aquaculture in August 2000. In addition to the time of stocking, these fish have been sampled four times by

seining with the most recent sampling being completed on October 3, 2001. Hence, sampling has spanned a period of 14 months. Fish in ponds were fed once daily through June 27, 2001, and then twice daily thereafter. Size grading to reduce cannibalism was limited to removing individuals collected during routine sampling that were substantially larger than the mean size. Survival over the 2000-2001 winter was relatively low in two ponds. The pond owner made a unilateral decision to combine fish from these two ponds into the third pond (in which walleye survival was good) in February 2001. This action was taken without consulting the project Principal Investigator. Consequently, averaged growth results from all three ponds and subsequently from the single remaining pond will be reported. The total number of surviving fish through October 2001 is estimated to be approximately 1,000. An exact count will be made when the fish are harvested.

Walleye mean length reached 23.6 cm (9.3 in), just under the minimum food-market size of 25.4 cm (10.0 in) within 14 months of pond growth. Examination of length percentiles of walleye on October 3, 2001 showed that fish size range in the pond was quite broad, that the larger 50% had reached market size, and that upper-quartile fish reached sizes of 28–43 cm (11.0–16.9 in), well beyond the lower market limit. Hence, a potential is indicated for a substantial portion of walleye stocked at approximately 7.5 cm (3.0 in) to reach market size in a little more than a year in southern Missouri ponds. The need for additional measures to reduce overwinter losses in ponds was indicated. These measures might include more aggressive size grading efforts than were used in the present study, and possibly, overwinter feeding.

OBJECTIVE 2
Kinnunen has exerted tremendous effort in organizing the first Hybrid Walleye Culture Workshop to be held in February 2002 in conjunction with the Michigan Aquaculture Association Annual Meeting in Cadillac, Michigan.

WORK PLANNED
OBJECTIVE 1A
During the reporting period, experiments conducted at FFO were terminated; no further work is planned. OSU researchers will be preparing a manuscript to be submitted to a peer-reviewed aquaculture journal that will synthesize the data obtained from the two years of experiments.

OBJECTIVE 1B
Final data collection by UW-Madison researchers will continue for the existing pond studies described under Progress and Principal Accomplishments. The data will be analyzed, and a manuscript reporting the results of the study will be prepared for publication.

The study by UM researchers at Flower's Aquaculture will be terminated in October 2001. Total numbers of fish will be determined at harvest. The walleye stocked into four ponds at Harrison Fish Farm in August 2001 will be sampled throughout the remainder of 2001 and 2002. Results should provide information on the extent that walleye growth rates differ from southern to northern Missouri.

OBJECTIVE 2
Kinnunen is planning to organize the second Hybrid Walleye Culture Workshop in Missouri during the winter of 2003.

IMPACTS
The field trials described under Objectives 1a and 1b have generated some baseline information on production parameters (including, but not limited to, fish growth rate, survival, and feed conversion) that can be expected for commercially raising hybrid walleye to food size in recirculation tanks and in ponds in the upper and lower portions of the NCR. In addition, the trials generated detailed information that can be used to plan

studies on economic models outlining the production costs of producing food-size walleye hybrids with these different systems.

New and existing fish farmers in the NCR have already started to express interest in the implications of an economical approach to indoor recirculating systems for the raising of high-value fish like hybrid walleye. Based on commercial experience to date with rainbow trout, farms in Michigan, Minnesota, and Ohio are considering the use of the WaterSmith designs. It is an important part of the beneficial impact of this technology transfer that indoor systems like these help solve many problems associated with outdoor culture of fish. The main benefits are: (1) year-round production cycles instead of winter down time, (2) improved waste handling and management, (3) exclusion of wild bird and animal predation, (4) containment of aquaculture species to prevent wildlife impacts, (5) prevention of off-flavors derived from algal blooms as seen with pond cultured fish, (6) improved control over fish diseases and parasites compared to outdoor culture, (7) reduced cost and labor at harvest, (8) expansion of aquaculture production into areas where water quantity or quality may be limiting, (9) development of aquaculture facilities closer to markets and population centers, and (10) decreased space and land requirements for indoor intensive fish farming compared to extensive pond culture (<2% of area needed for ponds).

There is substantial interest in the potential to rear walleye in Missouri for food markets. Results from this study should begin to define this potential including possible pitfalls.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the appendix for a cumulative output for all NCRAC-funded Walleye activities.

SUPPORT

YEAR	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-00	$63,750	$45,027	$750[a]			$45,777	$109,527
2000-01	$57,350	$71,780	$1,500			$73,280	$130,630
TOTAL	$121,100	$116,807	$2,250			$119,057	$240,157

[a]Freshwater Farms of Ohio, Inc., Urbana, Ohio

SUNFISH[9]

Progress Report for the Period
September 1, 1999 to August 31, 2001

NCRAC FUNDING LEVEL: $200,000 (September 1, 1999 to August 31, 2001)

PARTICIPANTS:

Ira R.Adelman	University of Minnesota	Minnesota
Robert S. Hayward	University of Missouri-Columbia	Missouri
Joseph E. Morris	Iowa State University	Iowa
Robert J. Sheehan	Southern Illinois University-Carbondale	Illinois
Mark A. Sheridan	North Dakota State University	North Dakota
Robert C. Summerfelt	Iowa State University	Iowa
Industry Advisory Council Liaison:		
Curtis Harrison	Harrison Fish Farm, Hurdland	Missouri
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
Curtis Harrison	Harrison Fish Farm, Hurdland	Missouri
Myron Kloubec	Kloubec Fish Farms, Amana	Iowa

PROJECT OBJECTIVES

(1) Conduct field trials of bluegill and F_1 hybrid sunfish (female green sunfish × male bluegill) in commercial size production facilities defined as ponds >0.04 ha (0.10 acre) and indoor recycle systems in the upper and lower portions of the North Central Region. A minimum of three replicates will be used in all pond and recycle system studies; commercial feeds to be used will be those identified in previous studies.

(2) Evaluate grading strategies to enhance grow out in commercial systems to market size (≥227 g; 0.5 lb), including the culture potential of discards.

ANTICIPATED BENEFITS

OBJECTIVE 1

The main question is whether either bluegill or hybrid sunfish can be grown to market size in a time period needed to be economically feasible. Work under Objective 1 is expected to provide sound indication of the economic feasibility of rearing hybrid sunfish versus bluegill to market size as a food fish.

A number of factors and procedures (some developed quite recently) will be evaluated for their potential to increase sunfish growth rates and thereby reduce rearing times required for grow out. These include: (1) an assessment of the influence of latitude (largely thermal regime) on growth rates of sunfish in ponds, (2) a preliminary effort to

[9]NCRAC has funded five Sunfish projects. Termination reports for the first two projects, or components thereof, are contained in the 1989-1996 Compendium Report; a termination report for the third and fourth projects is contained in the 1998-99 Annual Progress Report. This progress report is for the fifth Sunfish project, which is chaired by Robert S. Hayward. It is a 2-year study that began September 1, 1999.

diminish the negative impacts that strong social interactions among sunfish have on size variation and growth rates, (3) application of recently acquired knowledge of optimal daily feeding frequencies for sunfish, including feeding rhythms, (4) use of fry spawned out-of-season, making them available for stocking earlier in the year and allowing substantially longer growth periods in the first year, and (5) a rigorous evaluation of the capacity to grow sunfish to market size in indoor recycle systems where optimal growth environments can be maintained continuously.

OBJECTIVE 2

The work undertaken for this objective will evaluate the potential to increase growth rates, improve feed conversion, and reduce size variation of commercially-reared hybrid sunfish by eliminating small individuals that possess inherently low growth capacity. The work under this objective evaluates improvements in growth and the percentage of fish reaching market size when using only the largest fish for pond stocking.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

A test of a three-year sunfish production cycle is underway at Southern Illinois University-Carbondale (SIUC). The intent of the study is to determine whether edible-size sunfish can be produced in three years if management effort, expense, and pond/facility use are minimized during the first year for both hybrid sunfish and bluegill.

In April 1999 eight 0.04-ha (0.10-acre) ponds were stocked with sunfish brood stock; four ponds with bluegill (five males and five females) and four with bluegills and green sunfish (five male bluegills and five female green sunfish). Other than stocking the brood fish, the only management done in the ponds was fertilization using small amounts of old fish feed once a month for about a month to promote zooplankton production. On April 12, 2000 each spawning pond was seined to depletion and production of age-1 fish estimated. These fish were then stocked into four 0.04-ha (0.10-acre) ponds per taxa group (12,000 fish/ha; 4,856 fish/acre) and fed a commercial diet for the 2000 production season. There was no significant difference between the taxa in numbers of age-1 fish produced; mean production ranged from 172,206–229,830 fish/ha (69,692–93,012 fish/acre). Upon stocking into production ponds, age-1 bluegill were significantly heavier and longer than were the hybrid sunfish. Hybrid sunfish averaged 0.2 g (0.007 oz) and 24 mm (0.9 in) total length (TL) and the mean size for bluegill was 0.4 g (0.014 oz) and 29 mm (1.1 in) TL. Fish were fed a 50-50 (by volume) mixture of the sinking Silvercup© diet and a floating hybrid striped bass feed.

Growth during Year 2 of the three-year cycle was assessed on October 11 2000. Even though the hybrid sunfish were smaller at the time of stocking, they significantly outgrew the bluegill; absolute growth (final size - initial) was 147.5 g (5.20 oz) and 108.1 g (3.81 oz) for the hybrid sunfish and bluegill, respectively.

Another component of this project was for SIUC to evaluate production of bluegill and hybrid sunfish fingerlings that had been spawned out of season at Iowa State University (ISU). Brood fish provided by SIUC to Morris at ISU during 1999 died due to equipment failure. In 2000, SIUC was unable to secure sufficient numbers of brood fish in time for ISU to spawn them. Therefore, as an alternative, SIUC researchers are and will be evaluating growth of black crappie in raceways, cages, and ponds. In May 2001 young-of-year

(YOY) black crappie (40–50 mm [1.6–2.0 in], 1g [0.035 oz]) were stocked into a 1,040-L (275-gal) raceway at a density of about 6 g/L (0.05 lb/gal) for feed training. The crappie showed a strong feeding response to freeze-dried krill, essentially the first time it was offered. Within three days, the majority of the fish were actively feeding. At this point, a small amount of high-krill Biodiet© was fed along with the krill. Once fish were eating Biodiet©, transitions to larger pellet sizes were not a problem. Overall training success was 80%. Of the non-feeders, 75% died and the other 25% were emaciated.

Morris at ISU initiated an 18-month study using six ponds (0.08–0.21 ha; 0.2–0.5 acre) at a commercial fish farm in Iowa; three ponds were stocked with bluegill and three ponds were stocked with hybrid sunfish. Hybrid sunfish were stocked November 1999, whereas bluegill were stocked May 2000. All ponds were stocked at 12,000 fish/ha (4,856 fish/acre). Fish were graded to remove the top 70% of the pond harvest; these top-graded fish were then used to stock the ponds (12,000 fish/ha; 4,856 fish/acre) as well as for a recirculation tank study done by Summerfelt at ISU, which is described below. Beginning May 2000, fish were fed a 36% crude protein commercial diet at a feeding rate of 3% body weight daily, using automatic feeders until October 2000. Fish were once again fed beginning May 2001 and then harvested June 2001.

Evidence of over-winter growth (increase in body weight and gonad weight) was exhibited by hybrid sunfish from November 1999 to May 2000. The hybrid sunfish sex ratio was highly skewed towards males, as expected from previous literature.

Direct comparison between bluegill and hybrid sunfish was possible during summer 2000. Bluegills were more evenly split between sexes with a higher percentage of males in July. The cause of this phenomenon was most likely due to spawning behavior, which causes males to reside in the shallow regions of the ponds. Summer sampling of hybrid sunfish produced almost 100% males.

In both bluegill and hybrid sunfish, females tended to be smaller than males. Additionally, the weight of female gonadal tissue was higher than male gonadal tissue (1–2% female versus <1% male); therefore, a greater percentage of male sunfish in ponds, devoting more energy for the development of somatic tissue, may be advantageous for fish culturists producing food fish. Overall specific growth rates (SGR) were not significantly different, 0.25 for bluegill and 0.35 for hybrid sunfish.

At harvest, the populations of hybrid sunfish and bluegill were 89% and 53% males, respectively. Hybrid sunfish had significantly greater final weights compared to bluegill; hybrid sunfish showed lower survival rates of 42% versus 62% for bluegill. The likely reason for the low survival in both fish populations was winterkill, which plagued Midwestern ponds during the 2000-2001 season. There were no differences in gross yield and survival between bluegill and hybrid sunfish.

Hybrid sunfish had a significantly lower percentage of reproductive tissue compared to bluegill, although this is most likely associated with the low number of hybrid sunfish females. As expected, reproductive tissue relative to total body weight was the highest during late spring and early summer. At harvest, it appeared that bluegill had a high amount of reproduction compared to hybrid sunfish; no quantitative assessment of YOY was conducted. Bluegill are renowned for reproduction at small sizes in

ponds; therefore, fish stunting may occur over longer periods of time, especially if YOY are not harvested annually or removed by stocked predators, e.g., largemouth bass.

Bluegill possessed significantly greater dress-out percentages than hybrid sunfish. The reason for the difference in dress-out percentages appeared to be due to the larger head size of hybrid sunfish.

Summerfelt conducted two 16-week growth trials using an indoor recycle system that is on the campus of ISU. The first compared age-1 bluegill and hybrid sunfish. Three comparisons were made: (1) low versus high density (initial densities were 5 and 10 g/L [0.04 and 0.08 lb/gal]), (2) bluegill versus hybrid sunfish, and (3) bluegill alone (monoculture) versus bluegill grown in the same tank as hybrid sunfish (polyculture). Growth and food conversion for bluegill were significantly better at the low density compared to the high-density treatment, and growth and food conversion for hybrid sunfish was similar at both densities. Also, at both culture densities, growth rates of bluegill and hybrid sunfish cultured together were not significantly different from that of bluegill or hybrid sunfish cultured alone. The findings demonstrate that for experimental purposes, bluegill and hybrid sunfish can be cultured together without affecting the performance of either one; however, it may be undesirable to culture both bluegill and hybrid sunfish together in pond culture, where it is possible for hybrid sunfish to backcross with other hybrids or bluegill.

A second 16-week growth trial was undertaken in Year 2 to evaluate the use of density as a culture technique. This experiment was undertaken because the aggressive behavior to the development of social hierarchies is regarded as a major contributor to slow growth rates and size variation in intensive culture of sunfish. The second growth trial used initial densities that ranged from 3–8 g/L (0.03–0.07 lb/gal), a range that bracketed the 5 g/L (0.04 lb/gal) used in the first growth trial. The fish used in this trial were the largest fish from the first trial (the third grading of the largest 70% of the original pond population).

At the end of the experiment, a sample of 50 bluegill and 50 hybrid sunfish were dissected to determine sex ratio (male:female:undeterminate sex). The ratio for bluegill was 40:10:0 and for hybrid sunfish was 40:1:9. The gender of nine hybrid sunfish could not be determined by gross examination, but they were probably males with very small testes. The high proportion of male bluegill (80%) occurred because the grading resulted in the selection of the largest fish, which typically selects for males because they have faster growth. In a 2000 electrophoresis analysis of sunfish used in the ISU studies, SIUC researchers classified bluegills as being pure while the hybrid sunfish were determined to be F_1 hybrids.

Because of size variation in the fish, a 75%/25% blend of 2.5 and 3.5 mm (0.10 and 0.14 in) size Silver Cup® (Nelson & Sons, Inc., Murray, Utah) feed was used throughout the second 16-week growth study. There was no mortality of either bluegill or hybrid striped bass in any tanks during this trial. To examine density effects, correlation analysis was used to describe the relationship between average density and measures of growth (length/day, weight/day, percent gain, and SGR). Results suggest that hybrid sunfish are sensitive to increases in density across this gradient of average density values, which ranged from 4.3–12.1 g/L (0.04–0.10 lb/gal). Variation in growth rates with density suggest that for bluegill, an optimum average density would be 3.5 g/L (0.03 lb/gal), however, percent gain for

hybrid sunfish ranged from 29.0– 49.3% with the highest percent gain (49.3%) at the lowest average density (1.9 g/L; 0.02 lb/gal).

The field trial at the University of Minnesota (UMn) was delayed while awaiting the completion of another NCRAC project (Wastes/Effluents) using the production facilities. Bluegill and hybrid sunfish had been obtained from Osage Catfisheries in Osage Beach, Missouri at the beginning of the funding cycle. The two strains were held at ambient well water at a temperature of 12°C (54°F) and fed a maintenance ration until they were stocked in the production tanks in the summer of 2001.

Consultations with the staff at Osage Catfisheries indicated that holding fish back at low temperatures and feeding levels would not impact their growth potential. To verify this, additional fish with a normal production history were obtained from the same source for a concurrent growth comparison.

In late October, there appeared to be far fewer fish in some of the tanks than were originally distributed to them, yet this was puzzling because no substantial mortality was observed. Perhaps because of cloudy water, there were far more post-handling mortalities than were observed. Upon draining the tanks it was determined that there were significantly fewer fish than had been previously stocked.

Because UMn researchers did not have sufficient funds to purchase new fish and restart the experiment, the project chair and NCRAC administration agreed on a revised project to conduct an experiment to evaluate the effect of long-term handling on the growth rate of hybrid sunfish and bluegill in a flow-through system in 12, 265-L (70-gal) circular tanks. Several comparisons will be made: (1) bluegill versus hybrid sunfish, and (2) fish that were held back for a year versus fish that were not. Fish will be grown out for about one year. Results from this study will be useful in confirming the findings of the North Dakota and Missouri groups regarding the growth advantage bluegills.

North Dakota State University (NDSU) researchers initiated their study March 2000. Using six 18,925-L (5,000-gal) indoor systems, (3,000 fish/system) and three tanks/taxa. Juvenile bluegill and hybrid sunfish were obtained from Osage Catfishery, Osage Beach, Missouri in October 1999.

Losses were high during the first three to six months of trial initiation, possibly due to parasites. The disease was self-limiting and numbers stabilized. After the heavy losses, fish were counted and 2,035 fish were randomly stocked into each tank. The fish were not graded during the restocking.

The hybrid sunfish appeared to be more aggressive in their feeding habits and less fearful of humans than the bluegill. Although hybrid sunfish are often considered to be more aggressive and to have faster growth rates, the data collected from the NDSU study indicate that the bluegill out-performed the hybrid sunfish. Bluegill had significantly larger percent weight gain at 7 and 18 months into the study as well as having a larger number of fish that reached market size. Seven months into the study, the average bluegill weight gain was 56.5 g (2.0 oz) compared to 49.4 g (1.7 oz) for bluegill. At 18 months, the mean weight gain of bluegill was 187.2 g (6.6 oz) compared to 101.4 g (3.6 oz) for hybrid sunfish. On both sampling dates, bluegill had significantly gained greater weight than did hybrid sunfish. There were no significant differences between the taxa in survival or FCR values.

OBJECTIVE 2

University of Missouri (UM) researchers secured age-1 hybrid sunfish from a single production pond at Flower's Aquaculture in Dexter, Missouri. Fish were graded into two size groups: small (mean length = 41.3 mm [1.63 in], mean weight = 1.03 g [0.036 oz] wet weight), and large (mean length = 62.7 mm [2.47 in], mean weight = 3.94 g [0.139 oz] wet weight). The fish were transported to Harrison's Fish Farm in Hurdland, Missouri in April 2000 and stocked into seven 0.20-ha (0.5-acre) ponds. Three ponds were stocked with large fish (3,231 fish/pond), three ponds received 3,000 small plus 3,000 large fish, and one pond received 14,000 small fish. Treatments were designated as Lg, Lg-Sm, and Sm, respectively. Stocking densities (dry biomass/area) were matched in the ponds receiving large and large plus small fish; stocking biomass was lowest in the pond receiving only small fish.

Fish were fed twice daily. Results for the first 63 days after stocking showed significantly greater weight gain (almost 2×) and final weights in Lg ponds versus the Lg-Sm ponds. Results indicate a substantial growth advantage associated with excluding smaller hybrids by size grading at the beginning of grow out.

Partial seining of each pond to determine weights and lengths of samples of 30–50 fish has been carried out six times from one month post-stocking through early October 2001(approximately every three months). In June 2001 fish were removed from each pond by multiple seine hauls and only the larger 33% (by length) were re-stocked; the smaller fish were sold by the producer.

Absolute growth rates (AGR) of fish were estimated using data from the 535-day study (April 2000-October 2001). Results show increasing AGRs and final weights for hybrid sunfish across the three treatment groups in accordance with increasing fish sizes at stocking. Mean AGRs and the final weight of fish cultured in Lg ponds were significantly larger than those in Sm-Lg ponds. Projected grow-out times to 227 g (8 oz) ranged from 3.17 yr for the Sm pond to 2.37 yr in the Lg ponds. Findings to date indicate that growth rates are higher and times required to reach food-market weights will be lower in ponds where the larger hybrids were stocked. However, results also indicate that grow out will have to continue well into a third year to reach food-market weights, even in ponds where the largest hybrids were stocked.

Laboratory studies dealing with both bluegill and hybrid sunfish were also conducted by UM. Though not part of the original Sunfish project outline, the results are described here because they relate to and hold potentially important implications for the broad objective of developing approaches to rearing sunfish to food-market sizes within two grow-out years.

In addition to measuring consumption rates, FCRs, and social costs, UM researchers compared inherent growth capacities of bluegill and hybrid sunfish reared under identical conditions. In both studies fish received ample food (commercial diet) under a favorable thermal regime for growth and were freed of competitive interference from other conspecifics by individual holding. The first experiment involved age-1 bluegill and hybrid sunfish with initial mean weights near 7 g (0.2 oz), and ran for 100 days (May through August 2000). The second experiment began in August 2000 with age-1 bluegills and hybrid sunfish and ran for 200 days through March 2001.

During the first 50 days of Experiment 1 hybrid sunfish initially outgrew and then grew at a similar rate as bluegill.

Subsequently, in July, hybrid sunfish growth rates declined to levels well below that of bluegill. Experiment 2 showed dramatic weight gains by bluegill in excess of the hybrid sunfish with final mean weights of approximately100 and 50 g (3.52 and 1.76 oz) for bluegill and hybrid sunfish, respectively, by March 2001.

Subsequent analysis of the same data set with attention given to growth rates of bluegill and hybrid sunfish according to sex, revealed that male bluegill substantially outgrew male hybrid sunfish as well as female bluegill and hybrid sunfish in both experiments. Results demonstrate that growth capacity of male bluegill substantively exceeds that of female bluegill and both sexes of hybrid sunfish.

WORK PLANNED

The SIUC bluegill/hybrid sunfish pond study is currently ending—data are being collected and analyzed at this time.

Black crappie from the training study are being used to assess methods for keeping this species on prepared diets in a pond setting. This study will continue through October 2001 at which time fish will be harvested, and survival, feeding success, feed conversion, growth, and dress-out weights will be recorded.

Another study is being initiated by SIUC researchers. A 90-day growth trial of black crappie in indoor recycling systems is being done to compare the effectiveness of two different prepared diets. Fish will be harvested in December 2001 at which time growth and dress-out weights will be collected and reported. At ISU, researchers will also investigate the use of feed training techniques by SIUC in training pond-reared black crappie to commercial fish diets; this study will involve a combination of krill and krill-based diets and is scheduled to be completed in Fall 2001.

UMn will conduct an experiment to evaluate the effect of long-term handling on the growth rate of hybrid sunfish and bluegill in a flow-through system as described above.

Growth traits of hybrid sunfish in production ponds at Harrison Fish Farm will be continued through calendar year 2002 to determine growth times required to reach market size as well as associated costs and returns at sale. Results of the laboratory study (dealing with growth of bluegill and hybrid sunfish by sex groups) will be submitted for publication within the next few months.

IMPACTS

While many fish producers throughout the North Central Region rear bluegill and hybrid sunfish for pond stocking, there is also substantial interest in rearing bluegill and hybrid sunfish for the food-fish market. Development of procedures that help to reduce grow-out periods for food-market fish is expected to markedly increase the economic feasibility of raising sunfish for this purpose.

Sufficient numbers of sunfish fingerlings can be produced in a single 0.4 ha (0.10 acre) pond to stock more than 20, 0.4-ha (0.10-acre) ponds at the stocking densities of 12,000/ha (4,856/acre). Based on previous SIUC studies, it should be feasible to produce edible-size ($\geq$227 g [0.5 lb]) hybrid sunfish during Year 3 of a three-year production cycle.

Bluegill showed poor growth in both SIUC production as well as in Iowa ponds through the end of the second growing season. This can be attributed, at least in part, to increased competition for resources in bluegill ponds as the number of young fish increased with each reproductive cycle during the growing season. During Year 2, YOY became abundant in the bluegill ponds, whereas the hybrid sunfish ponds had

few or no YOY. Bluegill growth may be improved under a strategy where YOY fish are removed. The production of edible-size bluegill in ponds using a three-year production cycle was not promising.

Hybrid sunfish, on the other hand, showed considerable promise for pond culture. This is the second consecutive year in which hybrid sunfish achieved about 76 g (2.7 oz) during Year 2 of the production cycle. SIUC researches are currently analyzing growth of hybrids during Year 3—based on this preliminary information, a substantial proportion of hybrids that achieve 76 g (2.7 oz) during Year 2 will go on to achieve edible size (227 g; 0.5 lb) by the end of the third growing season.

Little work has been focused on crappie in aquaculture due to the difficulty of feed training. Furthermore, crappie generally fail to utilize prepared diets to any great extent in pond settings. For these reasons, bluegill and hybrid sunfish have been thought by many to be better for food fish production in ponds. However, if the barriers of training and maintaining crappie on feed can be overcome, crappie may well prove to be superior for food fish production in ponds.

Feed training of black crappie at SIUC was successful with minimal effort. A success rate of 80% is similar to the best results obtained in previous studies. Furthermore, krill is a much more convenient first feed to use as compared to others (i.e., carp eggs) that have achieved similar success. If it proves possible to develop methods that ensure that crappie will continue to efficiently use prepared diets in ponds, then food fish production may be economically feasible.

ISU investigators found that it is difficult to raise either sunfish taxa to a market size within 30 months in indoor recycle systems. After a total of 17 months in ponds and 12 months indoors at favorable growing temperatures (about 25°C [77°F]), fish had not reached marketable food size even with repeated grading. Thus, these studies indicate a serious practical problem for intensive culture of bluegill and hybrid sunfish in indoor recycle systems at 25°C (77°F) under conditions when water quality should not have been limiting.

The findings also demonstrate that hybrid sunfish growth rates were inversely related to tank density in the second year. Hybrid sunfish fingerlings may be more expensive than bluegill because the producer must have separate ponds for bluegill and green sunfish brood stock to produce the hybrids. The only advantage of hybrid bluegill might be a higher resistance to disease. However, bluegill did appear to grow better and perhaps reach marketable size in indoor recycle systems located at NDSU as well as laboratory studies at UM.

The work at UM, based on rough projections of growth rates, indicate that male bluegill possess the inherent capacity to grow to food-market weights within two years while female bluegills and both sexes of the hybrid sunfish fall substantially short of this benchmark even under the best of growing conditions. This data provide evidence that efforts to rear *Lepomis* species to food-market weights within the established two-year benchmark for grow out, should focus on male bluegills.

The UM pond study will also indicate whether size grading of hybrid sunfish effectively reduces grow-out times to food-market size. These results should add significantly to a scant data base that will indicate the feasibility of rearing hybrid sunfish in food-market aquaculture. The laboratory study indicates how reduced growth times to food-market weights might

be possible by rearing male bluegill and this finding may substantially improve the economic feasibility of rearing sunfish for food markets.

Definitive results to date are:

- evidence that male bluegill have the capacity to substantially outgrow both hybrid sexes as well as female bluegill in indoor systems;
- there is a tendency for hybrid sunfish to grow better in ponds due, in part, to bluegill's tendency for substantial in-pond reproduction, higher social costs of bluegill, and hybrid sunfish being better able to utilize natural feeds;
- bluegills appear to grow better than hybrid sunfish in indoor recycle systems tanks (NDSU studies); and
- merit continues to exist concerning the use of black crappie as food fish in this region.

PUBLICATIONS, MANUSCRIPTS, AND PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Sunfish activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-01	$200,000	$200,617				$200,617	$400,617
TOTAL	$200,000	$200,617				$200,617	$400,617

SALMONIDS[10]

Project Termination Report for the Period
September 1, 1997 to August 31, 2001

NCRAC FUNDING LEVEL: $160,000 (September 1, 1997 to August 31, 2001)

PARTICIPANTS:

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REASON FOR TERMINATION
The project objectives were completed.

PROJECT OBJECTIVES
(1) Develop and evaluate practical and economically viable diets that are fish meal free or as fish meal free as practical:
- using soy, or other oil-seed products that are regionally available, and
- using Shasta, Donaldson, and Kamloop strains of rainbow trout and/or Arctic charr for the evaluation.

(2) Evaluate the effects of water temperature on the growth/stress response in salmonid strains or species (as listed in Objective 1) under outdoor commercial culture conditions in the upper and lower portions of the North Central Region.

[10]NCRAC has funded four Salmonids projects. Project component termination reports for objectives of the first two projects are contained in the 1989-1996 Compendium Report; termination reports for the remainder of the first two projects and all of the third are contained in the 1996-97 Annual Progress Report. This termination report is for the fourth project, which was chaired by Paul B. Brown. The fourth project built upon the first three projects. It was originally a 2-year study that began September 1, 1997.

(3) Investigate the effects of trace mineral supplementation on the growth and stress response of rainbow trout in high density culture, as evaluated by plasma cortisol levels and fin nipping behavior.

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Researchers at Purdue University (Purdue) developed a new series of 10 experimental diets and fed those to Shasta strain rainbow trout of 52 g (1.8 oz) initial weight. Weight gain, feed intake, feed conversion ratio, and specific growth rate of fish fed two of the formulations free of fish meal were not significantly different from fish fed a control diet. However, both diets contained fish oil as the lipid source. Another study was completed using rainbow trout that compared a variety of lipid sources in practical diets. The lipid sources evaluated included fish oil, canola oil, solvent-extracted soybean oil, cold-pressed soybean oil, and flax oil. In addition, each oil was evaluated as a 1:1 mixture with all possible combinations of lipid sources. Weight gain, feed consumption, and feed conversion ratios were not significantly different among dietary treatments. Tissues were analyzed for their fatty acid concentrations. This project was designed to continue research on new dietary formulations for rainbow trout. Appropriate vitamin and mineral premixes and several lipid sources were identified that can be used in practical diets.

Purdue also conducted two separate studies in which a fish meal free basal diet formulation for trout continued to be modified. In the first experiment, the focus was on vitamin and mineral premixes as these had been identified as problem areas in previous studies. In the second experiment, the focus was on lipid sources. In both experiments, Purdue researchers acquired Shasta strain rainbow trout and fed triplicate groups of them a variety of diets, 10 in each experiment. All fish were greater than 50 g (1.8 oz) starting weight so both experiments represented the grow-out phase of production. In the first experiment, fish were fed several different types of vitamin and mineral premixes. Based on weight gain, tissue mineral concentrations, and mineral retention, a supplemental mineral premix was best. A nutritionally complete mineral premix resulted in decreased weight gain. There were no differences with the vitamin premixes used. In the second experiment, Purdue researchers identified several lipid sources that contained sufficient n-3 fatty acids to meet the requirement of trout. Those were fed alone or in combination; no significant difference in weight gain of fish was observed. Further, tissue fatty acid concentrations did not indicate essential fatty acid deficiencies. Lipid sources used were flax oil, canola oil, cold-pressed soybean oil, and various combinations. These data are significant advances in the ability to formulate fish meal free diets for rainbow trout. In many species, as fish meal is reduced, mineral supplementation must be increased. This is not the case in trout. Further, they are very tolerant of a wide range of vitamin premixes. Alternative lipid sources appear to be appropriate for meeting the energy and essential fatty acid needs of rainbow trout.

Two feeding experiments were carried out at Ohio State University (OSU). First, a 16-week feeding trial was conducted to examine the feasibility of using a fish meal analog (FMA) as a fish meal replacement in diets for juvenile rainbow trout. Fish weighing 0.96 ± 0.07 g (0.034 ± 0.002 oz) were divided into 15 groups and three groups were fed one of five isonitrogenous diets containing 0, 20, 40, 60, or 100% of FMA protein (control, FMA20, FMA40, FMA60, and FMA100, respectively). The FMA consisted of 25% of meat and bone meal, 24.5% of leather meal, 20% of squid liver powder, 15% of feather meal, 7.5% of blood meal, 7.5% of poultry by-product meal, and 0.25% each of methionine and lysine. Fish began to show differences in growth rate from the eighth week followed by significant differences at the 12^{th} and 16^{th}

weeks. At the final 16th week weighing, fish fed diets FMA40, FMA60, and FMA100 exhibited significantly lower weight gain, feed efficiency, protein efficiency ratio, and specific growth rate than fish fed FMA20 and control diet. Hematocrits of fish fed FMA-containing diets were significantly lower than that of fish fed a control diet. FMA inclusion up to 60% in diets did not show differences in apparent protein digestibility compared to the control (85.0 ± 1.9%), whereas the FMA100 group was significantly lower (77.7 ± 4.4%). These results suggest that a FMA could be used up to 20% as fish meal protein substitution in diets for juvenile rainbow trout without adverse effect on growth rate and hematological indicators.

In the second experiment at OSU, fish meal protein was replaced partially or entirely with a mixture of animal by-products and/or plant protein mixtures (soybean and cottonseed meals, SM and CM, respectively). Fish averaging 0.96 g (0.034 oz) were divided into 18 groups (three replicates per diet). Six diets were formulated as follows (expressed as % protein): (1) control diet = 100FM; (2) APM 50 = 50 APM + 50 FM; (3) APM100 = 100 APM; (4) CM-CA = 25 CM (California product) + 25 SM + 50 APM; (5) CM-TN = 25 CM (Tennessee product) + 25 SM 50 APM; and (6) CM-AR = 25 CM (Arkansas product) + 25 SM + 50 APM. The results of the weight gain and feed efficiency showed that fish meal can be entirely replaced by a mixture of animal by-products and either of two cottonseed meal products (1,370 ± 17, 1,330 ± 16, and 1,350 ± 10% body weight gain for control, CM-TN and CM-AR diets, respectively). Significantly lower hematocrit levels were found in fish fed five test diets compared to those fish fed the control diet. Higher concentrations of total gossypol were found in feces of fish fed CM-TN and CM-AR diets than those fed CM-CA diet. The percentage of dietary gossypol accumulated in the whole body indicated that the majority of this substance is excreted in feces. The gossypol isomer selectively accumulated in liver and bile is the (+) isomer, whereas equal proportions of (+) and (-) isomers were found in diet, whole body, and feces. The findings suggest that a fish meal free diet could be used without adverse effects for 16 weeks on growth performance and histopathological changes in liver in juvenile rainbow trout.

At Michigan State University (MSU) tanks were stocked with rainbow trout and experimental or reference diets were randomly assigned. Dietary treatments consisted of: (1) negative reference (sub-optimal protein), (2) positive reference (fish meal based), (3) soybean meal substituted-untreated diet, and (4) soybean meal substituted-pretreated with phytase. Experimental diets were formulated with 35% crude protein, protein to energy ratio of 100, and vitamin and mineral premixes added to meet the requirements of the fish. The fish were subjected to a two-week acclimation period prior to the start of the study to allow them to adjust to their new surroundings and feeding regime. Diets were fed three times a day to three replicates of 16 fish per treatment for a period of 10 weeks. Feed rates were calculated on a percent body weight basis, which was determined during the two-week acclimation period by feeding the fish to satiation. Fish were weighed every two-weeks and feed rates were adjusted according to weight gain. Initial findings showed that phytase pretreatment of soybean meal: (1) significantly increased weight gain and protein deposition above the fish meal based diet and (2) significantly improved feed conversion ratios. Results from this study were presented at the World Aquaculture Society meeting in Sydney, Australia in April-May 1999. The data showed that phytase pretreatment of plant products in diets increased growth significantly above fish meal diets. The data also showed that without phytase pretreatment diets could be formulated that were not significantly different from fish meal diets. The Insulin-

Like Growth Factor (IGF-I) isolation procedure was also refined to work on rainbow trout.

A study on dietary iron retention in rainbow trout was also completed. Blood serum levels were tested for IGF-I and re-tested a second time for accuracy. On the treatment level for the eight-week study the fish meal based diet was significantly higher from all other dietary treatments. When IGF-I levels were analyzed by week the fish meal based diet was significantly higher compared to all other dietary treatments for the first six weeks. In the eighth week both the fish meal and the soybean meal diets treated with phytase were significantly higher than all other dietary treatments, but not each other. These data suggest that IGF-I serum levels can be used as a rapid indicator of nutritional status in rainbow trout as early as two weeks. Statistical analysis of the data by week in the first study demonstrated that the fish meal treatment was significantly different from all others at weeks two, four, and six. This research also shows that there may be a long term effect of phytase treatment on circulating IGF-I levels resulting in increased IGF-I levels in the blood, as shown in week eight where there were no differences between the fish meal based diets and the soybean meal diet treated with phytase.

Tanks at MSU were stocked with rainbow trout and experimental or reference diets were randomly assigned. Dietary treatments consisted of: (1) positive reference (fish meal based), (2) soybean meal substituted-phytic acid added, (3) soybean meal substituted-pretreated with phytase, and (4) commercial diet. Experimental diets were formulated with a 35% crude protein, protein to energy ratio of 100, and vitamin and mineral premixes added to meet the requirements of the fish. The fish were subjected to a two-week acclimation period prior to the start of the study to allow them to adjust to their new surroundings and feeding regime. Diets were fed three times a day to three replicates of 12 fish per treatment for a period of at least six weeks. Feed rates were calculated on a percent body weight basis, which was determined during the two-week acclimation period by feeding the fish to satiation. Fish were weighed every two weeks and feed rates were adjusted according to weight gain. There were no significant differences in growth for all dietary treatments. The IGF-I isolation procedure was refined to work on rainbow trout. Blood serum samples for both studies were tested by RIA (radioimmuno assay) for IGF-I serum levels. Because of a material shortage, blood samples were pooled by week and treatment for IGF-I analysis.

On the treatment level there were no significant differences among the commercial, fish meal based, and soybean meal phytase treated dietary treatments in both IGF-I blood serum levels and in growth. The soybean meal diet with phytic acid added treatment was significantly lower then all other dietary treatments in both IGF-I levels and growth. These data suggest that IGF-I can be used as a rapid indicator of nutritional status and that phytic acid may have a effect on circulating IGF-I levels in the blood.

OBJECTIVE 2

The plan of work in the initial proposal was to conduct studies on Arctic charr and Donaldson strain rainbow trout at Rushing Waters Fisheries, Inc., Palmyra, Wisconsin. By the time of initiation of the project, however, Rushing Waters personnel determined that they would be unable to conduct the study. Accordingly, as per the backup plan detailed in the original proposal, the Arctic charr study was conducted at the University of Wisconsin-Madison (UW-Madison) campus.

In March 1998, approximately 120 Arctic charr (average total length 160 mm [6.3 in], weight 31 g [1.1 oz]) and 100 rainbow trout (average total length 150 mm [5.9 in], weight 34 g [1.2 oz]) were obtained from

Rushing Waters Fisheries, Inc., Palmyra, Wisconsin, and Trout Haven, Bryant, Wisconsin, respectively. The fish were held in separate 750-L (198-gal) flow-through tanks at a water temperature of 12.5°C (54.5°F). In April 1998, the fish were weighed, measured, and 25 fish were transferred into each of four 120-L (32-gal) flow-through tanks (two tanks of rainbow trout, two of Arctic charr). Over the next two weeks, the water temperature was gradually raised to 15°C (59.0°F) in two tanks (one rainbow trout tank, one charr tank) and lowered to 10°C (50.0°F) in two tanks. After three weeks acclimation, six fish from each tank were quickly removed, anesthetized, and bled via the caudal vasculature. The remaining fish were given an acute stress challenge test by holding them out of the water for 1 min, then randomly placing them into separate tanks. Groups of six fish were then netted, anesthetized, and bled at 1, 3, and 24 h following the stressor.

In October 1998 UW-Madison researchers validated the cortisol enzyme linked immnosorbent assay (ELISA) for use with Arctic charr serum and analyzed the samples in November. Results indicate a significant difference in cortisol concentrations over time between fish held at 10°C (50.0°F) and 15°C (59.0°F) (mostly due to differences in baseline [time 0] cortisol concentrations), but no significant difference in stress responsiveness between rainbow trout and Arctic charr.

In spring 1999, Freshwater Farms of Ohio, Inc. (Urbana, Ohio) stocked Shasta and Donaldson strain rainbow trout in an outdoor raceway and monitored growth, survival, and incidence of disease. The experiment was completed in October 1999 when the cortisol stress response was measured in fish subjected to an acute stress challenge test. The Donaldson trout had a significantly lower cortisol stress response compared to the Shasta trout. At both time 0 (baseline, resting) and 3 h post-stress, cortisol levels in the Donaldson strain were lower than in the Shasta strain. It is concluded from these data that Donaldson trout may be more resistant to the harmful effects of stress than the Shasta strain fish.

OBJECTIVE 3

A questionnaire was designed by MSU researchers to evaluate the extent and impact of trout fin nipping/erosion in the North Central Region (NCR). The questionnaire was reviewed by two MSU social scientists with expertise in survey methods and by three North Central Regional Aquaculture Center (NCRAC) extension contacts. Minor revisions were made prior to pre-testing the questionnaire. The questionnaire was pre-tested in Michigan by sending it to 15 trout producers.

NCRAC extension contacts in eight states were asked to provide the names and addresses of up to 15 trout producers in their state. One state contact and the State Aquaculture Coordinator chose not to cooperate in the survey, three states had too few producers (1 or 2) to participate, and one state specialist (Nebraska) chose to survey his producers by phone interview using the questions provided. Responses were received from 34 of 42 producers surveyed in Michigan, Missouri, and Wisconsin which represented an 87% response rate. Fin nipping/erosion was rated as not a problem with significant economic impact by 30 producers (88%) who responded by mail and by those who participated in phone interviews. Two producers each indicated a moderate or severe fin nipping/erosion problem. Because so few producers indicated that fin nipping/erosion was a problem, causes of their problems could not be identified.

IMPACTS

OBJECTIVE 1

Grow-out diets that are free of fish meal have been developed and tested in Shasta strain rainbow trout at Purdue. Fish fed two formulations exhibited responses that were

not significantly different from fish fed a control diet. Results from this research are being used in the NCR as the basis for new dietary formulations using regional feed ingredients that are manufactured in this region. The advantages of this approach should be to reduce cost of feeds and improve profitability of aquaculture operations. These formulations can be used by producers in the NCR and provide the impetus for regional dietary manufacturing using local ingredients. Further, a new feed mill has been established in Ohio that focuses on manufacturing fish diets that are free of fish meal. These impacts should ensure profitable trout production in the NCR. There is significant interest in adding other salmonid species to the overall regional production. These new diets, or modifications of them, should be evaluated in additional strains of trout and alternative species suitable for culture in the NCR.

Research at OSU has provided strong evidence that a diet with 15% cottonseed meal, 15% soybean meal, and 20% animal by-product meal can be used to produce grow-out diets for rainbow trout without compromising growth rate or health indicators (liver histology). Taking into account current prices for fish meal ($560/ton) and cottonseed meal ($140/ton), this replacement should make considerable difference in feed costs. It is recommended, however, that cottonseed meals should be used with caution for rainbow trout because of the phytoestrogens and gossypol content.

MSU research has shown that improved utilization of dietary phosphorus and nitrogen will reduce the impact of aquaculture on the water quality of streams receiving water discharge from fish farms. This research demonstrated that phytase can be used to improve utilization of phosphorus and nitrogen and that IGF-I can be used as a rapid indicator of nutritional status in rainbow trout. Circulating IGF-I levels in the blood can be used as a rapid indicator of nutritional status in rainbow trout and that phytase treatment may have a long term effect on circulating IGF-I serum levels. This research also showed that pretreatment of plant feedstuffs with phytase can improve growth in rainbow trout all plant diets that makes them comparable to fish meal based diets, and that phytic acid does have a negative effect on growth.

OBJECTIVE 2

The identification of additional trout strains or species which can be reared under sub-optimal thermal conditions in the NCR will maximize productivity and profitability of aquaculture facilities in the region. In addition, the availability of rainbow trout strains or species with improved growth rate, feed conversion, and disease resistance will greatly improve the production efficiency of private and public fish hatcheries throughout the region.

UW-Madison data showed a lower stress response in Donaldson strain trout which suggests that this trout strain might be used to improve the production efficiency of private and public rainbow trout hatcheries in the NCR. Such stress-resistant fish are likely to show improved growth rates, feed conversion, and disease resistance compared to more stress-prone strains. It is recommended that farmers further evaluate this strain.

Data did not support the hypothesis that Artic charr might be used in place of rainbow trout to maximize productivity and profitability of aquaculture facilities in the region, particularly in the cold winter months. Both rainbow trout and Arctic charr performed well under the culture conditions evaluated in the UW-Madison study and no advantage of charr was detected. Indeed, one regional producer has recently abandoned charr production because of the high cost of charr eggs, and because charr sales had a negative impact on their rainbow trout sales.

RECOMMENDED FOLLOW-UP ACTIVITIES

- Although much is known about general salmonid nutrition there is still a need for additional information on the requirements of these fishes raised under the conditions that are common in the NCR;
- there is also a need for continued efforts into finding ways of lowering the cost of fish meal replacements using locally available ingredients; and
- additional work is needed in regard to shortening the time needed for diet evaluations and strain comparisons using techniques such as IGF.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Salmonid activities.

SUPPORT

YEAR	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1997-98	$80,403	$92,640	$23,500[a]		$23,750[b]	$139,890	$220,293
1999-00	$79,597	$134,145	$23,500[a]		$23,750[b]	$181,395	$260,992
TOTAL	$160,000	$226,785	$47,000		$47,500	$321,285	$481,285

[a]Ohio State University Korean Project
[b]National Cottonsead Products Association

TILAPIA[11]

Progress Report for the Period
September 1, 1998 to August 31, 2001

NCRAC FUNDING LEVEL: $150,000 (September 1, 1998 to August 31, 2001)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
Donald L. Garling	Michigan State University	Michigan
Susan T. Kohler	Southern Illinois University-Carbondale	Illinois
Industry Advisory Council Liaison:		
Gene Watne	North American Fish Farmers Cooperative, Velva	North Dakota
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-Funded Collaborators:		
Myron Kloubec[2]	Kloubec Fish Farms, Amana	Iowa
Dan Helfrich	ADM (Archer, Daniels, Midland), Decatur	Illinois
Chris Shimp[12]	Grayson Hills Farms, Harrisburg	Illinois
Dan Selock	Aquaculture Consultants for the Heartland, Carbondale	Illinois

PROJECT OBJECTIVES

(1) Compare feeds developed through the first North Central Regional Aquaculture Center (NCRAC)-funded Tilapia project as well as the Wastes/Effluents project to standard commercial feeds in different commercial scale recirculating aquaculture systems based on growth, performance (survival, health, feed conversion), water quality, and economic impacts. To ensure the applicability of results to commercial systems, the minimum size of an experimental recirculating unit must be 18,927 L (5,000 gal) per biofilter and the minimum replicate tank size must be at least 3,785 L (1,000 gal).

(2) Conduct "break-even analysis" for raising tilapia in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

[11]NCRAC has funded two Tilapia projects. A termination report for the first project is contained in the Annual Progress Report for 1998-1999. This progress report is for the second project, which is chaired by Paul B. Brown. It was originally a 2-year study that began September 1, 1998.

[12]Collaboration with Myron Kloubec, Kloubec Fish Farms, Amana, Iowa ended in 2001. Collaboration with Chris Shimp, Grayson Hills Farms, Harrisburg, Illinois ended July 2001 after completing their participation in Objective 2.

ANTICIPATED BENEFITS

Significant modifications in dietary formulation for tilapia are needed if the industry is to be competitive with foreign imports. The move to all-plant diets, continued research on alternative ingredients, and waste management issues should allow tilapia producers in the North Central Region (NCR) to realize some of the competitive advantage they have by producing fish close to major markets.

This project also includes a comprehensive analysis of the costs involved in commercially raising tilapia in an indoor recirculating system. These figures can then be compared with expectations about market prices to determine if the production of tilapia in indoor recirculating systems is economically viable.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

In the first Tilapia project, researchers at Purdue University (Purdue) found that a minimum of 28% crude protein was required in fish meal free grow-out diets for maximum weight gain. They also explored the optimum energy to protein ratio using the 28% crude protein concentration. The Purdue researchers found the optimum energy and lipid concentrations of grow-out tilapia (Nile tilapia, *Oreochromis niloticu*s) were similar to values developed for smaller fish using purified diets (3,000–3,200 kcal/kg [1,361–1,452 kcal/lb], or 4–6% dietary lipid). Dress-out percentages and nutritional composition were not significantly impacted at dietary lipid levels of 8% and lower.

Additional research conducted by Purdue in the first year of the present project indicated that choline is a required vitamin in diets fed to tilapia when methionine concentrations are at the minimum requirement and that phosphatidylcholine exerts a beneficial effect on weight gain and feed conversion. Both nutrients are limiting in all-plant diets fed to tilapia.

During the first two years of this project, Southern Illinois University-Carbondale (SIUC) researchers worked with Grayson Hills Farms in Harrisburg, Illinois to modify their greenhouses to accommodate tilapia production. Eight 18,927-L (5,000-gal) concrete tanks were constructed. Four of these tanks were equipped with bead biofilters and pumps and stocked with 3,000 tilapia (*O. niloticus*) fingerlings. Water from the tanks is distributed through tomato plant roots grown directly above the fish tanks hydroponically. The bead biofilters serve to collect solid wastes while providing media for bacterial nitrification. The tomato plants serve to remove dissolved nutrients from the system. Inorganic fertilization use for the tomato production has been reduced by half as a consequence. Unfortunately, the first crop of fish were lost in late fall 1999 when new electrical generators were being installed and water temperatures dropped to lethal levels when the installations took longer than anticipated. Grayson Hills Farms subsequently decided to reconfigure their aquaculture units from eight 18,927-L (5,000-gal) units to four 37,854-L (10,000-gal) units and to incorporate solids removal systems. These modifications were never completed. Accordingly, the production and economical studies have been switched to the ADM tilapia facility in Decatur, Illinois. ADM has allocated nine 37,854-L (10,000-gal) aquaculture units, each with a bead filter, to this study.

Several laboratory studies were conducted at SIUC to test the feasibility of using beet pulp in tilapia diets (conducted in conjunction with the second NCRAC Wastes/Effluents project). The nature of

tilapia feces, which string out in gelatinous strands, proved not to be conducive to this strategy as it was initially envisioned. However, it is felt that the incorporation of beet pulp may still be advantageous in a recirculating aquaculture system. Specifically, the effects the additional fiber material might have on bead filter performance and in potential reduction of nutrients in effluents as a result of absorption to the fiber is being examined. Biological oxygen demand, NH_3, NO_2, NO_3, and total phosphorus will be monitored bi-weekly in the culture tank and in the waste effluent. Dissolved oxygen, oxygen supplementation rate, feed intake, and back flush data will be monitored daily. Six tons of feed with and without fiber were produced by Land O'Lakes, Kansas City, Missouri. A preliminary feeding trial was conducted at ADM to compare these feeds to those currently in use. No differences in growth rates were observed.

Michigan State University (MSU) completed an extension publication on feeding methods for tilapia to enhance production in recirculating aquaculture systems. The publication has been reviewed and is currently under revision.

OBJECTIVE 2

The capital costs for construction of the Grayson Hills Farms concrete raceways and associated equipment were determined by researchers at SIUC during the first year of the project. Site preparation and excavation costs for eight raceways at Grayson Hills Farms included $2,400 for labor and $3,300 for equipment rental. Each raceway required $550 in concrete, $200 for sealer, and $450 in labor. Each raceway was equipped with heating coils at a price of $150, a ½ hp high volume low head submersible pump ($800 each), and a BBF-4™ bead biofilter ($1,250 each). One 1.0 HP regenerative blower ($400) was purchased to service four raceways. Accordingly, capital expenditures were $4,162 per completed raceway. Cost of production costs are now being determined for the ADM facility.

WORK PLANNED

Research planned by Purdue scientists to evaluate several new diet formulations at commercial production sites in Illinois (ADM) and Iowa were delayed by unexpected changes in management at both facilities. However, those studies were initiated in 2001 at ADM.

Researchers at SIUC will test two experimental (36% crude protein) and the current 36% crude protein diet being used by ADM. These studies will employ nine 37,854-L (10,000-gal) systems and are scheduled to commence October 12, 2001. The fixed and variable costs will be determined in conjunction with the tilapia feeding trials. Actual figures for capital, fixed, and variable costs will be used to calculate the break-even analysis. Sensitivity analysis will also be conducted on production costs.

IMPACTS

Gross formulation guidelines for grow-out diets that are free of fish meal have been developed. The basic formulation will be expanded to incorporate other ingredients that are readily available in the NCR. These formulations could be taken to local feed mills, which should significantly reduce feed costs, one of the most expensive annual variable costs in tilapia production.

A NCRAC fact sheet on feeding tilapia in intensive recirculating systems has been submitted for publication. The publication summarizes the results of practical feed recommendations and feeding strategy research that was developed during the first Tilapia project. In order to maximize

production efficiency, minimize demands on the biofilter, and minimize costs, tilapia should be fed:

- nutritionally complete diets formulated to meet their dietary requirements,
- the optimum crumble or pellet size,
- at the optimum feeding rate (% of fish weight),
- at the optimum time intervals (4-5 h depending on the energy and composition of the diet), and
- based on the size of the fish and the culture conditions.

This project provides information on economic conditions and constraints affecting profitability of a commercial tilapia aquaculture system. It ultimately will provide information on production costs and potential revenues as well as costs per unit of production to cover expenses. The information on factors affecting profitability and measures to be taken to reduce costs and/or increase revenues will enable producers to make informed decisions on the potential of indoor recirculating aquaculture systems for tilapia. The project has the added impact of providing information on potential reduction of nutrients in effluents via fiber absorption.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Tilapia activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1998-99	$74,773	$82,052				$82,052	$156,825
1999-00	$75,227	$82,642	$5,000			$87,642	$162,869
2000-01			$25,000			$25,000	$25,000
TOTAL	$150,000	$164,694	$30,000			$194,694	$334,694

AQUACULTURE DRUGS: EFFECTIVENESS OF FLORFENICOL, OXYTETRACYCLINE, CHLORAMINE-T, AND HYDROGEN PEROXIDE[13]

Progress Report for the Period
October 1, 1999 to August 31, 2001

NCRAC FUNDING LEVEL: $16,615 (October 1, 1999 to August 31, 2001)

PARTICIPANTS:

Alan A. Moore	Iowa Department of Natural Resources, Rathbun Fish Culture Research Facility	Iowa
Non-Funded Collaborators:		
Jeff Bernardy, Mark Gaikowski, Jeff Rach, and Guy Stehly	U.S. Geological Service Biological Resource Division's Upper Midwest Environmental Sciences Center	Wisconsin

PROJECT OBJECTIVES

(1) To evaluate the effectiveness of florfenicol and oxytetracycline to control mortalities caused by *Flavobacter columnare* in selected cultured fish and to evaluate the effectiveness of chloramine-T to control mortalities caused by bacterial gill disease in selected cultured fish.

(2) To collect tissue residue depletion data for florfenicol, oxytetracycline, chloramine-T, and hydrogen peroxide in selected cultured fish.

ANTICIPATED BENEFITS

Data from the studies will help complete the necessary data packages required by the Food and Drug Administration (FDA) for approval and labeling of these drugs. Once approval is secured, these drugs will be legal to use in aquaculture in the United States. The cost benefits of this study proposal are tremendous if one takes into account the funding level already committed to the Investigational New Animal Drug/New Animal Drug Applications (INAD/NADA) process through the cooperative federal/state aquaculture drug approval partnership project, the U.S. Fish and Wildlife Services's (USFWS) own INAD program, and other state and private INAD programs.

This study has national significance in that an approved drug label for the use of these drugs in fish will benefit the entire aquaculture community including federal, state, and private aquaculture interests located throughout the United States. This study will provide direct benefits to the 37 states involved in the federal/state aquaculture drug approval partnership project to obtain approval for drugs for public fish production that is based upon a

[13]NCRAC has funded three Aquaculture Drugs projects. A termination report for the first project is contained in the 1996-97 Annual Progress Report; a termination report for the second project is contained in the 1997-98 Annual Progress Report. This progress report is for the third project, which is chaired by Alan A. Moore. It was originally a 1-year study that began October 1, 1999.

Memorandum of Understanding between the International Association of Fish and Wildlife Agencies (IAFWA), the U.S. Geological Service's Biological Resource Division, and the USFWS. In the long run, it will also directly benefit the remaining 13 states in the United States. Virtually all recreational fish species that have a culture/propagation component to their management program will benefit.

All recreational fisheries opportunities that are in part based on culture/propagation for stock enhancement will benefit from this study. While in certain parts of the country there are indeed naturally reproducing, wild (not necessarily native) fish populations which support recreational opportunities without stock enhancement, this situation is certainly the "exception rather than the rule." From Pacific salmon on the west coast, to trout, walleye, and muskellunge in the midwest, to catfish and striped bass in the southeast, to Atlantic salmon on the east coast, many recreational fishing opportunities are dependent upon culture/propagation programs. As the popularity of fishing and associated recreation continues to rise in this country, the pressure on existing fish populations will also continue to increase.

PROGRESS AND PRINCIAL ACCOMPLISHMENTS

OBJECTIVE 1

In 2000, work conducted at Iowa's Department of Natural Resources Rathbun Fish Culture Research Facility was designed to test the effectiveness of oxytetracycline to control systemic infections of *Flavobactor columnaris* in walleye. In this study walleye were induced by stress to break out with a columnaris infection. Fish were divided into two replicate groups of three controls receiving untreated feed and three treated groups receiving oxytetracycline feed treated at 82.7 mg active ingredient/kg fish. Each replicate contained 145 walleye. Treated feed was fed for 10 consecutive days, and a 14 day post-treatment period was used to monitor fish mortality. Two days into the study an infection of the protozoan chilodonella was detected and a 1.0% salt treatment was administered to cure the infection.

The three tanks that received treated feed had fish mortalities of 29.7%, 32.4%, and 17.2%. Tanks receiving untreated feed had total mortalities of 31.0%, 20.7%, and 26.9%.

Data analysis was performed after the September 18, 2000 post-treatment period. Analysis showed no significant difference between groups fed oxytetracycline treated feed and groups fed untreated feed.

During August 2001, walleye were stressed and became infected with *Flavobacter columnare*. A study was begun August 17 to test the effectiveness of feeding oxytetracycline to control this bacteria. Fish were randomly divided into groups of three controls receiving untreated feed and three groups receiving oxytetracycline treated feed. Each replicate tank contained 187 walleye.

The study was terminated after only two days because the walleye developed an infection of bacterial gill disease. Food and Drug Administration guidelines do not allow the acceptance of results compounded by a secondary infection.

OBJECTIVE 2

In October 1999, a study performed at the Rathbun Fish Culture Research Facility was designed to gather residue depletion data of oxytetracycline in cultured fishes. This data was gathered for walleye during the contract period. The label currently restricts the administration of oxytetracycline to control

specific diseases in salmonids and catfish. This residue depletion study was conducted to support the extension of the label to include all cool water fish species cultured at public and private aquaculture facilities. In this study, 461 walleye weighing a mean of 61.2 g (2.2 oz) each were offered 3.87% of their total body weight per day of a slow sinking walleye diet (Walleye Grower 9206). The diet top-coated with oxytetracycline (89.0 mg/kg/day) was fed for 10 consecutive days. Fifty fish were sampled as control fish before feeding of the treated feed and 20 fish were sampled 1, 2, 3, 4, 7, 9, 11, and 14 days after treatment. Skin-on fillets were analyzed for oxytetracycline-base concentration at the U.S. Geological Service Biological Resource Division's Upper Midwest Environmental Sciences Center (UMESC). Water temperature during the treatment period ranged from 16.7–18.4°C (62.1–65.1°F) and was 12.9–17.0°C (55.2–62.6°F) during the depuration period.

The maximum mean oxytetracycline-base concentration in the fillet tissues of walleye fed the medicated grower was 721 ng/g. This concentration is below the current oxytetracycline-base tolerance limit of 2,000 ng/g.

Expanded Scope of Work (Hydrogen Peroxide)

The scope of work for this project was expanded to include the efficacy testing of hydrogen peroxide for fungus on channel catfish eggs, *Flavobacter columnare* on channel catfish, hydrogen peroxide for parasites on walleye, and hydrogen peroxide and chloramine-T for *Flavobacter columnare* infections on walleye.

Rsearch was conducted to expand the label of 35% Perox-Aid™ to include channel catfish eggs for the treatment of fungus. Treatments were run at 500 mg/L and 750 mg/L Perox-Aid™ as a flow through. There were three replicates for the control and each treatment concentration. Egg volumes ranged from 6,600–7,700/jar. Eggs were treated for four consecutive days until eggs began to hatch on day 5. No fungus was present in any of the treatment groups, but fungus was present in all untreated control groups. Even though fungus was present, no affect on hatch was detected. Perox-Aid™ concentrations did not reach desired levels in any treatments with a mean of 324 mg/L at the 750 mg/L treatment concentration and 241 mg/L at the 500 mg/L treatment concentration. It was later determined the Perox-Aid™ concentration had been inadvertently diluted by the company from 35% to 15%.

Another study was conducted in 2000 at the Rathbun Fish Culture Research Facility to evaluate the effectiveness of hydrogen peroxide and chloramine-T to control *Flavobacter columnare* in walleye.

Fish held in a rearing tank, prior to the study, were naturally infected with *Flavobactor columnare*. When a columnaris infection was detected on some of the test fish and mortalities began to increase, treatment began. Treatments were conducted in two portable systems with one system containing 12 tanks and one system containing 9 tanks. All tanks contained 40 L (10.6 gal) of water.

Hydrogen peroxide (commercial grade 35% active, DuPont, Memphis, Tennessee) and chloramine-T (commercial grade 99–100% active ingredient, AKZO Chemicals, Dobb Ferry, New York) were prepared as stock solutions. Treatments were 50, 100, and 150 mg/L hydrogen peroxide, and 10, 20, and 30 mg/L chloramine-T. Controls in three tanks were used for both treatments. Hydrogen peroxide was administered as 30 min exposures and chloramine-T as 60 min exposures.

Active chemical concentrations calculated by water testing were 50.9, 101.2, and 149.3 mg/L for hydrogen peroxide and 9.7, 18.5, and 27.5 mg/L for chloramine-T.

Results showed mean fish mortalities in the hydrogen peroxide trial were 17.3% (control), 17.3% (50 mg/L), 38% (100 mg/L), and 90% (150 mg/L). Hydrogen peroxide treatments were toxic at 100 mg/L or greater.

Mean fish mortalities in the chloramine-T trial were 17.3% (control), 16.0% (10 mg/L), 23.3% (20 mg/L), and 18.7% (30 mg/L).

None of the treatments resulted in a statistically significant reduction in fish mortalities. These data also support the conclusions of other researchers that walleye are one of the most sensitive species to hydrogen peroxide.

During July 2001, walleye held in rectangular tanks contracted a natural infection of the protozoan parasite chilodonella. A study was conducted to test the efficacy of 35% Perox-Aid™ in eradicating the parasite.

Tests were conducted in six 288-L (76 gal) circular tanks. A prestudy parasite evaluation on 31 walleye showed 21 fish had >25 chilodonella per gill arch and 10 fish had from 1–16 per gill arch. Each circular tank was stocked with 250 walleye in a random order to give three treatment tanks receiving Perox-Aid™ and three untreated control tanks.

Treatment tanks received 100mg/L Perox-Aid™ for 30 min. Water samples were taken 15 min into the treatment from each treatment tank and one control tank for titration to determine the hydrogen peroxide concentration. At the end of 30 minutes all tanks were drawn down and flushed to eliminate the hydrogen peroxide. Dissolved oxygen, pH, temperature, and mortalities were recorded for each tank on a daily basis.

Two Perox-Aid™ treatments were administered on alternate days and fish were then evaluated for the presence of chilodonella 2 days and 8 days post treatment. Ten fish were examined per tank on day 2 and six fish on day 8 post treatment.

Post-treatment examination of treated fish for chilodonella showed no parasites present at day 2 or day 8. The number of chilodonella on untreated control fish ranged from 0–11/gill arch on day 2 post treatment and from 0–181 on day 8 post treatment, with a mean of 49 per gill arch.

Mean mortality after one treatment was 22 in treated tanks and 38 in control tanks; however, after the second treatment, mean mortality was 87 in treated tanks and 14 in control tanks. By day 7 post treatment, mean mortalities were 20 in the control tanks and two in the treated tanks. While Perox-Aid™ is effective in controlling childonella, care must be taken when treating walleye due to chemical sensitivity.

A second study was conducted in 2001 to evaluate the efficacy of Perox-Aid™ 35% hydrogen peroxide to control *Flavobacter columnare* on channel catfish. Six raceways containing a mean of 1,940 channel catfish were naturally infected with columnaris. Three raceways were randomly selected as treatment groups to receive 75 mg/L hydrogen peroxide, and three were selected as untreated controls. Treatments were administered daily for 30–45 min depending on the behavior of the fish in the raceway.

Perox-Aid™ treatments began on July 18 and were applied through July 25. The

columnaris reappeared in one of the treatment raceways on July 30 and in another on August 2. The first raceway was treated again on July 30, 31, and August 1 and the second raceway was treated on August 2 only. These subsequent treatments halted the infection. Mortalities became unacceptable in the control group on July 20 and Reward™ Diquat was administered for six consecutive days. Mean mortalities during the first eight days of the study were 8.8/day for the Perox-Aid™ treated fish and 11.5 for the control fish. Maximum mortalities per day for treated fish were 59 and were 150 for the control fish. Perox-Aid™ will effectively control *Flavobacter columnare* and channel catfish are less sensitive to the chemical than walleye.

WORK PLANNED

An additional extension of this grant to May of 2002 has been requested, along with again expanding the scope of work to include hydrogen peroxide. This expansion of work will depend on research needed to complete the NADA process for drug approval.

OBJECTIVE 1

Research is being planned to conduct studies using chloramine-T to control bacterial gill disease and to again evaluate the effectiveness of oxytetracycline to control *Flavobacter columnare* in cultured fish. These studies are again planned because bacterial gill disease was not generated for testing during the past reporting period and as of this writing a *Flavobacter columnare* infection in walleye has not been generated for oxytetracycline feeding. Testing of florfenicol is also being planned for channel catfish infected with *Flavobacter columnare* because of the lack of a viable INAD.

OBJECTIVE 2

At this writing research is being planned to conduct residue depletion studies with florfenicol. This is necessary for florfenicol as no viable INAD was available in 1999-2001. The chloramine-T residue depletion was completed at the UMESC using yellow perch. Walleye dedicated to this study that were transferred from Rathbun to the UMESC were not used because of disease problems. This part of the study will be dropped.

IMPACTS

OBJECTIVE 1

Research in 2000 to evaluate the effectiveness of oxytetracycline to control *Flavobacter columnare* overlapped the reporting period and at this writing data is being evaluated. The study was unsuccessful and the work was rescheduled for 2001.

Research conducted during 2001 showed that hydrogen peroxide will effectively control chilodonella on walleye but that walleye are extremely sensitive to the drug. This data package will be submitted to FDA as either pivotal or supporting data to add this parasite to the label. Also, hydrogen peroxide will control *Flavobacter columnare* on channel catfish and these fish have less sensitivity to the drug than walleye. This work will be submitted to FDA as supportive data to add columnaris to the label.

OBJECTIVE 2

Research in 1999 proved oxytetracycline did not reach the upper tolerance limits when fed to walleye under cool water conditions. These data were submitted to FDA and will assist in the approval of a zero withdrawal time for the use of this drug in percids.

EXPANDED SCOPE OF WORK

In 2001 hydrogen peroxide was again tested and reported on in the appropriate sections.

The use of hydrogen peroxide in 2000 to control fungus in channel catfish eggs was proven effective, even though treatment rates were one-half of the desired level. These levels also did not adversely affect hatch when compared to untreated controls. This work was submitted to the FDA as supportive data and will help allow channel catfish eggs to be added to the Perox-Aid™ label for fungus control.

Testing of hydrogen peroxide on walleye once again showed the sensitivity of this species to concentrations at or above 100 mg/L. This sensitivity may be reduced by using shorter exposure periods or by first treating fish with a low concentration then gradually increasing concentrations with subsequent treatments.

Even though results were not statistically significant, data show that chloramine-T is not toxic to walleye up to 30 mg/L for a 60 min exposure period.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Manuscripts for review by the Food and Drug Administration are in preparation by the participants and non-funded collaborators.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-01	$16,615						$16,615
TOTAL	$16,615						$16,615

APPENDIX

EXTENSION

NCRAC Extension Fact Sheet Series

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Midwest Regional Cage Fish Culture Workshop, Jasper, Indiana, August 24-25, 1990. (LaDon Swann)

Aquaculture Leader Training for Great Lakes Sea Grant Extension Agents, Manitowoc, Wisconsin, October 23, 1990. (David J. Landkamer and LaDon Swann)

Regional Workshop of Commercial Fish Culture Using Water Reuse Systems, Normal, Illinois, November 2-3, 1990. (LaDon Swann)

First North Central Regional Aquaculture Conference, Kalamazoo, Michigan, March 18-21, 1991. (Donald L. Garling, Lead; David J. Landkamer, Joseph E. Morris and Ronald Kinnunen, Steering Committee)

Crayfish Symposium, Carbondale, Illinois, March 23-24, 1991. (Daniel A. Selock and Christopher C. Kohler)

Fish Transportation Workshops, Marion, Illinois, April 6, 1991 and West Lafayette, Indiana, April 20, 1991. (LaDon Swann and Daniel A. Selock)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 15-16, 1991. (LaDon Swann)

National Aquaculture Extension Workshop, Ferndale, Arkansas, March 3-7, 1992. (Joseph E. Morris, Steering Committee)

Regional Workshop on Commercial Fish Culture Using Water Recirculating Systems, Normal, Illinois, November 19-20, 1992. (LaDon Swann)

In-Service Training for CES and Sea Grant Personnel, Gretna, Nebraska, February 9, 1993. (Terrence B. Kayes and Joseph E. Morris)

Aquaculture Leader Training, Alexandria, Minnesota, March 6, 1993. (Jeffrey L. Gunderson and Joseph E. Morris)

Investing in Freshwater Aquaculture, Satellite Videoconference, Purdue University, April 10, 1993. (LaDon Swann)

National Extension Wildlife and Fisheries Workshop, Kansas City, Missouri, April 29-May 2, 1993. (Joseph E. Morris)

Commercial Aquaculture Recirculation Systems, Piketon, Ohio, July 10, 1993. (James E. Ebeling)

Yellow Perch and Hybrid Striped Bass Aquaculture Workshop, Piketon, Ohio, July 9, 1994. (James E. Ebeling and Christopher C. Kohler)

Workshop on Getting Started in Commercial Aquaculture Raising Crayfish and Yellow Perch, Jasper, Indiana, October 14-15, 1994. (LaDon Swann)

Aquaculture in the Age of the Information Highway. Special session, World Aquaculture Society, San Diego, California, February 7, 1995. (LaDon Swann)

Second North Central Regional Aquaculture Conference, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson, Lead; Fred P. Binkowski, Donald L. Garling, Terrence B. Kayes, Ronald E. Kinnunen, Joseph E. Morris, and LaDon Swann, Steering Committee)

Walleye Culture Workshop, Minneapolis, Minnesota, February 17-18, 1995. (Jeffrey L. Gunderson)

Aquaculture in the Age of the Information Highway. Multimedia session, 18 month meeting of the Sea Grant Great Lakes Network, Niagra Falls, Ontario, May 6, 1995. (LaDon Swann)

AquaNIC. Annual Meeting of the Aquaculture Association of Canada, Nanaimo, British Columbia, June 5, 1995. (LaDon Swann)

Yellow Perch Aquaculture Workshop, Spring Lake, Michigan, June 15-16, 1995. (Donald L. Garling)

Rainbow Trout Production: Indoors/Outdoors, Piketon, Ohio, July 8, 1995. (James E. Ebeling)

North Central Regional Aquaculture Center Hybrid Striped Bass Workshop, Champaign, Illinois, November 2-4, 1995. (Christoper C. Kohler, LaDon Swann, and Joseph E. Morris)

Third North Central Regional Aquaculture Conference, Indianapolis, Indiana, February 6-7, 1997. (LaDon Swann)

Overview of Sunfish Culture. Missouri Joint Aquaculture Conference, Springfield, Missouri, March 4-6, 1998. (Joseph E. Morris)

Seafood and Food Safety Issues Related to Aquaculture, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (Ronald E. Kinnunen)

Overview of Sunfish Culture. North Central Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (Joseph E. Morris and Charles C. Mischke)

Angel Fish Production, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (LaDon Swann)

Potential of Recirculating Systems in the North Central Region, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (LaDon Swann)

Overview of Freshwater Shrimp Culture, North Central Regional Aquaculture Conference, Columbia, Missouri, February 24-26, 1999. (Laura Tiu)

Fertilization Regimes for Fish Culture Ponds, Wisconsin Aquaculture Conference, Green Bay, Wisconsin, March 12-13, 1999. (Joseph E. Morris)

Extension Programming in the North Central Region, SERA-IEG-9, Frankfort, Kentucky, March 14-16, 1999. (Joseph E. Morris)

Description of the Aquaculture and Bait Fish Industries: Threat Evaluation and Identification of Critical Control Points, International Joint Commission Workshop on Exotic Policy, Milwaukee, Wisconsin, September 22-26, 1999. (Jeffrey L. Gunderson)

Fisheries Management in the North Central Region, 9th National Extension Wildlife, Fisheries, and Aquaculture Conference, Portland, Maine, September 29-October 2, 1999. (Joseph E. Morris, and S.K. Whitcomb)

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YELLOW PERCH

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SOME COMMONLY USED ABBREVIATIONS AND ACRONYMS

AquaNIC	Aquaculture Network Information Center
BOD	Board of Directors
°C	degrees Celsius
CES	Cooperative Extension Service
cm	centimeter
°F	degrees Fahrenheit
FDA	Food and Drug Administration
FFO	Freshwater Farms of Ohio, Inc.
FMA	fish meal analog
ft, ft^3	foot, cubic foot
g	gram(s)
gal	gallon(s)
h	hour(s)
ha	hectare(s)
HACCP	Hazard Analysis Critical Control Points
IAC	Industry Advisory Council
IAFWA	International Association of Fish and Wildlife Agencies
IGF-I	insulin-like growth factor
in	inch(es)
INAD	Investigational New Animal Drug
ISU	Illinois State University Iowa State University
JSA	Joint Subcommittee on Aquaculture
kg	kilogram(s)
L	liter(s)
lb	pound(s)
m, m^3	meter, cubic meter
µm	micrometer
mg	milligram(s)
min	minute(es)
mL	milliliter(s)
mm	millimeter(s)
MSU	Michigan State University
N	number
NADA	New Animal Drug Applications
NCR	North Central Region
NCRAC	North Central Regional Aquaculture Center
NDSU	North Dakota State University
OAA	Ohio Aquaculture Association
OSU	Ohio State University
oz	ounce(s)
ppm	parts per million
Purdue	Purdue University
RAC(s)	Regional Aquaculture Center(s)
RAS	recirculating aquaculture systems
SGR	specific growth rate
SIUC	Southern Illinois University-Carbondale
TC	Technical Committee (TC/E = Technical Committee/ Extension; TC/R = Technical Committee/Research)
TL	total length
TSS	total suspended solids
UM	University of Missouri
UMn	University of Minnesota
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
UW-Madison	University of Wisconsin-Madison
YOY	young-of-the-year
yr	year(s)