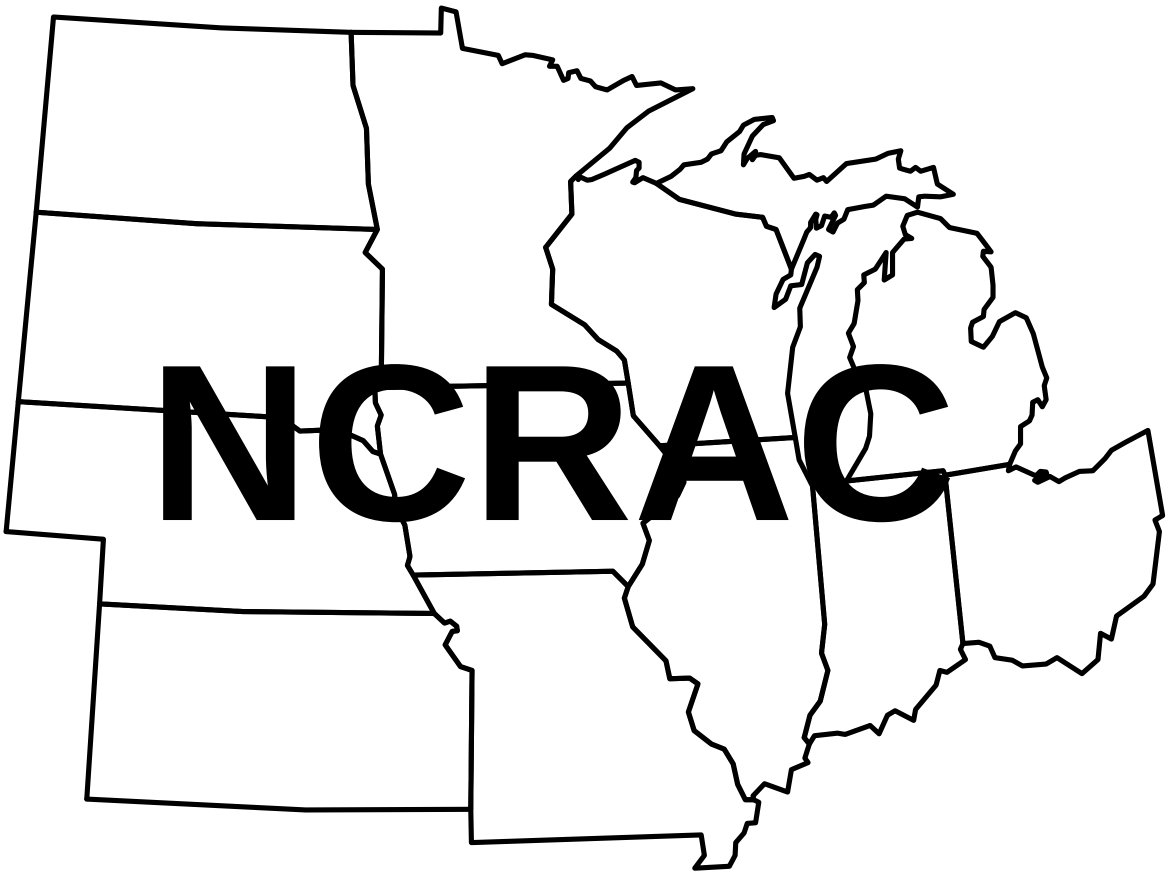
NORTH CENTRAL
REGIONAL AQUACULTURE CENTER



ANNUAL PROGRESS REPORT 2001-02

JANUARY 2003

ANNUAL PROGRESS REPORT

For the Period
September 1, 2001 to August 31, 2002

January 2003

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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 2000 was about 823 million pounds and generated approximately $973 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 has substantially increased over the last two decades. In 2001, the U.S. imported $18.5 billion of fisheries products and the trade deficit was $6.7 billion for all fisheries products, almost all 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 Farm Security and Rural Investment Act of 2002 (P.L. 107-171), 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 NCRAC's Office for Publications and Extension Programs at ISU is under the direction of 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 15 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), FY2001 (#2001-38500-10369), and FY2002 (#2002-38500-11752) with monies totaling $10,946,985. Currently, five grants are active (FY98-02); the first ten grants (FY88-97) 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, 2002, the Center has funded or is funding 60 projects through 320 subcontracts from the first 14 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 eight separately funded projects in regard to Extension and Yellow Perch. 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, 2001 to August 31, 2002. Projects, or Project components, that terminated prior to September 1, 2001 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	$38,000	97-38500-3957
	7	9/1/99-8/31/01	$94,000	99-38500-7376
	8	9/1/01-8/31/03	$28,500	99-38500-7376
			$18,000	2001-38500-10369
			$521,552	
Economics/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	$47,916	97-38500-3957
			$302,904	
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	$185,458	97-38500-3957
	7	9/1/98-8/31/00	$92,370	98-38500-5863
	8	9/1/01-5/31/04	$326,730	00-38500-8984
			$125,016	2001-38500-10369
			$1,433,866	
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
	7	9/1/01-5/31/04	$98,043	98-38500-5863
			$211,957	2001-38500-10369
			$976,960	
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	

Project Area	Project Number	Proposed Duration Period	Funding Level	Grant Number
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	$199,748	99-38500-7376
			$853,788	
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
	3	9/1/01-8/31/04	$106,186	00-38500-8984
			$88,814	2001-38500-10369
			$448,300	
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	$8,415	97-38500-3957
			$36,365	
White Papers	1	7/1/98-12/31/98	$5,000	96-38500-2631
	2	9/1/99-12/31/99	$17,495	97-38500-3957
			$22,495	

PROJECT TERMINATION
OR
PROGRESS REPORTS

EXTENSION[1]

Progress Report for the Period
May 1, 1989 to August 31, 2002

NCRAC FUNDING LEVEL: $503,552 (May 1, 1989 to August 31, 2002)

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 eight Extension projects. The first three were chaired by Donald L. Garling, the fourth project was chaired by Fred P. Binkowski and projects 5-8 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 eighth project is a 2-year project that began September 1, 2001.

(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 as well as other conferences and symposia.
- 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. In the past year, AquaNIC has received over 9 million file transfers of which over 75,000 were to the NCRAC Web site. During the same time period, people from over 170 countries have visited this Web site.

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 and 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; refilling that position has been put on hold.

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 regional workshops on general aquaculture, fish diseases, HACCP training, fish nutrition, commercial recirculation systems, leach and baitfish culture, aquaculture business planning, crayfish culture, pond management, culture of specific taxa (yellow perch, hybrid striped bass, rainbow trout, hybrid walleye, and sunfish), and in-service training for high school vocational-agricultural teachers. 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. Often the individual contact is the principal contact between the aquaculture industry and governmental/academic institutions.

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. Binkowski has also worked with the State of Wisconsin as well as the Wisconsin Aquaculture Association to plan the establishment of the Northern Wisconsin Aquaculture Demonstration Facility in Ashland, Wisconsin.

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. Kinnunen coordinated a three-day HACCP course at St. Croix Waters Fishery near Danbury, Wisconsin, one of the largest recirculation aquaculture systems in North America, in 2002.

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 facilities in Piketon, Ohio operated by Ohio State University are used to inform the public about aquaculture as well as foster grass root support for this agriculture enterprise. The aforementioned Northern Wisconsin Aquaculture Demonstration Facility will be a valuable addition.

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 completed by Southern Illinois University-Carbondale staff.

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 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.

A satellite workshop has been designed by Tiu to explore the pros and cons of converting existing agricultural buildings into fish culture facilities. This workshop is sponsored by NCRAC and will be broadcast to several sites throughout the Midwest. The workshop is scheduled for November 16, 2002 in Lima, Ohio.

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 6,000 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. In the last year AquaNIC's home page received over 9 million file transfers, of which over 75,000 were to the NCRAC Web site, by people from more than 170 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.
- Participants in 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. Specific HACCP models related to aquaculture drugs and other contaminants have been developed by Kinnunen.
- Strategic planning by the Ohio Aquaculture Association resulted in the identification of mission, vision, values and goals statements for the Association. It has also has given producers the forum necessary to encourage appropriate legislation necessary for the success of the aquaculture industry in that state.
- Closer working relationships with the Ohio Department of Natural Resources resulted in the first electronic database of Aquaculture Permit Holders in Ohio.

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	$38,000	$110,559				$110,559	$148,559
1999-01	$94,000	$108,124				$120,816	$215,816
2001-02	$28,500	$99,181					
TOTAL	$503,552	$1,055,347	$5,000	$334,000	$55,000	$1,362,858	$1,838,910

ECONOMICS/MARKETING[2]

Progress Report for the Period
September 1, 1999 to August 31, 2002

NCRAC FUNDING LEVEL: $47,916 (September 1, 1999 to August 31, 2002)

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 (NCR).

(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.

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[2]NCRAC has funded four Extension/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 Patrick D. O'Rourke. This progress report is for the fourth Economics/Marketing project which is chaired by Edward M. Mahoney. It was originally a 2-year project that began September 1, 1999 but has been lengthened for no additional cost.

ANTICIPATED BENEFITS

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

U.S. consumption of fish and seafood products has been relatively steady over the last decade at about 15 lb/capita. The fish industry lacks a strong national promotion group due partially to its fragmentation into specific species organizations. In order to increase per capita consumption, the industry needs to work together. Expenditures for fish products in the NCR are substantially lower than in other regions of the United States and the major types of fish consumed are not produced or caught in the region. Again, these facts led to the need for a strong regional organization.

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 was made and approved. However, due to retirement of an associate in the Department of Food and Nutrition at NDSU, this objective has not yet been achieved.

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.

Walleye was the clearly preferred fish in consumer perceptions, scoring the highest in comparison to orange roughy, cod and sunfish in each category of appearance, flavor, mouthfeel and overall. Sunfish scored last in the same comparison, similar to tilapia in an earlier study. These consumer sensory tests along with supplier opinions and market information provide strong rationale for continued research on production of walleye and for expansion of farm raised walleye. Given the difficulty of competing with low cost imports, the region needs to focus on the “high-end” species. Sunfish, with only one exception, was rated low as to commercial potential. The widespread familiarity with sunfish as the most commonly caught fish did not result in strong market potential and work completed in Indiana and Michigan supported the common knowledge in food markets, i.e., consistent quality, taste, and appearance are the most important attributes in marketing fish products.

SUB-OBJECTIVE 4

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 were 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 was 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. 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. A total of 31 of 46 firms that brokered or bought fish in Michigan returned questionnaires. This represents a response rate of 67%. Non-respondents were contacted and were either closed, no longer in business, or declined involvement in the study. Seventeen large wholesalers of fish were identified. For the purpose of this study, firms were either categorized as large wholesalers (15 firms), small wholesalers (21 firms), retailers (5 firms), or institutions (5 organizations). In terms of who responded, 15 completed surveys were received from larger wholesalers (66%), 14 surveys from small wholesalers (66%), 4 surveys from retailers (80%), and 3 from institutions (60%).

The overall response rate for large and small wholesalers, retailers, and institutional buyers was 68%. 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.

In regards to the types of fish that these firms have bought or sold, 86% of the sample had bought or sold wild harvested saltwater fish. Sales of these types of fish represent 36.7% of total sales for those firms. Furthermore, 96.4% had bought or sold wild harvested freshwater fish. Sales of these types of fish represent 48.0% of total sales for those firms. Finally, 89.2% had bought or sold farm-raised fish. This represented 24.8% of total sales.

In regards to the types of farm-raised fish bought or sold in 2000, salmon, catfish, trout, and tilapia were the predominant species purchased or sold. Each of these types of fish were carried by more than half of the organizations surveyed

In regards to walleye, 28 respondents had bought or sold wild harvested walleye. The average length of time that they have bought or sold wild harvested walleye was 24.61 years. Furthermore, they rated their experience with wild-harvested walleye very highly (a mean of 8.96 on a ten-point scale with 10 being excellent). In regards to farm raised walleye, only 3 respondents had ever bought or sold this type of fish. The average length of time was 6.33 years and they rated their experience very high (mean of 9.67).

In regards to sunfish, 15 respondents had bought or sold wild harvested sunfish. The average length of time that they have bought or sold wild harvested sunfish was 17.57 years. Furthermore, they rated their experience with wild-harvested sunfish highly (a mean of 7.93). In regards to farm raised sunfish, only 1 respondent had ever bought or sold this type of fish. They only started carrying the fish during the past year but rated their satisfaction with the fish as excellent (a score of 10).

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, 9 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.

SUB-OBJECTIVE 5
This objective was jointly completed by ISU and MSU. Clearly, lack of marketing support and lack of product quality are the two most important potential barriers for the successful introduction of farm-raised walleye and sunfish. Furthermore, these farm-raised fish will have to directly compete with wild walleye and sunfish.

The information collected indicates there are potential markets for farm-raised walleye and sunfishes, 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. 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 fish buyers include fresh whole, fresh fillet, and frozen fillet.

Based upon surveys of behavior and taste-testing as well as market analysis, walleye and hybrid walleye exhibits the greatest current and potential demand. It is a preferred species in the region and possesses characteristics demanded by fish consumers as verified by its market price and responses by the industry. It appears that reduction of production problems and costs are the only limiting factor 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. 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. Although sunfish has name recognition, it appears that it would compete at a level with tilapia fillets based on its similarity in consumer response to taste and appearance tests.

SUB-OBJECTIVE 6
Results indicate that walleye and hybrid walleye are preferred fish in the region. Both consumer reaction and the industry responses clearly indicate expansion possibilities for increased walleye production without a high probability of negative price effects.

WORK PLANNED
SUB-OBJECTIVES 1–6
Completion of all final reports and publications will be done during the fall/winter of 2002-03.

IMPACTS
Based upon the 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/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	$20,094	$55,910				$55,910	$76,004
TOTAL	$47,916	$53,777				$109,687	$157,603

YELLOW PERCH[3]

Progress Report for the Period
September 1, 2001 to August 31, 2002

NCRAC FUNDING LEVEL: $156,215 (September 1, 2001 to August 31, 2002)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
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Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Donald J. McFeeters	Ohio State University	Ohio
David A. Smith	Freshwater Farms of Ohio, Inc.	Ohio
Laura G Tiu	Ohio State University	Ohio
Geoffrey K. Wallat	Ohio State University	Ohio
Industry Advisory Council Liaison:		
Rex Ostrum	Ostrum Acres Fish Farm, McCook	Nebraska
Extension Liaison:		
Donald L. Garling	Michigan State University	Michigan
Non-Funded Collaborators:[4]		
Pat Brown	Red Lake Hatchery, Redby	Minnesota
Harvey Hoven	University of Wisconsin-Superior	Wisconsin
David L. Northey	Coolwater Farms, LLC, Deerfield	Wisconsin
Todd Powless	Zeigler Brothers, Inc., Gardners	Pennsylvania
Lloyd Wright	Hocking Technical College, Nelsonville	Ohio
Tom Zeigler	Zeigler Brothers, Inc., Gardners	Pennsylvania

PROJECT OBJECTIVES

(1) Develop or investigate reliable, profitable, and sustainable production systems to rear feed-trained yellow perch to market size.

(2) Continued development of grow-out diets and feeding strategies for feed-trained yellow perch in ponds and recirculating systems.

[3]NCRAC has funded eight 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; and a project component termination report for the remainder of the sixth project and the seventh Yellow Perch project is contained in the 2000-01 Annual Progress Report. This progress report is for the eighth Yellow Perch project which is chaired by Jeffrey A. Malison. It is a 3-year project that began September 1, 2001.

[4]Sunny Meadow Fish Farm and Willow Creek Aquaculture, who were included in the Project Outline as non-funded commercial cooperators, have withdrawn from the study. Red Lake Hatchery has chosen not to participate in the first year of the project.

(3) Extension
   a. Conduct additional yellow perch forums and publish proceedings.
   b. Develop fact sheets that not only review the literature but also indicate successes and failures of commercial yellow perch aquaculture.
   c. Identify a yellow perch information specialist who can visit state associations.

ANTICIPATED BENEFITS

The work conducted under Objective 1 will document the production parameters (including expected growth and survival rates, food conversion, and density and loading limitations) that can be expected using open pond, net pen, flow through, and recirculation systems. In addition, information will be generated on the relative costs of raising market-size yellow perch using different types of systems. This information will be made available to outreach specialists, who can then make informed recommendations to current and prospective perch producers regarding the most profitable methods for producing yellow perch. The work conducted under Objective 1 will also provide opportunities for individuals interested in yellow perch aquaculture to observe different production systems and management strategies. The studies conducted under Objective 2 will provide key information on the best available diets and feeding strategies for raising yellow perch to food size. This information, in turn, should help perch producers increase their efficiency by maximizing fish growth rates, improving food conversion, and reducing food costs. The extension efforts conducted under Objective 3 will provide updates on the status of yellow perch culture in the North Central Region (NCR) and help transfer the latest technological innovations to the industry.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Key production parameters are being documented by University of Wisconsin-Madison (UW-Madison) researchers for raising feed-trained fingerlings to market size in ponds in southern Wisconsin, using best current practices.

In May 2002, four ponds (two ponds, each, at the Lake Mills State Fish Hatchery and Coolwater Farms, LLC, Deerfield, Wisconsin) were stocked with age 1 yellow perch fingerlings (19–23 g; 0.67–0.81 oz) at 37,200 fish/ha (15,055 fish/acre). Throughout the summer, the fish in each pond were fed daily to satiation (at dusk) using a standard floating trout grower diet. In general, a strong feeding response was observed in all of the ponds. The fish were sampled regularly for weight and length, and the sampling indicated that the fish in all four ponds were growing well (0.25–0.40 g/day; 0.009–0.014 oz/day). Water quality measurements taken throughout the summer indicated that ammonia and nitrite concentrations were always negligible, and dissolved oxygen levels were always at or above the level needed to allow for good perch growth (3 mg/L; ppm). Except for a 2-week period during a mid-July heat spell, water temperatures remained below 27.0°C (80.6°F). During the heat spell, however, temperatures increased to 27.0–28.0°C (80.6–82.4°F), and the feeding activity of the fish diminished. Ponds will be harvested in mid- to late October. The data collected to date indicate excellent fish growth (0.25–0.40 g/day; 0.009–0.014 oz/day) and survival (>80%) in all of the ponds.

The same parameters described above are being compared by UW-Madison researchers for yellow perch raised at three densities. In May 2002, three ponds at the

Lake Mills Hatchery were stocked with age 1 yellow perch fingerlings (19–23 g; 0.67–0.81 oz) in the following manner: one pond at 37,200 fish/ha (15,055 fish/acre), one pond at 49,600 fish/ha (20,073 fish/acre), and one pond at 62,000 fish/ha (25,091 fish/acre). Otherwise, these ponds were treated exactly like those described above in Objective 1. Throughout the growing season no obvious density-related differences were observed in fish production characteristics or water quality. Ponds will be harvested in mid- to late October. The data collected to date indicate excellent growth (0.25–0.40 g/day; 0.009–0.014 oz/day) and survival (>80%) in all of the ponds.

Ohio State University (OSU) researchers concurrently used three types of production systems supplied by the same water source (lake water) to rear feed-trained yellow perch fingerlings to market size. The rearing systems used were 6, 2,044-L (540-gal) flow-through tanks, 6, 3,785-L (1,000-gal) flow-through raceway tanks, and 6, 3,028-L (800-gal) cages placed in ponds. Production stocking rates of 60 gm/L (0.5 lb/gal) for flow-through tanks were used to calculate the density of feed-trained fingerlings placed in each system. Two feeding strategies were also employed (percentage body weight and satiation feeding), with three replications in each system. Both growth performance data (feed conversion ratios, weight gain, and survival) and economic data (e.g., labor hours, purchase price of systems, construction costs, system operating costs, feed costs) were collected for all three systems and both feeding strategies.

Researchers at the University of Wisconsin-Milwaukee (UW-Milwaukee) have begun case studies using their in-house recycle aquaculture system and at two commercial facilities in Wisconsin using recycle aquaculture systems to provide comparative cost and production case histories for representative NCR recycle aquaculture operations rearing fingerling perch to marketable size. Each of these recycle aquaculture system configurations differs in significant ways that will provide information on the variety of these systems being operated by perch culturists in the NCR.

Case study 1 uses the UW-Milwaukee 25-m^3 (6,604-gal) recycle aquaculture system. The system components include a 15–18-m^3 (3,963–4,755 gal) oval rearing tank, a floating bead clarifier, and a fluidized bed biofilter (approximately 5 m^3 [1,321 gal]) powered by two 1.0 hp circulating pumps. From February 2002 through October 2002, the UW-Milwaukee recycle aquaculture system was used to grow out approximately 10,000 yellow perch fingerlings (128 kg; 282 lb) to market size. During this period, food, water, salt, and bicarbonate usage were recorded daily; the amount of settleable solids backwashed from the bead filter clarifier was determined; and rearing water quality records were kept for pH, total ammonia nitrogen, nitrite nitrogen, dissolved oxygen, chloride concentration, and conductivity of the rearing water. From daily maintenance records, hours of labor required for daily system operation and incidental maintenance will be estimated. Zeigler Brothers, Inc. will provide UW-Milwaukee with perch feed for the duration of this project. Monthly evaluations of perch growth performance and food conversion were made. Estimates of electrical usage for pumping, lighting, and aeration have been calculated. From UW-Milwaukee purchasing records the fixed costs of purchasing and installing this system have been documented.

After 231 days of operation, 618 kg (1,362 lb) of perch were harvested from the system. The growth and costs during the grow-out cycle of yellow perch from fingerling to marketable-size perch are being analyzed. The data will be compared to the performance and cost data collected from UW-Milwaukee cooperators.

UW-Milwaukee also produced about 10,000 perch fingerlings from their in-house brood stock for restocking the UW-Milwaukee recycle aquaculture system in the Fall of 2002. These fish will be grown to marketable size through the summer of 2003 to evaluate their growth, survival, and performance and to estimate production costs.

Case study 2 uses a privately owned and operated recycle aquaculture system. The system components include a 29-m^3 (7,661-gal) rectangular poly-lined rearing tank (with unistrut supported plywood side walls), a rotating-drum filter clarifier with a suction cleaner, and three trickling filter style biofiltration towers each with a recirculating pump operated by a 1½ hp 3-phase motor. This system has been used to rear yellow perch fingerlings to marketable size since 1995. The owners have been rearing 2001 year class perch fingerlings to marketable size with their recycle aquaculture system. They have agreed to grant access to their records for current and previous batches of perch grown in their system.

Case study 3 also uses a privately owned and operated recycle aquaculture system. The system components included 6.1-m-(20-ft-)diameter circular fiberglass rearing tanks (approximately 36 m^3 [9,510 gal]) equipped with a dual-drain system combined with a rotating drum filter clarifier; the biofiltration system consists of three 1.1-m^3 (291-gal) poly-lined tanks and a 6.4-m^3 (1,690-gal) poly-lined tank as a biofilter reserve. One of the 1.1-m^3 (291-gal) tanks with Koch rings serves as a biofilter and O_2 contact chamber, the other two 1.1-m^3 (291-gal) biofilter tanks contain Bee-Cell 2000 filter media. The 6.4-m^3 (1,690-gal) tank has bio-strata media and an airstone grid. The system is circulated with a ¼ hp pump. It has been operated this way for several years but the owners are in the process of completing the system by installing a second rearing tank that was planned for in the original sizing of the biofiltration system.

In December 2001, 17,080 fingerling yellow perch (5.0–11.5 cm [2.0–4.5 in] total length) were stocked for growth to marketable size; harvesting is scheduled for November 2002. The operator has supplied information on the fixed costs of setting up the system, fingerling costs, and partial information on their variable costs of operation.

A preliminary trial was conducted by Freshwater Farms of Ohio, Inc. from March to August in 2002. One tank in a WaterSmith System recirculating module was used to test its operational suitability for high-density perch culture. Unlike the previous demonstration research with hybrid walleye in these systems, the in-tank lighting system and the center post with the clock-sweep feeder were removed. A new fecal collection apparatus was fitted on the bottom of the 3,596-L (950-gal) conical-bottom tank. A mechanical belt feeder was installed on a board over the top of the tank, and overhead lighting controlled on a dimmer circuit was used.

To achieve the demonstration of high density, 10,000 fingerlings were put in one tank. At the time of stocking the fish were 276 to the kilogram (125 to the pound), and were approximately 7.6 cm (3.0 in) long. When they were weighed in August, the fish were 49 to the kilogram (22 to the pound) and averaged 10.8 cm (4.25 in). These perch were noticeably heavy for their length and robust. Mortalities were less than 5%. Aeration in the system was sufficient, and total ammonia was kept below 1.0 ppm. Unfortunately, technical difficulties with the heater used in this trial did not maintain the water at the targeted temperature of 21.1°C (70.0°F); was usually around 15.5–18.3°C (60.0–65.0°F).

OBJECTIVE 2
Research at Purdue University (Purdue) was designed to develop the optimal dietary essential amino acid (EAA) profile to grow out yellow perch. Six experimental diets were formulated that contained the EAA profile for fish, the predicted profile; the predicted amount plus 20%; the predicted amount plus 40%; the predicted amount plus 20% additional threonine, isoleucine, and tryptophan; or the predicted amount plus 40% additional threonine, isoleucine, and tryptophan. That study is currently in the eighth week of feeding and several of the diets are being consumed better than others. Fish were weighed at 7 weeks and those fed the diet containing 40% additional threonine, isoleucine, and tryptophan were significantly heavier than those fed the predicted EAA concentrations. Those three EAA are typically retained for a shorter period of time (more rapid turnover) and need to be provided in higher than predicted amounts. These data indicate that the EAA profile can be predicted for new aquaculture species and that EAA turnover in cells should be considered when formulating diets using this strategy. A commercial diet containing the predicted levels of EAA will be less expensive than a diet containing higher levels and will result in a reduction in ammonia excretion.

Studies conducted by UW-Madison researchers are designed to compare the growth, feed conversion, and fillet yields of perch raised in ponds using three feeding strategies: fish fed to satiation once daily at dusk, fish fed to satiation twice daily at dawn and dusk, and fish fed a set ration once daily at dusk (0.5 g [0.02 oz] food/fish/day—slightly less than satiation). In May 2002, three ponds were stocked with age 1 yellow perch fingerlings (19–23 g; 0.67–0.81 oz) at 37,200 fish/ha (15,055 fish/acre). Except for the different feeding regimes, these ponds were treated exactly like those described above in Objective 1. Throughout the growing season no obvious differences were observed related to feeding regime in fish production characteristics or water quality. The ponds will be harvested in October 2002. The data collected to date indicate excellent growth (0.25–0.40 g/day; 0.009–0.014 oz/day) and survival (>80%) in all of the ponds.

OBJECTIVE 3
Although emphasis was placed on Objective 1 during year one of the 3-year study, UW-Milwaukee outreach personnel have had discussions with industry producers regarding the content and format for a perch producers' workshop. Using contact and participant listings of perch producers from the last North Central Regional Aquaculture Center (NCRAC) Yellow Perch Producer Forum held at Hudson, Wisconsin in January 2000 and advisory service contacts, contact information on active yellow perch producers is currently being updating. This will identify the pool for inviting potential participants and presenters for convening a producers' workshop.

WORK PLANNED
OBJECTIVE 1
At UW-Madison, final data collection for the 2002 growing season will continue for

the ponds described above. A second and third series of grow-out trials will be conducted in 2003 and 2004, respectively. Accurate records for each pond are being kept on key economic inputs (including fingerling costs, feed costs, labor, and electricity) and outputs (including seasonal production per unit area and fillet yields). This information will be made available as actual production data for incorporation into an economic model developed previously that used theoretical inputs and outputs.

Researchers at OSU will hold the surviving perch in a pond over the winter, and these will be randomly mixed with a new group of similar age and size yellow perch, to repeat the stocking rates and feeding regimes for year two culture to market size (130 g [4.59 oz] fish) in raceways, round tanks, and cages. The water supply to the hatchery building for raceways and tanks will be passed through a large underground storage tank, to use ground temperatures to cool the water below 26.0°C (78.8°F).

UW-Milwaukee researchers will gather rearing costs and production information for each of the three recycle aquaculture systems identified above during the project period. With production performance and financial information obtained through consultation with recycle aquaculture system owner operators, and from the in-house UW-Milwaukee recycle aquaculture system, the production performance and associated costs for these three recycle aquaculture systems will be compared.

Freshwater Farms of Ohio, Inc. has delayed beginning another trial because of a shortage of fingerlings. A full experiment will begin again as soon as sufficient numbers of fingerlings can be procured.

OBJECTIVE 2

Researchers at Purdue will continue exploring the optimal EAA pattern for grow-out diets for yellow perch and begin testing those in larger scale production systems. In the next two years, production diets will be developed and tested in tanks and in experimental earthen ponds at Purdue.

Researchers at UW-Madison will continue their study on the effects of different feeding strategies on pond-reared yellow perch, in a manner similar to that described under Objective 1.

OBJECTIVE 3

Outreach personnel at UW-Milwaukee will host a yellow perch producers' workshop (Sub-objective A) in early 2003. The program content will be industry driven and topics will address information needs for pond, flow through, and recirculating perch production systems. A final decision on a site within the NCR that will facilitate access to the meeting by producers from several adjacent states within the region and that will possibly have access to a hands-on perch rearing or tour of an existing perch rearing facility will be chosen.

The development of fact sheets (Sub-objective B) describing the successes and failures of commercial perch aquaculture will occur subsequent to the initial producers' workshop. Industry needs will be accessed during the workshop. UW-Milwaukee outreach personnel will conduct a survey using the updated list of perch producers to gather the industry's perspective on perch aquaculture issues. The identification of a yellow perch information specialist(s) (Sub-objective C) will also follow the initial producers' workshop and survey of producer input.

Another producers' workshop will be held near the end of the project. The workshop content will be based on the findings of the first workshop and survey.

IMPACTS

OBJECTIVE 1

Flow-through tanks, raceways and cages have been proven reliable and cost-effective in the rearing of several economically valuable aquaculture species (catfish, trout, and salmon). Little information is currently available for aquaculturists on the performance of yellow perch in these systems, or if these systems could be a profitable alternative to recirculating or pond rearing systems. In the experiment conducted by OSU researchers, an unusually warm summer caused higher than normal water temperatures in the deep lake reservoir. These temperatures reached sub-lethal ranges for yellow perch, and subsequently led to high mortalities in all systems. The only apparent benefit of these results may be to serve as a caution for those individuals considering culture of yellow perch in these systems and similar water source temperatures. It is apparent that these systems, especially flow-through tanks, must be maintained at temperatures below 26.0°C (78.8°F) in order to ensure high survival and increased weight gain.

The proposed field trials described under Objective 1 by UW-Madison researchers are generating baseline information on production parameters (including, but not limited to, growth, survival, and feed conversion) that can be expected for commercially raising yellow perch to food size in ponds in the upper part of the NCR. The trials will also generate detailed information that can be used to develop economic models outlining the production costs of producing food-size yellow perch using this method.

Accumulatively, the studies conducted under this objective will generate information on the relative costs of raising market-size yellow perch using different types of systems. This information will be made available to outreach specialists, who can then make informed recommendations to current and prospective perch producers regarding the most profitable methods for producing yellow perch.

OBJECTIVE 2

Developing a diet that meets the unique nutritional needs for yellow perch will result in better quality diets, while maintaining or reducing costs. Further, based on work conducted in other NCRAC projects, minimizing EAA concentrations to just the amounts needed by the fish will reduce ammonia excretion.

OBJECTIVE 3

Extension programs will provide yellow perch producers and prospective aquaculturists with information based on case studies to make informed decisions.

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	
2001-02	$156,215	$165,327	$17,500			$182,827	$339,042
TOTAL	$156,215	$165,327	$17,500			$182,827	$339,042

HYBRID STRIPED BASS[5]

Progress Report for the Period
September 1, 2001 to August 31, 2002

NCRAC FUNDING LEVEL: $98,043 (September 1, 2001 to August 31, 2002)

PARTICIPANTS:

Paul B. Brown	Purdue University	Indiana
Christopher C. Kohler	Southern Illinois University-Carbondale	Illinois
William C. Nelson	North Dakota State University	North Dakota
Industry Advisory Council Liaison:		
Forrest Williams	Bay Port Aquaculture, Bay Port	Michigan
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborators:		
David LaBomascus	Genesis, Inc., Cedar Rapids	Iowa

PROJECT OBJECTIVES

(1) Marketing
   a. Investigate and document current and potential demand (prices and quantities) for hybrid striped bass (live and processed), clearly identifying consumer groups, processors, and distributors by location, seasonality of demand, size preferences, unique demand attributes, i.e., "healer fish" in Chinese culture, and impact of increased supplies on market prices of hybrid striped bass and competitive species.
   b. Estimate the processing and distribution costs (supply chain costs and margins) to derive expected "farm gate live weight" prices as a function of producer and consumer locations.
   c. Conduct limited taste testing on hybrid striped bass to determine the effect of different feed rations.
   d. Develop a Web page that would be a component of the NCRAC Web site that would provide analysis results to clientele quickly and to allow easy updates.
   e. Design and investigate willingness of hybrid striped bass producers to become a part of a current market information system.

(2) Compare phase III production parameters and feed costs of hybrid

[5]NCRAC has funded seven 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; and a termination report for the remaining objective of the fifth project as well as the objectives of the sixth project is contained in the 2000-01 Annual Progress Report. The first five projects were all chaired by Christopher C. Kohler and the sixth project was chaired by Joseph E. Morris. This progress report is for the seventh Hybrid Striped Bass project which is chaired by Christopher C. Kohler. It is a 3-year project that began September 1, 2001.

striped bass/sunshine bass (female white bass × male striped bass) in ponds and recirculating aquaculture systems using commercially available diets (32, 36, and 40% protein) in a minimum of two locations (three feed treatments/location), with 100 g ± 20 g (3.5 oz ± 0.7 oz) phase III fish (minimum of three replications/treatment), in ponds at least 0.4 ha (0.1 acre), with a stocking density of 7,413 fish/ha (3,000/acre), or in tanks at least 1,893 L/tank (500 gal/tank) with a 60 g/L (0.5 lb/gal) at harvest loading density. A need also exists to identify cost-effective, commercial available diets for phase III production.

ANTICIPATED BENEFITS

Success in the marketplace requires efficient production processes of products desired by consumers. Objective 1 of this project focuses on providing additional information to producers about the industry and market for their product. Better market information leads to better marketing decisions and increased revenue to the producer. The first three marketing objectives will provide a detailed picture of the current market conditions for hybrid striped bass while the last two objectives focus on providing a better system for future information flow and marketing decisions. The overall objective is to assist producers in improving their marketing decisions and thereby increasing revenue and profits.

This project was designed to take laboratory-derived data from other funding sources, and use it in the production of hybrid striped bass on a larger scale. Thus, developing data that will be directly useful to producers of hybrid striped bass, including new dietary formulations that could be manufactured in the North Central Region (NCR). Full production characteristics will be developed that should provide a complete picture of production using new diets under environmental conditions in the NCR. The dietary formulations used in these studies will also be available for producers to take to their feed mills.

The studies will be conducted in highly replicated, commercially-simulated experimental designs. Feeds are typically the largest component of annual variable costs in aquaculture operations and any modification can improve overall farm production characteristics. More importantly, there are new formulations that can be manufactured in the NCR, yet those formulations have not been tested in larger scale pond production systems. This project will result in data that should be immediately useful in the NCR. These studies will also clearly demonstrate the commercial feasibility and potential for raising hybrid striped bass in the NCR.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

In this first year of this 3-year project, little progress was made but no project funds were spent by North Dakota State University (NDSU) researchers. This was both a function of circumstances and strategy as the funds allocated for year 1 were not sufficient to employ the researchers who will be devoting nearly full time to the project in the remaining two years. In Sub-objective 1a, background research on domestic and international aquaculture markets was conducted to gain knowledge on the general structure of the aquaculture industry. This included identifying sources of information and documenting general trends in the industry. There was no activity on Sub-objectives 1b, 1c, or 1d. In Sub-objective 1e, the general format of the Web page, representing an operating information cooperative, was designed and most of the information to be included was identified.

OBJECTIVE 2

To produce phase III hybrid striped bass, researchers at Southern Illinois University-Carbondale (SIUC) obtained in June 2001, 10,000 phase II fish from Keo Fish Farm, Keo, Arkansas. Fish were stocked in floating vertical raceways (~8 m^3 [282 ft^3]) and reared at two densities (188 fish/m^3 [5.3 fish/ft^3] and 125 fish/m^3[3.5 fish/ft^3). Fish with a mean starting weight of 0.7 g (0.02 oz)were fed a 40% crude protein diet to satiation for 121 days, with fish in the low-density treatment reaching a final mean weight of 160.0 g (5.6 oz), which was significantly larger than the 136.9 g (4.8 oz) final mean weight in the high-density treatment. Survival in the low-density treatment (81.1%) was significantly higher than the survival in the high-density treatment (73.8%). No significant differences occurred between treatments in terms of dissolved oxygen, total ammonia, un-ionized ammonia, or temperature. Temperature remained destratified inside the raceways throughout the growing period, allowing for cooler temperature profiles during the warmer months. Water temperature outside the raceways remained stratified throughout the summer and early fall.

The ongoing phase III production study is utilizing twelve 0.04-ha (0.1-acre) ponds at the SIUC Touch of Nature Aquaculture Research facility. Three dietary protein levels were used: 32, 36 and 40%. Fish are being fed once daily in the evening to apparent satiation using practical diets formulated at SIUC and milled by Farm Land/Land-O-Lakes Industries. The feeding trial was initiated May 22, 2002 with fish averaging 215 g (7.6 oz) each at a density of 250 fish/pond. Production rates are expected to be at commercial levels for ponds and aeration is continuous. The feeding trial is expected to be complete in mid-November 2002 when the fish should average 0.9 kg (2.0 lb) each. Dependent variables of interest include production rates, growth, survival, feed conversion ratio, dress out, fillet composition, and production cost. Initial within-pond size variation will be compared to the final within-pond size variation as a function of diet.

To have additional phase II fish for 2003 production, 4-day posthatch hybrid striped bass were obtained from Keo Fish Farm in May 2002 and stocked at a rate of 375,000 fish/ha (151,760 fish/acre) in 15, 0.04-ha (0.1-acre) earthen ponds as described above, harvested in July 2002, and restocked at 25,000 fish/ha (10,117 fish/acre) for phase II production in the same 15 ponds. Fish are being fed a 40% crude protein diet twice daily to satiation. Fish will be harvested in mid-November for re-distribution in ponds, as well as for indoor culture using a recirculating aquaculture system, for phase III production in 2003.

Researchers at Purdue University (Purdue) developed three production diets for grow-out of hybrid striped bass. Those diets contained 32, 36, or 40% dietary crude protein, high levels of soybean meal, low levels of fish meal and the essential amino acid profile determined optimal in previous laboratory studies. All three feeds were manufactured by a commercial feed mill and the extruded diets shipped to Purdue for testing. Fish were acquired before the project actually began, and stocked into nine earthen culture ponds at the Purdue Aquaculture Research Laboratory. Triplicate groups of fish have been fed their respective diets this year and feeding will continue for a second year. Final harvest will occur in late September or early October of 2003. Final production data will be available at that time.

WORK PLANNED

OBJECTIVE 1

A research associate will work nearly full time on the project for the next two years at NDSU. There will be two major efforts and one supporting item of research.

In Sub-objectives 1a and 1b, the current industry will be the primary source of information. Additional review of literature (academic and mass media), survey of each of the entities in the supply chain by phone, e-mail and surface mail, and limited direct survey of major consumer groups will occur.

In Sub-objective 1c, as the other partners in this research have fish produced on different feed rations, NDSU researchers will conduct taste-testing to determine any differences from the consumer perspective. Sub-objectives 1d and 1e will require the design and construction of Web pages. It is planned that this component of the objective will be completed during the next year. The survey of producers to determine the feasibility of a Internet based market information cooperative will occur in the third year.

OBJECTIVE 2

Researchers at SIUC will harvest phase II and III fish in mid-November 2002, as described above. In 2003, additional pond studies will be designed based on the results from the 2002 production cycle. In addition, a phase III grow-out trial will be conducted in an indoor recirculating system.

Researchers at Purdue will continue their current feeding trial through next year and conduct additional laboratory studies that will help define formulation strategies for hybrid striped bass.

IMPACTS

While the principal impact will be upon producers' profits, it is impossible to estimate the degree of the impact of the information generated and effect of a market information cooperative at this time.

Compared to a previous NCRAC-funded study at SIUC in which hybrid striped bass were reared in ponds adjacent to the impoundment (90.2 g [3.2 oz] mean weight of best pond treatment), floating vertical raceways produced larger fish at both densities tested much larger in size. The floating raceway system offers considerable promise as an alternative rearing system for deep-water impoundments due to performance of fish, water quality, and ease of use.

Based on sampling of phase III fish, SIUC researchers anticipate demonstrating the feasibility of raising hybrid striped bass to a size well in excess of the minimum marketable-size of 680 g (1.5 lb). Moreover, SIUC researchers will be in a position to provide information that will facilitate decision making by phase III hybrid striped bass producers in the NCR with regard to the protein/nutrient density that optimizes production.

Developments in dietary formulations will result in new, modern diets that meet the unique nutritional requirements of this species, while reducing ammonia and carbon dioxide excretion. Further, these diets contain ingredients that are available in the NCR and that can be manufactured in the region.

PUBLICATIONS, MANUSCRIPTS, AND 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
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001-02	$98,043	$128,053				$128,053	$226,096
TOTAL	$98,043	$128,053				$128,053	$226,096

WALLEYE[6]

Project Termination Report for the Period
September 1, 1999 to June 30, 2002

NCRAC FUNDING LEVEL: $127,000 (September 1, 1999 to June 30, 2002)

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
Non-Funded Collaborators:		
Kevin Flowers	Flowers Aquaculture, Dexter	Missouri
Laura G. Tiu	Ohio State University	Ohio

REASON FOR TERMINATION

The project objectives were completed.

PROJECT OBJECTIVES

(1a) Carry out commercial-scale field trials for rearing hybrid walleye fingerlings to food size (25.4 cm; 10.0 in minimum) in tanks.

(1b) Carry out commercial-scale field trials for rearing hybrid walleye fingerlings to food size (25.4 cm; 10.0 in minimum) in ponds (at least three ponds at each site) at sites in the upper and lower portions of the North Central Region (NCR).

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

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1A

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. For these studies, the Spirit Lake (Iowa) strain of walleye and Mississippi River strain of sauger were used as brood fish because previous studies showed this particular cross to be faster growing than others. The water flow was set at 4.0–5.0 Lpm (1.1–1.3 gpm) and there were two surface spray points supplying an additional 0.75 Lpm (0.20 gpm) 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

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[6]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 termination report is for the seventh Walleye project, which was chaired by Konrad Dabrowski. It was a 3-year project that began September 1, 1999.

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 8.0 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 the study, OSU researchers were not able to produce sufficient numbers of 5.0–7.5 cm (2.0–3.0 in) feed-trained hybrid walleye juveniles for all of the tank and pond rearing experiments as originally proposed. Therefore, 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 Columbus 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 of 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%).

In tank 6 a bimodal distribution of fish sizes was observed: 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 Freshwater Farms of Ohio, Inc. (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 (2.0 in) 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 better adapt 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 from OSU 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 and 1/8 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 at 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 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

University of Wisconsin-Madison

Commercial-scale pond studies conducted by the University of Wisconsin-Madison (UW-Madison) at the Lake Mills State Fish Hatchery near Madison, Wisconsin represented a site in the upper, or northern, portion of the NCR. In 2000, hybrid walleye fingerlings (using the same parental stocks as those used by OSU; Spirit Lake, Iowa female walleyes and Mississippi River male saugers) were raised to the appropriate size needed (20–80 g; 0.7–2.8 oz) for subsequent pond grow-out studies. In May 2001, these fingerlings were stocked into four ponds, each at 898 fish/ha (2,220 fish/acre). The fish in two ponds were fed a floating diet, and the fish in the other two ponds were fed a sinking diet. All fish were fed once per day at dusk. The grow-out study lasted 156 days.

Fish growth rates were excellent over the course of the study, averaging 0.79 g/day (0.0279 oz/day) and 0.60 mm/day (0.0236 in/day). No growth differences were found between the two diets (0.80 versus 0.78 g/day [0.0282 versus 0.0275 oz/day] and 0.62 versus 0.57 mm/day [0.0244 versus 0.0224 in/day] for fish fed sinking and floating food, respectively). A strong feeding response was observed in all ponds during the late spring and early summer. An unusually warm summer, however, resulted in high pond temperatures (>28°C; 82.4°F) during July, and was likely responsible for a sharp decrease in feeding activity that was observed during this time. A strong feeding response was again observed when water temperatures declined (<25°C; 77.0°F) in August.

After harvest, the fish were identified for sex and processed as scaled skin-on fillets. Important production and carcass characteristics were as follows, for males and females, respectively: (1) total length—25.6 ± 0.6 versus 26.3 ± 0.5 cm (10.1 ± 0.2 versus 10.4 ± 0.2 in); (2) weight—160.0 ± 11.8 versus 170.0 ± 9.3 g (5.6 ± 0.4 versus 6.0 ± 0.3 oz); (3) fillet weight—74.9 ± 5.7 versus 78.2 ± 4.4 (2.6 ± 0.2 versus 2.8 ± 0.16 oz); (4) fillet yield (%)—46.7 ± 0.6 versus 45.9 ± 0.5; and (5) gonadosomatic index* (%)—1.1 ± 0.1 versus 0.5 ± 0.2 (* significantly different at $P > 0.05$).

As the above data shows, sexually-related dimorphic growth was not apparent in this study. This result was not surprising, since other studies in our laboratory have shown that female walleye do not begin to outgrow males until the fish reach approximately 230 g (8 oz) total weight and 30 cm (12 in) total length.

Fish survival in two of the ponds was very poor (<25%). This poor survival was due to severe predation by blue herons, which were frequently observed catching fish during feeding times. The Lake Mills State Fish Hatchery is located in the center of a small city and municipal regulations prohibit the use of firearms, noisemakers, or traps to control predation. Subsequent to this study, it was found that bird netting can be used to effectively eliminate the activity of the important predators at the Lake Mills ponds.

At the conclusion of these studies, groups of hybrid walleye fillets were sent to investigators at Michigan State University and North Dakota State University for sensory evaluations and marketing studies on hybrid walleye.

University of Missouri

The major goal of the University of Missouri's (UM) portion of the study was to develop information on growth and survival rates of hybrid walleye reared to 25.4–30.5 cm (10.0–12.0 in) in commercial production ponds in the lower, or southern, portion of the NCR. Findings were to be compared, ultimately, to those from a parallel pond study conducted near Madison, Wisconsin, to portray differences in survival and times to market size due mainly to differences in thermal regimes.

Bioenergetics Modeling

A walleye bioenergetics model was used at UM to gain insight into effects of the different thermal regimes in Madison, Wisconsin ponds and ponds located in southern Missouri on both consumption and growth rates of hybrid walleye. Modeling results indicated that juvenile hybrid walleye should grow substantially faster under the warmer thermal regimes in southern Missouri ponds and that fish appetites (cumulative consumption) will average 1.4× greater than in the Madison, Wisconsin ponds. However, the modeling also indicated that adult hybrid walleye would consume more food and grow faster in the northern location because of fewer days with pond temperatures in excess of 26°C (78.8°F). The model also predicts adult walleye to grow poorly and to ultimately lose weight at temperatures above 26°C (78.8°F). Overall, bioenergetics modeling suggested that ponds in the southern Midwest may be more favorable for growing hybrid walleye to low-end market size (25.4–30.5 cm; 10.0–12.0 in) but that thermal conditions are more favorable in the north for rearing hybrid walleye to larger sizes. This relates to the tendency among fish to grow best in early life stages at temperatures higher than those that are most favorable for adult fish growth.

Commercial Pond Study

Hybrid walleye (3.8 cm [1.5 in] mean length) received from OSU on May 5, 2000 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 ponds due to the low survival rates. 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. Consequently, 9,000 pure walleye were secured from the Spirit Lake State Fish Hatchery in Iowa, with the assistance of Mr. Alan Moore (Iowa Department of Natural Resources), Ms. Donna Mumm (the hatchery manager), and others. 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 high (mortality <10%) and fish were released into three ponds (*N* = 3,000 fish/pond) on July 29, 2000. Fish were sampled from the ponds by seining on three different dates over a 14 month period, with final harvest on October 3, 2001 when the ponds were drained. Fish had been 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. Because walleye survival through February 2001 was low in two ponds, the pond owner combined fish from these two ponds into the third pond (in which walleye survival had been substantially better) in February 2001. Consequently, averaged growth results from all three ponds is reported.

Walleye mean lengths and weights across all ponds reached 23.6 cm (9.3 in) and 118 g (4.2 oz) in 14 months, just under the minimum food-market size of 25.4 cm (10.0 in). Examination of final length showed that the fish size range was quite broad. However, the upper 50th percentile of fish had surpassed the low-end market size of 25.4 cm (10.0 in), and upper-quartile fish reached sizes ranging from 28–43 cm (11.0–16.9 in), beyond the lower market limit. Hence, a potential was indicated for a substantial portion of walleye stocked at approximately 7.6 cm (3.0 in) to reach low-end food-market size in a little more than one year in southern Missouri ponds. Comparative data for 14-month growth of pure walleye in northern ponds were not available. However, rough projections of the time required to rear fingerling walleye to 40.6 cm (16.0 in) based on extrapolation of the data from southern Missouri ponds indicated it would take 23.9 months, whereas a study of northern Midwest ponds indicated it would take roughly 27.3 months to reach 40.6 cm (16.0 in). Taken in combination, southern Missouri pond results and bioenergetics modeling provide some evidence that walleye or hybrid walleye can be grown to low-end food market sizes (25.4–30.5 cm [10.0–12.0 in], petite walleye) more rapidly in the southern portion of the Midwest than in more northerly portions.

Cannibalism was considered the primary cause of mortality of walleye in the southern Missouri ponds. Total mortality across all ponds appeared persistent throughout the 14-month study period. Periodic, absolute mortality rates were estimated as: July-October 2000 (69%), October 2000–February 2001 (50%), and February–October 2001 (69%), with an overall mortality rate of 95%. It is believed that four factors led to the high mortality rates in the southern Missouri ponds: (1) that it was necessary to stock walleye rather than hybrid walleye, the latter being known to show lower rates of cannibalism, (2) that the warmer southern Missouri water temperatures, though apparently favorable for juvenile growth, likely also elevated walleye appetites (by 1.4×), and increased the potential for cannibalism, (3) that a once-daily feeding frequency with sinking feed, applied throughout most of the study may not have sufficiently satiated the walleye, and (4) that combining of fish whose mean lengths and length ranges differed by more than 2.54 cm (1.0 in) and 12.7 cm (5.0 in), respectively, likely promoted cannibalism. Parallel comparisons of mortality rates in two of the study ponds, one with substantially more walleye size disparity than the other (total ranges of walleye length being 17.8 cm [7.0 in] versus only 5.3 cm [2.1 in] in the other), showed rather modest differences in mortality rates (60% versus 40%, respectively) during the period October 16–February 23. These results suggest that while grading for increased size uniformity may hold some benefits in terms of improving survival, substantial mortality still occurred in the pond with relatively uniform fish sizes. Efforts beyond promoting size uniformity will be necessary to achieve high survival.

Finally, an analysis of profit margins with respect to rearing walleye or hybrid walleye to a range of food-market sizes (25.4 cm [10.0 in], 35.6 cm [14.0 in], and 40.6 cm [16.0 in]) with fish survival rates ranging from 25–100% was performed. Cost factors included fingerling walleye ($0.50/fish) and feed; selling price was considered $4.87/kg ($2.21/lb) live weight; the analysis was based on starting with 9,000 fingerlings. The most striking results of this rough analysis was that profit margins appeared extremely narrow for 25.4-cm (10.0-in) fish relative to those for rearing 35.6-cm (14.0-in) and 40.6-cm (16.0-in) fish. At 100% survival, profits for rearing those three size fish were indicated as $467, $8,745, and $16,195, respectively. Results suggest that for rearing 25.4-cm (10.0-in) fish, if markets for fish of this size truly exist, a very high volume would be needed in combination with high survival rates for reasonable profits to be made. Given the increase in profit margin potential indicated for rearing fish to larger sizes, it appears that targeting for 30.5-cm (12.0-in) fish for the petite walleye market may be most reasonable.

In summary, this study provided evidence that there may be benefits to rearing hybrid walleye in ponds in the southern Midwest ponds for petite walleye food markets due to a more rapid growth potential associated with warmer thermal regimes. However, higher appetites associated with warmer temperatures may also promote cannibalism. Future work should focus on rearing hybrid walleye rather than pure walleye in southern Midwest ponds. The use of removable physical structures for the purpose of predation interference could be considered if additional means for reducing cannibalism are warranted. Rearing walleye to 30.5 cm (12.0 in) versus 25.4 cm (10.0 in) for petite walleye markets appears more reasonable due to much increased profit margins for the former.

Kinnunen of Michigan State University (MSU) organized the first Hybrid Walleye Culture Workshop in February 2002 in conjunction with the Michigan Aquaculture Association Annual Meeting in Cadillac, Michigan. Researchers from OSU, UW-Madison, and UM involved with this project made presentations on the growth and sex control of hybrid walleye; status report on hybrid walleye rearing, polyploidy, and sex determination; growth rates of walleye in southern Missouri ponds; marketability of hybrid walleye; and preliminary results of industry and consumer surveys. After the presentations the researchers participated in a hybrid walleye panel discussion and answered questions from aquaculture producers. At this workshop, participants had the opportunity to taste test hybrid walleye fillets and they rated the final product as highly acceptable. The workshop ended with a focused discussion on producer perspectives on the feasibility and opportunities for producing and marketing hybrid walleye.

Kinnunen, working with Bob Pierce of UM, has organized a second Hybrid Walleye Culture Workshop that will be held in Cape Girardeau, Missouri on March 5, 2003. The second workshop will be conducted similarly to the first.

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.

Results of the UW-Madison study demonstrate that hybrid walleye can be grown in ponds in the upper part of the NCR to a marketable size by the end of the second growing season. The UW-Madison researchers documented expected production parameters and key information on the economic inputs and outputs for this species and system type. The results of these studies have provided important information regarding grow out of hybrid walleye to market size in ponds.

Those who took part in the Michigan workshop all rated hybrid walleye as an extremely high quality product.

RECOMMENDED FOLLOW-UP ACTIVITIES

In a study performed outside of this project, researchers at OSU demonstrated that triploid saugeye produced by pressure shocking has potentially better growth than diploids. This research should be continued with respect to intensive rearing systems.

Economists should use the information generated by these studies to develop economic models for defining the production costs of hybrid walleye raised using the various system types evaluated in this project. Key bottlenecks that limit the profitability of raising hybrid walleye to food size should be identified, and subsequent research should be directed at removing these constraints.

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
2001-02	$5,900	$25,475				$25,475	$31,375
TOTAL	$127,000	$142,282	$2,250			$144,532	$271,532

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

SUNFISH[7]

Project Component Termination Report for the Period
September 1, 1999 to August 31, 2002

NCRAC FUNDING LEVEL: $168,000 (September 1, 1999 to August 31, 2002)

PARTICIPANTS:

Ira R. Adelman	University of Minnesota	Minnesota
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 A. 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 Collaborator:		
Myron Kloubec	Kloubec Fish Farms, Amana	Iowa

REASON FOR TERMINATION
Work on the objective was completed.

PROJECT OBJECTIVE
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 (0.1 acre) and indoor recycle systems in the upper and lower portions of the North Central Region (NCR). 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.

PRINCIPAL ACCOMPLISHMENTS
POND STUDIES
Pond studies were conducted by researchers at Southern Illinois University-Carbondale (SIUC) and Morris of Iowa State University (ISU) representing the lower and upper portions of the NCR, respectively.

Bluegill showed poor growth in both sets of ponds used by SIUC and ISU researchers through the end of the second growing season. This was attributed, at least in part, to increased competition for resources in the ponds as the number of young fish increased with each reproductive cycle during the growing season. During the second year, young-of-the-year (YOY) bluegill became abundant in the ponds stocked with bluegill,

[7]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 project component termination report is for the first of two objectives of the fifth Sunfish project which was chaired by Robert S. Hayward. It was originally a 2-year project that began September 1, 1999 but was lengthened for no additional cost. A progress report for the second objective of the fifth Sunfish project is contained elsewhere in this annual report.

whereas the ponds stocked with hybrid sunfish had few or no YOY. Bluegill growth may be improved under a strategy where YOY fish are removed. The production of edible-size bluegill using a 3-year production cycle did not prove to be promising in ponds used by SIUC researchers even though those same researchers had shown hybrid sunfish reaching an edible-size (>227 g; 0.5 lb) during the third year of a 3-year production cycle in previous studies.

Conversely, hybrid sunfish showed better promise even though they didn't reach edible market size (227 g; 0.5 lb) by the third year of a 3-year production cycle. During the first two years of production, the hybrid sunfish grew about 76 g (0.17 lb) per year. However, their growth rates were unexpectedly lower during the third year and didn't reach the 227 g (0.5 lb) market size. The slower growth during the third year of production was attributed to increased competition due to YOY and 1-year old fish that were found at the time of final harvest. It was suspected that this problem had not been a factor for the hybrid sunfish during the first two years of production because they grew sufficiently during that period. Results from the ISU study indicate hybrid sunfish will have a skewed population towards males that consume relatively greater amounts of prepared and natural feeds compared to bluegill; acceptance of prepared feeds is critical in intensive-pond production where natural feed organisms are rapidly depleted. Stocking the top 70% (in regard to size) of both bluegill and hybrid sunfish does not appear to produce marketable sizes within a 2-year production cycle. It also appears from these studies that production of edible-size bluegill or hybrid sunfish using a 3-year production cycle is not too promising unless YOY fish are systematically removed.

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 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 evaluated growth of black crappie in ponds, cages, and raceways.
In May 2001, 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.

The 80% training success by SIUC is similar to the best results obtained by others in previous studies. Furthermore, krill is a much more convenient first feed to use as compared to other types of feed (i.e., carp eggs) that have achieved similar success. Additional data from ISU also supported this feed training technique, however, improved fish growth was not evident until 30 days after the initiation of the study.

Another study was initiated by SIUC researchers to assess growth of this species on prepared diets in a pond setting. A growth comparison was made of black crappie held in 1,425-L (376-gal) cylindrical cages with those held in those same size cages for only 30 days before being released into a 0.04-ha (0.1-acre) pond. Growth and survival were similar for both culture methods. Surprisingly, crappie released into the pond remained on feed but did not grow well. In the absence of a natural food source, it is possible to keep black crappie on prepared diets. However, the prospect of growing black crappie to market size during one growing season does not appear to be promising at this time.

SIUC researchers also compared growth of black crappie on two different diets (Silvercup™ trout feed and Fishbelt™ catfish pellets) in indoor recycle systems. Growth was low for all fish in this study and no difference was found between the black crappie fed different diets. There was a clear delineation between fish that remained on feed and those that became emaciated and starved during this study. Low growth in this study was attributed to competition for food and space.

INDOOR RECYCLE SYSTEMS
ISU investigators found that it is difficult to raise either bluegill or the hybrids to a market size (227 g; 0.5 lb) within 30 months in an indoor recycle system (six, 1,135-L [300-gal], circular fiberglass culture tanks). 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 a limiting factor. However, bluegill did appear to grow better and perhaps reach marketable size in the significantly larger (18,925 L [5,000 gal]) indoor recycle system located at North Dakota State University (NDSU).

Findings from this project also demonstrated that hybrid sunfish growth rates were inversely related to tank density during the second year of production. 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 the hybrids might be a higher resistance to disease.

The trial at UM 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 by UM researchers. 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; remaining monies from this portion of the project were then made available to other project participants to pursue additional related sunfish studies.

The work at UM, based on rough projections of growth rates, indicates that male bluegill possess the inherent capacity to grow to marketable food size within two years while female bluegills and both sexes of the hybrid sunfish fall substantially short of this time-frame even under the best of growing conditions. These data provide evidence that efforts to rear *Lepomis* species to marketable food size within an established 2-year grow-out time-frame should focus on male bluegills.

Conclusions for these studies are: (1) male bluegill have the capacity to substantially outgrow female bluegills as well as both sexes of the hybrids; (2) there is a tendency for hybrid sunfish to grow better in ponds due to, in part, the bluegill's tendency for substantial in-pond reproduction as well as a higher social cost and their better ability to utilize natural feeds; (3) bluegill appear to grow better than hybrid sunfish in larger indoor recycle systems (UM and NDSU studies); and (4) merit continues to exist concerning the use of black crappie as a food fish in the NCR.

IMPACTS

- Bluegills showed better growth in UM and NDSU indoor tank studies and male bluegills were noted for having greater growth capacity than females or either sex of the hybrid sunfish in UM studies.
- It does not appear possible to successfully rear edible market-size, >227 g (0.5 lb) bluegill or hybrid sunfish, in a 3-year production cycle. However, information garnered from UM researchers indicates that the use of male bluegills in these same systems holds a good potential to achieve a market-size fish in the same time period.
- It was determined that grading sunfish of either taxa at either pond site or over a repeated number of times in indoor systems did not significantly increase the number of food-size sunfish of either taxa in ISU studies.

RECOMMENDED FOLLOW-UP ACTIVITIES

- Future studies should focus on the production of male bluegill, which then could be used to produce edible market-size sunfish in either ponds or indoor systems in a more efficient manner.
- Given the inherent ability of bluegill to reproduce in ponds, the use of a predator, e.g., largemouth bass, to control excess bluegill production should be investigated as a practical method of excessive sunfish reproduction.
- Given the initial success of feed training black crappie using the methodology described above, additional research is needed to raise these feed-trained fish under commercial-scale aquacultural operations. For instance, what are the nutritional requirements of these fish?
- Although black crappie still have potential for aquaculture, further research efforts should focus on stocking densities and feed rations.

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	
1999-02	$168,000	$189,862				$189,862	$357,862
TOTAL	$168,000	$189,862				$189,862	$357,862

SUNFISH[8]

Progress Report for the Period
September 1, 1999 to August 31, 2002

NCRAC FUNDING LEVEL: $32,000 (September 1, 1999 to August 31, 2002)

PARTICIPANTS:

Robert S. Hayward	University of Missouri-Columbia	Missouri
Industry Advisory Council Liaison:		
Curtis Harrison	Harrison Fish Farm, Hurdland	Missouri
Extension Liaison:		
Joseph E. Morris	Iowa State University	Iowa
Non-Funded Collaborator:		
Curtis Harrison	Harrison Fish Farm, Hurdland	Missouri

PROJECT OBJECTIVE

Evaluate grading strategies to enhance grow out of F_1 hybrid sunfish (female green sunfish × male bluegill) in commercial systems to market size (≥227 g; 0.5 lb), including the culture potential of discards.

ANTICIPATED BENEFITS

This study will indicate whether stocking the larger half (upper 50th percentile) of spring-available age-1 hybrid sunfish in ponds will result in higher growth rates and reduced grow-out times to food-market weights, versus when full size ranges of available fish are stocked. The study will also provide much needed information on the potential to rear hybrid sunfish to food-market weights within two years in mid-latitude ponds.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

This study represents a field test of findings from a previous, North Central Regional Aquaculture Center (NCRAC)-funded laboratory study wherein age-1 hybrid sunfish ranging in lengths from 8.2–10.2 cm (3.2–4.0 in) were held individually and reared with unrestricted feeding at 24°C (75.2°F) for 112 days. Laboratory results showed that age-1 fish that were initially larger consumed more food, grew faster, and had better feed conversion than counterparts that were initially smaller. The indication that poorer performing hybrid sunfish reveal themselves early on (by being smaller than same-age counterparts) suggested that stocking fish in the upper end of available size ranges may lead to faster growth and shorter grow-out times to food-market sizes. Also, by stocking upper-end, presumably better performing fish, size variation among individuals at harvest might be less (because of less disparate growth rates) than when full size ranges of available fish are stocked.

In April 2000, age-1 hybrid sunfish were collected from a single production pond at

[8]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; and a termination report for one of the two objectives of the fifth project is contained elsewhere in this annual report. This progress report is for the second objective of the fifth Sunfish project which is chaired by Robert S. Hayward. It was originally a 2-year project that began September 1, 1999 but has been lengthened for no additional cost.

Flower's Aquaculture in Dexter, Missouri and graded into two size groups: smaller half (mean length = 4.1 cm [1.6 in], length range = 3.3–5.3 cm [1.3–2.1 in]; mean weight = 1.03 g [0.04 oz] wet weight), and larger half (mean length = 6.3 cm [2.5 in], length range = 5.4–7.7 cm [1.2–3.0 in]; mean weight = 3.94 g [0.14 oz] wet weight). The fish were transported to Harrison's Fish Farm in Hurdland, Missouri on April 17, 2000 and stocked into 7, 0.20-ha (0.5-acre) ponds. Three ponds (designated "L") received only larger-half fish (3,231 fish/pond), three ponds (designated "S-L") received 3,000 smaller-half plus 3,000 larger-half fish, and one pond (designated "S") received 14,000 smaller-half fish. Stocking densities (dry biomass/ha) were matched in the ponds receiving large only and large plus small fish; stocking density was lower in the pond receiving only small fish.

Fish were fed twice daily with a floating commercial diet. Partial seining of each pond was done six times from 1 month post-stocking through early October 2001 (approximately every 3 months) to monitor hybrid sunfish weights and lengths; samples of 30–50 fish from each pond were measured and weighed on each outing. In January 2001, a broken drain pipe caused the loss of all fish in one of the three "L" ponds. In June 2001 it was decided that fish biomass in all ponds had become too high to allow desired growth rates. Therefore, to improve growth conditions, an attempt was made to remove all hybrid sunfish from each pond by multiple seine hauls. Only the larger 33% (by length) were re-stocked; the harvested smaller fish were sold by the producer.

The pond experiment was ended in June 2002, 26 months after the hybrid sunfish were stocked. All fish from the six ponds were removed by multiple full-pond seine hauls. Lengths and weights of 50 randomly selected fish were determined from each pond. Total counts were made of fish removed from each pond and total biomass was directly determined by weighing groups of fish as they were removed from a pond.

Previously reported results based on seining at 3-month intervals showed that absolute growth rates of hybrid sunfish increased significantly across the three treatment groups ("S," "S-L," and "L") in accordance with increasing initial fish sizes at stocking. Mean weights of hybrid sunfish after 26 months of pond rearing were 109 and 113 g (3.84 and 3.99 oz) in the two "L" ponds; 64, 65, and 97 g (2.26, 2.29, and 3.42 oz) in the three "S-L" ponds; and 32 g (1.13 oz) in the single "S" pond. There were significant differences in mean weights of hybrid sunfish among the six ponds. Fish in the "L" ponds were larger on average than in the "S-L" ponds, and that hybrid sunfish in the "S" pond were smaller than fish in the other two treatments. Hybrid sunfish in the upper quartiles of weight in the two "L" ponds reached 65% of 0.23 kg (0.5 lb) (considered the lower limit of food-market weight) on average in 26 months of pond growth, while those in the "S-L" and "S "ponds reached only 53 and 24%, respectively. Fish densities ranged two-fold across the ponds, but observed patterns of final mean weights of hybrid sunfish were not due to fish density effects. There was also support for the prediction, based on results the previous laboratory, that stocking larger hybrid sunfish would lead to less size variation among fish in a pond. Size variation of hybrid sunfish declined across ponds as final mean weight increased ($P <$ 0.05).

Overall, the 26-month pond study provided further evidence that stocking larger-end, age-1 hybrid sunfish will lead to higher growth rates with less development of size variation. It is expected that there would be similar benefits from using upper-end hybrid sunfish when rearing these fish in indoor recirculating tanks as well. It is emphasized that larger fish were likely produced in the ponds that were stocked by upper-end hybrid sunfish not simply because the fish were larger to begin with, but because they grew faster than counterparts that were initially smaller. These findings also provide much needed information on time periods required to rear hybrid sunfish to food-market sizes in ponds. Even when stocking larger-end, age-1 hybrid sunfish, upper quartile fish reached only 65% of the minimum food-market weight of 0.23 kg (0.5 lb). This finding suggests that for middle-latitude ponds, at least three years of rearing is likely needed to get significant numbers of hybrid sunfish to food-market sizes.

Laboratory studies comparing bluegill and hybrid sunfish growth rates were conducted at the University of Missouri-Columbia (UMC) during the past two years supported, in part, by NCRAC funding. Though not described in the original Sunfish project outline, results are briefly described here because they relate to and hold potentially important implications for the broad objective of developing approaches to rear Lepomid sunfish to food-market sizes within two grow-out years.

Two laboratory experiments compared inherent growth capacities of bluegill and hybrid sunfish reared under identical conditions. All bluegills and hybrid sunfish used in the two experiments were purchased from a major Missouri fish producer in April 2000.

During the first 50 days of Experiment 1, hybrid sunfish initially outgrew and then grew at a similar rate as bluegills. Subsequently, in July, hybrid growth rates declined markedly to levels well below those of bluegills such that the growth-in-weight trajectory of bluegills crossed above that of the hybrids by the end of Experiment 1 in August. Experiment 2 was run to determine if the modest growth advantage that bluegills had developed over the hybrids by August 2000 would continue. Experiment 2 showed dramatic weight gains by bluegills in excess of the hybrids with final mean weights of approximately 100 and 50 g (3.53 and 1.76 oz) for bluegills and hybrids, respectively, by March 2001.

Subsequent analysis of the same data set with attention given to growth rates of bluegills and hybrids according to sex, revealed that male bluegills substantially outgrew male hybrids as well as female bluegills and hybrids in both experiments. Male bluegills accounted for much of the higher growth of bluegills versus hybrid sunfish that was observed in the initial analysis of the data. However, even female bluegills outgrew male hybrid sunfish. Most importantly, during the 11-month span from April 2000 (when the age-1 fish were first secured) to March 2001, male bluegills grew from 7 g (0.25 oz) to 163 g (5.75 oz) which is 71% of the lower-end food-market weight or 227 g (0.5 lb). No other group surpassed 34% of 227 g (0.5 lb) during this period. Rough projections of growth rates indicate that male bluegills 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.

WORK PLANNED

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.

IMPACTS

- The work at UMC, based on rough projections of growth rates, indicate that male bluegills 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 pond study also indicates whether size grading of hybrid sunfish will effectively reduce 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 that much reduced growth times to food-market weights would be possible by rearing male bluegills and this finding may substantially improve the economic feasibility of rearing sunfish for food markets.

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	
1999-02	$32,000	$10,765				$10,765	$42,765
TOTAL	$32,000	$10,765				$10,765	$42,765

WASTES/EFFLUENTS[9]

Progress Report for the Period
September 1, 2001 to August 31, 2002

NCRAC FUNDING LEVEL: $80,766 (September 1, 2001 to August 31, 2002)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Douglas J. Reinemann	University of Wisconsin-Madison	Wisconsin
Robert C. Summerfelt	Iowa State University	Iowa
Steven E. Yeo	University of Wisconsin-Milwaukee	Wisconsin
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan
Extension Liaison:		
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Non-Funded Collaborators:		
Michael Becker	Odbek Industries, Inc., St. Paul	Minnesota
Von Byrd	USDA Forest Products Laboratory, Madison	Wisconsin
Chuck Ehlers	Ehlers Enterprises, Manning	Iowa
Jae Park	University of Wisconsin-Madison	Wisconsin
Mark Raabe	REM Engineering, LLC, Evansville	Wisconsin
Todd Rogers	Odbek Industries, Inc., St. Paul	Minnesota
Roger Rowell	USDA Forest Products Laboratory, Madison	Wisconsin

PROJECT OBJECTIVES

(1) Document the fate of aquaculture waste components (phosphorus, nitrogen, solids) relative to feed input into traditional and newly designed aquaculture systems.

(2) Evaluate the technical and economic feasibility of rapid solids removal/recovery appropriate for new aquaculture facility designs.

(3) Demonstrate economically sound processing methods for beneficial use of aquaculture waste.

(4) Provide workshops and fact sheets that address best management practices (BMPs) for waste control.

ANTICIPATED BENEFITS

OBJECTIVE 1

Researchers at Iowa State University (ISU) are monitoring aquaculture waste

[9]NCRAC has funded three Wastes/Effluents projects. The termination report for the first project is contained in the 1989-1996 Compendium Report; a termination report for one of the two objectives of the second project is contained in the 1998-99 Annual Progress Report, and a termination report for other objective of the second project, which was chaired by Fred P. Binkowski, is contained in the 1999-00 Annual Progress Report. This progress report is for the third Wastes/Effluents project which is chaired by Robert C. Summerfelt. It is a 3-year project that began September 1, 2001.

components (phosphorus, nitrogen, and solids) relative to feed input in a commercial recycle aquaculture facility whose effluent discharges to a septic tank. The research findings will demonstrate mass balance between nutrient input in feed with concentrations of nutrients and solids discharging to the septic tank, and the septic tank effluent and the composition of slurry pumped from the septic tank. Results of the present study will characterize a unique fish hatchery wastewater and solids disposal system that is operated to prevent discharge of nutrients to surface waters. The findings may also be used to support the development of best management practices (BMPs) to meet the proposed U.S. Environmental Protection Agency (USEPA) guidelines and standards for aquaculture effluents.

OBJECTIVE 2

Cost-effective methods are needed for rapid removal of waste feed and fish feces from culture tank effluents of a recycle aquaculture system to maintain water quality for the fish, to prevent leaching of nutrients from the solids, and the breakdown of solids to particle sizes smaller than can be efficiently removed by practical microscreen filtration. Excessive suspended solids can mechanically clog a biofilter and high concentrations of dissolved solids encourages overgrowth of the biofilter with heterotrophic microorganisms that displace the nitrifying bacteria needed for conversion of ammonia to nitrates. Also, organic solids from waste feed and feces have a large biochemical oxygen demand (BOD) and they are major sources of nitrogen and phosphorus pollutants. Control of suspended solids in the culture system is also important to maintain an environment favorable to sustaining healthy fish stock. Both ISU and University of Wisconsin-Madison (UW-Madison) scientists are conducting research on this topic which should benefit those employing recycle aquaculture systems.

UW-Madison researchers are also evaluating use of natural wood fibers as a filter material. After minimal processing, the surface area of many fibers is very large per unit area. They are inexpensive, renewable, and biodegradable. The cost of the raw material is very inexpensive because the technology is ideally suited to the use of waste and by-product materials. The use of filtration systems using natural fiber filters may reduce the amount and concentration of organic solids that are discharged into the environment from aquaculture raceways and ponds. The retention of solids by these filters will significantly reduce the amount of nutrients entering the receiving stream, resulting in improved water quality downstream from existing fish culture facilities.

This technology can be integrated into the design of new raceways and ponds. However, it also provides an affordable option to aquaculturists who must reduce the discharge of solids and nutrients from existing raceways and ponds. Disposable natural fiber filters can be made inexpensively from a variety of wood and plant fibers. Thus, the application of natural fiber filters to aquaculture will provide economic opportunities to the agriculture industry to market low value fiber or waste fiber. One additional benefit to this technology is that spent fibers can be composted and used as a soil amendment for agriculture.

OBJECTIVE 3

University of Wisconsin-Milwaukee (UW-Milwaukee) researchers are evaluating vermiculture and vermicomposting as a beneficial use of biosolids from aquaculture waste. For small-scale recycle aquaculture system operations, typical of some of the systems currently operated in the North Central Region (NCR), integrating these methods with fish production offers an appropriately scaled and on-site means of converting solid waste to salable baitworms and worm castings that could be niche marketed to fishermen or organic gardeners. Future expansion of regional aquaculture requires lowered water usage and reduction of potentially harmful waste discharge. Vermicomposting has the potential to increase both the cost effectiveness of a recycle aquaculture system operation by converting the recovered solids that these systems produce into beneficial reusable and salable by-products. Used along with aquaponic plant production to recover dissolved nutrients, more fully integrated, sustainable, and cost-effective rearing systems may be developed that will overcome current constraints and allow further industry development.

Worm and worm compost production would not involve the high energy inputs for pumping or lighting that are necessary for integrating aquaponics with recycle aquaculture system operation. Depending on further examination of costs and the marketability of worms and worm-produced by-products, these techniques could provide favorable alternatives to disposal by diversion of aquaculture solids to public sewage treatment facilities that lessens the quality of the sludge through mixture with a variety of municipal and industrial waste. Worm composting provides a superior form of stabilized compost that is more suitable and valuable for potted plant or smaller scale gardening users than liquid septic storage sludge that is now typically spread thinly in outdoor field application situations. Diversion of biosolids to worm composting would lighten the load to on-site septic facilities, reducing the size of septic storage facilities needed, and perhaps increasing the maintenance intervals. Stabilized worm compost can be readily stored compared to liquid sludge and when diverted to gardening and indoor planting uses could assist in avoiding the seasonal climatic limitations on land application.

OBJECTIVE 4

The USEPA is considering effluent limitations guidelines and standards for aquaculture operations that grow, contain, or produce aquatic organisms at amounts above 45,360 kg (100,000 lb) for three subcategories: flow-through, recirculating (recycle), and net pen systems. The proposed guidelines and standards include technology-based regulatory options. Thus, producers, regulators, and researchers need science-based information on strategies for rapid solids removal, disposal, and use of biosolids and nutrients from aquaculture effluents. These strategies must be based on understanding nutrient mass balance of nutrient inputs and outputs relative to feed characteristics and feeding strategies. To help in this endeavor, a detailed literature search of computerized databases will be summarized. Findings of the current and other studies can provide guidance for development of BMPs. Information will be distributed as hard copy in fact sheets and technical bulletins, made available electronically via the North Central Regional Aquaculture Center's (NCRAC's) Web site, and presented at conferences and workshops.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

ISU researchers commenced activity to describe nutrient (nitrogen and phosphorus) inputs in water and feed, and nutrient and solids outputs in the effluent of a state-of-the-art, commercial recycle aquaculture facility in west-central Iowa (Ehler Enterprises) raising both rainbow trout and walleye. The information is to be used to document the fate of aquaculture waste components (phosphorus, nitrogen, solids) relative to feed input. The facility has unique recycle and effluent treatment systems that may serve as a model for a BMP strategy for waste management for an intensive, closed-system commercial aquaculture facility.

During the first year, ISU staff examined and evaluated the operation of the fluidized bed sand filter, the ozonation system, and gathered information on fish stock (stocking, mortality, sales), feed type, feeding schedule, and feeding rates. It was also necessary to determine total water volume and volume of each of the system components (biofilter, head tank, sump, triple standpipes, sidewall drains, and plumbing). Culture tanks were 78.5% of total system volume of 196,100 L (51,810 gal), and the other components made up the balance (21.5%). Thus, the total volume of a recycle aquaculture system such as this can be estimated at about 1.3× the volume of the culture tanks.

Because the recycle system lacks flow meters, it was necessary to characterize rates of inflow of freshwater, flow rate between the system components, and the multiple sources of effluent. Beginning at the sump, two 7.5 hp electric motor driven centrifugal pumps moved water to the biofilter; the maximum flow rate at any point in the culture system was 4,084 Lpm (1,079 gpm). Inflow is controlled by a water level actuated float valve located in the sump. Inflow of freshwater to the culture system was 7.5 Lpm (2.0 gpm), which is 4.3% of total system volume (volume of culture tanks and volume of all other system components) each day, which is much less than most recycle systems. The inflow to the culture tanks provided an equivalent of 1.25 exchanges per hour.

The dual-drain tank design had two discharges; 77% from the sidewall drain and 23% from the center drain. The center drain carried most of the suspended solids from the culture tank to the triple standpipe from which most of the flow went to the drum filter and a small flow of heavy solids was diverted to the septic tank by manually pulling the standpipe once per day.

Daily inflow was only that needed to replace water loss. The major sources of water loss were from the drum filter backwash (40.2%), biofilter floc drain (33.5%), triple standpipe (18.7%), and evaporation (7.5%). Three of the four major sources of water loss produce effluent from the culture building to the septic tank: floc drain, drum filter backwash, and discharge from the triple standpipe.

Nutrients and solids were measured in both the recycle system as well as the septic tank. Water quality assurance methods were developed with written procedures, work instructions, and record keeping protocols. Quality control included measurements of concentration recovery of spiked samples (known addition method) for every parameter on every sample date.

Solids accumulation in the septic tank were analyzed from samples of the slurry pumped from the septic tank. Effluent from the septic tank was collected with an autosampler over 3- and 12-h intervals, but because there was not a significant difference between values for 3- and 12-h collections, the 3-h sample is to be used in future samples. Septic tank sludge is collected when the septic tank is drained. The normal schedule for septic tank draining and pump out of sludge was twice per year, but it will be more frequent during the study to provide information on septic tank treatment of the fish hatchery waste. Septic tank sludge (a slurry) is surface applied to 0.8 ha (2 acres) of crop land used for soybeans.

From July 22 through August 29, 2002, six sets of samples were obtained to measure inputs of total solids and nutrients from the freshwater supply and the feed, and outputs of solids and nutrients from the culture system to the septic tank, and from the septic tank effluents and solids. In this interval, the fish feed input averaged 16.2 kg/day (35.7 lb/day) (dry weight basis), 1.27

kg (2.80 lb) total nitrogen (TN), and 0.23 kg (0.51 lb) total phosphorus (TP). The combined effluent from the drum filter and the triple standpipe to the septic tank was 9.13 kg/day (20.13 lb/day) total suspended solids (TSS), 0.98 kg/day (2.16 lb/day) TN, and 0.09 kg/day (0.20 lb/day) TP. TP in the effluent to the septic tank was 5.6 g TP/kg of feed per day (0.090 oz/lb), which compares with published values of 5.0–5.9 g TP/kg feed per day (0.080–0.094 oz/lb).

TP leaving the septic tank to the tile drainage field was 3.1 g TP/kg of feed per day (0.05 oz/lb), implying that 55% of the TP input to the septic tank leaves the septic tank in the fluid flow and 45% is retained in the solids portion of the septic tank. There is no other published literature with this information. Including a septic tank in the waste treatment process will reduce TP output to surface water by about half of the output from the culture system. Because it is well known that phosphorus is strongly attached to soil, the distribution of the septic tank effluent into septic tank drainage tile will nearly eliminate half of the TP effluent problem.

A slurry of septic tank contents that accumulated in the 90-day interval in July through September contained an average of 4,750 mg/L (ppm) TSS and 112 mg/L (ppm) TP. Based on input and output measurements, an average of 91% of the TSS input to the septic tank was metabolized by the septic tank; only 6% left the septic tank to the septic tank drainage field and 3% was present in the slurry pumped out from the septic tank after the 90-day interval. The TSS in the effluent from the septic tank to the field tile was 51 mg/L (ppm), comparable to a range of 45–65 mg/L (ppm) for household septic systems.

The TN content entering the septic tank averaged 0.98 kg/day (0.035 oz/day) and the output in the effluent from the septic tank averaged 0.80 kg/day (0.028 oz/day), indicating that 82% the nitrogen entering the septic tank leaves in the effluent to the field tile.

OBJECTIVE 2

ISU researchers measured rapid solids removal from the culture tank effluent by the triple standpipe and drum filter. The dual-drain tank design had two discharges; 77% from the sidewall drain and 23% from the center drain. The center drain carried most of the suspended solids from the culture tank to the triple standpipe from which most of the flow went to the drum filter and a small flow of heavy solids to the septic tank. The major sources of water loss were from the drum filter backwash (40.2%), biofilter floc drain (33.5%), triple standpipe (18.7%), and evaporation (7.5%). The floc drain, located near the top of the fluidize bed of the biofilter, discharges to the pipe from the drum filter that empties to the septic tank. The floc drain removes floating particles of sand (sand covered with biofilm) from the top meter of the biofilter. The effluent from the culture building goes to a septic tank.

Of the solids (TSS) output from the center drain of the culture tank, the drum filter removed 78% and the triple standpipe 22%, however, the triple standpipe removed 67% of the TP and the drum filter 33%. Data on TN removal from the culture system was not available, pending completion of total Kjeldahl nitrogen analysis.

The team of UW-Madison researchers and collaborators conducted experiments to evaluate the feasibility of using wood fiber filters to capture solids from raceway and pond effluents. Prior to designing the fiber filters, information on the particle size of solids in raceway and pond effluents was needed. The particle size of three types of effluents was characterized as follows. The first was effluent from fingerling production ponds at the Lake Mills State Fish Hatchery (LMSFH). The effluent from the final 5% of the water was sampled during pond draining, because previous studies have shown that this portion of the effluent contains the highest concentration of solids. The second effluent characterized was from coho salmon production raceways at the LMSFH collected during "sweep" cleaning (a commonly used method to clean raceways). And the third was effluent from coho salmon production raceways at the LMSFH collected during "pump" cleaning (another commonly used method to clean raceways).

A small-scale filter box (designed for a flow rate of 4.0–6.0 Lpm [1.1–1.6 gpm]) was designed and built by UW-Madison researchers and engineers from the U.S. Department of Agriculture Forest Products Laboratory (FPL). This box contained a set of graded "Nytex" screens to measure particle size and distribution. These studies have just been completed. The results indicate that a high percentage (>60%) of solids from all three effluent types is retained by a 75 μm screen. Pond effluent contained a higher percentage of small particles than raceway effluent. According to FPL engineers, these data suggest that it should be possible to design wood fiber filters to retain a high percentage of solids and at the same time permit high flow rates through the filters.

The small-scale filter box is currently being fitted with the first of a series of wood fiber filters to begin studies on the efficacy of a variety of wood fiber filters to retain solids. The construction of a larger scale (150.0 Lpm; 39.6 gpm) filter system has also begun, using information gathered during the particle size-distribution studies.

OBJECTIVE 3

UW-Milwaukee scientists investigated processing methods for beneficial use of aquaculture waste. Their work is categorized into two sub-objectives as follows.

Sub-objective A: Develop methods to recover and partially dewater biosolids from intensive yellow perch aquaculture for use as a feedstock for vermicomposting using red worms and warmer-temperature tolerant "cultured" nightcrawlers. Back-flushed waste solids from a bead filter/clarifier of UW-Milwaukee's 25-m^3 (6,604-gal) recycle aquaculture system, and to a lesser extent, some solids from a 3.3-m^3 (872-gal) circular flow-through tank of yellow perch fingerlings was obtained for use as worm food. A graduated conical-bottomed 560-L (148-gal) tank was used to separate the solids by settling from the remaining wastewater. From January through June 2002, approximately 449 kg (990 lb) dried weight of commercial fish feed was used to feed the perch. During that same period, a total of 2,540 L (671 gal) of settled sludge material (66 kg [146 lb] dried weight) was recovered from the bead filter back washings. A total of 14.7% of dry weight of fish food used to grow out approximately 10,000 perch fingerlings in the recycle aquaculture system was recovered for reuse as worm feedstock.

Sub-objective B: Propagating worm stocks using continuous composting bins. Seed stocks were obtained of two species of earthworms with recognized potential for vermicomposting of organic materials: "cultured" nightcrawlers, *Eudrilus eugeniae*, (approximately 400 totaling 0.384 kg [0.847 lb]), and red worms, *Eisenia foetida*, (approximately 500 totaling 0.081 kg [0.179 lb]). In January 2002, these worm stocks were introduced into separate commercial continuous-vermicomposting bins. Worm bedding was prepared using of a mixture of 20 kg (44 lb) of hardwood sawdust, 5 kg (11 lb) of peat, and 1.1 kg (2.4 lb) of crushed limestone that had been previously prepared and moisturized in each bin over several days with 49-L (12.9-gal) water/bin. Initial bedding weight was 75 kg (165 lb) and depth of the bedding ranged between 10–20 cm (3.9–7.9 in). The surface area of each bin was 0.66 m^2 (7.10 ft^2). The bins were placed on wooden palettes and the bottom tray was modified so that water dripping through the worm bed could be collected in a drip pan placed underneath the composters.

The beadfilter sludge was dewatered by draining the sludge through the worm bedding. The majority of the solids from the bead-filter sludge were retained in the upper layer of worm bedding and excess water was dripped by gravity through the bed and collected in a drip pan. Occasionally, additional sawdust was added to the bedding. Feedings of settled sludge were measured volumetrically and poured from a 3.0-L (0.8-gal) graduated pitcher. From January through June 2002, a total of 388 L (102 gal) of sludge per bin was added as worm food. Individual feedings were generally in 3.0 L (0.8 gal) increments and varied from 0–18 L (0–4.8 gal) per bin on a given date. Keeping in mind the initial difficulties encountered by other researchers in feeding trout manure to red worms in shallow bins, initial feedings were applied to cover only a portion of the bedding surface to insure that the worms could find a refuge from extreme conditions. Additional feedings were applied in a manner to prevent accumulation of unused food as that could create anaerobic conditions, odor problems, and adversely high temperature conditions in the beds. Additional food was added when the previously added material had been worked over by the worm stocks.

Worm populations in the bins were sampled at 2, 9, 14, and 23 weeks after stocking. Both species of worms prospered when fed the yellow perch recycle aquaculture system bead-filter backwash sludge. Reproduction and cocoon deposition was observed in the first few weeks. The estimated worm initial stocking density (% by weight) in the bedding was 0.1% for the red worms was 0.1% and 0.5% for the nightcrawlers. The red worm bin population tended to increase steadily over the 23-week period both in terms of percent worms by weight (0.1–2.6%) and estimated number of worms (500 to ~13,000) in the bin. The nightcrawlers fluctuated in percent worm density by weight (range 0.5–6.4%). Nightcrawler density increased to 4.6% due to rapid initial growth, but then decreased as the larger older individuals died off gradually through the first nine weeks and were replaced by an abundant cohort of young worms after 42–48 days. In the nine-week sample worm density by weight (1.9%) was less than half of what it was at two weeks, while the estimated number of worms in the bin had gone from an original 400 to approximately 12,000. By 14 weeks the nightcrawler bin had regained high worm density by weight (6.4%) and estimated numbers appeared to remain around 13,000. However, by 23 weeks the worm sizes were mixed and not as clearly dominated by a single cohort in both numbers (~4,000) and density by weight (1.8%). Variation between samples on a given sampling date was high and hand-picking subsamples was laborious.

It is difficult to obtain accurate inventory of worm stocks in continuous batch culture in order to predict of the numbers of harvestable bait-size worms. Although the continuous vermicompost bins with mixed generations of worms would be suitable for compost production and waste recycling, for vermiculture of appropriately sized baitworms an approach that separates cohorts of worms by age and size would insure better inventory control, and avoid problems with trying to separate harvestable worms from the numerous smaller sized worms. At a commercial vermiculture operation in Racine, Wisconsin cultured nightcrawlers are grown in plastic pails (approximately10.0 L [2.6 gal] capacity) with ventilation holes punched into the upper rim. At about two-week intervals the worms are separated from the cocoons and fed a formulated commercial diet. Use of modular bins and a cohort separation management strategy is better suited for inventory control in an operation intending to produce predictable numbers of harvestable bait-sized worms.

UW-Milwaukee researchers compared bead filter sludge as a foodstuff for vermicomposting/vermiculture to a commercial worm diet. The influence of the addition of hardwood sawdust and shredded paper as worm bedding additives were also examined. This research was done with the assistance of an undergraduate participant in the National Science Foundation "Research Experience for Undergraduates" program from July through August 2002, an experiment was conducted using ventilated commercial production pails.

Three worm feeding treatments (no supplemental feeding, commercial worm food, and bead filter recycle aquaculture system sludge) were combined with three types of bedding ("black peat" soil alone [9.0 L; 2.4 gal]; black peat [6.0 L; 1.6 gal] plus sawdust [3.0 L; 0.8 gal]; and black peat [6.0 L; 1.6 gal] plus shredded paper [3.0 L; 0.8 gal]). Each treatment combination was assigned to a commercial production worm pail and 20.0 g (0.7 oz) (about 50 African nightcrawlers, or 70 red worms) batches of each worm species were randomly assigned to each of the nine pails. The treatment array was replicated three times on successive dates resulting in triplicate pails for each of the nine treatment combinations for each worm species (27 pails total for each species). Food treatments consisted of either 3.0 L (0.8 gal) of sludge, 29 g (1.0 oz) of commercial worm food followed by 3.0 L (0.8 gal) of recycle aquaculture system water, or no food followed by 3.0 L (0.8 gal) of recycle aquaculture system water. The amount of commercial food fed to the worms (29 g; 1.0 oz) approximated the equivalent dried solids in 3.0 L (0.8 gal) of biosolids sludge. Growth and survival in each pail was evaluated at two and four weeks.

Yellow perch recycle aqauculture system beadfilter backwash sludge was a suitable feedstock for both "cultured" nightcrawlers and red worms. Buckets of nightcrawlers fed bead-filter sludge increased 489% in overall mass with a 96% survival after four weeks. After four weeks, the weight of red worms fed beadfilter sludge increased 224% percent with 73% survival. Between the second and fourth week several buckets of both sludge fed and commercial food fed red worms experienced some mortality.

In this experiment, recycle aquaculture system sludge as a worm feedstock was as successful as, or outperformed the commercial worm food. After four weeks, the weight of nightcrawlers fed commercial worm food increased 415% with a 99.8% survival. Red worms fed commercial worm food had a 63% survival rate and a worm biomass increase of 187% after four weeks. The fed worms grew much better than the worms without supplemental feeding; at four weeks unfed nightcrawlers increased only 154 % with 100% survival and red worms increased 127% with 97% survival. All substrate types tested were successful in maintaining worm cultures. No differences in worm growth and survival could be attributed to the various substrates. However, preliminary results suggest that the addition of sawdust allows better drainage and drying of the bedding. Addition of sawdust would probably reduce the labor costs required for separation and picking of the worms from the substrate at harvest.

WORK PLANNED

OBJECTIVE 1

Monthly measurements will continue to be made by ISU researchers of nutrients (nitrogen and phosphorus) and total solids inputs in water and feed, and nutrient and solids outputs in the septic tank effluent from Ehler's commercial aquaculture facility in west-central Iowa. A yearly cycle of monthly measurements is needed to identify the range in water quality parameters of the effluent in relation to fish stock (numbers, mean size, total biomass) and feeding rates (nutrient inputs). The database will characterize effluents of a modern recycle aquaculture system that discharges to a septic tank from which a liquid effluent is discharged to field tile under row crop field, and solid wastes are periodically pumped for field application.

OBJECTIVE 2

ISU researchers will continue efforts to describe rapid solids removal/recovery in Ehler's commercial recycle aquaculture facility that uses a drum filter and triple standpipe for rapid solids removal from the center drain of a dual-drain tank. Comparisons will be made of the effectiveness of the two components of the system used for solids removal. Solids from the aquaculture facility that collect in the septic tank are pumped out and either field applied or dried. The researchers will describe efforts by the producer to develop the commercial potential of using the solids as a horticulture fertilizer.

UW-Madison researchers will continue using the small-scale filter box to compare the filtration performance of a variety of wood fibers. Also, key production parameters of the fiber mats (e.g. thickness, porosity, and density) will be tested. The primary endpoints will be particle size retention, percent of total solids retained, flow rate per unit of filter area, and total capacity of the filters. This information will then be used to test selected filters in large-scale (150.0 and 1,500.0 Lpm; 39.6 and 396.3 gpm) filter boxes.

OBJECTIVE 3

UW-Milwaukee researchers will sample worms, bedding substances, and composts from both the continuous compost bins. Worms are currently being freeze-dried for isotope analysis and caarbon:nitrogen ratio to characterize the alteration in the biosolids during the vermicomposting process.

Because bait worms command a higher market value compared to worm castings, a system capable of handling the full waste production of a commercial-scale recycle aquaculture system is needed. Therefore, future work will shift in emphasis from continuous style vermicomposter to use of a modular vermiculture strategy involving cohort separation for more predictable worm production. For such a system, the associated costs of labor (as man-hours), energy (for environmental control and preparation of feedstock/bedding), and materials used in the recovery of sludge, initial setup, maintenance, and harvest of the compost and worms will be determined in terms of the unit weight of fish sludge processed. In the third year of the project UW-Milwaukee will conduct a trial to evaluate the acceptability of worms produced from recycle aquaculture system biosolids sludge as fish food.

OBJECTIVE 4

Arrangements will be made for a regional workshop on the USEPA "Draft Guidance for Aquatic Animal Production Facilities to Assist in Reducing the Discharge of Pollutants" and BMPs to meet the effluent limitation guidelines and standards. The workshop will compare characteristics of aquaculture facilities with effluent limitation guidelines and standards, and regulatory and commercial perspectives on the rules.

IMPACTS

OBJECTIVE 1

ISU researchers are demonstrating facility design features and operation procedures that can be used to develop BMPs for a commercial dual-drain tank recycle aquaculture system using a septic tank and land application of solid wastes to row crops. This system incorporates highly integrated BMPs (rapids solids removal, a septic tank for collection, storage, and decomposition of the wastes, and field application of the wastes) to eliminate (i.e., zero-discharge) waste discharge from the farm property. To date, the findings lead to the recommendation that adding a septic tank in the waste treatment process can eliminate discharge of TSS, BOD, and TP output to surface water. Field application of septic tank solids required only 0.8 ha (2 acres) of crop land.

OBJECTIVE 2

The goal of the ISU research is to demonstrate design features of a recycle aquaculture system that rapidly removes solids. Efficient solids capture and disposal are important to operating efficiency of the recycle aquaculture system, water quality for the cultured fish, and waste management. The system under study uses dual-drain tanks that allows the operator to set the proportion of flow from the culture tank to sidewall and center drains, which can facilitate rapid solids removal and reduce the size and cost of the drum filter. This contrasts with traditional recycle aquaculture systems that direct all of the flow from the culture tanks to the a microscreen filter (drum or disk) or other type of system for trapping solids (bead filter).

UW-Madison researchers are evaluating the use of natural wood fibers as a filter material that will hopefully effectively remove organic solids from raceway and pond aquaculture production facilities before being discharged into the environment. The retention of solids by these filters will significantly reduce the amount of nutrients entering the receiving stream, resulting in improved water quality downstream from existing fish culture facilities.

Disposable natural fiber filters can be made inexpensively from a variety of wood and plant fibers. Thus, the application of natural fiber filters to aquaculture will provide economic opportunities to the agriculture industry to market low value fiber or waste fiber. One additional benefit to this technology is that spent fibers can be composted and used as a soil amendment for agriculture.

OBJECTIVE 3

UW-Milwaukee researchers have demonstrated that fish waste sludge from recycle aquaculture systems is a viable feedstock for worm culture. This can be beneficial to aquaculture, especially recycle aquaculture systems because vermicomposting can potentially decrease the amount of waste released and produce salable worms and organic compost to defray some of the high operating expense of recycle aquaculture system rearing.

OBJECTIVE 4

The goal of the research in Objectives 1, 2, and 3 is to provide options for waste management and use of wastes as a valuable by-product feedstuff for worm culture. Researchers will assemble, interpret, and communicate science-based information to stakeholders through workshops, conferences, and technical bulletins thus providing commercial-aquaculture operators with information on environmental regulations and the best available technology needed to meet the regulations.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Wastes/Effluents activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001-02	$80,766	$58,752	$299,980	$21,060		$379,792	$460,558
TOTAL	$80,766	$58,752	$299,980	$21,060		$379,792	$460,558

TILAPIA[10]

Project Termination Report for the Period
September 1, 1998 to August 31, 2002

NCRAC FUNDING LEVEL: $150,000 (September 1, 1998 to August 31, 2002)

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[11]	Grayson Hills Farms, Harrisburg	Illinois
Dan Selock	Aquaculture Consultants for the Heartland, Carbondale	Illinois

REASON FOR TERMINATION

The project objectives were completed.

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

[10]NCRAC has funded two Tilapia projects. A termination report for the first project is contained in the Annual Progress Report for 1998-1999. This termination report is for the second Tilapia project which was chaired by Paul B. Brown. It was originally a 2-year study that began September 1, 1998 but was lengthened for no additional cost.

[11]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.

biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

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 niloticus*) 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.

Researchers at Purdue, using data generated in previous NCRAC projects and projects funded by other groups, formulated an experimental diet for use with tilapia raised in recirculating systems. That diet was free of fish meal, contained 32% crude protein, and the minimum amount of essential amino acids and dietary energy. Minimizing essential amino acid concentrations should help reduce ammonia excretion and place less of a load on the biological filtration system. Minimizing energy should reduce carbon dioxide excretion, which will reduce the need for bicarbonate addition to systems and reduce the drop in pH caused by excess carbon dioxide excretion. The diet was manufactured by a private feed mill (Nelson and Sons, Murray, Utah) and shipped to ADM in Decatur, Illinois for testing. Three separate diets were tested in 302,832-L (80,000-gal) production tanks. The experimental diet from Purdue, the standard ADM diet, and a standard tilapia production diet acquired from a commercial feed mill were fed to duplicate groups of fish for a portion of the production cycle. Mean initial weight of fish was 14 g (0.5 oz).

Total consumption of the Purdue diet was less than the other two diets; consumption of the ADM diet was highest. Mean weight gain, determined from a sample of fish, was lowest in fish fed the Purdue diet and highest in fish fed the commercial diet. Total bicarbonate addition was almost 50% lower in the tanks fed the Purdue diet compared to fish fed the ADM diet, which required the highest amount of bicarbonate addition. Average ammonia-nitrogen (NH_3-N) concentration was lowest in fish fed the ADM diet, intermediate in fish fed the Purdue diet, and highest in fish fed the commercially-available diet. Average nitrite-nitrogen (NO_2-N) concentration was lowest in fish fed the Purdue diet, intermediate in fish fed the commercial diet, and highest in fish fed the ADM diet. Average nitrate-nitrogen (NO_3-N) concentration was lowest in fish fed the Purdue diet, intermediate in fish fed the commercial diet and highest in fish fed the ADM diet. Costs associated with this project prohibited extending the experiment to a complete grow-out cycle.

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 was distributed through tomato plant roots grown directly above the fish tanks hydroponically. The bead biofilters served to collect solid wastes while providing media for bacterial nitrification. The tomato plants served to remove dissolved nutrients from the system. As a consequence, inorganic fertilization use was reduced by half for the tomato production. 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 were switched to the ADM tilapia facility in Decatur, Illinois.

ADM initially allocated nine 37,854-L (10,000-gal) aquaculture units, each equipped with a bead filter, to this study. Two diets (isonitrogenous and isocaloric) were formulated and manufactured (5,443 kg; 6 tons each) by Farmland Feeds/Land of Lakes (Denzil Hughes) to be consistent with the nutritional requirements of tilapia raised under intensive culture conditions (crude protein 36%; estimated digestible energy [catfish] 3,080 kcal/kg [1,397 kcal/lb). Fat was varied with beet (fiber) level to conserve energy content. A third dietary treatment formulated and typically used by ADM could not be replicated adequately and was therefore dropped from the study. The treatment diet (beet pulp) was modified relative to the control diet by decreasing dietary carbohydrate sources (grain-based feedstuffs) and increasing lipid to allow conservation of proximate composition. A trial starting October 18, 2001 and ending December 21, 2001 (duration 65 days) was carried out with culture systems and day-to-day labor provided by ADM. Bead filter operation was interrupted for back flushing when a gauge measuring backpressure reached 15 psi. Filtration was offline for approximately 15 min while particulate waste retained by the filter was separated from the beads and subsequently drained from the system. The normal interval between back flushing events was approximately 2 days (range: 1–4). Six systems (3 control, 3 fiber) were operated in a manner consistent with ADM's normal tilapia production procedure for early grow out. Fish were fed by hand approximately twice daily. As biomass within each culture system increased, feed application rate increased until limited by water quality (~36 kg [79 lb] of feed/system/day) and or feeding activity of the tilapia. Sodium bicarbonate was used to control pH (targeted range 7.0–7.25) as a method for reducing the toxic affects of NH_3-N. During the period of normal operation the intervals between back flushing and pressures, as well as temperature and dissolved oxygen were recorded. Immediately prior to back flushing, culture and wastewater was sampled for NH_3-N, NO_2-N, and biochemical oxygen demand (BOD). Production in terms of specific growth rate and feed conversion ratio did not vary as a function of dietary fiber. System dissolved oxygen, oxygen infusion rate, and bead filter backpressure did not vary as a function of dietary treatment. Filter backpressure and water quality variables monitored did not vary significantly. Intensive water quality observations (2-h intervals) occurred during the final 12 h that started and ended with a back flushing. Filter backpressure did not differ significantly between treatments as measured at 4-h intervals, nor did the water quality parameters measured. Concentrations of NH_3-N and NO_2-N were consistently high (5–13 mg/L (ppm) and 2–39 mg/L (ppm), respectively). BOD was not affected in the culture or waste water by incorporation of dietary beet pulp. Photoperiod was natural for Decatur, Illinois and daily temperatures during the feeding trial were less than considered optimal for tilapia (ranged 24.0–27.5°C; 75.2–81.5°F).

OBJECTIVE 2

Michigan State University completed an extension publication on feeding methods for tilapia to enhance production in recirculating aquaculture systems (NCRAC Fact Sheet Series #114, in press).

Due to the closure of the Grayson Hill Farms' facility and the poor water quality that occurred in the ADM commercial system, SIUC researchers were unable to conduct a meaningful "real-world" cost of production analysis. Accordingly, the annual operating costs for a hypothetical system capable of producing 4,000,000 lb (all values expressed in English units except for fingerling weights where both metric and English units are given) of tilapia per year were estimated to provide tilapia producers in the North Central Region (NCR) with useful information on variable costs which are indicated in bold. Information for the estimates was obtained, in general, from the American Tilapia Association 2001 Situation and Outlook Report and Southern Regional Aquaculture Center Publication #456.

Fingerlings: Four million 10-g (0.35-oz) fingerlings are needed annually, assuming 80% survival at harvest and a mean individual market weight of 1.25 lb. At a cost of $0.25/fish, total fingerling cost would be **$1,000,000** (4,000,000 × 0.25).

Feed: Feed is invariably the highest variable cost in raising fish. Fingerlings from 10–100 g (0.35–3.53 oz) in weight require higher quality feed (~$0.30/lb compared to growout diets at ~$0.20/lb for fish to reach market size). Assuming the higher costing feed represents approximately 25% of the feed purchased, the average cost of the feed will be ~$0.225/lb. Assuming a total feed conversion ratio of 1.5, the annual feed bill to rear 4,000,000 lbs of tilapia would be **$1,350,000** (4,000,000 × 1.5 × 0.225).

Labor Costs: Labor costs will include a manager, assistant manager, and six hourly employees, one of which would serve in a clerical role. The annual payroll is estimated as follows:

Manager	$60,000
Assistant manager	$40,000
Other Professionals (6 @ $25,000 ea)	$150,000
Subtotal	$250,000
Fringe benefits (30%)	$75,000
Total	**$325,000**

Energy: In SRAC publication #456 detailing cost in recirculating aquaculture systems, the authors estimate a requirement of 2.3 kwh/lb of production. Therefore, for this hypothetical system, at a price of $0.05/kwh, the cost of energy would be **$460,000** (4,000,000 × 2.3 × 0.05).

Oxygen: Injection of oxygen is necessary to maintain high levels of production in a recirculating aquaculture system. The amount of oxygen required per pound of feed is 0.3 lb. Accordingly, multiplying pounds of feed by 0.3 and multiplying this figure by a conversion factor of 12.05 to determine cubic feet, annual oxygen use can be calculated. Oxygen cost at a price of \$0.003/ft^3 would, therefore, be **\$65,070** for 6,000,000 lb of feed fed (6,000,000 × 0.3 × 12.05 × 0.003).

Bicarbonate: Bicarbonate (as sodium bicarbonate, i.e. common baking soda) must be added to a recirculating aquaculture system to counter acids released in the oxidation of ammonia and nitrites to form nitrates (this takes place in the biofilters), as well as production of carbon dioxide by bacteria in the biofilters and the fish themselves. The goal is to maintain pH near neutrality (pH = 7.0). Buffering needs will be 0.175 lb of sodium bicarbonate per pound of feed fed. Bicarbonate costs at a price of \$0.19/lb would, therefore, be **\$199,500** for 6,000,000 lb of feed fed (6,000,000 × 0.175 × 0.19).

Maintenance: General maintenance of the system, estimated at approximately \$0.03 per pound of fish produced, would cost **\$120,000** (4,000,000 × 0.03).

Chemicals: Chemicals (excluding sodium bicarbonate), estimated at \$0.01 per pound of production, would cost **\$40,000** (4,000,000 × 0.01).

Interest: The amount of interest on all of the variable costs (subtotal of above), estimated at 9%, would be **\$320,361** (3,559,570 × 0.09).

Fixed Costs: Fixed costs, estimated at 15% of the total operating costs (variable costs plus interest) would be **\$581,990** (3,879,931 × 0.15).

Total Operating Cost: Variable costs (\$3,559,570) + interest (\$320,361) + fixed costs (\$581,990) = **\$4,461,921**.

In summary, breakeven cost per pound live weight of fish is projected at **\$1.12** (4,000,000 lb fish costing \$4,461,921 to produce). This equates to \$3.36/lb of fillets (excluding processing charges and assuming a 33% dressout). This projection is based solely on the fixed and variable costs and does not take into account capital investment. Producers would need to substitute their own costs wherever possible to arrive at a closer breakeven cost for their particular operation.

IMPACTS

It seems clear from these studies that improvements can be made in diets fed to fish in recirculating systems. By careful dietary formulation, carbon dioxide excretion can be reduced, which, in turn, will reduce the amount of bicarbonate needed to buffer the system from decreases in pH. This represents a significant reduction in total production costs. It also seems clear that ammonia excretion can be reduced, which reduces the toxic compounds on fish raised in the system, which, in turn, will reduce the level of stress on the fish caused by degraded water quality.

Incorporation of dietary fiber sources (beet pulp and cellulose) up to a level of 8% does not affect growth of tilapia during grow out in water reuse systems. Dietary fiber did not influence water quality or production parameters in a commercial-scale tilapia production facility that utilized bead filters alone for filtration in water reuse systems. Incorporation of beet pulp into diets for tilapia grow out using water reuse system with bead filters provided no obvious benefits for improving water quality parameters of NH_3-N, NO_2-N, and BOD in the culture volume or the waste effluents. Dietary formulation had no effect on water quality. Survival is unknown owing to the production cycle duration not allowing for generation of marketable size animals that could be inventoried. Regardless of fiber content, filtration was inadequate, thus constraining the maximum feed ration to be less than 3% body weight daily. NH_3-N and NO_2-N concentrations were chronically high in all culture units and were used as the guide for limiting feed application rates. Prolonged exposure of waste in bead filter to water cycling between the filter and culture tank resulted in apparent leaching of nitrogenous waste back into the culture water.

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 (#114) on feeding tilapia in intensive recirculating systems is in press. 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.

Although SIUC researchers were unable to conduct a meaningful "real-world" cost of production analysis due to the closure of the Grayson Hill Farms' facility and the poor water quality that occurred in the ADM commercial system, the annual operating costs for a hypothetical system capable of producing 4,000,000 lb of tilapia per year were estimated to provide tilapia producers in the NCR with useful information on variable costs. Information for the estimates was obtained, in general, from the American Tilapia Association 2001 Situation and Outlook Report and Southern Regional Aquaculture Center Publication #456.

RECOMMENDED FOLLOW-UP ACTIVITIES

In this first attempt to control water quality through diet, consumption of feed and resulting weight gain were lower than in commercial diets. Addition of flavor additives to diets might alleviate this decreased consumption. However, if fish consume more of a diet that contains the minimum amount of dietary nitrogen and energy, whether or not the improved water quality parameters will remain is unknown. This needs to be explored. Additionally, the possibility that improved water quality might result in the same weight gain if fish had been grown for the entire grow-out cycle needs to be studied.

Further studies should be concentrated with systems that are designed to minimize contact time between waste products. Bead filters as used at the ADM facility retain organic waste too long and force the culture system to degrade materials that consume oxygen and liberate nitrogenous waste products while being digested. Cost of production estimates on specific systems may not be as useful as information on variable and fixed costs obtained from a variety of locations and recirculating system configurations.

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[12]

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

NCRAC FUNDING LEVEL: $8,415 (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

REASON FOR TERMINATION
The project objectives were completed.

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.

PRINCIPAL 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%.

[12]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 termination report is for the third Aquaculture Drugs project which was chaired by Alan A. Moore. It was originally a 1-year study that began October 1, 1999 but was expanded and lengthened for no additional cost.

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.

Work that was planned for September 1, 2001 to May 30, 2002, using a no-cost grant extension was not performed because disease outbreaks of *Flavobacter columanare* could not be generated during this period.

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.

<u>Expanded Scope of Work (Hydrogen Peroxide)</u>

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.

Research 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 they 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.

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.

Work with florfenicol that was planned for September 1, 2001 to May 30, 2002, using a no-cost grant extension was not performed because of INAD problems during this period. Hydrogen peroxide work also planned was not performed because disease outbreaks could not be generated.

IMPACTS

Work from this project has provided data that will be used toward gaining NADA approval for several aquaculture drugs. If approved, these drugs will benefit the entire aquaculture community, including federal, state, and private aquaculture interests located throughout the United States.

This project demonstrated the following:

- The problem of complicating, unwanted diseases and the difficulty of designing and performing disease field studies.
- Hydrogen peroxide will effectively control chilodonella on walleye.
- Walleye are extremely sensitive to hydrogen peroxide.
- Hydrogen peroxide will control *Flavobacter columnare* on channel catfish.
- Channel catfish are less sensitive to hydrogen peroxide than walleye.
- Oxytetracycline residue did not reach upper tolerance limits when fed to walleye under cool water conditions.
- Hydrogen peroxide will control fungus on channel catfish eggs
- Chloramine-T is not toxic to walleye up to 30 mg/L for a 60 min exposure.

In addition:

- Data from these studies were submitted to the Food and Drug Administration as pivotal or supportive data packages in support of NADA work on these drugs.
- The work done under this grant led to additional unfunded pivotal studies with hydrogen peroxide for the treatment of *Flavobacter columnaris* on walleye. These studies were conducted in 2002.

RECOMMENDED FOLLOW-UP ACTIVITIES

Additional aquaculture drug-related studies are needed to complete other data packages required by the Food and Drug Administration for approval and labeling of other much needed drugs for the aquaculture community.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

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

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1999-01	$8,415						$8,415
TOTAL	$8,415						$8,415

APPENDIX

EXTENSION

NCRAC Extension Fact Sheet Series

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

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

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Riepe, J.R. 1997. Costs for pond production of yellow perch in the North Central Region, 1994-95. NCRAC Fact Sheet Series #111, NCRAC Publications Office, Iowa State University, Ames.

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NCRAC Technical Bulletin Series

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

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

Hushak, L.J., C.F. Cole, and D.P. Gleckler. 1993. Survey of wholesale and retail buyers in the six southern states of the North Central Region. NCRAC Technical Bulletin Series #104, NCRAC Publications Office, Iowa State University, Ames.

Meronek, T., F. Copes, and D. Coble. 1998. The bait industry in Illinois, Michigan, Minnesota, Ohio, South Dakota, and Wisconsin. NCRAC Technical Bulletin Series #105, NCRAC Publications Office, Iowa State University, Ames.

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

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

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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)

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

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SOME COMMONLY USED ABBREVIATIONS AND ACRONYMS

×	cross; times
ANS	aquatic nuisance species
AquaNIC	Aquaculture Network Information Center
BMPs	best management practices
BOD	Board of Directors biochemical oxygen demand
°C	degrees Celsius
CES	Cooperative Extension Service
cm	centimeter
EAA	essential amino acid
°F	degrees Fahrenheit
FFO	Freshwater Farms of Ohio, Inc.
FPL	[USDA] Forest Products Laboratory
ft, ft^3	foot, cubic foot
g	gram(s)
gal	gallon(s)
gpm	gallons per minute
h	hour(s)
ha	hectare(s)
HACCP	Hazard Analysis Critical Control Points
IAC	Industry Advisory Council
in	inch(es)
INAD	Investigational New Animal Drug
ISU	Illinois State University Iowa State University
kg	kilogram(s)
L	liter(s)
lb	pound(s)
LMSFH	Lake Mills State Fish Hatchery
Lpm	liters per minute
m, m^3	meter, cubic meter
µm	micrometer
mg	milligram(s)
min	minute(es)
mm	millimeter(s)
MSU	Michigan State University
N	number
NADA	New Animal Drug Applications
NCC	National Coordinating Council
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)
P	probability
POW	Plan of Work
ppm	parts per million
PREC	Piketon Research and Extension Center
Purdue	Purdue University
RAC(s)	Regional Aquaculture Center(s)
SIUC	Southern Illinois University-Carbondale
TC	Technical Committee (TC/E = Technical Committee/ Extension; TC/R = Technical Committee/Research)
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
UM	University of Missouri
UMESC	Upper Midwest Environmental Sciences Center
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
UW-Madison	University of Wisconsin-Madison
UW-Milwaukee	University of Wisconsin-Milwaukee
YOY	young-of-the-year
yr	year(s)